António Alberto Lopes Fernandes Duarte Correia

FABRICATING ARCHITECTURE
From Modern to Global Space

VOLUME I (THESIS)

Tese de Doutoramento em Arquitectura, orientada pelos
Professor Doutor Luís Simões da Silva e Professor Doutor Vítor Murtinho e apresentada ao
Departamento de Arquitectura da Faculdade de Ciências e Tecnologia da Universidade de Coimbra

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António Lopes Correia

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From Modern to Global Space

VOLUME I (THESIS)

PhD thesis in Architecture, advised by
Prof. Dr. Luís Simões da Silva and Prof. Dr. Vítor Murtinho
and presented to the Department of Architecture of the
Faculty of Sciences and Technology of the University of Coimbra

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à Sofia e ao Jorge

Table of Contents

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Resumo

Esta tese estabelece uma visão modular da pré-fabricação sob uma perspetiva da produção arquitetónica. É fundamentada tanto de um ponto de vista taxonómico, delineado de uma herança modernista, com o problema da habitação como veículo principal, e de um ponto de vista estruturalista, delineado a partir de elementos linguístico/semióticos, constituintes essenciais de processos socioculturais. Pretende esclarecer vínculos entre a produção arquitetónica e uma esfera industrial na abordagem dos requisitos contemporâneos da habitação, favorecendo modelos de alteridade (e.g., implementando flexibilidade ou abordagens de adaptabilidade) em detrimento de modelos de controlo mais rígidos (e.g., propostas funcionalistas) e endossando uma égide modular. A partir daí, propõe-se um contributo mais geral para o debate sobre o papel da arquitetura num mundo globalizado, na sua inevitável evolução epistemológica para um lugar diferente, (re)fabricando-se. Assim, num nível mais abrangente, esta tese é sobre a observação da pré-fabricação de habitação como um caso particular do que poderá ser o diálogo epistemológico da arquitetura com o estado tecnológico e o paradigma informacional de um mundo globalizado.

Na origem desta tese está um desenvolvimento prático de um caso de estudo de prefabricação de habitação para fins residenciais de baixa ou média densidade habitacional, com recurso a uma filosofia estrutural ligeira. De forma direta e indireta, esse caso contribuiu para resultados concretos, como a criação de uma empresa de construção pré-fabricada, um protótipo de habitação em escala real e uma patente registada sobre construção modular. Todavia, o trabalho inicial suscitou várias perplexidades, nomeadamente na relação histórica entre a prática arquitetónica com métodos pré-fabricados e no que parece ser uma sujeição a um preconceito social, ou na validade de alguns discursos arquitetónicos em face às idiossincrasias de algumas práticas construtivas [aparentemente] inovadoras. Esse questionamento manifesta-se numa revisão crítica do caso de estudo inicial, que coloca um foco em aspetos de sistematização de processos de produção arquitetónica, mas também em todo o seu enquadramento e contextualização histórica, teórica e crítica. Parte desta tese tem, pois, intuitos metodológicos no que concerne uma clarificação da lógica que levou aos desenvolvimentos tangíveis iniciais (construção do protótipo, etc.). Além disso, constitui um esforço para relacionar um discurso arquitetónico com uma prática onde uma semântica de pré-fabricação desejavelmente possa ocorrer com desassombro.

Abstract

This thesis lays a modular insight on prefabrication from an architectural production perspective. It is grounded both from a taxonomic standpoint, outlined from the modernist architecture inheritance, with the housing problem as main vehicle, and from a semiotic, structuralist standpoint, outlined from the linguistic/semiotic socio-cultural building blocks. It aims to clarify bonds between architectural production and an industrial sphere in the addressing of contemporary house requirements, favoring alterity models (e.g. enacting flexibility or adaptability approaches) in detriment of more rigid control models (e.g. functionalist proposals), and endorsing a modular aegis. From there, a more general contribution is proposed to the debate about the role of architecture in a globalized world, in its inevitable epistemological evolution to a different place, re-fabricating itself. Thus, on a broader level, this thesis is about observing house prefabrication as a particular case of what can be architecture's epistemological dialogue with the technological state and informational paradigm of a globalized world.

On the origin of this thesis is a practical development of a case-study of house prefabrication for residential purposes with low or medium density, making use of a lightweight structural philosophy. Directly and indirectly, the case has contributed to real-world outputs such as the creation of a prefab construction company, building a real-scale house prototype, and a registered patent on modular construction. The initial work has nonetheless ignited several perplexities, namely in the historical relation of architectural practice with prefab methods and what it seems a subjection to social bias, or in the validity of some architectural discourses facing the idiosyncrasies of some seemingly innovative constructive practices. This questioning is manifested in a critical revision of the original case-study, particularly focusing on systematization aspects of the architectural production, but also in its historical, theoretical and critical framing. Thus, part of this thesis constitutes a clarification of the rationale that has led to the tangible developments (prototype construction and so forth), which is set with methodological purposes. Additionally, it constitutes an effort to bind architectural discourse with a practice where a prefab semantics can have a dauntless, unbiased existence.

Introduction

1 An ongoing epistemological debate

Born out of the growing pains of industrialization, the modernist period and its *CIAM* (*Congrès Internationaux d'Architecture Moderne*) counterpart would signal a remarkable epistemological change in architecture. With it, in brief, favorable conditions were set to bring architecture to the masses, and not so much as a privilege of some elites. The process occurs bonded with a strong focus in addressing the housing problem and correlated urban planning issues. The moment demanded both a rationalizing spirit, and a compliant cast of a new formal and conceptual vocabulary, with inputs coming from multiple sources, from arts to sciences, from industry to nature or vernacular built forms. To a certain extent, this resulted in a clash with previous architectural conceptions, as it was notorious with a prevailing *Beaux-Arts* criticism.

Anyhow, this was a central formative period for the architecture we have today. Namely, it was through its proponents that architecture arguably made its first serious, extensive effort to think itself outside the *inevitability of form*, that is, (proto)scientifically, through functionalism and the like. Nonetheless, in our days the context has changed, modernism has long undergone a review process, and an information age has been installed. With his announcement of the end of the *Gutenberg galaxy*, in an early reflection on our global age, Marshall McLuhan[1] hammered one more nail to Victor Hugo's *ceci tuera cela*[2]. But still, the clash that modernism represents from the previous architectural conceptions remains referential to acknowledge what it seems to be an age-old, permanent epistemological debate.

There is an inherent open-endedness, or ambiguity, in a general definition of architecture's *object*, which can cross wholly different scales/scopes. Moreover, since the rise of the discipline of industrial design, in the early XXth century, many different areas of design have been specializing, and many have been created just in the past decades bonded to IT's (*Information Technologies*), signaling the inevitability of ever more setting collaborative practices, and so forth. Likewise, the work in objects of a virtual sphere, first as an extension of the work in a physical reality, and then as objects in their own right, contributed to change the game. These are just some examples of the many relatively recent aspects contributing to accelerate the change of what has been traditionally perceived as the architect's role, and architecture's object both in its production and theorization, indelibly expanding their scope to such a breadth that one can easily loose track. Perhaps prophetically, or perhaps simply signaling an antient *raison d'être*, in 1968, Hans Hollein was making a funeral eulogy: "*All are architects. Everything is architecture*"[3]. Even so, and aside its open-endedness and evolution throughout the times, we believe that, in the least, architecture's humanistic relevance cannot easily vanish.

If a certain mechanistic realm was already underway when architectural modernism was in ebullition, the issue gained new contours and relevance with the arousal of a review of the modernist ideas (and ideals). The latter occurred in the mid XX[th] century, when there is a general accusation of a certain emptiness, or inadequate orthodoxy, of modernity's forms, and a corresponding attempt to instill deeper levels of significance. This kind of perspective was notably expressed by figures such as Aldo Van Eyck and some of his contemporaries in the aftermath of *CIAM*. However, in a post-modern(ist) stance, some others, such as Robert Venturi, would also be accused of focusing too much in the signification issues, with too much of rhetoric, historic, or semiotic concerns. Finally, theorists, such as Giorgio Grassi, have pointed to what may appear to be a more consensual way somewhere in between, where architecture could be regarded as a rational discipline, seeking order, a place where rigor and coherence should be the ultimate modes of expression—"*in architecture, the absence of order becomes materially impossible*"[4].

The latter view values reason above form, giving no room for aesthetical or moral indulgences, so to avoid rhetorical and formalist approaches to architectural production. In this sense, architecture would ought to be a discipline finding sense among itself, through a logic of the praxis, and not through methodological adoptions of other fields. That raises a pertinent, but perhaps unanswerable question of a procedural order. On the other hand, it is a view that underlies architecture's autonomy through its techniques and forms. However, these cannot be conceived as occurring by uncritically repeating gestures and approaches, since these are necessarily subjected to conditions and signification building processes that change overtime[5]. Instead, as genetic relatives, these will most likely evolve through the praxis, while somewhat preserving the traces that originated it.

Notwithstanding, in current conditions it is seemingly harder and harder to keep track of the meme carried techniques and forms, as they expand and mingle at an amazing speed, often blurring to the point of unrecognition. Moreover, in last resort, a purely rational *architectural way of thinking*, as it could radically be interpreted from such a call for order, would mean that there was not necessarily an architectural object implied, at least not one that we would consider as so—in a pure rational milieu, that would lead to a logical dead-end, where everything would be possible, but impractical, since ultimately the [architectural] *artifact* would become the thought of the *artifact* and not the *artifact* itself, and recursively so forth. In last resort, pure rationality eliminates any trace of bond with a tangible reality, with forms self-referenced to previous forms, lost in a *ouroboros* serpent of pure topology, not allowing the imperfectness of reality to engage towards a production of meaning or a real-world concretion, thus a *dead language*[6]. Anyhow, the architecture that we address here is not exclusively of a systematic order as in a Kantian architectonic, but eminently deals with material things [complement with: **Annex, I.1 Architecture: An etymological draft**].

At first, the idea of house prefabrication may seem to be off this discussion. However, there are several parallelisms implied. For instance, we can point to what may be considered a generally suspicious scrutiny from the architectural community towards this often accused of *empty* mode of bringing forms to life, and the way architectural modernism has been regarded at some point by its critics, as somewhat vacant of meaning production. Additionally, the idea of prefabrication that is often assumed by most people is a lot closer to the contemporary idea of product, which can conflict with the notions of place that archetypally pervade the architectural conceptions of space and time. Besides, by limiting the observation of prefabrication to its cases in house production, although in a specific context, we are revisiting the home, the quintessential architectural object of study since Vitruvius, the minimum unit for a socially signifying impact.

2 Prefabrication between the factory of modernity and a global space

Directly or indirectly, the Industrial Revolution had a profound impact on architectural production, to which we can associate a modern conception of space of a Cartesian matrix. With the Information Revolution, there was a new shift towards a space of relativistic (or relational) nature, whose mapping requires different logics of analysis. Thus, after a hierarchical, gravitational logic, inherited from Vitruvius, and pursued by the moderns', it would now make sense to think of a heterarchical, networked and relational logic. Despite this, the architecture we are making today is, to a large extent, an architecture of modernist heritage, in which a more or less rigid control of space overlaps with what would be a logic closer to our times, where there is (or should be) freedom of use, of choice, of change, of dwelling, … of thinking.

To a certain extent, it is the *machine*, real and metaphorical, that subsists as one of the central elements uniting these two civilizational times. It is to the *machine* that the modernist parents also sought inspiration, translated into an aspiration to change the conditions of life through the built environment, the dwelling and the city, as eloquently expressed by the *CIAM*. It is also to the *machine* that we can, albeit partially, associate the introduction of new formal conjectures of that epoch, where aspects such as function and economy were seen as superlative aspirations to translate into architectural form. It is with the *machine* that information is nowadays processed and transmitted seemingly instantly, allowing new ways of working, of producing, of relating to each other… of living. It is also with the *machine*, now increasingly dematerialized, that a certain symbolic and iconographic side translates into a ubiquitous dissemination of brands, marketing strategies or other modes related to a generalized commodification of goods or services, vehicles par excellence of a consumer society. These lead to an indelible control of the architectural space-time by a sphere of consumption that is primarily regulated by global mechanisms of capital, and where architecture itself is used as a manipulator vehicle at the service of what it also seems to be a global capitalist *ideology*.

In this perspective, desires and aspirations are inculcated in a spatial user who is primarily a consumer. These modify the conception of the productive *machine*, which thus leaves a sphere of strict constraint to the canonical brute force of mass-production and opens itself to the possibilities of other forms and methods that allow a scalable variability, that moreover can be algorithmically established. Therefore, despite common traits—e.g. human intelligence, creativity and spatial action, or constraint to the Newtonian gravitational condition—it also changes the paradigm of space-time control, and with it, inexorably, is architecture itself that changes once more.

As a discursive object in architectural circles, prefabrication peaks in a modernist context. However, circumstances have changed, architecture's production modes have evolved, as have its observation modes and its very objects of analysis. Nonetheless, despite the changes and an inevitable fragmentation of a modernist narrative, a certain notion of prefabrication has subsisted, often scarred by misconceptions or equivocal connotations. Early on, prefabrication appears as one of the arrows pointing to a path of progress and positivist belief of an industrial era. More or less local materials and modes of building, leave their founding *place*, and new materials, technologies, and production methods emerge, transforming the ancestral architectural modes of intervening, that had archetypally been based on a patient dialogue with their close environment. The sphere of the natural and vernacular—an organic evolutionary consistency—is progressively abandoned, and it is moved towards the construction of a taxonomical, abstracting and typifying reality—a numerical consistency—in which the scale of production becomes the superlative mantra, it too pointing to increasingly global processes.

The (hi)story of prefabrication is itself a global history. Furthermore, it is a history whose outlines go beyond what is typically considered architecture's field of action, and in this aspect, it has become the target of both prejudice and acclaim. On the one hand, a relationship with the means of industrial production has been looked upon with fascination by some. On the other hand, it seems to be apart of an *official* architectural history in the majority of cases in which its implementation succeeded in larger production scales. Nevertheless, the modern masters themselves have proclaimed it as a hypothesis to take seriously, testing and using it throughout. It is also in this progressive motion beyond a comfort zone of what can be described as the architectural *field of action*, that we can find some of the added value that prefabrication can bring to the architectural discursiveness—in the relations that can be established with the industry, with the language of the economy, or with certain sociocultural dynamics.

On the other hand, prefabrication lacks an assertive definition, which introduces an added difficulty to the debate. However, it is also in this difficulty that a broader field of reflection can be found about architecture itself, inquiring about how it is *fabricated*, both materially (e.g., thinking in terms of modules or constructive components) as conceptually (e.g., thinking on knowledge modules or taxonomic concepts such as system or type). Finally, closing the cycle, prefabrication brings to the forefront the notion of product, architecture as commodity (or consumable), which brings us back to the idiosyncrasies of a globalized world, which can be expressed in dialectics such as *local* vs. *global*, *control* vs. *alterity*, or *art* vs. *reproducibility*, and observable in its natural, anthropological, linguistic (semiotic) or typological dimensions.

3 A methodologic potential and improvement of human habitat

Prefabrication has numerous faces. Thus, we must limit the object of study, which in this case primarily focuses on single-family housing. There are several justifications that can be appended to this restriction, but there are two that particularly deserve attention. Firstly, a focus on the problematic (human and architectural) of housing and dwelling. Secondly, the idea of prefabrication of houses as a product in architectural terms—industrialized, publicized, … consumed. It is thus about understanding architecture from a methodological point of view, in which the sphere of design and construction are regarded as collaborating parts, yet excisable in the whole. A perspective of *modularity* of an industrialist nature, which does not necessarily have to restring architectural creativity or formal or functional outputs—e.g. as is the case of mass customization. On the other hand, a perspective that in its opposite does not have to be captive of industrial practices—i.e. not alienating ancestral constructive practices. Finally, above all, that may frame a contribution to the improvement of the human habitat. Thus, this thesis is also a proposal to look at the practice of architectural design under a modular, discrete aegis, closely linked to an industrial language and with intentional reflexes in constructive efficiency, quality or economy—admittedly modern adages, nonetheless impossible to ignore in any period.

Finally, if on the one hand, as a discipline of social and mediatic visibility, architecture is fed by formal feats and the like, on the other hand, it also evaluates these same formalities or stylizations in a binomial action-reaction between practice and criticism. In addition, although there are many architects, many with great quality (others not so much), and an extensive framework of regulations, with many mechanisms of possible scrutiny, recognition of lack of quality in the built environment is [too much often] observable. Architects are, on the one hand, positioned in the legitimate and proper aspirations of their art and, on the other, tied to an immense complexity of social, environmental or economic constraints, where the levels of freedom of creative action are, for better or for worse, subjected to a sphere of control located upstream, where the architect has little or no direct intervention. Notwithstanding the cases in which the negative aspects end up coming from the very architects, the complexity of constraints has the pernicious effect of fading the relevance of the profession, while paradoxically the human habitat is deteriorated.

At a global level, demographic or resource availability prospects do not draw optimistic scenarios for a general improvement of the built environment, although resource constraints may have the indirect positive effect of triggering more pragmatic responses. Unarguably, the problems are visibly out there—sometimes closer than what we may think, from [extreme] poverty to lack of access to water, sanitation or fuel, and so on—and a response in a *business as usual* mode will probably be insufficient. It is known that an unlimited belief in progress has limits, and that technological development alone will not suffice[7]. In a way, while the future was viewed with positivism in modernity, we now distrust that same future—and perhaps prefabrication makes as much sense as before, but for completely different reasons. On its own, architecture cannot solve *society's ill*s. Nevertheless, architects will probably have to get used to leave their comfort zones (perhaps more than ever before), adjusting practices to new realities and the reality of global resource constraints. In this perspective, the confrontation with some of the *old demons* of prefabrication has here an intention that is both scrutinizing and provocative.

It also matters to show prefabrication as an option, not always regarded favorably by architects, which may carry other values that are not necessarily focused on the inevitable *aesthetics* in which much of the mainstream production and dissemination of architecture has largely been focusing. Whether cherished or not, these alternatives do exist, are part of the ecosystem of human constructions, and can contribute to the overall improvement of the built environment. In brief, it is useless to exclude them, but instead bring them a sense of normality in the praxis. Therefore, it also aims to be a contribution to the (re)centralization of focus of the disciplinary action of architecture in the improvement of the built environment quality, in the belief that it is through it that the profession will continue to make sense and to be relevant in the future.

Prefabrication, or *the idea of prefabrication*, has long rendered visible another bias that persists among architects, which in many cases can be related to a certain ego of authorship. Moreover, more or less based fears that the prefabrication is hazardous to the built environment, by connotations such as low constructive or architectural quality, in fact are not that different from fears such as those that can be attributed to the speculative real-estate of great footage. Ultimately, that can be considered as a matter of standpoint and perception, and perceptions may be deceiving. In the end, the great difference can at best lay in doing things well, instead of not so well, keeping professional and human integrity, and that certainly that does not depend on any constructive method or technology, prefabrication or any other.

4 Road Map

This thesis is distributed over a main volume and an annex volume, the latter complementing the subjects of the first. The main volume is organized in four parts, containing two main chapters, conclusions and an epilogue. The first part establishes a general background to the theme: starting by addressing the subject of industrialization and the housing problem in a modernist context; to subsequently formulate a review of a (post)modern period through structuralist building blocks; and finally expounding several taxonomical perspectives that establish a background of systematic approach possibilities towards architectural production. The central part, the second, is where the prefabrication theme is thoroughly expanded: from the establishment of a prefabrication vocabulary through a view on the historical evolution of constructive practices and a definition of terms; to the expounding of archetypal comparison paradigms of an industrial sphere with architectural production modes; the addressing of variability aspects; the clarification of a modularity lexicon; and finally culminating in an extensive description of the development of a modular prefabrication case-study. The third part extracts the main conclusions in respect to the central prefabrication theme, expounding them in the form of take home notes. Finally, the fourth part constitutes an epistemological epilogue, where we more freely express concerns related with the ways architecture is contemporarily and globally *fabricated*.

I A Mechanistic Inheritance

A task is thereby set for thought: that of contesting the origin of things, but of contesting it in order to give it a foundation, … that origin without origin or beginning, on the basis of which everything is able to come into being.

—Michel Foucault[8]

Somos fragmentos e projectamos isso uns nos outros.
[We are fragments and project it on each other. *(Free translation)*]
—Ana Teresa Pereira[9]

Marco Polo describes a bridge, stone by stone. "But which is the stone that supports the bridge?" Kublai Khan asks. "The bridge is not supported by one stone or another", Marco answers, "but by the line of the arch that they form". Kublai Khan remains silent, reflecting. Then he adds: "Why do you speak to me of the stones? It is only the arch that matters to me". Polo answers: "Without stones there is no arch".

—Italo Calvino, *Invisible Cities*[10]

1 INDUSTRIALIZATION AND THE HOUSING PROBLEM: ARCHITECTURE'S FOUNDATIONS THROUGH MODERNISM

1.1 Echoes of a Cartesian space and time

The space-time[11] conceptions inherited from Enlightenment's remarkable figures such as Newton and Descartes were key to the formulation of a Modern world-view[12], installing a mechanistic approach on phenomena, embedded by a positivist spirit founded in scientific objectivity, influencing a coming era and architecture throughout. That is noticed in aspects such as the typically cartographic modes of spatial representation—e.g. nautical charts or ruled architectural drawings—or in the conceptions and mechanisms developed to observe and optimize production purposes—e.g. those embedded by organization of Henry Ford's assembly line—and so forth.

René Descartes (b.1596-d.1650) understood space from the perspective of a geometrical extension, laid in the dualistic grounds of the *res cogitans* and *res extensa*, measurable, sub-dividable, neutral, and finally frameable by a set of coordinates[13]. The conception was enveloped by the *method*[14], which persists to our days enrooted in the ontologies of knowledge, in the basis of the scientific quest. In physics, Isaac Newton (b.1643-d.1727) was the first to provide a comprehensive mathematical model of "*space, time and motion*"[15] in his *Philosophiæ Naturalis Principia Mathematica* (1687). But it was not until Albert Einstein's (b.1879-d.1955) *Generalized Theory of Relativity* (1916), that came a confirmation that space and time are inseparable, and a space-time causality with gravity was disclosed[16]. The theory can be regarded as the Rosetta stone of a series of philosophical implications, where all things have a *relational* consistency, from where analogies can be established with nature (e.g. through the notion of ecosystem), with a human sphere (e.g. through the notion of social network), and so on.

In 1941, Sigfried Giedion (b.1888-d.1968) published the well-known *Space, Time and Architecture: The Growth of a New Tradition*[17]. Giedion's writings denote a certain operative, or even a dogmatic tone, which broadly lines up with the mainstream architectural discourse of those days, where it is fundamentally implied a Cartesian outset of methodic shades. Subsequent authors, such as Manfredo Tafuri (b.1935-d.1994) with his *operative criticism*[18], have criticized the modernist tone and its strings of dogmatisms, without which architecture's freedom could apparently be limitless and potentially richer. On the other hand, we must recall that architectural modernity has had its virtues, and that our multi-referential world also needs critical (thus implicitly partial) modes of describing history, as Giedion did, to establish and endorse those references which otherwise may fall under the radar. To recall certain aspects of some discourses, as that of *space and time* in architecture, is not a way to devaluate the importance of any sort of *operative criticism*. All the contrary, it can contribute to locate and understand our world through an architectural perspective, which too needs to nurture and refresh its references outside a vociferous loop of trends and superficial imagery where it seems to recurrently fall: un-referential, purely relational, or instantaneous [complement with: **Annex, I.2 The fragment experience of space-time**]. Anyhow, in the architectural praxis, the modernist posture, as embodied in Giedion's *space and time* exposure, is implicitly still largely in action, and its Cartesian outset still mostly inevitable.

As in any other human activity, in architectural production everything ends up being related with some sort of organization and/or conformation of space-time related phenomena. Instead of plainly surrendering it to a sphere of Cartesian control, we can understand it more as expressing the potential for multiple directions, and hence multiple forms, as many examples subsequent to a modernist era have arguably attempted. For instance, that was the case with the principles implied in Jørn Utzon's (b.1918-d.2008) *additive architecture* manifesto (1965)[19] or, in a broader dimension, with the *architectural structuralism* rule-based design proposals[20]. Of the first we can find built manifestations such as the *Kingo houses* (1958), or the *Espansiva System* (1969), and of the latter works such as Aldo Van Eyck's (b.1918-d.1999) *Orphanage* (1960), or Moshe Safdie's (b.1938) *Habitat'67* (1967) (Figure 1). These examples cross distinct architectural manifestations, different proposals by different architects with different interests and conceptions. Yet, in common they all contributed with an analysis and projection of specific space-time realities, namely by typifying elements that can be connoted with principles of economy—through production scales or repetition, or use of industrialized methods of construction, and so forth. This has occurred without relinquishing an idea of diversity, or even a certain organicity in the outputted forms. By doing so, they have also shown that the industrialized methods of construction that modernity brought about to the stand, did not have to be looked as restrictive, limited or downgraded approaches, as biased by some. Instead, they could be profoundly Modern, while disclosing something beyond.

It is not our purpose to evaluate the impact of Giedion's or any of his pairs' ideas had in outcomes such as these. Yet, the latter would certainly not be conceivable without a modernist precedence. Indeed, we can observe modernism as the peak expression of a Cartesian conception in architecture, with its *space and time* references and the like. Similarly, we can affirm that its primary critics, and some of its inheritors, have explored under a relativist frame, more concerned with relational elements in a multi-referential, dynamic process of construction, where the space-time referrals are too not unique, and an Darwinistic evolutionary stance is also implied. In this sense, the latter is too a conception that has opened room for architecture to deal with other referrals which are not only those of the canonic physical space (Newtonian), but also the virtual, utopian or imaginary, as well as of networking conceptions or heterarchical distribution of constructive or spatial elements. Finally, it is a conception whose current

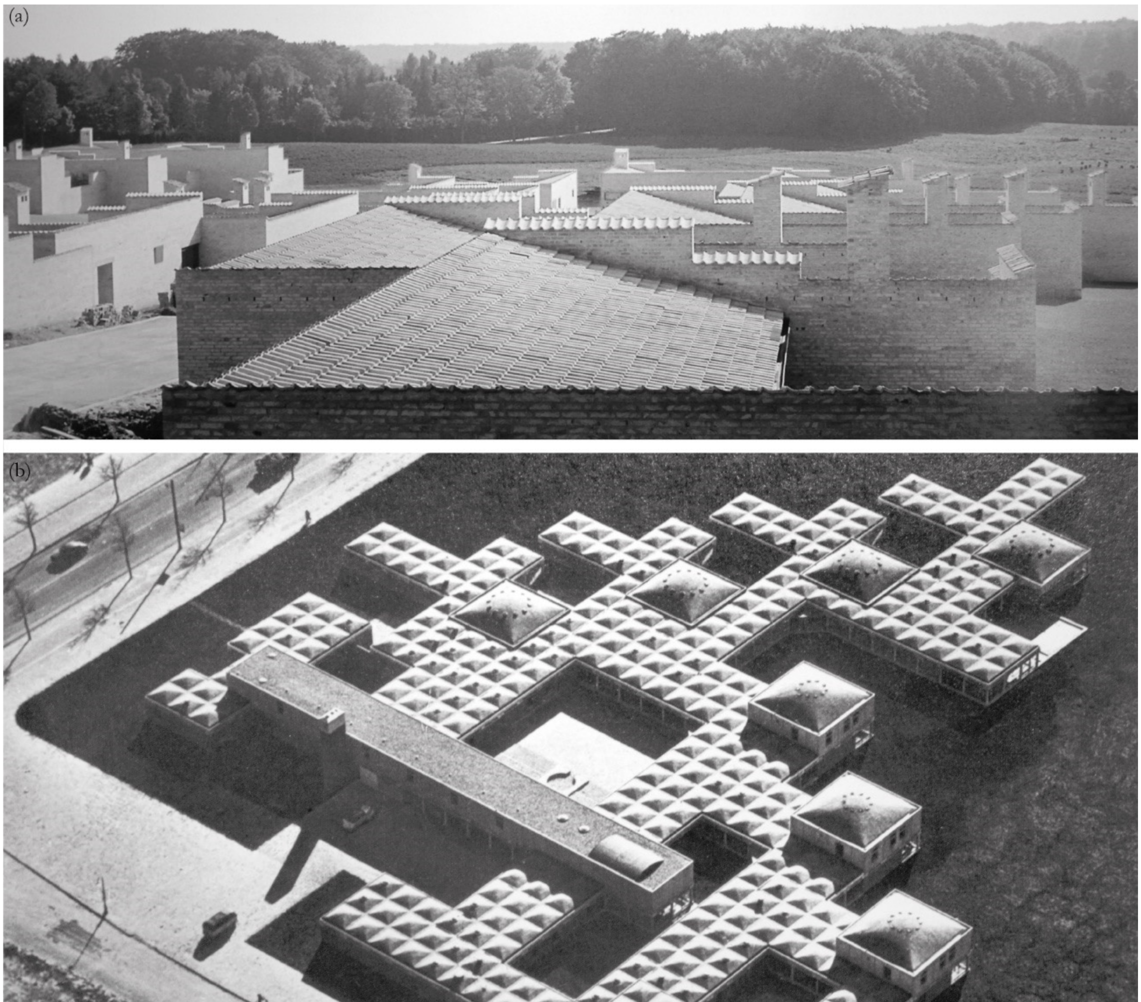


Figure 1. Utzon's *Kingo houses* (a), Eyck's Orphanage (b) and Safdie's *Habitat'67* (c).

global context enacts an ease of information availability like never, rendering architecture's *secrets* more accessible, which leaves it more vulnerable, but also potentially more powerful.

Since Einstein's days, science has conceived multiple dimensions standing beyond the humanly intelligible *3+1* of a space-time continuum[21]. Nevertheless, the dimensions of analysis that commonly matter for architectural production have not fundamentally changed for centuries, mostly located within a space-time frame that is both Newtonian and intrinsically phenomenological[22]. Indeed, architectural production, as we have come to know it from history, typically deals with a tridimensional space, and at most with its conformation within a certain time frame[23]. Also, we must not forget the *experiential* dimension, subjectively occurring throughout building's lifespan—as Stewart Brand[24] pointed out, buildings do not crystalize in one moment in time, but are ought to be lived and experienced (inhabited), having a life of their own. In western architectural culture, these spatial notions are traceable back to Vitruvius, which refers the horizontal ground plane of reference—smoothing and leveling the terrain, to create a stable ground where things can be swiftly be built upon—and the vertical reference—pictured by the man standing upwards, with the head facing the cosmos and the feet facing the earth[25]. From that notion, buildings are thus earthly erected facing gravity—the upright directional reference—the elements, its users, and these altogether in time. This already indicated not simply a *3+1D* space, but a space-time which had at least another kind of *experiential* dimension provided by the user, that is, a relationally human space.

Indeed, the architectural production, in its re-conformation of space-time ought to require an attitude that transcends a geometrical dimension, a strictly purposeful action or functionalist prediction[26], since it implies interference in behavioral necessities. Ultimately, the latter are not aprioristically definable, even if statistically more or less expectable, since subjectable to volatile desires, aspirations, and the iterative path of relations with a changing surrounding world. Moreover, the human social being is a cultural being, with implications that have come a long way from the fundamental human act of appropriation of space, quintessentially illustrated by the mythic occurrence of the gathering by the fire[27]. To the Vitruvian vertical and horizontal dimensions, its references given by the ground and the upright figure with head facing the *firmament* and feet the earth, a social and cultural stance rhetorically introduced the public and private dimensions of man's life. As a hub from where multiple switches emanate, the quintessential dwelling—ontological artifact for human inhabitation—was hence located between the public and the private spheres, as an essential element for human life, both as protective device and social core[28]. In this sense, the dwelling can be regarded as proto-city and its microcosms, both subject to the same principles. It is thus in the fiery warmth of this both mythical and familial gathering of Man in an atavic space-time, that arguably too architecture finds its birthplace[29]. It is too in the dwelling's milieu that a new modernist architecture would initially focus.

1.2 The establishment of a modernist architecture through *CIAM*

Modernist architecture echoed a certain fascination on the industrial production. "*A house is a machine for living in*" are the famous Le Corbusier's words in *Vers une Architecture* (1923)[30]. This new, modern, machine age, ruptured previous conceptions both artistically and intellectually. As it had happened in the arts, an interest grew in exploring beyond figurative or stylistic modes. Concordantly, as implied in the declaration of La Sarraz, for the early *CIAM* congressional representatives, modern architecture had to be viscerally created from the most basic relations. Furthermore, the new way had to be widely endorsed to the public[31].

On the one hand, a critique was made to the historical-based aesthetics, most notably to the neo-classical approaches, but also to the typical XIX[th] century eclecticisms and the like. On the other hand, in due time, it would also become clear that the fascination on the new, limitless possibilities would not reach full maturity. The considerations found a superlative metaphor in the *machine*, which could be connoted with causes (e.g. industrialization and consequent urban growth), effects (e.g. new social and working paradigms, different family structures, birthrates), or idealized aspirations (e.g. produce houses as if were machines)[32].

While a new idea of progress flourished, it grew a renovated interest in ancient and remote cultures[33]. Alongside, the natural and anthropological findings, added to the technical (e.g. photography) or the scientific (e.g. relational space-time in physics), contributed to the artistic boiling of the turn of the century. As arts were becoming more abstractly *modern*, with the *constructivism* or the *gestalt*, they were also becoming aware of earlier and remote cultures, of a nature leaving the enlightened precisions of the *realism's* or *naturalism's*, and acquiring different humanistic features, as reflected in the works of leading artists such as Gaugin, Picasso, Klee or Modigliani. Broadly, the influence of the rich intellectual and artistic developments of the turn of the XX[th] century in architecture can be put between a certain aesthetics of the machine (e.g. *Futurism*) and a certain aesthetics of nature (e.g. *Impressionism*) anchored in humanist convictions and a positivist spirit, producing a rich and varied legacy of outputs. Architecturally, it was neither a hollow aesthetics, as a subsequent critical accusation of a modernist *tabula rasa* could lead to presume. It was an aesthetics where the aspects of the human nature, as represented by vernacular traditions or by the needs portrayed by the urban hygienization, were firmly present.

The *CIAM*, as its terminology denotes, would be set up to develop and promote the modernist ideas, with main discernable focuses in housing and urbanism[34]. Its first five meetings took place before WWII, and through the spoils of WWI and the Great Depression. Its foundation, with the declaration of La Sarraz (Switzerland, 1928)[35], revealed the famous four-part division of functions subscribed in the early *CIAM*, while it rejected the formal archetypes that had been a trademark of the XIX[th] century architecture. That came in favor of a conceptual core laid in science—"*house life is* *about a regular series of precise functions*", as put by Le Corbusier in 1929 in the Frankfurt congress[36]. In its inceptions, the movement became the playground par excellence of notable members such as Giedion, Gropius or Le Corbusier, which took the forum's opportunity to spread their doctrine. At times, the tone sounded more propagandistic or idealistic than substantiated in a methodology of some sort[37]. Nonetheless, the seriousness and relevance of the proposals is unquestionable and an analytic tone prevails, as recognizable by the ramifications that extended far beyond their historic conjuncture. The contributions are foundational in the least by means of their radical and valuable, interventive and provocative ideas, addressing the great architectural issues of their times, with a firm translation in the idea of a new, modern spirit—*l'esprit nouveau*.

If the declaration of La Sarraz served as a model to embrace a modern discourse, an also relevant landmark followed in 1942. That was the year when, after a ship cruise session on the Mediterranean, Le Corbusier publishes the *Chartre d'Athénes*[38], based on the *Ville Radieuse* book (1935), containing an account derived from the discussions taken from the first five meetings. The charter set a total of ninety-five points, numbered as if epistles, distributed in six topics: *habitation*, *leisure*, *work*, *traffic*, *the historic heritage of cities*, and *conclusions – main points of the doctrine*[39]. Unmistakably ascribing to a credibility that can typically be associated with a presumed scientific objectivity, it was expressed with a rationalistic, analytical tone. With it, buildings should have ideal solar orientation, ideal spacing, ideal location, provided by ideal green spaces, served by ideal transportation to minimize commute troubles, in streets with ideal width, and using ideal speeds—the perfect place for an ideal Man. Moreover, historically relevant buildings were to be kept only if considered of good value, and their conservation of no much trouble to the implementation of the modern predicates, and so forth[40].

However, the deterministic tone became unacceptable to the younger members who joined the congress after WWII. In fact, two phases can roughly be distinguished when considering the overall *CIAM* meetings[41]. A first phase arising from the housing problem of the industrial metropolis, embodying the functional city, building or greenery, under concepts such as Giedion's *space and time*[42]. A second, attempting to establish different, more emotional links between social and built structures, which the first stage did not ignore but seemed to have been somewhat forgotten, with consequences in how urban planning and form were understood. The difference can probably be explained by the period of WWII that had intermediated the two stages, with traumatic implications also through some massive post-war reconstruction undertakings, and concomitantly because there was a new generation on the course of making its affirmation.

1.3 The housing problem in the modernist formulation

The origins of the foundational *CIAM* had many faces, namely social (e.g. housing for workers migrating from rural areas and overcrowding cities) and artistic (e.g. new conceptions of form). The most profound roots were related with the housing and concomitant urban issues, the difficult inheritances of the establishment of an industrial age, as of WWI, or as of the economic depression. Sanitizing cities which were of escalating size and complexity, providing proper conditions to its affluent workers, were among the key aspects commanding (and demanding) a *new scientific approach* to architecture in the first decades of the XX^th^ century[43].

As it is well-known, the Industrial Revolution had established a new period in the development of human settlements. The dwelling, a shelter for individual and family use, and the urban setting as the dwelling's background towards community life, would be deeply transformed by a set of significant technical and political innovations. Reforms initiate when the issues of urban and territorial organization emerging from the industrialization begun to be more clearly understood. It became obvious that the rules on which the pre-industrial city had been based would not fit the new developments. Thus, with the wild development of the industrial metropolis in the XIX^th^ century, housing became a major social issue. Big territorial shifts occur, with a massive migratory flow from rural to urban areas, where people would come, e.g., in the search for work in the factories located in the city fringes. Alongside, there was population boom in the second half of XIX^th^ century in most countries where industrialization took a stronger pace. As result, there was a widespread housing deficit, with many people accommodated in cities whose pace of growth could not keep up with the demand.

Likewise, for the first time in history, home and workplace division occurs on a mass scale. The workforce became detached from the workplace, and a new set of issues aroused from the conflicts between people and transportation. The rise of the big industries and of new modes of transportation, such as the car or the train, contributed to urgent house demands, which ultimately led to a change in planning philosophies. The railway sliced the city, non-residential business centers sprang up, market mechanisms contributed to break cities into differentiated zones, and so forth. Constrained to the valuation of land price, the residential, commercial or industrial areas naturally ended up getting economically [and thus socially] segregated.

The dramatic growth of urban population was confronted with the lack of proper water, sanitation or energy sources for heating or cooking. The insufficiencies were confirmed by epidemic surges of cholera, typhoid or tuberculosis, particularly before the occurrence of some important advances in medical sciences during the second half of the XIX^th^ century. The first international economic crisis, a period of a relative economic stall between the 1870s and the end of the XIX^th^ century known as the Long Depression, did not contribute to any improvement. Starveling rural workers escaped in even higher numbers to already crowded cities and, consequently, conditions were further deteriorated. Adequately providing proper housing conditions in the cities thus became a central matter from the second half of the XIX^th^ century onwards. In the early XX^th^ century, the WWI (1914-1918) and, successively, the effects of the Great Depression in the 1930s, would further stress the house problem. The case of Berlin during the Weimar Republic (1919-1933) is remarkably illustrative of the issues in the industrialized metropolis in the beginnings of the XX^th^ century[44]. The sort of reported problems, although intrinsically dated in their specificities, can certainly be regarded as universal in their type, as observable by their historical recurrence, and their sound similarity to the growing pains of the developing countries in our days.

Dwelling and city, house and urban policy, became interdependent with industrialization. Initially, the poor housing conditions were the purview of engineers and city planners involved in the water supply and sewer management. With the shift of production and social structures, cities become territory for experimentation and urban and house research. There are several examples, more or less conceptual, more or less utopian, or more or less implemented. Some addressed urbanism through innovative dwelling concepts, with examples that can be regarded as groundbreaking or even utopian for their epoch. Nonetheless, some cases would become true prototypes of modern housing. In this sense, the *New Harmony* of Robert Owen (b.1771-d.1858), the *Phalanstère* of Charles Fourier (b.1772-d.1837), the *Victoria* of James Silk Buckingham (b.1786-d.1855), or the *Familistère de Guise* of Jean-Baptiste André Godin (b.1817-d.1889) are some of the most representative. Other examples, each at their scale and purposes, denoted even more ambitious programmatic intentions for the city. Proposals thoroughly describing the sort of actions to undertake, from the block and street to the dwelling level, where examples such as the *Barcelona Eixample* of Ildefons Cerdà (b.1815-d.1876), the *Linear City* of Arturo Soria y Mata (b.1844d.1920), the *Industrial City* of Tony Garnier (b.1969-d.1948), or the *Athens Charter* of *CIAM* are unavoidable references. These had the merit of surpassing the classical urbanism and, additionally, to be both true theoretical and practical essays of the modern urbanism[45]. In all cases, of all the undertakings, the gravitational sphere of *CIAM* would echo more intensely than any other.

With exceptions, such as those we have referred, architects would only begin to develop a widespread interest in the house problem of the working-class in the beginnings of the XX^th^ century. Examples of this period can be found, e.g., in speculative communal blocks of *Karl Marx Hof* in Vienna[46], or of Gropius, Haesler, Fisher and others for the *Dammerstock* neighborhood in Berlin[47]. The problem moved to the top of political agenda in the end of the 1910s. For instance, in Moscow, in 1919, the state promoted a competition for a model neighborhood of what would be a new city[48]. In the end of the 1920s, architects joined forces through *CIAM*. Rotterdam, Frankfurt, Warsaw, Paris, Prague, Amsterdam, Madrid, Budapest, Brussels, Vienna, Berlin, or Moscow, from these and other places, projects were scrutinized by leading architectural professionals. From these, studies and designs would be produced, and buildings constructed, through new, modern and functional principles.

The content was to master the form. Adhesion to a revolutionary ideal and a renewed social and political commitment was accompanied by the conviction that all this should correspond to radically new artistic forms, freed of any bond to past traditions. On the other hand, the ideals of the architects and artists were also based on naive and romantic (or delusional) assumptions, as expressed on the utopia that architecture is able to solve society's ills—"*On the day when contemporary society, at present so sick, has become properly aware that only architecture and city planning can provide the exact prescription for its ills, then the time will have come for the great machine to be put in motion and begin its functions*", writes Le Corbusier[49].

A *New Objectivity* renounced the cosmic pathos and the abstract outburst of *expressionisms*. In Gropius' words, buildings were to be made of "*precisely defined forms, simplicity in multiplicity, repartition according to function and restriction to typical basic forms. It should also be sequential and repetitive*". These would be "*shaped by internal laws without lies and games; all that is unnecessary, that veils the absolute design, must be shed*"[50]. The *new spirit of building*, based on technological achievements was about to conquer the *civilized world* and *building as the way to shape life's processes*. Architecture's formal outputs denote artistic references spanning from the *Constructivist* approach of El Lissitzky, to the *De Stijl* of Theo van Doesburg, or, the *Gestalt* in the *Bauhaus*. In the 1920s, the Modern spirit of *CIAM*, embedded in an implied Taylorist philosophy of scientific management, would look for objective ways to optimize floor plans, minimize areas to the least conceivable relatively to their assigned functions. In a way, form could no longer be distinguished from function, and so the academic compositional principle, typical of the XIXth century no longer made much sense. The catchphrase of the American architect Louis Sullivan, "*form follows function*", would long stand as a popular mantra.

1.4 Convolutions of a modernist science

The demand of a standard dimensional reduction of the social housing production—required by both the general situation of scarcity, derived from the Great Depression, as for the actual decline in the household characteristics—coincides with the process of rationalization of the distribution of elements in a plan, consistent with the investigations to optimize housing via rationalistic methodologies. A whole series of proposals of plans distributions and sizes, including those presented in the *Existenzminimum* exhibition in Frankfurt, of the 1929 *CIAM*, would be proposed with a priority objective of minimization. Generally, the exhibited proposals renounced a review of the internal housing structure, attested the lack of a critical insight regarding the existing conditions, and were limited to a sectorial rationalization of the typologies.

Related research flourishes throughout this period, addressing housing types and their aggregations, the development of building and urban standards, or issues related with solar orientation and ventilation. In addition, there are developments in the field of prefabrication and modular or dimensional coordination, of which Le Corbusier's *Modulor* stood as one of the most famous examples. It is also of relevance the development of the concept of *standard*, understood by the rationalists as guarantee of a minimum, not only quantitatively, but also qualitatively, in the production of modular elements applied to the social house[51]. The high quality of some of the outputs is an impartial testimony. Broadly, it is emphasized the need to devise methodologies that could clarify the project, that is, clarify the architectural job from the adoption of practices that should not be based only in subjective intuition, but in scientific observation that might be transmitted and controlled.

Research would have a large production in the study of ergonomics, in circulation optimization or in production rationalization. Some developments transported efficient production techniques to the building design. Floor areas for a certain activity, the description of each single function (eating, sleeping, cooking, and so on), how that could spatially relate to others, and so forth, soon made sense conceiving them through quantitative prescription. While some researchers, through ergonomics, mapped the human body to find out the healthiest and least tiring postures in the different activities, other have tried to map the activities that take place day in day out in a house. A well-known example, by Alexander Klein, was a series of diagrams of how a house is used day and night. By establishing when and how a certain action takes place, it would be possible to infer the minimum space it required. By grouping functional units (e.g. bedrooms, living and dining rooms, kitchen or bathrooms) precisely according to the optimum, a sense of objectivity would be retained (assuming the space would be used as originally designed, i.e., with little or no change over time). In 1936, Ernst Neufert coordinated the publication of a comprehensive volume entitled *Bauentwurfslehre*, depicting information on the measurements necessary for any imaginable activity—from the dimensioning and spacing of chairs in an auditorium, to road traffic and park dimensioning—becoming a reference for generations to come. Le Corbusier's *Modulor*, first published in 1948, and with an addition, the *Modulor 2* (1955), became a reference as a dimensional regulating system, an attempt to universalize dimensions and proportions through a progressive scale, based on the Fibonacci sequence and the related golden ratio φ.

Housing thus becomes an architectural research laboratory par excellence. The minimum dwelling problem, says Gropius in the *CIAM* of Frankfurt, "*is to establish an elementary minimum of space, air, light and heat essential to humans to fully develop their vital functions without restrictions due to housing, or at least establish a modus vivendi rather than a modus non moriendi*"[52]. It is a *modus vivendi* in which, in the least, every adult should be provided by a *practical minimum* invaded by light and sun[53]. However, to a rational pursuit of an *Existenzminimum*—the biological minimum of air, light and space essential for life—Alexander Klein and others add psychological objectives[54], a notion reinforced through the *Chartre d'Athènes*[55].

To the *house* it was attributed the function of refuge against the contradictions and conflicts of the city, i.e., the privileged place for privacy, rest and strength recovery of the workers' force. As in Vitruvius', the house was again revisited as cell and proto-cell of the city—from the mirror of its intimacy, (urban) man becomes a social being, finding its place culturally in the world. As put by Giedion, the simple housing cell leads to the organization of the construction methods, and these lead to the organization of the entire city: *the house is the molecule of the urban organism*[56]. With tools such as the *Modulor*, it was finally possible to link it *scientifically* all together.

Overshadowed by more famous figures, such as Gropius, Taut, Giedion or Le Corbusier, the works of Alexander Klein or of Karel Teige figure among the strongest advocates of a scientific spirit. Klein had a remarkably innovative and mathematically rigorous methodology, comparing various types of dwellings, aiming to determine objective terms for the valuation of the design quality[57]. Teige accounted the Frankfurt's derived *Existenzminimum* exhibit, revealing a scientific, functionalist approach grounded in Marxist principles[58]. In 1929 Teige would notoriously criticize Le Corbusier's never built *Mundaneum* project, affirming that the rational functionalism from where Le Corbusier would have had departed was being lost, on a way to become a caricature, a mere stylistic mode. Teige's belief on rational methodologies can be summed up in the words: "*the only aim and scope of modern architecture is the scientific solution of exact tasks of rational construction*"[59] [complement with: **Annex, I.3 Illustrating ideological incongruities**].

Anyhow, it is notorious that much of the early agenda of *CIAM* deals with critical housing and urban issues[60]. With nuances, the theme would be continually revisited until the latter stages of *CIAM*'s meetings. Indeed, from the foundation (1928, La Sarraz, Switzerland), until the dissolution (1959, Otterlo, The Netherlands), the grand themes in discussion consistently verse housing and its entourage, from the most atomic level of analysis (e.g. the dwelling cell), to a larger territorial level (e.g. the urban planning). La Sarraz's programmatic setup had been clear through its four main points—"*General Economic System*", "*Town Planning*", "*Architecture and Public Opinion*", and "*Architecture and Its Relations with the State*"[61]—where the underlying idea was to create an agenda to implement a new architecture in a new world. That agenda is pinpointed by a general idea of rejection of a certain bourgeoisie establishment of the very architectural profession. Despite the quarrels, as those portrayed by Teige's critic to Le Corbusier's *Mundaneum* never-built project, intuition and art of building were to be commanded by science, configuring a true flagship of a Cartesian positivism. With no less relevance, these also embodied an ideological program, as well as a propagandistic plea, setting the tone for the subsequent *Chartre d'Athènes*.

Implicitly denoting a Marxist philosophy, and a Socialist affiliation, in the first point of the founding La Sarraz's declaration, architecture was regarded in terms of a transversal idea of economy. The purpose was to achieve economic efficiency to deal with the impoverishment problems largely affecting society. Towards this goal, make use of rationalization and standardization methods both in architectural conception, as in the building industry realization. This meant making both architecture and industry to evolve single-handed, through working methods simplification both in factory and in-situ, through reduction of unskilled labor and increasing skilled technicians, and finally through a re-education of *consumers*. The latter would be prompted to have less individual demands for the sake of a greater common good, which was housing to be available for the maximum number of people. Machine production was placed in the opposite pole of craftsmanship, a statement which referred both to a seemingly inertia of traditional academia to adopt new methods and forms, and a hint to embrace the vocabulary of industry and its methods, whether in processes, forms or even philosophy of design and building production. In the second point, planning was regarded as an essential way towards an overall organization of life in all regions, both in urban and rural areas, through means of a functional order and not by aesthetically derived pre-conceptions. The famous four-part functionalist division—i.e. *dwelling*, *work*, *transportation* and *recreation*—is therein drafted through *dwelling*, *working* and *relaxing*, and focusing action on the *division of the soil*, *organization of traffic* and *legislation*. A key point was to follow a rigorous causality between statistical data derived from the economic and social environment (e.g. demographics) and spatial occupancy and distribution of inhabited areas, green areas and traffic. These were to be constantly monitored for updated status, so that legislation and an ever-evolving technical sphere would be kept in close pace. In the third point, a call was made for architects to spread these ideas on public opinion, referring the misconceptions to which architecture was often taken for—e.g. aesthetical preconceptions or expensive connotations—and which had diverted it from what should be its main concern: properly articulating the house problem. Set in a long term, the goal was to, through schools and academia, educate people—clients, architects, builders, and so forth—for them to embrace new ideas and leave behind the old connotations. Finally, on the last point, it was reinforced a statement on the obsolete and inertial academia establishment, and its role and influence in the State decision-making over planning and architectural works. References span through works revealing inefficiency, economically disastrous, monumental, or aesthetically or formally outdated, nonsensical to the spirit of the times. These would occur at the expense of the urgent tasks of housing and planning; at the expense of the ultimate reason for all the concerns, which was the very idea of progress, of future, of new: of modern.

Our zeitgeist is certainly different, and the modern(ist) architectural history had much more to it besides *CIAM*. However, despite the efforts, and with due differences, generally the preconceived opinions manifested in the public opinion as expressed in La Sarraz's, as well as many of the sort of problems criticized, are still observable to these days. This can mean many things. For instance, that the noble intention to *educate* has failed, which in the least reflects a change of entourage, or even that the way the problematic was laid was doomed to be dated. It can also mean that the sort of *vices* whereby the profession was implicitly criticized *by the public* persist, and which can be summed up in a tendency for privileging certain formalistic or stylistic approaches. In that respect, Teige's critique to *Mundaneum* should remain valid, not necessarily just in what refers to a reasoning for a scientific approach, but especially in what refers to what can be called of truthfulness of form, which subsequent authors such as Giorgio Grassi have so vividly addressed[62]. In the least, it should echo towards irrefutable ethical stances.

Possibly this clash will never change, as architecture will always be about formalizing artifacts, hence necessarily overlooking a part of the available reality in favor of other, in part science, in part free, individual, artistic expression. Furthermore, implicitly, artifacts are not consensual, except in an ideal—unreal, utopian and dictatorial—isotropy. Past records are representations subjectable to distortion, but still is all there is as ultimate validation tool. Yet, the radicalism of a seemingly *tabula rasa*—as historically but not entirely accurately, to some extent, the Modern Movement may be suspect of—can sometimes enable a fresher insight, as it did with the clash embodied by the early *CIAM* and the previous academia establishment. However, as relativism epistemologically implies, there is no absolute referential, thus no definite grand answers, and no solutions *the solution*. In the reality looked from human eyes, there is no single universalism, just attempts, questionings, an endless path of investigation for the *Homo Significans*. In time, *CIAM* would be questioned and later more clashes would arise. Nevertheless, the burst of *CIAM* certainly took architecture to a different place and we could not conceive it today without its shockwaves.

1.5 *CIAM* dismissal towards a new modernity

A younger generation of architects begun emerging in the post-WWII *CIAM* meetings[63], revealing a gradually sharper critique of what had become a certain modern orthodoxy, which had, in their views, turned the early modern ideals in a sort of stylistic, technocratic, and socially unresponsive approach[64]. Broadly, the final period of *CIAM* is pinpointed by a determination to overcome a certain Cartesian fundamentalism of the early stages.

Postwar reconstruction was a primary igniter of this purpose. Whole cities had to be rebuilt in a short period, with priorities in many cases given to provide housing in large scale, and with the *Chartre d'Athènes* widely adopted as methodological guidance. Prominent examples can for instance be found in The Netherlands, as is the case of the reconstruction efforts undertaken in the city of Rotterdam[65]. In some cases, such as in the social suspicion laid over UK's postwar temporary housing program, reconstruction urgency led to a perception of a qualitative decline and a consequent criticism[66]. In the first post-WWII congress, the *CIAM 6* (1947) entitled *Reconstruction of the Cities*, though with a quite explicit general theme in terms of tackling postwar reconstruction, the spirit was set to address the *emotional* and not only the *material* needs[67]. However, if different concerns were being expressed, the functional schemata seemed to be kept. Elder *CIAM* leaders kept bounded to earlier conceptions and such did not please a new generation of participants. From that point ahead two sides began diverging.

The younger generation of architects participating in *CIAM 6* brought fresh ideas and the debates with the elder anticipated the challenges to come. Although a seven-point resolution would be issued at the end of *CIAM 7* (1949) some older delegates charged that *CIAM* was "*losing its working character*"[68]. Among other advances, the theme of the emotional needs would be further developed by the *MARS* group (*Modern Architectural Research Group*), the British-*CIAM* think tank formed in 1933. As preparation to *CIAM 8* (1951), the *MARS* group prepared the topic entitled *The Core*, a title suggestive of a concern in re-centering the focus of urban discussion in issues of identity and community.

With *CIAM 9* (1953) came a decisive division between the old guard[69] and a younger generation[70], with the new proponents challenging the functionalist schemata of the *Chartre d'Athènes*. The dissatisfaction was reflected in a critical reaction to *CIAM 8*, with a famous sentence by the Smithson's synthetizing the concerns: "*Man may readily identify himself with his own hearth, but not easily with the town within which it is placed. 'Belonging' is a basic emotional need—its associations are of the simplest order. From 'belonging'—identity—comes the enriched sense of neighbourliness. The short narrow street of the slum succeeds where spacious redevelopment frequently fails*"[71]. Instead of a set of abstractions, they sought for structural principles of urban growth founded on the basic unit of the family cell, re-asserting the significance of the social, as well as of the symbolic features of the built environment. The position also stressed the significance of the values embodied by the vernacular building forms.

The dissatisfaction with the orthodoxy of early *CIAM* prompted national discussion groups and more or less informal international meetings to gather in between the congresses. The drive was to propose a different course for *CIAM*. The first meeting of what would later turn out to be *Team 10* (aka *Team X*) was held at Doorn, The Netherlands, in January 1954, under the direction of Jaap Bakema. The agenda was to make the preliminary arrangements for the next congress, *CIAM 10* (1956) in order to revise the *Chartre d'Athènes* into the *Chartre d'Habitat*. The new generation meeting at Doorn was united by the plea to make towns in which *vital human associations* would be expressed. Despite some divergences, the debates resulted in the *Statement on Habitat*, a document that was to be the first step towards the *Chartre d'Habitat*. Georges Candilis, one of the active members of *Team 10*, asserted that the senior members preconized the creation of a *Chartre d'Habitat* in the same fashion as the earlier *Chartre d'Athènes*. Such would be regarded by the elders as a great success whereas to them, the critics, "*it seemed totally bogus*"[72]. In the end, the pretense new *Chartre d'Habitat* would never came to life.

The *Statement on Habitat* viewed the *Chartre d'Athènes* as an adequate way to address the problems of the XIXth century city, but inadequate to the XXth century reality, which fundamentally carried new social concerns[73]. It envisioned a planning philosophy in which the whole of a community and its specific characteristics would be considered. The concept would be synthesized in the *Scale of Association* diagram[74], which was presented in Aix-en-Provence by the Smithsons[75]. The diagram proposed a replacement of the functional hierarchy of *dwelling*, *work*, *transportation*, and *recreation* emanated from the *Chartre d'Athènes*, with scaled unities of *house*, *street*, *district* and *city*. This was in line with *MARS*'s earlier proposals for the *CIAM 7*, which had recommended the inclusion of the category of scaled settlements from village to metropolis[76]. Through it, the dwelling was understood as the core of the community, and not the representational city center with its public notorious buildings. Architecture was to be made inside-out, returning to its meaning inducting origins, i.e. in man and its habitat. In this perspective, a primary, higher hierarchy structure (e.g. infrastructure) acquired a preeminent role as facilitator of a community, key to give coherence while inducing freedom to the remaining urban thing. Overall, the *Statement on Habitat* was to replace *CIAM*'s functionalist methodology to analyze and compare settlements in different places, as the "*story of the four functions was far too simple*"[77].

Besides *Team 10*, several other discussion groups had been formed throughout the years. That was the case of the already referred *MARS Group*, in the 1930s, or the British artistic avant-garde *IG* (*Independent Group*), in the 1950s, as well as more or less formal, *CIAM* national discussion groups—e.g. the French *ASCORAL* or *Paris-Jeune*, the Dutch *Opbouw*, the Norwegian *Pagon-Norway*. Notwithstanding, from the fertile ground of the criticizing youth sphere of *CIAM*, no group or movement would get a wider visibility than *Team 10*[78]. Some influent older *CIAM* members, namely Le Corbusier, would recognize the value of the young's proposals. It was time to "*turn the page*"[79], he affirmed, supporting the new proponents[80]. Indeed, the *CIAM 11* (1959), in Otterlo, would mark the dissolution of the congress by *Team 10*[81]. Several attempts were subsequently conducted to re-ignite *CIAM*, such as the *ICAT* (*International Congress for Architecture and Town-Planning*), promoted by Jos Weber and other European architects, which would meet in Otterlo (1982), Hamburg (1983) and Copenhagen (1984)[82]. Nevertheless, the *CIAM* formula was inevitably wasted.

In the final *CIAM 11*, Aldo Van Eyck[83], called for a new awareness based on the core elements of human existence expressed in his *Otterlo Circles*[84]. The circles can be seen as a synthesis of *CIAM*'s dismissal and turning point towards a different, refreshed modernity[85]. Anyhow, Van Eyck's proposal is not in rupture, yet fundamentally subscribes a reconciliatory thought. What is foremost valued is the establishment of relationships, to integrate, rather than keeping apart, and by that enriching the whole that is produced. A dialectic of complementaries'—what Van Eyck called *dual phenomena*—arises from this thought, where past and present, classic and modern, archaic and avant-garde, constancy and change, simplicity and complexity, organic and geometric can have a seamless coexistence. It is architecture opening itself to a relational sphere, to the "*shape of relativity*"[86] [complement with: **Annex, I.4 Aldo Van Eyck's Orphanage synthesis**].

Van Eyck, as other *Team 10* participants, sought after architecture as an expression of the community. They aimed to dispense the rigor of determinist, functionalist thinking, dismissing the creation of symbols of community, as it had been implied by some of the monumental works in direct lineage with the *Chartre d'Athénes*. The 1950s planning and building of *Chandigarh*, master-planned by Le Corbusier, and particularly *Brazilia*, by Lúcio Costa and Oscar Niemeyer, would stand as superlative examples of such criticized monumentality, with their deterministic structures, their formally sublime, yet somewhat alienating abstraction. If for the most orthodox *CIAM* modernists architecture could be regarded as a sort of mediated representation, for the *Team 10* participants there should be more a sort of primal language, where meaning and form are interconnected. Ground was thereby open to understand architecture from a new relational way, which was both relativist and structuralist. The aesthetical austerity, a certain monotonic rigidity of the initial modernism, was being replaced by an aesthetics of a new complexity based in a relationally dynamic understanding of structures.

The emphasis on how space-time could be embodied was too set in opposition to a prevailing modernist conception of space in architecture, iconically formulated through Giedion's *space and time*, where the essence of modernist architecture is regarded as the blend of space and time through the experience of movement. Architecture, "*the masterly, correct and magnificent play of masses brought together in light*", as had been formulated by Le Corbusier in *Towards a New Architecture* in 1923, emphasized such idealization of space[87]. Aldo Van Eyck's concerns would depart from a different standpoint, expressed in his famous words: "*Whatever space and time mean, place and occasion mean more. For space in the image of man is place, and time in the image of man is occasion*"[88]. The arising question was not how to emulate movement and produce forms out of space-time, but how could people create a sense of place, that is, how could people create their own subjective spaces, or how could relativity find its intentionality in shape. In short, the grand issue was how to humanize the machine of mass rationalization.

These were pivotal times where, in brief, the structural synchrony of the modern transitioned to a historically informed, post-modern diachrony. It is a fertile period, where there were different approaches arising, with distinct conceptual basis and different formal outputs. Anyhow, in common there seems to be an overall return to history and, fundamentally, there seems to be a new critical attitude installed. In brief, the modernist research path seemed to be exhausted, or in the least, the plea for newer and fresher references far exceeded what had earlier been the modernist appeal through its foundational *CIAM*.

In between the rhetoric of theorists linked with what can be regarded as *postmodernism*, and what were the theoretical approaches of groups such as the *Team 10* or the *Metabolists*, there seems to be an agreement that it was time to build a different, denser modern. As Charles Jenks explained in *The Language of Post-Modern Architecture* (1977), at least rhetorically, *postmodernism* succeeded in reviving the narrative potential, and thus a certain historicity of architecture[89]. The rejection of a modernist *moral language* and cherishment of an ambivalent, richer and wider pool is explicit in theoretical works such as the referential Robert Venturi's *Complexity and Contradiction in Architecture* (1966)[90]. However, the greatest criticism towards labels such as *postmodernism* could be placed in an often too literal interpretation of history in the formal outputs, overstating rhetoric. Notwithstanding, the *postmodernism* has had an appealing rhetoric of *complexity and contradiction*, as highlighted by a Las Vegas strip, with its pop imagery or advertisement-like shapes[91]. In a culture of consumption and a secularized society, the great architectural symbols in history, the temples or pyramids, were paralleled to the worship of ordinary forms of product, brand or fashion; with money, as the uttermost symbol *making the world go round*, in the roots of the genetic tree of human artifacts.

The semiotic implications are unequivocal. Architecture, historically connoted as a symbol of power allied to capital, as Tafuri vividly expressed[92], leaves the sacred plinth towards the profane ordinary. To the death of the author, expressed by the *postructuralists* in literature, is proclaimed the death of the architect, as he is a reader in himself, interpreter of everyday signals. *I am a monument* is thus a suggestive motto, paralleling the ordinary with the sophisticated, and from where forms of capital are so utterly obvious that are no longer concealable behind ideological or power representations.

However, the rhetoric of a re-symbolization of space also derived towards a sort of an iconographic revival of historical forms, where the subtleness and intricacy appraised in the discourse gave place to what can be regarded as literal, even caricatural formal acts appraising history. Indeed, if a duck shape may announce a content in the Las Vegas strip, on the other hand a classical, academically informed precision is used in compositional underlays, particularly visible in reinterpretations of columns, entablatures, pediments, and the like.

In other developments, as in what can be acknowledged as a structuralist approach, there are also proofs of a return, or attempt of reconciliation of modernity with history. Such is flagged, for instance, in Aldo Van Eyck's *Otterlo Circles* and is utterly visible in what can be described as a broad-range search for a re-foundation of principles through e.g. anthropology, the study of the historical vernacular built environment, or a refreshed look onto natural forms. In any case, it is clear, or so has stood in a seemingly *tabula rasa* myth, that in a way *history* (or depth of significance) had been neglected with modernism. It is a period when architecture seems to be freed, opening to the entire universe of possibilities, instead of being restringing itself to any sort of canon. Such appears to be an essential point of departure of any movement recognizable as such that have counterpointed modernism. From then on, architecture not only recovers a broad sense of history, as it proceeds with a different reengagement with *nature* or the *archaic* and/or *ordinary vernacular*, while also takes the first numerical steps towards a *digital* sphere.

The moderns such as Gropius had sought for the "*internal laws without lies and games*"[93]. Yet, somewhat in the process, a bound with a non-idealized, with the (imperfect) real, had been lost. In some cases, depth of significance was even purposefully (operatively) discarded. The fact that the Bauhaus school had no history discipline upholds the statement; a fact, as presented by Gropius in the *Bauhaus Manifesto and Program* (1919), was due both to a visceral reaction to the old school, as of and understanding that arts and architecture should return to a profound knowledge of the crafts[94]. Approaches such as *structuralism* also went deeper in search of *inner relations*, but without losing sight of the connotative bounds with the surface. They went deeper without losing sight with the levels of significance without which the structure loses its bounds with any possibility of humanism, as in a pure self-reflexivity of craft; the significance without which the structure has no density, no body, no touch, mere thin air, pure abstract representation.

2 ENGAGED STRUCTURES IN A (POST)MODERN WORLD: CONCEPTS, TRENDS, FORMS AND ALTERITIES

2.1 Structuralism, semiotics and significance

What we can call *structuralism* can broadly be described as a philosophy, or an overall worldview that provides an organic instead of an atomistic account of reality[95]. It can be regarded as a reference word for a *mode of thought*, of *viewing things*, a *method* to investigate and approach in a particular way[96]. Thus, it can be described as about inspecting systems' relations through their elemental structures. Historically, it arises mostly in the XXth century, with notoriety from the second half onwards, manifested in multiple areas, although with emphasis on the social sciences and humanities—ranging from Linguistics, Logics, Semiotics, or Anthropology, and eventually reaching Architecture. It consensually develops from linguistics, particularly from Ferdinand de Saussure's (b.1857-d.1913) referential work[97] prior to WWI[98]. However, it would only be right after WWII, that the pioneering works of Claude Lévi-Strauss (b. 1908-d.2009), using it as model for his anthropological observations, reignited the interest in the approach, and decisively took it outside the field of linguistics. It is arguably from there that it acquires a wider recognition[99], namely the acquaintance of an architectural audience avid of new references.

By understanding that a structural analysis of linguistics could be methodologically derived to language, and thereby to the general analysis of phenomena, Saussure anticipated the discipline of *semiology*. His American contemporary, Charles S. Pierce, devised an analogous label, naming it *semiotic*. Lévi-Strauss' contribution in anthropology, or Barthes' work as critic and social theorist, namely in his *Elements of Semiology*[100] (1964), updating many of Saussure's basic principles, were key to decisively take the analysis outside the scope of linguistics. From there the notion evolved onto a wider conception of language as sign system, providing a common vocabulary to investigate conventions and codes of all types, from the lexicon of fashion, food, or art, to the rules of folk narrative, architectural or even medical codes, through literature, the world of images or the signals of the body, and so forth. As the structural approach pervaded the analysis of sign systems, a critical, poststructuralist reaction arose, fundamentally criticizing an apparent universalism or determinism of the first.

2.1.1 LANGUAGE AND SEMIOTICS

Language is a condition for social or thinking processes[101], to understand who and what we are, intervening between us, human beings, and the world, thus a determining element, even for the very survival. It is what enables dialogue, communication, but that is only possible if we previously subscribe the meanings that precede our own familiarity with it—i.e. if we previously acknowledge the images and/or symbols it entails. The way things are classified through language interfere on our perspective on them[102], yet most of the times we do not have such consciousness, even if we may be rationally aware of it—in the limit, language is invisible to us, transparently pervasive[103]. Finally, the notion of language can be expanded to include all signifying systems which enable access to information, whatever kind that is, thus implying a semiotic.

Ferdinand de Saussure was the precursor of this understanding. Among his contributions, it is worth acknowledging with greater detail four related key notions: the distinction between *synchronic* and *diachronic* observation of language; the notion of meaning through *difference*; the distinction between *language* (*lange*) and *speech* (*parole*); and finally, the arguably more relevant notion of language as a *sign system*.

Saussure was predominantly interested in a *synchronic* approach to linguistics, rather than in a *diachronic* approach[104]. The latter, classically followed by his predecessors, entails a historical or evolutionary kind of examination following from etymologies, phonetic change, and the like. Conversely, the synchronic approach entails a conception in which language is, so to say, frozen at a certain point in evolution to understand its functional principles. Surely that any pretension to make a comprehensive study of language must cover and combine both diachronic and synchronic angles. Saussure did it himself, and defended the usefulness and complementariness of both. Similarly, in a structuralist approach is not refused one over the other[105]. It is nonetheless unquestionable that the synchronic perspective revolutionarily opened a new territory for exploration, with repercussions far exceeding linguistics.

Perhaps one of its most relevant impact aspects is that, departing from a social and cultural perspective, it founded a *structural* way of looking to phenomena. That means that social-related occurrences could thereon also be regarded with a scientific, systematic, or structural spirit, and with it contributing to strengthen some typically loose bounds with the natural-derived sciences. With it, order, method, structure, construction, and so forth, are strengthened as object of philosophy. Conversely, humanities acquire a status similar to the so-called exact sciences, where a synchronic perspective can be paralleled with the search of universal laws—e.g. as in physics. The notion is in structuralism's backbone, in the intention of approaching reality, its phenomena and construction, under a methodological thinking in which there is a guiding principle, or structure.

In that sense, Lévi-Strauss' work stood out, as he used the structures borrowed from linguistics in his anthropological works, thereby leaving the door wide open for others to use analogous methods in their respective fields of research. By getting closer to the anthropological structural relations, his work opened way to understand the world through a return to a beginning, to an aspired ontology.

This conviction in a return to the basics as a source for understanding society was undoubtedly strengthened by the adaptation of the new linguistic model[106].

Saussure formulated that words do not name things, but ideas, or, in other terms, "*language is a form and not a substance*", adding: "*this truth could not be overstressed, for all the mistakes in our terminology, all our incorrect ways of naming things that pertain to language, stem from the involuntary supposition that the linguistic phenomenon must have substance*"[107]. In this sense, what defines an idea is its relation to the other words in the system, and that leads to the concept of *difference* in language. Each sign has a meaning, because it is different from other signs within the same language, rather than because of any linguistic reason to be so. Thereby, the relation between these is expressed as a difference in negative terms, as when saying e.g. *ocean* and *fish* are different. Language can thus be understood as constructed of differences without positive terms. Nevertheless, these are positive when considered in their totality—e.g. to reach a definition of *intense*, we can say *not weak*, expressing the meaning by the negative term of another. As more negative interpolations of this kind are found, the clearer a word is rendered to us, with the resulting meaning thus produced being positive.

In brief, without *difference*, meaning is an impossibility—"*in language there are only differences*"[108]. Meaning is not mysteriously immanent in a word or sign, but it is functional, the result of its difference from other signs. Moreover, a one-term language would be an impossibility, since *difference* requires at least two terms. Thereby, it is reasonable to consider possible, even if rudimentary, to describe an entire universe from a two-term, or binary language, as Saussure himself implied[109]. Such a binary notion entails an evolutionary perspective, one that is organic since it is made of unfolding constructions of meaning, but also one that can ultimately be machined—and it is worth noting that this occurs decades before Alan Turing's formulation of the backbone of today's computing.

Thoughts and sounds, images and symbols, work together through *speech* (*parole*), which is framed by *language* (*langue*), thus enabling ideas to be expressed, and so forth. All of this moves back and forth. Language denotes a shared system with its own rules, that is, the language as a whole (e.g. Portuguese, English, and so on). Speech denotes a particular use of units of language, or what individuals use, from the resources of language in their day-to-day use—speaking, writing, or uttering[110]. In this sense, the language is the entire system, the frame, the reference. Conversely, the speech is its atomic constituents, which are subjected to language, but poised to transform it in time, as it is empowered with the recombination of existing forms in new ways.

A language is not complete in any speaker. Its perfection lies solely in a collective, and therefore it implies a social sphere—i.e. at least two or more subjects. It is not purely personal nor private since such does not allow dialogue, hence hardly qualifiable as language at all. As Saussure expressed: *"Language furnishes the best proof that a law accepted by a community is a thing that is tolerated and not a rule to which all freely consent"*. When, in the inceptions of the biological sciences, naturalists classified animals or plants, labelling them according to some classification system, they were no more than manifesting a natural human tendency (or need) to put names on everything. By doing so, we weave an invisible linguistic bridge between us and the world—or, as Heidegger formulated, the *Dasein* (i.e. the *being there* or *existence*)[111].

Language is a fundamental social process, in which meaning is symbolized in modes that can also be understood and replicated by others. Moreover, language can be altered, it is not a crystalized entity, but in consistence with its *collective requisite*, that can only occur if others adopt the changes. Otherwise, communication is not possible, and consequently such disengages the production of meaning. The speech is where from new words are fetched, linking to what is for us revealed as new meanings, and how these relate to, or limit our thinking. Old words can be used in unfamiliar ways, or terms can be coined to make a different sense from what would be initially expected. Moreover, words produce different thoughts in different languages. Since there are always subtleties, it is often hard to find a perfect match, except perhaps in the logics-based languages that we use to communicate with machines.

In brief, *language* is the whole (formal) system used in communication, which can be analyzed apart from its use (e.g. in grammar or syntax), and is not complete in any speaker. On the other hand, the *speech* is the use of language to deliver a thought or accomplish a purpose, is flexible and changing, and is as diverse and varied as the people who use the language.

As with Saussure's *language* and *speech* distinction, almost a century later Noam Chomsky would similarly differentiate linguistic *competence* and linguistic *performance*, i.e., in brief, the theory we carry on our heads and the practical use we make of it. Another similar distinction can be found between *structure* and *event*, i.e., between the abstract systems of rules and the tangible individual occurrences produced within those systems[112]. As this discussion is progressively detached from natural linguistics, we begin realizing some relational patterns between different elements[113], implying a *structuralist* way of observing phenomena. On their root, is the notion of *sign system* and its *semiotic* implications.

Saussure's conception of language as a sign system is installed in a synchronic focus on the relationships of system's components, and/or with a system as a whole, in a particular state, regardless of changes over history. The sign system is methodologically dividable into two components—the *signifier* and the *signified*[114]. Succinctly, the signifier can be looked as what comes to the mind of the speaker or hearer when the signified is expressed. In other words, the signified can be regarded as a graphical or sound element (e.g. image), and the signifier as the meaning of such element (e.g. concept aroused by image).

To illustrate, the words composed by the letters h-o-r-s-e (signified 'horse') form a signifier in the mind of English readers evocative of, e.g. a highly domesticated four-legged mammal, which has commonly been adapted to work, ride, entertainment, therapeutic or sport purposes, and so forth

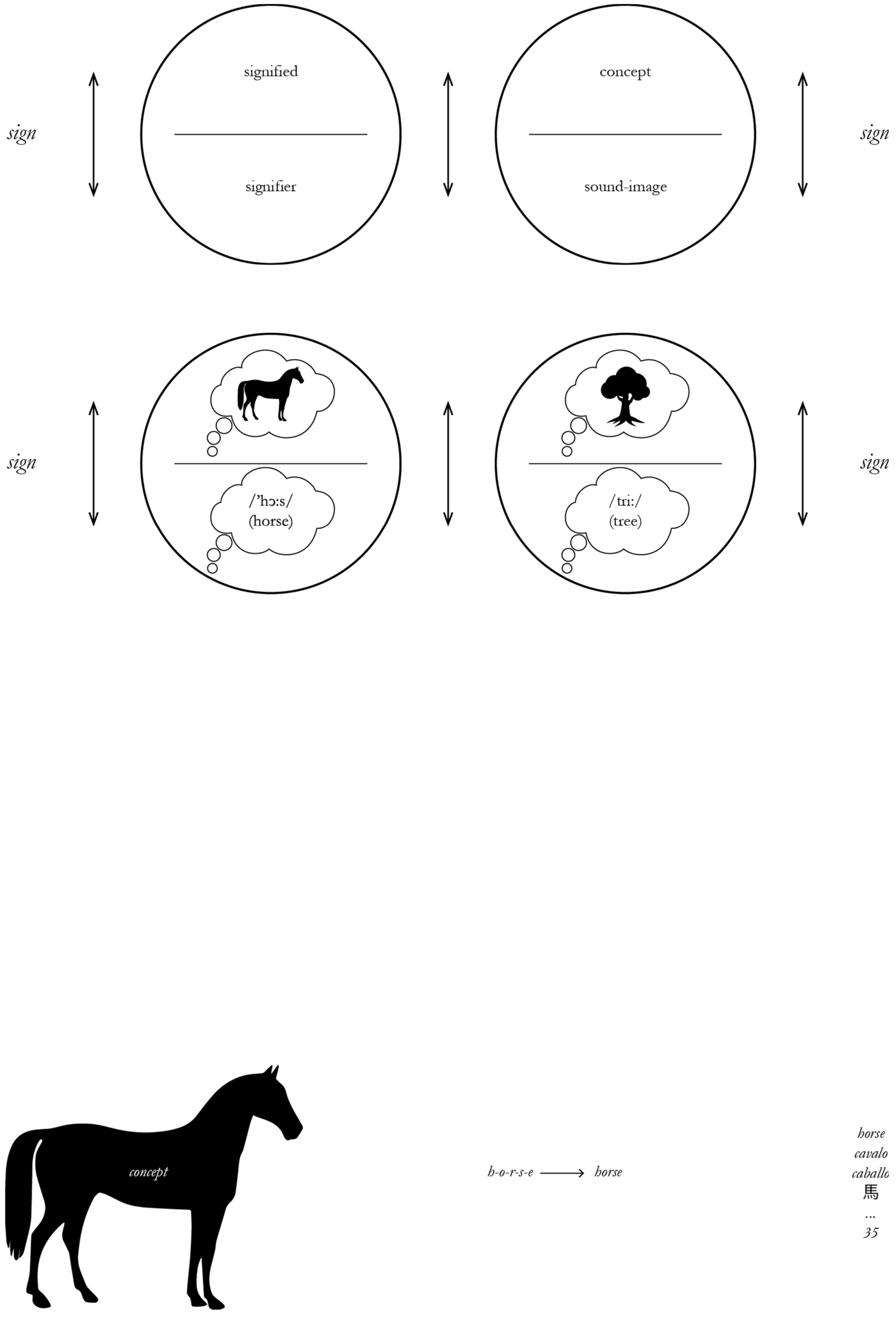


Figure 2. Signifier and signified.

(*signifier* 'horse')[115]. 'H-o-r-s-e' thus expresses a concept with which we had to get acquainted with in some point in our lives. That is why we now know that this particular set of graphemes 'h-o-r-s-e' combined make the word 'horse' that means what we know as being a horse. So, this 'horse' is in fact what we can also call a concept, a mental-image or idea. But to a very same 'horse' we can call 'cavalo' in Portuguese, 'caballo' in Spanish, '馬' in Cantonese, and so forth (Figure 2). We could even call it '35' or '24', or some sort of apparently nonsensical combination of graphemes or phonemes. However, we will no longer be using a previously codified language, we will be making our own codification. Since language only works in a social context, in the least we need two intervenient participating—i.e. a sender and a receiver—besides the codification itself and its knowledgeability by the users.

Words are not the only signifiers, it can be a group of words, such as *how do you do?*, or eventually not even words. What happens is that we are used to signifiers to the point of not questioning them. They are everywhere, in traffic lights and signs; or in gestures we make, shaking hands, smiling, or waving goodbye; screaming of scare or giggling of joy; in the arts, when painting a portrait, making a sculpture, or writing a poem. As *reality*, they are everywhere, so much to the point of being rendered invisible. For instance, when children begin to distinguish meanings of things, they are in the process of incorporating the signifier, that is, in the process of making it *invisible*. Similarly, as grow-ups, when we learn a new signifier, we engage in a process of discovery, eventually ending up internalizing it. In our minds, when things are attributed with a name, progressively the name becomes the things named, to the point we do not distinguish it anymore, until it is just one more sign in our (mental) lexicon of signification.

Certainly, in ordinary circumstances, the distinction between signifier and signified within a sign system is purely methodological, sustaining a semiotic perspective of language which is analogous to the Kantian dichotomy of *phenomenal* (mental) and *noumenal* (material) worlds. Other theorists, such as Charles S. Pierce have conceived the components of the sign system through other relations, in the case expressing a trichotomic, rather than dichotomic dialectic, through *sign*, *object* and *mind*[116]. The distinction between components works for a language theorist methodology. However, it does not seem to work in concrete use, as we do not experience a signifier which does not signify and vice-versa—in language, each sign is a conjunction of all its components, hence its invisibility as a *sign system*[117].

Thereby, in the sense of language as a sign system, every *object* is both *present* and *absent*, where before words make sense, we must make sense out of words, otherwise they are just unknown random graphical elements or unarticulated sounds. For instance, it is plausibly impossible to read Sanskrit without ever having seen its graphical representation before, the same applying to any other language. Once a certain sense is established, words become objects on their own, they become *absent* and, simultaneously, available to be re-combined, to again become *present*. That is, from their internalized absence (their state rendered *invisible*) we will be apt to engage in new meaning.

Concomitantly, a thing is never fully *there*, it is only there to the extent that it appears before us. However, it is not there insofar as its existence is determined by its relation to the whole system of which it is a part. A system that does not appear to us, that it is there but transparently. In this sense, each *object*, even in its quasi-absence, ultimately reflects the total system, and the total system is present in each of its parts. This intrinsically structuralist outline has been remarkably depicted in Lévi-Strauss' *myth*, where broadly it is conceptualized that all mythological stories can be regarded as illustrations of a single one[118]. In a radical interpretation of this proposal, things could be reduced to elemental relations.

If we could affirm that consciousness[119] is not the origin of the language we speak and the images we recognize, so much as the product of the meanings we learn and reproduce; conversely, with or without our intervention, surrounding conditions keep changing, modifying the significances that we may take for granted. In a considered individual sign, the change of the surroundings implies a change in the sign as a whole, and hence in all the methodologically split constituents which are embedded in it. Therefore, ultimately the representation of the sign itself will not suffice, leading to a reality where only simulacra can be conceived and all references are shred. The example of Magritte's paintings eloquently illustrates this line of thought, which ultimately may end up in a sort of nihilism [complement with: **Annex, I.5 Down Magritte's rabbit hole**].

Together, sign and its components, make up what Barthes called the *lexicon of signification*[120], which can also be regarded as a satisfactory proof of a particular affiliation to structuralism. That is also an essential notion to analyze manifestations other than those constituent of natural language, as in semiotics. Moreover, it also seems key to analyze onto those other systems or structures which can be understood if regarding language in a broader sense, that is, on the assumption that every signifier—i.e. a natural or artificial *thing*—can become a sign, as long as if engaged to communicate a message, that is, to signify[121].

2.1.2 BUILDING MEANING

It is generally acknowledged that structuralism values the deep structures over phenomena, thereby denoting a certain ahistorical universalization of concepts. Yet, such universalization is not full proof, since, as it is reminded by a post-Darwinian perspective, it also must be regarded historically and contingently. To some extent, we could observe structuralism in parallel to the Marxist or the Freudian conceptions, both concerned with fundamental causes—economy and family core respectively—that is, implying that individual man is driven by major forces. In this sense, individual choice and consciousness would be wiped out, since the background forces or unconscious motivations prevail[122]. To a degree, that implies that it is out of the scope of the individual to originate or control the bonds of his social or mental existence. In this sense, as it has been implied through Jean-Paul Sartre's existentialism, structuralism has also been regarded as anti-humanist. However, this radical view is contradictory to the generally acknowledged intents of the structuralist proponents, that regard it more as a humanist proposal rather than its opposite.

Because of its focus on the search of essential structures (more related to a certain concept of system, i.e. synchrony), rather than in the evolutionary processes (more related with the concept of evolution, i.e. diachrony), some have labeled structuralism as deterministic, and its outcomes have been regarded as overlooking phenomena and existence. Roughly, in structuralism reality is described has composed not of elements or things, but of relationships. The elements may change, but in a way they retain a dependency on the whole, which they are a part of, and where, regardless, fundamental relationships remain unchanged. Moreover, in this sense, reality is a substrate lying beneath *ideas* and emphasis is put on the logicality of systems from which meaning is to be constructed.

Therefore, structuralism can be regarded as a tendency to focus on the boundaries, on establishing what can be said, meant or thought; or, even more radically, on being reductive, as many complex subjects are seemingly condensed in a few key features, universal structures or truths, which may presumably explain everything, binding humans together, or what humans have in common. However, there are very different approaches to what can be called structuralist thinking, and summing it up in a deterministic path would be ignoring the myriad of *surfaces* that have been addressed.

Wittgenstein, a remarkable logician, aside philosopher, has implied that "*knowing everything is equivalent of knowing nothing*", outcomes are starting points, and hence that "*philosophy is worthless*", as it is "*never ending*", thereby opening a path through the very logicality to relativize even logics own achievements[123]. By questioning the deepest structures, some of the so-labelled structuralists have also acknowledged their partial role around and within other structures. In this sense, synchrony and diachrony cannot be regarded as opposites, yet recognizing that every system exists as an evolution, and that evolution is a character of a system. Saussure himself regarded both as complementary approaches.

Structuralism is also necessarily a label that can be used within many different scopes and contexts, and as in other *isms*, a label in which many so-labeled would not recognize themselves in. In fact, some were notorious for their critical position towards it, to the point of considering it as a gross violation of freedom of thought. On the one hand, there are those that can be considered Universalists—e.g. Lévi-Strauss and Lacan—concerned with the operations performed by the human mind in general, not just with the workings of particular minds at particular times. In that view, behind the diversity of empirical facts, there is a universal mental structure. By contrast, there as those appearing as relativists—e.g. Foucault or Derrida—worried with the surface where things occur and transform, where *things* can be re-enacted into the *things* beyond, not merely concerned with the deep, essential structures[124]. Regardless the greater or lesser criticism, regardless the different modes of approach, all share a vocabulary that is related with modes of producing meaning. That derives in last resort from Sausurre's work[125], whose core proposals bear the idea that the production of meaning fundamentally depends on language, particularly emphasizing into the nature of the essence of any language.

As put by Sartre, "*existence precedes essence*"[126]. The existentialists regard the human subject—how he thinks, acts, feels, lives, and so on—and its role in the bringing meaning to life, as a center reference, source and outcome, for the immanence of knowledge. They sustain that there is no predefined pattern, where we must fit into; that we must create our own meaning, place our own value on our acts, and that our individual freedom is absolute and unbounded. In structuralism, unlike in an existentialist perspective, in many ways man is no longer regarded as a reference point. The totality of things, the structure, acquires a predominance over man's autonomy as a creator and giver of significance: the *ego* dies. It is not about man as a creator, yet the unconscious collective awareness that constitutes man as an object in itself. *We*, and *It is*, replaces the *I*. As in Lavoisier's ancient expression, there is no creation, but transformation. In structuralism, man is a part of a system that precedes its existence and, too, will endure after, at least until there is a trace of humanity left.

This is nonetheless a radical view of structuralism, which may ultimately lead to a dangerous ground, where references can be hard to attain. Criticism came from the realm of art or literature, as the structuralist view seemed to imply a loss in creativity. The view of Man's freedom could be seen as ever entangled in the restrains of a system. However, as Sartre analyzed, the value of structural thinking could also be regarded not in opposition but in relation with man. Roughly, the important is not the man within the structure, yet what man makes of the things that are made out of him. What is important is to realize that man's doings are immanent history (i.e. evolution, transformation) and that that is also (and fundamentally) the matter of what structures are made of. This is not to be seen in either black or white. These are unrepeatable cycles made of ever-changing states, which may or may not reflect recognizable patterns. Structuralism acknowledges the structure, but it is not reductive, since it does not limit, instead it opens the door to, e.g., a poststructuralist understanding.

Conversely, the poststructuralist proposal generally implies that the knowledge of the things around us is not only derived from the things themselves, yet produced through filters rendered invisible to us, through the symbolizing systems, there, (un)awarely inscribed. It implies an account on how meaning is processed, but it also states a fundamental distinction between human beings and other animals, which is the capability to recognize difference, and, by such, build meaning. Other animals can also be social, but they are not cultural, as they produce nor transmit no meaning in a cultural sense, at least not one that can likely be accessible from a human perspective[127]. Such would find echo, for instance in Foucault's discussion of subject and identity[128], or Lacan's idea of human beings as organism in-culture[129].

Structure is an ancient word, long used in anatomical or grammatical circles. Yet, as Barthes expressed[130], the linguistic model originated by Saussure, along with the economics of a Marxist origin, have become in a great deal, the *true* science of structure. As an intellectual meta-language, the use of the word *structuralism* applies to an approach, where a *structuralist* vision is constituted. Even if refuting its labelling, its awareness, in a sense, makes its user *structural*. Yet *structuralism* is not a school or movement, making it useless trying to find a common corpus. Nonetheless, there is certainly a structural way of making things, in painting, writing, music, and so on, and one that does not need to be recognized as such. A structural way is not necessarily a formal way, in the sense that is reflected on a certain approach or result to form, as for instance the Russian *Construtivist* approach might denote. It is a mental way, or activity, not a formal way, certainly a lot closer, for instance, to the sort pointed by Malevich's *Black Square*, where the apparent simplicity of the structure seemingly entails all possibilities[131].

The goal, if a goal is there to be set, is to reconstruct an *object*, manifesting its rules of functioning. For instance, Wittgenstein did it through logic, while acknowledging logics limitations[132]. As Barthes wrote, "*structural man takes the real, decomposes it, and then recomposes it*"[133]. In this process, something new is added which has a different value, i.e., *creation*, or *evolution* occurs. That may indicate a copy or mimesis of the original object, which is taken and added to at least another order to make a seemingly new one. Yet structuralism is not about a homology of the initial object and its state—a pure homological development would likely indicate an entropic (de)gradation of the (original) object. It is instead a reconstruction from the understanding of its (apparent) fundamentals, heterologically and relationally confronted with a different object or surrounding. What matters is not necessarily the nature of the object, or its essence, yet what is added to it, i.e., the process in which the object is recomposed, and through it acquires a different meaning. What matters is the path, not the destination, life above its unavoidable ends. It is about what Barthes called the "*structuralist activity*"[134], that is, man's modes of producing meaning, of constructing culture, … of living.

The idea can be exemplified with the relation of *language* with the construction of *myth*. We can create new meanings and concepts, which do not necessarily need to be attached to what we may perceive as facts of the *real* or *reality*, or even to what we may call *truth*. All of this constitutes part of a human construction, and we can apply it to any kind of language—to a graphical language, to a spoken or written language, or even to body language (the dancer's movement, the musician's interaction with his instrument), and so forth. Indeed, as we leave the realm of *language*, adding layers upon layers of *signs*, we can say that somewhat we are entering the realm of *myth*, since the *(III) Myth* is not

Language	(1) Signifier	(1) Signified	
MYTH	(3) Sign (I) SIGNIFIER		(II) SIGNIFIED
	(III) SIGN		

Language	(1) Red rose	(1) Romance	
MYTH	(3) Red rose of romance (I)		(II) Love/Devotion
	(III) Giving the rose proves my love **MYTH**		

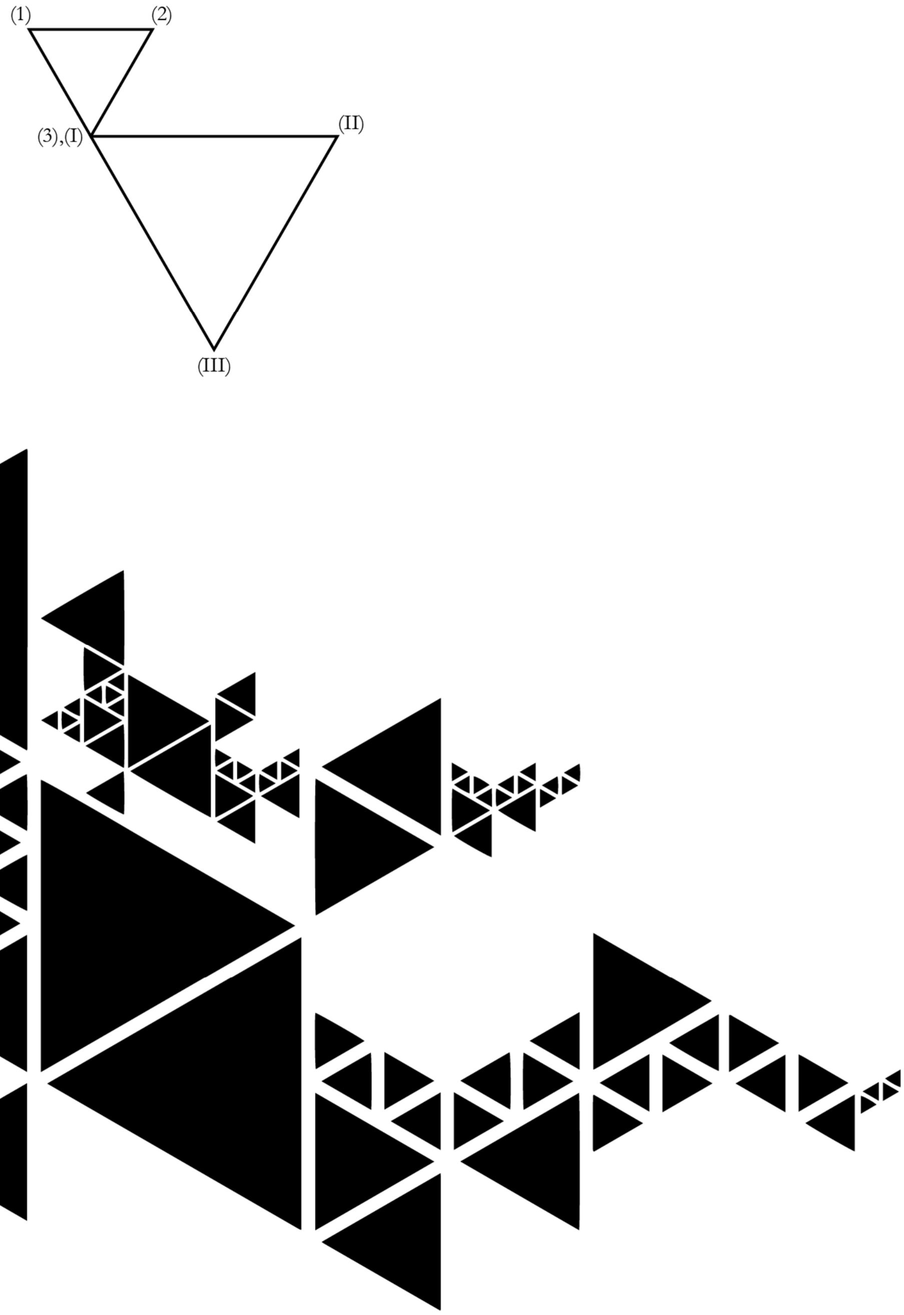


Figure 3. From *Myth* to form.

necessarily a truth, certainly not a fact of what we can assume as being *real*. Instead, we can make the equivalence between *myth* and *sign*, i.e. a codified representation (Figure 3). Then, again, everything is a sign, that our brain apprehends, interprets or represents—as de Pierce said, "*nothing is a sign unless it is interpreted as a sign*"[135]. Whatever the apparent degree of essentiality of the approach, as Jacques Lacan expressed, "*the signifier does not designate what it is not there, it engenders it*"[136]. Under the signifier there is nothing or a quasi-absence.

By dissecting an object, as the specialization has been making, the ultimate goal is reaching the fragment, which can be, e.g., a basic geometric shape, or a phoneme (and even those can potentially be reduced even more). The dissection produces a dispersion (fragmentation) but not necessarily an anarchy, as the re-distribution of the fragment, so implied in its meaning construction, is conducted by a sovereign principle which embeds *difference*, for minimal the difference may be. That *difference* guides a process of association. As in Kant's architectonic, a structuralist activity articulates the fragment onto a fragment-plus, that is, onto a system, or structure, or what other terminology or convention may be in use. To the basic fragment, a series of devised rules, more or less explicit, more or less iteratively developed, guide a combinatorial process by which form (of speech, of music, of painting, and so on) is *created*, and that is nonetheless limited by the subject's ability to acknowledge them.

It is truly a simulacrum process[137], where the world ends up rendered differently from what it was found, and yet is not necessarily *new*. In fact, it does not seem relevant to know whether a newly appeared object is *new* or not, but, again, the relevance seems to be in the path, or process. Although *form is the entire thing* as implied by Saussure, and regardless Russel's paradox, which puts the issue in an irresolvable loop, what is relevant is not the form, but the meaning, because ultimately the meaning is its production. The structuralist activity is not about the fragments, the meaning of each individual fragment, nor a universal essence. The fact, totally isolated, is as useless as its extreme generalization. What matters is not if it is *new*, but the humanistic production that it proceeds. Taking Barthes' expression, what matters is not the meaning of the fragment, but Man fabricating meanings, the *Homo Significans*[138].

The term *modern* can help to elucidate this argument. Between a process of *denotation* (i.e. of non-coded iconic message) and of *connotation* (i.e. coded iconic message), distinction can be difficult to attain, since *connotation* comes so immediate and natural that becomes extremely difficult to distinguish both terms[139]. As other terms, *modern* tendentiously follows Saussure's notion of difference in negative terms—i.e. what is modern is *not ancient*, *not medieval*, *not antique*, or *not traditional*[140]. It distinguishes a period by the negative of another. Yet, paradoxically, by associating *modern* to a specific period of the first half of the XXth century, as it occurs with modern*ism*, and concurrently, detaching it by naming a succedaneum *post*modern*ism*, modern*ity* becomes a thing of the past, when in its essence *modern* is nonetheless consensually connoted with *new*[141]. Indeed, *modern* can be seen through the negative difference towards *old*, or, as with *new*, by pairing with relatives. Nonetheless, such denotation is instantaneous (immediately volatilized), a fragment re-built with meaning in the fragment-plus connotation. For the *Homo Significans*, the word *modern* can mean many things. That is prove of a cultural (communal) richness as brought about by a diversity of insights, not of purely anarchically spread fragments, since that is subjected to language, hence to be shared, as language does not exist in a single subject.

The ancient atomists sought to unveil the essences in nature. However, the Demiurgical answer of their ontological quest has proven not to suffice. Embroiled in the shades of Plato's cave, the answers seem to only be graspable by the appearances of the images: no being, nor exactitude, just appearances. Analogously to the cave allegory, the ancient Indian parable of the blind men and the elephant also illustrates a range of truths and fallacies that are implied in the subjective experience. The story has different versions, but essentially tells that a group of blind men touches an elephant to get to know what it is like. Each touches a different part, then compare the description of their part with others, ending up in complete disagreement. Primarily, the stories vary on how each part is described. Soon they enter in conflict. In some versions this escalates, becoming unresolvable, in others they stop talking, and slowly start listening, collaborating to *see* the whole elephant. A sighted man passes by, observing the full elephant and then describing it. With it, they also learn they are blind. One's subjective experience can be true, but may not be the whole true. If the sighted man could not touch, he could not feel the beast as the blinds' did; if he could not smell, his experience, and hence the meaning produced, would also be truncated; if he could not hear he would additionally may not become aware of the blinds' discussion. Even if fully aware, he still certainly would be ignoring something, because in the least *looks can be deceiving*.

As Werner Heinsenberg once stated, "*we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning*"[142]. Indeed, the social and the cultural Man is a human construction, which differentiates us from other animals, and that ultimately lays in the distinction between organism and subject. Each individual of the natural world has inherited characteristics, which result of ages of evolution, and these develop, amplify or fade in interaction with the milieu. Additionally, the human subject is too an effect of culture, a result rather than an origin, and in that sense more likely to reproduce a range of uncertainties and beliefs than to resolve them. In that sense, if we lay claim to a certain *truth*, we are defining what we believe, but what we believe is not purely personal, yet a conviction that is proceeded through an inculcated culture. From here, it can be assumed that we are the result of something *Other*, alterity beings. However, knowledge does not go on without a subject, since we are unavoidably linked to both an upstream and a downstream *Other*, since in ourselves we are too an *Other*: subject-is-the-object-is-the-subject, alterity all around.

When the death of the author is claimed, as it has been by the poststructuralists, is as acknowledging what can be an easily forgotten evidence that the author is a reader, and in that sense that no work is universal, or no single interpretation is possible. There are unavoidable tautologies, but as the *text* changes from reader to reader, reading moment to reading moment, the structural *Homo Significans* too knows its very structuralism will change. As Barthes wrote, "*structuralism, too, is a certain form of the world, which will change with the world; and just as he* [structural man] *experiences his validity (but not his truth) in his power to speak the old languages of the world in a new way, so he knows that it will suffice that a new language rise out of history, a new language which speaks to him in his turn*"[143].

Implicitly challenging the Cartesian architectural utopia, structuralism has remarkably expounded the impossibility of a truly objective judgment, since we are all prisoners of language. In the absence of a last resource God, or any other ontological cornerstone, transcendent source of meaning for phenomena, there is no greater significance; instead, there is a continuously reshaped open loop of movement and structure, …of life. Such arguably carried profound implications in culture's episteme. In time, a Cartesian view was replaced by a relational new monistic view, which inevitably called also for different aesthetics. The art movements in the early XXth century had began disclosing a shift from the Cartesian representation to a relational new-monism[144]. In the literary author-reader relationship, the reader too acquired a new relevance as builder of significance—i.e. all authors are readers, and conversely all readers are authors. In relativity's relationality, space-time begins and ends in the subject. Conceptually, among such a fragmentation, can there still be room for architecture to truly be?

2.2 Research trends of a structuralist affinity [vernacular, natural, normative, numerical]

In the 1950's and 1960's the influence of structuralist thought was already well spread across Europe and the USA and began to influence architectural thinking in this period. Lévi-Strauss' work in anthropology had popularized the structuralist approach to a wider audience. The study of folk narratives or myths of traditional cultures inevitably also drew attention to their built forms. In a retrospective look to his own work, in *Myth and Meaning* (1978), Lévi-Strauss affirmed: "*Notwithstanding the cultural differences between the several parts of mankind, the human mind is everywhere one and the same and that it has the same capacities… I don't think that cultures have tried systematically or methodically to differentiate themselves from each other. The fact is that for hundreds of thousands of years mankind was not very numerous on the earth; small groups were living in isolation, so that it was only natural that they developed characteristics of their own and became different from each other. It was not something aimed at. Rather, it is the simple result of the conditions which have been prevailing for an extremely long time*"[145]. The arguments can help explain the diversity of human forms of habitat, framed under an evolutionary perspective, but also it can ultimately indicate a way towards a seemingly inescapable global homogenization. In any case, if there were deep structures organizing basic human aspects, with social and cultural manifestations, it seemed reasonable to consider that the built environment, a human creation, would too be influenced by these.

These notions induced a great impression in some architects and theorists at that epoch[146], with the study of the built environment overlapping many different disciplines—cultural geography, anthropology, history, urban planning, ethnography, cross-cultural studies, behavioral sciences, or architecture itself[147]. The developments signaled a research trend of structuralist inspiration, marked by travels to remote places, documenting ancient and remote cultures, or by the observation of natural structures. The observation of archaic vernacular built environments, embedded of an age-old wisdom, became an important subject of analysis[148] which carried valuable lessons to architectural production: a sense of essentiality, of proven, established and adapted forms, validated by ages of evolution.

Typically, the pre-industrial vernacular constructions can be described as made of economic principles, using locally available resources, with simple but effective construction methods. These are adjusted to the physical, social and cultural needs, as well as to the local climate, but also depict a strong resilience based in a morphological adaptability, by successive addition and transformation over time. The resulting forms are precise, in the sense that are directly reflecting the natural context, as well as the needs and life experiences originating them. By their truthfulness and simplicity, many of their principles can be easily recognizable. For instance, in different climates, in some cases the roofs are highly sloped, to face rain and snow, whereas in others they are flat and are often used as terraces to dry cereals in sunny times. The forms are organically exact, placed just where they belong, reflecting their contingencies. They are not planned or imposed, but *additive* (i.e. added in time, according to need) and are kept in close watch, cared, as there is no greater driving force than pure necessity[149]. However, these processes are not necessarily purely deterministic, as in the *anthropological functionalism* sense expressed by Bronisław Malinowski, since they also hold unpredictability and chance, and drive signification construction modes. For instance, at cases, a personal statement, a higher resource availability, or by no particular reason, a more elaborate expressiveness, or decorative imprint is manifested. In turn, this may or not be subsequently further reproduced, either eventually installing a new tradition branch, or simply standing as a one-off case.

The material formalization through construction is subjected to processes of choice that are not only constrained by a natural context, but also by the evolution of cultural processes related with "*fashion, tradition, religious proscription, or prestige value*"[150]. For instance, the use of wood construction may be pervasive in places where forests are abundant, but certainly, a traditional Japanese wood building carries a different pathos than a traditional North American wood building, even if the materials and technologies in use are somewhat similar. Indeed, construction practices are not merely biological in the sense of strictly answering to survival needs or natural conditions, but intrinsically of a cultural ballast. For instance, most probably the primitive cities were not biologically better to live in than in the countryside, as cities were more prone to diseases, and so forth. Nevertheless, these cities were culturally attractive, because in the least they embodied the idea of an improved knowledge exchange, which favored the development of crafts and the like, or because people came from squalor, and thus cities symbolized [the promise of] a better life. Anyhow, the idea of vernacular is unavoidably linked with an evolutionary stance of cultural practices, as these embody in the artifact what in biology natural selection represents to species—anthropologists call it *evolutionary anthropology*[151]. The perspective is that cultural practices guide an artificial selection, or selective breeding process where humans intentionally chose specific traits based on their knowledge gathered in time. Therefore, as memes, vernacular buildings embody a process carried and spread from person to person within a culture that too is evolving[152].

The study of archaic cultures, together with extensive travel reports was certainly not a novelty in the 1950s and 1960s, when the vernacular becomes an important subject of research. In science, the practices of the XIXth century naturalists had been embedded of a similar spirit. The travels and documentations of some of the XXth century architects would too display a certain exoticism of built structures, portrayed in bold photos or impressive sketches, poetical synthesis that fascinated the audience. Traveling and recording the great buildings and built environments of the past had long been a widespread practice, marking architectural thinking and production in modern times[153]. The famous *Grand Tour*, which became democratized as railways became pervasive, attests it. Le Corbusier's *The Voyage to the East* (1966)[154] is probably the most famous account of that way among architects along the XX[th] century. However, the curiosity on the vernacular or in popular building forms, although not new, apparently became more intense than ever.

The frugal and sincere beauty, evocative of a certain atavism, certainly impressed a public avid for the [old] unseen, and perhaps tired of a certain modernist orthodoxy. One of the icons of such recordings would be Bernard Rudofsky's superbly photographed *Architecture Without Architects: A Short Introduction to Non-pedigreed Architecture* (1964)[155]. To a certain extent, the archaic vernacular became a methodic ideal for the *new*, as from an exogenous perspective, its buildings and values apparently depict social and psychological well-being, seemingly perfectly adjusted to their setting. In this sense, vernacular's synchronic qualities, i.e. its universalist, evolutionarily tested values, became theme and validation-in-history of a trend of new proposed forms. Ascribing to the precursor steps of D'Arcy Thompson's *On Growth and Form* (1917)[156], the Darwinistic analogy would also be driven to the observation of natural structures themselves, in the search for naturally validated models to apply in the production of the built environment.

Besides the appealing imagistic, the idea of a *vernacular* reestablishes a sense of *place* construction. The example of the *Arquitectura Popular em Portugal* ["*Popular Architecture in Portugal*"] (1961)[157] enquire attests it, signaling a research trend for the age-old knowledge provided by the vernacular practices towards a redefinition of the modernist approach. Modern architecture, wisely adapted to the *place*, while qualified by artisanal objects, would subsequently enter the vocabulary of the Portuguese architectural practice. Fernando Távora´s *Casa de Ofir* (1958), or Álvaro Siza's *Casa de Chá da Boa Nova* (1964) are a proof of a wise approach to the setting, while providing it with a modern expression, which has as much of powerful, as of subtle. It is an expression truthful both to [the representation of a] *place* and to a design language with its own authorial, artistic idiosyncrasies. With different shades, namely a reconciliatory view between nature and machine, such a softened sense of place had already been explored by some referential modern architects, as Frank Loyd Wright or Alvar Aalto.

Wright's *Broadacre City* (sub)urban concept, envisioned a landscape gathering both nature and the machine, expressed in the artificial layout of the fields or a productive condition of the territory. With it, in a way, there was no longer a city, as the city was everywhere: for the adventurous, the nomadic, inspiring freedom and movement, entangled by multiple roads and highways, telecommunication lines, flow paths[158]. It was hence a communication city, in which each point could potentially be connected to all others, and in which nature appeared as a continuous medium, receptacle of the entire system, where all components are ought to work organically[159]. In that sense, Wright's *Fallingwater* (1935) was both archetypal and prototypical, as it established an ideal (and idyllic) bond of natural and artificial spheres. With the *Broadacre City*, it was also implied an understanding that modernity was not only in the city, but could hypothetically be everywhere, as all the territory is, in potential, to be cultivated by Man. Richard Neutra had already implied it in one of the initial *CIAM* meetings, setting a case for a liberalized modernity[160]. Wright's *Usonian* houses would reiterate the idyllic, and its implied political worldview of *Broadacre City*, but adding the dimension of design-constructive system, stressing the intention to make houses affordable to a large part of the population—the concept was inaugurated with the *Jacobs house* (1936), and would be accompanied by the *Usonian Manifesto*, published in the *Architectural Forum* in January 1938[161]. With it, design systems, types, function or technology are not to be opposed to a concept of *place*. Generic purposed design and construction systems, allied to firm and respectful intentionality towards a specific setting, are too conceivable in a peaceful coexistence between a sort of universalism and a place-aware stance. In *Usonia*, systems were no limitations, yet a way to embrace difference in a technological dialogue with nature[162], a condition that would notably be followed in propositions such as Albert Frey's *living architecture* [complement with: **Annex, I.6 Albert Frey's nature and industry synthesis**].

In a different context, the work of Alvar Aalto was too seduced by the world of living nature as an architectural metaphor[163]. In his view, the economic set of the vernacular built forms can only be surpassed by the greater essentiality of nature's forms. His buildings adopt additive forms adapted to place. Aalto's works come in line with a Nordic way epitomized in Erik Gunnar Asplund's, which broadly develops a synthetic relation with *place*, joining both the classical tradition and a modern stance, as had been eloquently depicted in the *Skogskyrkogården* ["*Woodland Cemetery*"] (1935-1940). Aalto's work was functional, but not mechanist, yet with a purposive intention forming and framing human activity. A staircase can simply be functional, or bind conditions and experience, building and topography, acting as place for social interaction—*Villa Marea*'s (1939) iconic stair, certainly announces something other than function. Aalto spoke of an *extended rationalism* comprising a reconciliatory attitude on both human[164] and natural[165] circumstances[166]. The Nordic way would find a remarkable legacy in Jørn Utzon's works, gathering influences coming both from the vernacular and the natural forms, engaged in a sphere of productive efficiency, as expressed in his *Additive Architecture* manifesto[167] [complement with: **Annex, I.7 The Additive Architecture of Jørn Utzon and the Espansiva System**].

The appeal of the archaic vernacular, as depicted in Bernard Rudofsky's photographic account or as portrayed in the humanist essence and natural-artificial bonds of Wright's or Aalto's works, finds a parallel in the appeal of the ordinary vernacular elements of the built environment. For instance, in the *CIAM 9*, the Smithson's exhibit photos of London street life by Nigel Henderson, illustrating their cherished *as found* concept, that is, the remembrances, the fabric of ordinary traces and scars of a place, which give it a particular feel, energy, character[168]. To a degree, the idea of the *as found* agreed with the main canons of modernism in terms of refusal of ornamentation, search of structural purity and, above all, truthfulness in the use of materials[169]. Materials ought to be used and seen as they were. Buildings were to treat the site as an *as found* object. The signification levels were to be found and built upon the proposed buildings. Other semiotic implications would also be expressed in works as Kevin Lynch's *The Image of the City* (1960)[170] or Gordon Cullen's *Townscape* (1961)[171]. As in Aalto's case, modernity was not to be understood from an idealized utopia enfolded by abstract, geometrical compositions. The available patterns and urban fabrics were ought to be transformed, not sponged out and converted into a formal abstraction. What it fundamentally changed was the view of the everyday, the valuation of the ordinary as an endless source of wisdom for the architectural production.

A related arising trend, endorsed an architecture that should be less about control and more about empowering a participatory role of the unfolding life. In a sense, architecture was no longer to be about high-pedigree buildings, or grand urban solutions. Instead, it should be holistically engaged in the broader scope of the *built environment*, and its *ordinary* forms, wiping out the old *high/low architecture* narrative. Many theoretical developments reflected these concerns. Amos Rapoport applied anthropological studies to habitability, laying the idea that the physical environment of man, particularly the built environment, is so complex, and overlapping so many disciplines, that has not been, still is not, and hardly will ever be controlled by the designer[172]. John Turner stressed the role of user participation through an enquiry on societal control levels towards the built environment[173], and a related self-building line would be pursued by Walter Segal[174] [complement with: **Annex, I.8 John Turner's network and hierarchy**]. John Habraken, and the work developed among the SAR (*Foundation for Architects Research*) group, led the concept to another level, where a fundamental distinction was made through the hierarchies of the *support* and the *infill* concept[175] [complement with: **Annex, I.9 John Habraken's Supports**]. Stewart Brand would add a new perspective to the *support* and *infill* distinction towards the design of buildings acknowledging different hierarchy and timespans of levels and the user participation in each level[176].

Among the developments[177], it is also important to refer what is a certain re-enactment of the discourse on the *type*. The topic can broadly be summed up as an inquiry into the deep, general structures, paralleling the linguistics' synchronism, and be included in an overall development of a normative perspective, developed from a research on systems. The research on type is too linked with a recovery of history. The early notions of Quatremère de Quincy (b.1755-d.1849) had set the terminological base for type. Jean-Nicolas-Louis Durand's (b.1760-d.1834) comprehensive depiction of types echoed the influence of a series of renaissance treaties, such as Serlio's practical treatise, and by that following an academic line that can be traced back to Vitruvius'. To a certain extent, modernism had ruptured this line, determined in abolishing the imitative character embodied in a 'demonized' *Beaux Arts*. The recovery of a *type* discourse thus followed the need to inscribe a social and cultural dimension into architecture, a purpose that modernism had somewhat deviated from its priorities.

The intrinsically normative *type* enabled both an analytical and a projective purpose, a tool to analyze history, and conversely to design architecture. Tafuri defined the *typological critique*, as a trend insisting on the formal invariants differentiated from the analytical masters of functionalism by its historicist character[178]. With *L'Architettura della Città*[179] and *La Costruzione Logica dell' Architettura*[180], between 1966 and 1967, Aldo Rossi and Giorgio Grassi reevaluate architecture, which should thereon be grounded into an understanding of the building types distinguishing the modern European city[181]. They asserted the inevitability of rationalism based on the generative potential of the types, with an historical twist. The rational methodology of type was not to be one of functional measure. Instead, it should set up architecture as measure of architecture, expounding its lineage and future outcomes through a record of autonomous principles, and thus essentially structuralist. Without interference, architecture may inadvertently (and dangerously) end up in a kind of self-referenced/redundant derivability, enclosed in a typological loop, where there is no real new input, but a sort of empty play of forms, i.e., ultimately, a *dead language*.

With the *Broadacre City* Wright had implied nature in the city and in a larger territorial view, within a liberal idea of land and production of built form[182], and Aalto had referred to "*nature as the best standardization committee*", ascribing to a genetic tree of human artifacts where industrialization of processes and forms completes the picture. Approaches to natural principles were also profusely addressed in the development of building structures, binding together architecture and engineering angles. In brief, as some structuralist sought for human patterns and gave an anthropological look to relations as a leitmotiv of architectural production, namely in observing the vernacular built forms, others sought for patterns and relations in the natural world. For many in the latter path D'Arcy Wenthworth Thompson's (b.1860-d.1948) *On Growth and Form* (1917) stood as a seminal reference. In this line, the search into the structural qualities of natural forms would find pioneer references among the practical and theoretical works of Antoni Gaudi (b.1852-d.1926), Friedrich Kiesler (b.1890-d.1965), Robert Le Ricolais (b.1894-d.1977), Buckminster Fuller (b.1895-d.1983), Frei Otto (b.1925) or Emilio Pérez Piñero (b.1935-d.1972). Using design models that investigate rules of structure or self-formation, processes and shape formations were drawn from an observing curiosity in nature's forms and principles. Architectural models delivered visual evidence of force flows that prompted towards analytical descriptions of the structures. The tangible experiments anticipated computer analysis, and provided base for derived design techniques. It was also a search for optimal structures, of building lighter to achieve the biggest spans as in Otto's *Münich Stadium* (1972), to comprise the biggest volume as in Fuller's *Geodesic Domes*, or to achieve both in self-erecting deployable structures as in Piñero's unbuilt designs for NASA of portable *greenhouses for the moon*.

The examples denote a shift from architectural language, or from a normative typology, towards the tactility of materiality and reaction to contextual impacts. Approaches spanned from establishing boundary conditions from where forms would be freely devised, to structuring devising processes according to rule sets differentiating relationships between form, mass and force. Broadly, in materiality, stressed systems tend to optimize themselves, and depending on strengths, by modulating densities, different behaviors and responses could be detected and calibrated towards a numerical objectification. If, in a first stage, such objectification served as a validating tool for construction purposes, analogous principles have also more recently been re-engaged in service of algorithmic ruled iterations.

In a different line, Christopher Alexander's works brought in approaches from mathematics and computer science, using set theory, graph theory and early computer tools, emphasizing the interaction between people and the environment, to attain an abstraction of vernacular architectural concepts. With *Notes on the Synthesis of Form* (1964), it was emphasized a numerical rationalism into solving design problems, defining a design problem as the "*requirements which have to be met*". Among these requirements, were interdependent relationships that made them extremely hard to fulfill. By methodologically mapping and analyzing relationships, the structure of the problem was to be brought about logically. As other observers of the built environment, Alexander has broadly documented how patterns may be recognized from and towards structuring our environments. It has significantly been an inspiration to architects, engineers or theoreticians, but it has also been criticized by what may be called a prescriptive dimension and an underlying aesthetically biased stance. Nonetheless, the work is invaluable for its linkages between archaic and ordinary built environments and the widespread materialism of modernist society expressed towards a digital sphere.

An important part of the legacy of the research onto a numerical objectification of the structural qualities of natural or vernacular derived observations has been foundational in terms of a more recent use of algorithmic digital tools, manifested in a search onto form via sets of rules and constrains, or on the problem of the automated space layout. The first developments start in the late 1960s, but it was only in the turn of the millennium, and with democratized internet communication, that progresses have boosted. Notwithstanding, crossing the data values with emotional needs or aspirations is a task still in its inceptions, as evidenced by the case seemingly basic, yet complex problem of the automated architectural layout[183].

2.3 Structuralist related forms

The formal approaches that can be related to a structuralist sphere, find its first acknowledgeable developments in the architectural panorama of the 1960s. These have been implied around many different labels and groups—such as *New Brutalism*, *Dutch Structuralism*, *Megastructures*, *Metabolism*, *Situacionism*, *Archigram*, and so on—although not necessarily manifesting a particular structuralist affiliation. The labelling is often unclear, with different terms sometimes referring to similar concerns, but addressed by different groups. Around the prolific 1960s, some of the most remarkable and imaginative signal inputs were revealed by the fertile production of resurgent utopian proposals[184]. Examples are abundant, as is the case of the Smithsons' city plan for *Berlin* (1958), as well as Yona Friedman's *Raumstadt* (1961) or *Spatial City* (1961), or in some of the *Metabolist* proposals such as Kenzō Tange's *Tokyo Bay Plan* (1960).

As also observed in the natural structures, the use of additive principles derived from the vernacular observation seemingly involved a limited array of related elements organized in a limited array of variants, disposed through certain sets of rules. For instance, in earlier times, the Fibonacci sequence had also been used in the *Modulor* from the belief that natural principles follow structural, universal principles[185]. With greater or lesser degree, similar principles as those entailed by Aldo Van Eyck's *aesthetics of number* would be paralleled in other architectural proposals. Aldo Van Eyck's *Orphanage* (1970), Louis Kahn's *Richards Medical Center* (1965), or Herman Hertzberger's *Diagoon* (1971), figure among the numerous examples where this sort of underlay can be clearly recognized. Formally, these generally reflected an architectural conception made of more or less flexible layouts of switchable but normally well-defined modulation. Space arrangements are combined by sets of rules and hierarchized according to expected patterns of use and the elements of form normally reflect a concern in establishing clear articulations, for instance, distinguishing load bearing from non-load bearing elements or service spaces from servant spaces.

The ties between *Team 10*'s concepts such as the *hierarchies of association*, a concern for cultural identity, or an acknowledgement of urban life through the relationships established by its inhabitants, assign to a key idea of primacy of relations over things valued in the structuralism of the humanities. The actions taken by *Team 10* members to create formally complex large-scale systems able to adapt to the city and the landscape led to different formal logics. The split can generally be placed between a certain formalistic approach, which can be foremost recognized in the Smithson's proposals, and a clearer inner intentionality in Van Eyck's or Candilis's. On the one hand, as in the Smithson's *Robin Hood Gardens* housing complex in Poplar, East London (1972), it is portrayed a certain interest in solving the *emotional* issues by designing spaces for *casual* social encounters whenever possible, with hybrid spaces, not entirely public nor private, where socialization could occur, through elements such as elevated pedestrian decks in mega-structural blocks.

However, in a way, such was not much more than a continuity of the modernist approach in the sense of imposing top-down design solutions, where the modern block was little more than disguised, with slightly more sophisticated spatial sociability solutions[186]. On the other hand, a resolute shift from a certain alienating abstraction brought about by modernism and its tendency of top-down design, to make an architecture open to its user, freed of design impositions, where there is a well-defined upper structuration that nonetheless enables users to freely engage in appropriating space. The Smithson's *as found* concept placed a new ethic stance, regarding the observation of the built environment, cherishing its most ordinary and/or potentially unaware characteristics. On the other hand, with the celebration of the natural qualities, as expressed in their *woodiness of wood; sandiness of sand*[187], it was implied a distinctive aesthetical stance.

The preference for raw materials, such as in-situ concrete, would give rise to a somewhat imposing architecture. In the end, the approach would be labeled *New Brutalism*, which implied negative connotations. Reyner Baham coined the term in his 1955 essay *The New Brutalism*, making reference to what he called a tendency to "*look toward Le Corbusier and to be aware of something called 'le beton brut (and) l' Architecture, c'est, avec des Matieres Bruts, etablir des rapports emouvants'* "[188]. It is a naked, crude architecture, where the Miesian more to achieve less allegedly does not take place[189], where things are supposed to be presented as they are, with no masks or disguises. It seems the *ism* of the *brut* is also linked to an idea of rupture with a certain functionalist approach. It does so using a discourse that employs vocabulary such as *connectivity* and *flow*, looking towards different aesthetical conceptions, where design values such as *image* and *composition* acquire a new intentionality that does not necessarily ascribe to the classical notions.

From that point, topology can gain relevance to a radical point of superseding geometry—where a brick can be regarded as equivalent to a billiard ball. However, a literal use of topology redounds in complete relativity, in amorphous, non-definable forms. With topology, a threshold is crossed, where architecture ultimately can no longer use concepts such as proportion and symmetry. In it, there is also no scale, opening up a perspective into a digital field where dimensions collide in numerical codification, the algebraic strength of vectors making a door handle equivalent to an entire building or a city. Conversely, that can also be referred on the perspective of an *a-formalism* as a positive force, as expressed in their contemporary artistic works of Alberto Burri (b.1915-d.1995) of Magda Cordell's (b.1921-d.2008). Reyner Banham writes: "*Even if it were true that the 'Brutalists' speak only to one another, the fact that they have stopped speaking to Mansart, to Palladio and to Alberti would make 'The New Brutalism', even in its more private sense, a major contribution to the architecture of today*"[190].

New aesthetical conceptions were also implied in what has been described as *mat-buildings*, a reference credited to Alison Smithson in the article *How to Recognise and Read Mat-Building. Mainstream*

Architecture as it has Developed Towards the Mat-Building (1974). The first designs to have such label assigned were both developed by George Candilis, Alexis Josic and Shadrach Woods, all disciples of Le Corbusier that founded their own office between 1955 and 1963, and where all at some point active participants in *Team 10*. They participated in two competitions, one for the *Free University* in Berlin (1963, and concluded ten years later), the other to the *Römerberg* in Frankfurt (1963). Among other designs that can also be ascribed to a *mat-building* formulation, can be noted Le Corbusier's project for *Venice Hospital* (1964-65)[191] or Van Eyck's *Orphanage* in Amsterdam (1960).

Mat-buildings apparently use different compositional philosophies of those of the early modernists. Geometrically they can be characterized as high-density, large-scale structures, organized through more or less regulated grids. However, above all, there is an underlying general, topological order influencing the disposition of units, which often share similar morphological characteristics. These principles can be related to what has been called *kasbahism*, a notion ascribed to the historical Kasbah urban structures, where buildings become less objects in themselves and more of elements of a larger structure. With its topological order, the larger structure prevails, even if orphan of some individual elements. With it, the overall form is an open-form[192]. As in the Kasbah, in *mat-buildings* the possibility to endure change seems to be one of the characteristics that are primarily cherished[193].

Despite a generic, topological character, metrics can nonetheless be important in these structures—Berlin, Frankfurt and Venice projects all share the use of Le Corbusier's *Modulor*[194]. However, these are just referential towards a formalization, as in a way these very same designs could easily be something else without losing their identity. There is an inner resemblance, using similar but apparently diverse units, which the immersed user is to experience as varied. As in an algorithm, this is achieved by combinatorial processes, enabling the creation of complex relations through the iteration of relatively simple rules. The resemblance of the seemingly diverse units is too one of a Vitruvian echo, placing house and city, unit and larger form, in a direct bond, sharing an identical nature, one on which the *mat-building* provides a structural synthesis.

This idea is strengthened by the open-endedness of the program. In Alison Smithson's words: "*Mat-building can be said to epitomize the anonymous collective; where the functions come to enrich the fabric, and the individual gains new freedoms of action through a new and shuffled order, based on interconnection, close-knit patterns of association, and possibilities for growth, diminution, and change*"[195]. From here, ultimately it makes no sense to consider forms aprioristically, yet human activities which will eventually define them. In this sense, in the *mat-building* form does not follow function. On the contrary, with it, the city is relational, not functional, and it is not [merely] elevated in *pilotis* over a green land. It is a built form in a permanent coming-to-be, spreading and absorbing any variation. In it, there is no place for singularity, except that of the system [and an equivalent structure] regulating the process. Similarly, analogous concerns would too be present in the larger scale, as is the case with the territorial *cluster-forms*, with their sequential and open shapes, tending to a spinal growth towards the exterior.

In the *mat-buildings* forms repeat and intersect, growing horizontally from within, until an intertwined structure and a flexible mesh is formed. The functional indeterminacy allows a seemingly endless growth and repetition, in an implied reference to evolutionary principles influenced by historical structures. There is no longer a grid in the modernist sense, but a regulating mechanism that is asymmetric, non-repetitive, and organic: a relational grid, following relativity's geometries. From the Cartesian inspiration of *Neo-plasticism* or *Purism*, it was now time to embrace the free forms, as those portrayed by the abstract expressionism. As the Smithson's write in *Urban Structuring* (1967), it was time to "*observe the paintings of Pollock or the sculptures of Paolozzi*"[196]. It was time to rethink the lexicon of the [inevitable] forms required by architecture to tangibly come about.

Outside *Team 10* other related ideas developed, influenced by Louis Kahn (b.1901-d.1974) in the USA, or Kenzo Tange (b.1913-d.2005) in Japan. The *Metabolists* in Japan[197], developed architectural formal concepts that included growth, change, flexibility, interchangeability, group forms or clusters, differentiation between primary and secondary structures or the role of transportation routes. Given such characteristics, the proposals undoubtedly echo the Dutch school, namely Habraken's supports theory. Kenzo Tange's utopian *Tokyo Bay Plan* was probably one of the most famous *Metabolist* proposal. It had too an unavoidable visual and conceptual affinity with the *mat-buildings*. Tange proposes a linear structure with many smaller centers. The structure works at several levels and with the possibility of different implementation degrees. There is the linear connection between Tokyo and the expansion, linking it to the existing transportation routes. In the central spine runs a civic core of office buildings traversing horizontally between vertical service hubs. Perpendicularly, a series of arraying ribs supporting housing. It is a vision of a future, which too, as in the *mat-buildings*, entails an open-endedness conception.

In 1962, Kisho Kurokawa, a Tange disciple, published the *Prefabricated Apartment House*. In it, he joined the idea of modular service units for kitchen, toilets and nursery units with pre-cast concrete construction. He subscribed the concept of *servant* and *served* spaces, and defended the idea of the building forms to be as precisely organized as the *space rocket*. In 1969, he would write his *Capsule Declaration*, paying homage to *cyborg architecture* and the *era of human mobility and electronics*. The concept of capsule living embeds an idea of spatial optimization to the most intricate detail. It is also embedded in the idea of an ultimate *placenessness*, where the lifestyles of individuals travel freely in the space of the metropolis, as they freely inhabit a *technotronic* society. The concept would be in the origin of some of his most remarkable creations, with the *Capsule House* inside the thematic pavilion of Expo'70, in Osaka, the *Takara Beautillion* pavilion, and most famously, in the *Nakagin Capsule Tower*, in 1972[198].

In a different context, the *Archigram* group also delivered technocratic idealizations in their utopian imagery. Visual references for projects such as *Plug-in City* (1964), *The Walking City* (1964), or *Instant City* (1968), span among comics, *pop-art*, popular sci-fi, technology of oil refineries or of space-age capsules, in post-apocalyptic or dystopian renderings. It is also about an architectural apocalypse, as it conceptually consisted in a deliberate assault on architectural conventions, invading its *seriousness* with popular art, all of which pinpointed by a great deal of irony and provocative spirit. There is, on the one hand, a concern in addressing urbanism, and on the other, the design and conception of individual buildings, where the injection of new subjectivity in the design and conception of architecture was simultaneously linked with an engagement with the urban frame. The idea is too remarkably visible in Constant Nieuwenhuys' architectural-artistic proposals, where the envisioned structures are as if floating in space, suspended, extendable, anarchical, limitless. The *New Babylon* (1956-1974), is in this sense envisioning a utopian anti-capitalist city, thought of as a flexible system in permanent change, made to provide pleasure, creativity, the situationist *detournement* and the human encounter. As it expands, it forms a cluster morphology, freely adapting to the ground conditions. In detail, the cities of the *New Babylon* are articulated sectors; each a macrostructure composed of microstructures where housing and public space may merge[199].

Above all, through *Archigram* or Constant's proposals, it can be witnessed an immanent promise of imagining alternatives, and effectively placing them at a communicational level which benefits its larger understanding in a wider, non-expert audience. Without such mesmerizing and promise of imagination, it is hard for architecture to live up to a liberating status that has potential to touch society, to engage people. However, that is also a dimension of a fantasy of disenchantment, where: "*Architecture is probably a hoax, a fantasy world brought about through a desire to locate, absorb and integrate into an overall obsession a self-interpretation of the everyday world around us*", as Warren Chalk wrote in an open letter to David Greene in 1966[200]. The Smithson's *as found*, as Van Eyck's *Kasbah's*, had been such a self-interpretation, where in its stride architecture ends up accumulating de-contextualized imagery. In a post-apocalyptic world*less* world, there will be no room for architecture to be seen, as we will all be in a elsewhere *spaceship* and can only look outside, from within, to the greater architecture of nature.

From all these examples, in which it can be recognized at least an implicit structuralist affiliation, we can observe recurrent concepts, such as: repeated use of identical elements; modularity of structures, elements, or relations; use of self-generative or rule-based mechanics; establishment of different hierarchical modes (e.g. structure and infill); causality between individual project and the city and vice versa. Many of these characteristics could be regarded from a mechanistic—algorithmic—point of view. Yet, given the broader range of structuralism, only a simplistic approach could endure such a perspective in exclusivity. Nonetheless, the temptation to place its interpretation from a mechanistic standpoint has endured in architectural circles. That figures a limited insight to structuralism, but nevertheless sets practical prospects towards a different understanding of the relations between architecture and optimized construction methods, which have more recently been revived with a new attention given the variability enabled by the technological evolution.

Herman Hertzberger provided a eloquent insight on this dispute, writing: "*Everything in architecture, good or bad, in which the constructive aspect occupies a visually prominent position, and which has to do with repetition of prefabricated components (whether of concrete or of some other material), with grids or frames, rigid or shaky or both – it is all labelled structuralism. The original and by no means empty meaning of structure and structuralism indeed appears to have been submerged by loads of architectural jargon*"[201]. On a contrasting argumentation, if taking structuralism literally to design, every form is ultimately structuralist. That inevitably results in voiding the pertinence of making any distinction between structuralism and other ways of approaching design[202]. As an *-ism*, structuralism is indelibly historically traceable, as many of the examples we have referred can portray. However, it embodies a much deeper potential, not only in binding a discursiveness of vernacular or natural with objectifying conceptions, but also in the framework it provides towards an engagement of alterity conceptions in architectural production.

2.4 Alterity in architectural production

Finally completing a new building seems such a glorious culmination. But it is an illusion… A building is not something you finish, a building is something you start.
—Stewart Brand in *How Buildings Learn, What Happens After They are Built*

Artists talk a lot about freedom. So, recalling the expression 'free as a bird', Morton Feldman went to a park one day and spent some time watching our feathered friends. When he came back, he said: 'You know? They're not free: they're fighting over bits of food'.
—John Cage

Freedom is amorphous.
—Salvador Dali

Don't ask for a rainbow, fetch it.
—Aldo Van Eyck

As free actors in space, we are nonetheless intrinsically constrained by the underlying context through which we are born and bred. As a semiotic point of departure, this notion is unquestionable. However, its radicalization has also been criticized. The extremes, which philosophically can be put in dialectics such as existentialism and structuralism, empiricism and rationalism, or freedom and constraint, can unobtrusively be regarded as opposed. In existentialism, man's ego (its individuality) faces an *Other* (i.e. a community, a nation, a world, and so on). In structuralism, the ego is seen as unavoidably located within a structure, implicitly conditioned by an *Other*. However, on the one hand, facts cannot be observed as facts alone, as observation implies a structure from which observation takes place. Conversely, structure cannot be reasoned by structure alone, as to reason we first need to observe facts to place them comparatively—e.g. without experiencing the sky, clouds never could be deduced from nothing. In this perspective, pure reason or logic are tautological, they cannot create new knowledge in themselves. They can only be based in previous axioms made from previous observations, thus ultimately stressing an ontological quest. On the other hand, pure sensorial input would be anarchic, fragmented, and not recordable, as if spray-painting a wall which is not there[203].

Architectural production implies some sort of control procedure. However, there are more obvious or subtle ways to exert it towards the experiential level of a user or observer. An application of the semiotic notions of *language* and *speech*, could imply a formulation of build objects open to free interpretation, or that somewhat could be freely appropriated by the user. However, unlike it can be in the humanities, in architectural production it will hardly suffice to theorize or speculate. In principle, something is to be brought about materially, in a graspable form. On the one hand, this indicates that perhaps architecture should be regarded with a special interest from the viewpoint of other areas of knowledge. Conversely, this is also signal of the problems which theorization faces when confronted with a praxis. In a physical world, the structural *Homo Significans* is frequently engulfed by the constructive, legal or economic impositions limiting architects' or users' freedom.

Regarded as a counterpart of control, freedom can be described as unconcealed, unlimited release. Unlike freedom's release, spatial formulation is ordered, targeted, even if it is of an emotional order, or an order that is impossible to define. Such as indicated by the *trap* of language evidenced by structural linguistics, freedom is too *virtual*, not attainable, intrinsically subjected to a sort of control, as a rainbow that can be seen but not fetched. Freedom is thus subjected to a (in)visible structure, so it is not independent. It takes no account of things, is anti-social, anti-authoritarian, anti-structure, or conflictual, and ultimately is in itself constrained. In that sense, there is no such thing as freedom of choice, as, by choosing, freedom is paradoxically diminished. Where everything is possible, there is no reference, no need, there is just an isotropic, non-referential void. In this sense, *freedom is amorphous*, thus non-architectural. The issue is eloquently illustrated by the paradox of choice, where is stated that, psychologically, the more autonomy and freedom of choice, the more difficult is for a choice to be made, as aspects such as chooser's anxiety increase, to the point of paralyzing decision: more is less, too much paralyzes[204]. Space-time creates a demand, which is manifested in a perceived form, and it is this formalized space-time that makes freedom understandable.

Within the multilayered construction business, architectural decision-making is often overwhelmed by upstream decision levels. This makes it difficult to escape a certain functionalist perspective, which typically favors, say, a certain financial accountability, which in turn may not be very consistent with user's spatial freedom: freedom is always conditional. Agreeing with the Marxist notion that economy has the primacy over political or social life, perhaps the main purpose of a functionalist perspective is to determine which couples with the requirements of predictability. This means to envisage what can be the expected effects of certain options taken during the course of the design process. On another level, determinacy can be a cause of detachment of the building with its user. People need to be identified with the spaces they inhabit[205], and that seems to be the best way for buildings to endure, as people will more likely be caring for what they value and cherish, than for any sort of overshadowing, controlling force[206].

Following the *language* and *speech* distinction, a participatory or co-determined architecture could be regarded through a perspective where, if *language* is the design, *speech* is given to the occupants. As Hertzberger wrote: "*The relation between a collective given and individual interpretation as it exists between form* *and usage as well as the experience thereof may be compared to the relation between language and speech*"[207]. Architecture or urban planning can be regarded as the result of an interpretation from the architect of both a material and an immaterial field that are read from a collective *language* sphere. In a way, the *speech* can too be seen as the unfolding integration of these elements, where built and social structures are met [complement with: **Annex, I.10 Enacting freedom in Herman Hertzberger's Central Beheer**].

That is an interpretation of archetypal social behaviors, but also something that we can allegorically ascribe to an endless *Musée Imaginaire*—an imaginary collection of images existing in the memory, as originally described by André Malraux[208]. Following the metaphor, architecture harvests its shapes from such an imaginary museum, translating it in the design, where thus *speech* is given to the architect. This *Musée Imaginaire* also recalls two essential parameters of architectural freedom: the architect designing from his own background, his personal museum; and the freedom of the user, also with a museum of his own. In each, control and freedom occur at different levels, with the architect exerting his spatial freedom under, e.g., economic or regulatory constraints, the user exerting his spatial freedom under, e.g., the constraint of the built form he inhabits, and both constrained by their individual traces and an underlying social bias. Buildings are thus where two human organizations meet, the intense group within, and the larger, slower, more powerful community outside. There is the experiencing human being, but there is also the frame of control—e.g. state, legislation, and so forth. A building can even be our own house, but, in many cases, we cannot do what we want with it—economic, social or environmental constraints limit options; regulation mechanisms have a word on what can be built, or on aspects of how a house looks like, and so forth.

In bringing form to a *material* sphere, the architect's freedom and responsibility is never fully eliminated, since in similar conditions, different architects most likely produce different designs. In this sense, the architectural solution is personal/subjective. With or without awareness, there is always a constraint of some sort when transferring though to the built environment, which will be manifested in the use of some sort of intermediary, control mechanism—e.g. urban regulations to communicate maximum building height allowed, graphic representation to communicate building's dimensions to contractor, and so on. Thereby, the architect's task occurs in a limbo, where the client's expectations must be met, while his own experience may in cases point to a different direction, or regulations yet another. That is, the subjective constraints of the individual sphere of the architect face the subjective constraints of the individual sphere of the client, to which it must be added the collective constraints, and so forth. Yet, because delivering form is a requirement, for the architect, the path through this threshold must be traversed to bring up the *artifact* to life, and that implies choices, funneling possibilities, going to one side while discarding other.

Anyhow, buildings seem to have a life of their own, and therefore a certain built form is not final, but a becoming—as Stewart Brand (b.1938) writes, "*a building is never really finished*"[209]. Implicitly or explicitly, to alienate or attract human participation, involve or not the user in the design process, purposefully specify or not parts of the design, leaving a greater or lesser degree of appropriation to the user's criteria, can be discouraged or stimulated (or perhaps just ignored) by the architect. This kind of perspective of control can also be set for a larger urban or territorial level and ultimately can be regarded as an ideological matter. For instance, the *Faculty of Architecture and Urbanism of the University of São Paulo* (1969), by Vilanova Artigas (b.1915-d.1985), is a remarkable example of ideology taken to an extreme, where freedom and equality are determining guiding principles. The spaces are wide open, seemingly without hierarchy. That is further stressed by its flow in half levels, connected soft and wide ramps, which give a sense of a single plan level. Nonetheless, there is an imminent order. Spatially such order is primarily given by the huge public atrium, a central void that physically and visually bonds the diverse spaces of the building, and from where the different levels and their connections can be perceived. This order is further stressed by the building envelope, particularly its roofing, which dominates the internal space, and by the precise rhythm of its solid columns that enable [and contrast with] the lightness of the roof, which is stressed by its geometrically precise skylight pattern. The order of the building is what enables its freedom; the central communal space represents a spatial order, which nonetheless is intended from a purpose of freedom. The fact that the building was though without entrance doors further stresses the ideology of a democratic, communal space, which finds its greater expressions in an idea of fluidity and certain programmatic open-endedness, through wide spaces and free flow communication. Anyhow, although beloved, the building is also criticized by its users, since its open-endedness can sometimes be chaotic. In a way, its polyvalence simply lacks order, and that simply does not always comes in handy: its ideology (i.e. freedom) is also its imprisonment. The architectural production is indeed an imperfect equation.

Social life is full of uncertainties and constraints. As Marx disclosed, control is inextricably bonded to [social] conflict. Likewise, any sort of user participation in an architectural design will inevitably origin conflict. Between the architect and the user, there is a potential conflict of a communicational or cultural nature. Although still revisited, the qualities and faults of Modernist control strategies have become clearer with time in respect to the alienation of human participation, invariably favoring other aspects. In any case, critique may be unfair to many of the modernist architects, as, in many ways, aspects of their designs were out of their control. For instance, architects in the postwar were in a large pressure to meet the huge demands for social housing, and quality had to make way for quantity. In everyday practice, architects are pressured to deliver in some way, and conditions are often far from ideal. It is not an easy task to focus in delivering quality to the design, as stuff as bureaucratic tasks and the like accumulate, limiting the architect's ability to devise responses. In another perspective, often there seems to be a lack of communication between architectural professionals and other actors involved in the building's construction or building's maintenance throughout its life span.

Anyhow, most of the modernist architectural archetypes were, in brief, fundamentally based in an alienating conception, where tight control mechanisms mostly impede user participation, or in the least result in less inviting forms[210]. Opposed to such a deterministic conception several voices aroused in praise of cross-cultural approaches towards non- or less-restrictive principles[211]. In the historically developed city, the palimpsest of built layers is rendered as result of open forms and a varied and stable network of relationships within the entire system occurring through the special sociability of the street. In it, there is seemingly no imposition, as control is socially implied. As it appears to an observer in the present, the network of streets, its relation of building heights with width of streets, it all seems to be a balanced game of economy, materials, techniques, social accepted values of privacy, security, and so forth. In our modern cities, control and the role of authorities are a major influence on the design and use of built environments. On the one hand, authorities are important to assure the existence and coherence of the urban infrastructure. On the other hand, their control should not extend so far that people lose any sort of influence[212]. The major problems seem to appear when control is liberated to voracious speculation. Ultimately, the users will inevitably be constrained by their ability to afford certain spaces, which often leaves them hostages of the profit-engaged mechanisms, with few or simply no chance of influence.

On the long run, between the control levels of public policies and their emanating regulations, building entrepreneurship, design, and using, the outcome is not always profitable to the built environment. In such a chain, the architect and the user are typically the least controlling in the entire process. Nonetheless, influence can be exerted from these, as it has been attempted in Jean Nouvel's *Nemausus I* state-financed social housing, built in 1986 in Nimes, France, where an ingenious method was devised to overcome dwelling's spatial limitations implied by regulations [complement with: **Annex, I.11 Alterity beyond Control through Jean Nouvel's Nemausus I**]. Inevitably, any kind of speculative design has probably a greater potential of mismatch between the design intentions and the building's normal use. Anyhow, most buildings are unavoidably speculative, and no architecture can suit all tastes. Architecture requires options to be taken, an order to be established, although not necessarily a totalitarian control. Whatever the order may be, that necessarily ends up pleasing some more than other. As in the sentence attributed to Abraham Lincoln, "*You can please some of the people all of the time, and you can please all of the people some of the time, but you can't please all of the people all of the time*".

There are thus no definitive answers on how to combine control and user freedom in architectural production. Moreover, the expressed intentions and the practice often lead to contradictory statements. When Mies van der Rohe reduced a building to an ideal '*fast nichts*' ["*almost nothing*"], as in the *Farnsworth* house, we could apparently understand it as an embodiment of a non-interference of the architect on the lives of the users. Nothing could be further from the facts[213]. With Mies' *nothingness* what was instead suggested, was a maximum opportunity for freedom of expression, but only and only if as not altering what the architect envisions. Such idealized *nichts* ["*nothingness*"] turns out to be a mirage of freedom which only some can afford, and few can cope with—a total, permanent, imposed, perfect, irrefutable, controlled, ideal, personal (the architect's view), non-universal freedom[214]. The *Fransworth* house is immaterial matter, metamorphosed in the prestidigitator hands. It indulges [a simulated] freedom, which lives and breathes in a utopian world, where the tiniest *contamination* will have devastating effects: change is ruin. It is a highly sophisticated, final *language* with no admissible *speech*. Edith Farnsworth, the client which had endorsed Mies to entirely fulfill his architectural beliefs into the design, would later attack Mies' famous axiom: "*Less is not more*", she wrote, "*It is simply less!*"[215] (but then, apparently there were also personal issues involved).

The more radical functionalist approaches reduced space design to a machine engaged with progress, with little or no concern for man's less quantifiable needs. The subject is recurrent since, with different sorts of approaches. One can be the putting into perspective the obsessive nature of an *immaculate* functional order by an appeal to flexibility. Another can be to regard research within the cultural context of an activity to be applications from which to reinterpret, rework and exploit the functional program[216]. In one, the technical answer, where the built spatial hardware is hard-wired towards user participation. In the other, the open-space with no predetermined meaning correspondence, available for free interpretation, where the space is materially released from its functional purpose, placing control not in a physically built form, but in implied regulatory design mechanisms which endure a potential of adaptability. The first can archetypally be ascribed to the type of approach endured in Gerrit Rietveld's *Schröder House* (1919), and can be contemporarily noted in the transformable apartment theme, using transformable, multi-purposed furniture and [high]-tech apparatus in order to optimize space through flexibility of use. The latter finds an eloquent archetype in Le Corbusier's conceptual *Dom-ino* (1915). The formalization of both the technical, and the open types, is intrinsically related on the structural and infrastructural design philosophy.

Rietveld's *Schröder House*, although built to a specific client, also renders a highly conceptual approach. Each activity in the house requires a choice. On each situation, the user can decide what the intended house configuration is. Such is enabled by a series of built-in sliding partitions. In the center of the living level, there is a fixed core with services and the stairs. The bedroom level is too following a principle of embedded sliding doors. There are numerous different spatial combinations hard-wired in the building. The concept got to concretization because the client keenly defended such concepts. Nevertheless, throughout its history, the concept would reveal its faults. What was probably playful in the beginning, would eventually reveal hard or unnecessary. The effort to constantly open or close the sliding doors ultimately led the clients to keep the same spatial configuration all the time, that is, to turn permanent their flexibility options[217].

A broad idea of user participation was notoriously implied in Le Corbusier's *Plan of Obus* in Algiers (1928-1931), based on an infinite linear curved block bounded to the structure of the motorway, where the possibility of participation by its inhabitants is left open. The earlier conceptual *Maison Dom-Ino* (1914-15) had already denoted an open-endedness in its free plan and façade, but nonetheless it had no formalization, conveying an idea of freedom through its bondless indeterminacy. The design is truly a proto-architectural concept, a framework, completely independent of the floor plans of the house: a concrete skeleton with three slabs, six pillars and a staircase, embedded in the idea of mass production and allowing a great deal of layout and façade variability. It is also the prototypical image of many designs later developed by Le Corbusier to address the housing problem—namely the *Maison Citrohan* (1920), the *Immeubles-Villas* (1922), the *Pessac* (1925), or the *Villa Savoye* (1931)—but also archetype of vacant, adaptable forms. The concept foresaw a bearing structure, which could be used as a base to take decisions about the plan divisions and windows location and size in a later stage of the design or even of the construction, and thus can be interpreted as an open-ended design, allowing user freedom. Fundamentally, it is foremost a concept, not too much compromised with a final form, and that may well be what made it prevail.

In common, the types depicted by *Schröder* or *Dom-Ino* houses ascribe to the need to make the spaces we inhabit our own, instilled with freedom purposes under a more or less explicit sphere of control. They convey a desire for a sense of permanence, for stability, for keeping a feel of shelter and reference to call a place our *home*. In this sense, Rietveld's concept-made-house may had worked fine if the house was not to be assigned to a single family, but instead temporarily occupied by different families over time. Nonetheless, the open-ended principles were unthinkable in the post-war mass housing: more freedom meaning more technical apparatus (*Schröder*) or more space availability (*Dom-Ino*), and in both *more is money*.

From the earlier modernist optimization studies, post-war construction urgency and so forth, compartmentalization of the building process through different, industrially-driven, construction components made more sense than ever, and control towards built-form could be more accurate than ever. With it, it has risen a preliminary methodological distinction between what can be called the *servant* and *served* spaces, a terminology which fundamentally distinguished those spaces with more variety and/or density of infrastructure terminals, such as kitchens or toilets, from those with less, such as bedrooms and living rooms. In brief, the *servant* would stand for a lesser potential of transformation, whereas the *served* for seemingly more freedom of space. Modernism had already provided the notion of the free plan and/or free façade. Alongside, it was distinguished a structural core of columns, beams or slabs, from a remaining free floor and façade space. With the introduction of discrete levels, the *services* were added to the distinction. To the structural core would be added a second, infrastructural core, the services.

Buckminster Fuller's *prefabricated bathroom* (1938) stood as an extreme concretization of such conception, adding both concepts of product rationalization and ergonomics towards the determination of its shape, and calculated exactly in agreement with the space that is assumedly necessary for it to be transported to site with ease. In the *Salk Institute*, in La Jolla, California (1959-1965), Louis Kahn implicitly distinguished *servant* and *served* spaces, with the program reflecting the requirements as well as mirroring the deepest wills of people for freedom and security. In the project, the complex is divided in three parts, each related with an aspect of the research institute, with a publicly accessible meeting center, semi-public research laboratories and a private dwelling center. In the research building, the *servant* spaces are articulately subordinated to the *served* laboratory area. The spatial concept is integrated with the structure, which enables a span that leaves the entire floor area free for any type of posteriorly intended subdivision.

Between a buildings' useful life and the need to typify human activities lies a central conflict. In a shorter or longer run, once a part of a city or a building is completed, it will invariably be occupied differently than what was initially suggested. Such unpredictability, has led some theoretical and/or design approaches to claim for a greater flexibility in use, calling for ease of adaptability or to design with polyvalence in mind. Different goals may be at stake, where generally is accepted the idea that the material elements of construction should not undermine eventual future changes in the building's use. A related idea has to do with the future prospect of totally or partially recycling built structures, discretely separating them in hierarchies conducted by life-span expectancy. The quest for flexibility can hence lead to different approaches. Some, by setting some material decisions to latter stages of the design process (or leaving them open). Others, by applying standardized, hence potentially more easily replaceable building elements. Others even, by distinguishing between primary and secondary elements, or between those that are to be permanent and those more easily replaceable. These approaches are not exclusive and may be found used simultaneously[218]. Moreover, as with the greater or lesser availability of space, the design brief will inevitably affect how freedom-enacting intentions may be transposed.

3 TAXONOMIC LANDSCAPES: (RE)MAPPING ARCHITECTURE'S STRUCTURES

Der Römische Brunnen

Auf steigt der Strahl, und fallend gießt
Er voll der Marmorschale Rund,
Die, sich verschleiernd, überfließt
In einer zweiten Schale Grund;
Die zweite gibt, sie wird zu reich,
III Der dritten wallend ihre Flut,
Und jede nimmt und gibt zugleich
Und strömt und ruht.

["*Roman Fountain*

The jet ascends and, falling, fills
The rounded marble basin up,
Which shrouds itself before it spills
Into a second basin's cup;
Growing too full, the second runs
Its surging billows to the next,
And all three give and get at once,
And run and rest."]

—Conrad Ferdinand Meyer, translated by A.Z. Foreman

3.1 A general notion of systems

Cognitive psychology indicates there is a human tendency from which seemingly complex operations, of which there is no prior knowledge of, are understood from what are thought to be their simpler terms, and by which difficult operations are solved by breaking them into smaller, easier to grasp, parts[219]. This reductionist notion also implies some sort of reference from where things are to be compared and understood, and that essentially raises the need of having some kind of taxonomy to relate the otherwise diffuse fragments. Anyhow, a reminder should be present to what has been said by the *Gestalt* psychologist Kurt Koffka, "*the whole is other than the sum of its parts*"[220], implying that when the human mind forms a percept (or *gestalt*), that the whole is something other, or different, than what appears to be grasped from what are hence its *parts*. To this, we can add the *Royal Society*'s motto, *nullius in verba* (Latin for "*on the word of no one*" or "*take nobody's word for it*"), which incites the breaking of boundaries and ever questioning. With an implied methodological call for science, the motto suggests that boundaries are there to be broke, but also that, recursively, when breaking them, there are new boundaries coming to life before us. As subscribed under a structuralist viewpoint, it is from the (sub)conscious *structures* that we are able to give a foundation, question and develop knowledge, thus going beyond existing boundaries.

In *Myth and Meaning* (1979), Lévi-Strauss expressed his understanding that "*science has only two ways of proceeding: it is either reductionist or structuralist… And when we are confronted with phenomena too complex to be reduced to phenomena of a lower order, then we can only approach them by looking to their relations, that is, by trying to understand what kind of original system they make up*"[221]. Regardless the approach, it stands out that some degree of simplification must be attained to understand seemingly more or less complex phenomena. Moreover, there is also a relational sphere, referring not only to isolated elements, but also how to rationalize their affiliation, implying a *systematicity*. The latter is thus key towards the production of knowledge, in the unfolding processes of building and structuring signification. It is what essentially enables a communicational platform, enabling ideas to be recognized, differentiated, and understood, affecting aspects such as language, prediction, inference, decision-making and all kinds of environmental interaction, and thus involving processes of choice. As *structuralism* implies, every discipline is supported in a particular language, defining its terms and establishing common grounds, and without a communication platform, no discipline or knowledge of any kind can be developed. The taxonomic mechanisms of a *systematicity* enable it. Thereby, a common ground between the notions of *structure* and *system* can be established[222].

Subscribing a Kantian *architectonic* notion, which can roughly be acknowledged as equivalent to a *systematicity*, the ways by which architecture is brought into being can be regarded as embedded of an organizational nature, where both a *nounomenal* (or *mental*) and a *material* (or *executive*) spheres meet. For instance, on the dialectic of design/construction, through *mental*/prospective notions such as *design system* or *compositional system*, or *executive* notions such as *constructive system*, *systems construction*[223], or *prefabricated systems*[224]. Transposing a *systems'* vocabulary to architecture, questions such as *what is a system?* or *what characterizes system?* can be translated into something such as *what is a building?* or *what characterizes a building?*, and so on. Even leaving philosophical interpretations of these questions aside, such questions are anyhow vague on their own, and would have to be further specified. In this case, the formulation implies an equivalence of *system* with *building*, hence where building is not an object of analysis in itself, but symbolically a *system*-object insofar as it is understood of being constituted of diverse parts. Furthermore, in answering to *what is a building?*, in the least it would have to be understood what can be meant with *building*, or what it symbolizes. That is, if it is being addressed a projective-constructive reality (which in itself can be split in to additional streams of analysis), or if it is also being addressed a perspective such as of architecture's functional program, building maintenance, or an experiential level of the use of space, and so forth. The taxonomies thus established for any such analytical process are intrinsically of a limited scope, and have to be regarded insofar as a transitory and inherently *symbolic* formulation. That is, there is an underlying practicality in establishing these kinds of distinctions, which can serve methodological and/or communicational purposes.

For methodological purposes, a distinction between a theoretical and an empirical *system* can be established[225]. The first can be said of being of an *in-out* type, traveling from a mind-set (a *mental*, *nounomenal* dimension of concepts, propositions, or suppositions) towards the world (a *material* dimension of real or imaginary beings, objects, or things), via empirical reference and logical integration. The second can be said of being of an *out-in* type, moving from a set of phenomena to theory. Laszlo and Krippner described the concept of *system* as serving "*to identify those manifestations of natural phenomena and process that satisfy certain general conditions. In the broadest conception, the term connotes a complex of interacting components together with the relationships among them that permit the identification of a boundary-maintaining entity or process*"[226]. A *system* can thus be regarded as a boundary condition, or directional reference—e.g. *in-out* or *out-in*—between two states acknowledged as being different. Furthermore, the establishment of a boundary condition implies a formalization through a symbolic device—i.e. setting a frame of reference of a reality (*symbol*) through a certain *form* (e.g. material, verbal, visual, and so forth), i.e. clarifying a scope.

Deepening the definition base, a *system* can formally be described as a frame acknowledging a set of two or more elements, where each element has an effect on the whole, each element is affected by at least another, and all its infra-groups or supra-groups have the first two properties[227]. Additionally, we can generally speak of four main characteristics of a *system*. One is *things*, that is, the objects, parts, elements, variables, or other (sub)*systems* within it, which may be physical, abstract or both, depending on the nature of the *system* and the intentionality of its use. A second is *attributes*, that is, its qualities or properties and its things. A third is *relations*, that is, the internal relationships among its things. A forth is *environment*, that is, the surrounding, or medium where it exists. From here, a broad definition of *system* can be put as a set of things that affect one another within an environment and form a larger pattern that is different from any of the parts[228].

Put in more visual terms, a *system* can be regarded as more of a pattern than of a thing in itself. Although not entirely accurate, a way of illustrating it would be through an analogy of moving in and out a visual representation of a Mandelbrot fractal set, in the sense that the fractal depicts interrelated elements, whose appearance is differently rendered in each moment or scale of observation, regardless their bonds, but nonetheless retain an invariance relating them. That is, more than a stagnant entity, the acknowledgment of a *system* serves a methodological purpose, but can only acquire significance when dynamically set alongside other so-called *systems*, that is, their value resides in their symbolic power as both referential (rational) and significant (semiotic) device.

From the diverse approaches that can be observed in the literature describing *systems*, stating aspects such as *wholeness* and *interdependence*, *hierarchy*, *inputs* and *outputs*, and so forth[229], perhaps the most comprehensive is the one emanating from the knowledge of the second law of thermodynamics. From there, it is suggested the exchange capabilities of a *system*, studying thermodynamic *systems* in terms of their kinds of boundaries and of transfers, addressing notions such as *openness* or *closeness*, *external* or *internal*, *dynamic* or *adynamic*, *permeable* or *impermeable*, and so forth, which can only be observed from the establishment of a boundary condition. Anyhow, distinctions such as *open/closed* are in last instance purely methodological (even in thermodynamics)[230], given the implied relativism of *systems*[231]. The above terminology stands for the thermodynamics approach, but analogous terms can be used to concepts such as exchanging *information* or *currency*, or also to describe nature's eco-*systems*, and so forth[232]. For instance, in architecture, a notion such as closeness can in spatial terms somewhat convey the idea of more of a controlled environment, or objectual sense, and conversely, openness may imply interaction, or the ability to cope with change[233].

From what has been said, in brief, a *system* can be considered as a boundary condition, representation, or classification, of a universe of elements. In broad terms, we could synthesize it in a set of the kind *S*={t, a, r, e}, with '*S*' standing for *system*; 't' for *things*, 'a' for *attributes*; 'r' for *relations*; and 'e' for *environment*[234]. In higher or lower ranks, each element in this formulation could be analyzed as an analogous *system* per se, meaning potentially obtaining an infinite set of *systems* from a given finite *system*—hence an open *system*(aticity). By opposition, it can be said that a closed *system* is one where is required a formal consideration onto where the range of analysis is limited, thus defining the scope of the *system*, enclosing it. Anyhow, for practical purposes, most *systems* so-considered are regarded from a closed perspective.

To illustrate such a *systems*' schematics in an architectural context, the *system* say *constructive component of a building*—e.g. steel truss—can be observed from the perspective of its diverse elements. Its *things*, i.e. the elements that make up the component—e.g. steel profiles, screws, bolts, welds, paint. Its *attributes*, i.e. the characteristics of the elements considered individually or their function in the whole component—e.g. paint can have both a protective and an aesthetic function, and so forth. Its *relations*, i.e. again considered in each of the individual elements or in the overall component—e.g. the relation between a steel profile and a screw, or how the steel truss will connect to its support, what visual effect will it produce. Finally, its *environment*, i.e. the supra or infra *systems* with which will it be a part of or contain—e.g. the building is the environment of the steel truss, but also a portico formed by the truss and its supporting columns can be considered as its environment, and so forth. Additionally, a steel-truss like the one described in our example, can be considered as a closed *system* from e.g. a spatial use perspective, but can also be considered as an open *system* from the perspective of e.g. its maintenance (e.g. painting to protect it from corrosion), and so forth. From here, it is also clear that besides its intrinsic formality, that an underlying intentionality is required to make a knowledgeable or an operative sense of a *system*—or, as Marchal has written, "*and, of course, what we end up looking for will depend on the kinds of systems that we have found it interesting to identify*"[235].

The mapping of a *system* is thus subjected to a set of purposes, scope, or on the resources available to proceed it, and so forth. Anyhow, some findings are just not readily possible to recognize or to assimilate, and thus frame onto a *system* of some sort, and some others may never will. Moreover, with the available knowledge at a certain moment, some realities are just too complex to be mapped onto a *system*, or their relevance too far from a certain core purpose for it to have any practical relevance in more immediate terms. Overall, given an inherently qualitative dimension, which we can relate with the very human condition—a dimension where the *homo faber*, following Hannah Arendt's description[236], meets the *homo significans*—it stands out that more than set towards strictly utilitarian purposes, *systems* are partial, rational means of a seemingly ever-unraveling human construct.

As the physicist Richard Feynman eloquently implied, we just have to allow ourselves to be in some framework where we have to make faith in what others tell us, otherwise risking on perpetually asking *why?*. That is perhaps why our civilization has come up with specialization, laws, standards, certifications, and so forth[237]. Whatever the work one makes, we are inescapably engaged in a societal frame, which involves tradeoffs and a degree of trust—implicit or explicit, aware or unaware—in what other people say or make, and thus we purposefully have to allow ourselves the *ignorance* and a socially engaged belief for our work to attain a *productive* sense. Anyhow, that does not mean disregarding the *nullius in verba* motto, which puts forwards a sense of dissatisfaction, where perfection or accomplishment cannot but fugaciously be fulfilled. As primarily an act of human intellect over space-time, whatever that may be, architecture must deal with the natural imperfectness and evolution of human spirit, and that is valid both for how architecture is produced as for the ways it is experienced. Moreover, as some of the most intrepid modernist works have shown, good intentions delivered in optimized fashion by brilliant architectural minds, although may be aesthetically (subjectively) appreciable and/or symbolically sharp, do not necessarily mean successful designs from other points of view—e.g. Brazilia.

It is our belief that the reality of architecture is not that of the perfection of universal laws that have the potential of explaining everything such as in physics, yet to act in the imperfectness of the unfolding human life. In that sense, architecture can be regarded as much more about social engagement than about science, less of a method, more of an ongoing praxis, carrying its memes, and in any case an artificial [and imperfect] human construction. Maybe the old adage of the computer world is true: the perfect *system* is one with no users. Nonetheless, through a more or less explicit statement of a *systematic* order, with greater or lesser accomplishment or influence, several remarkable authors throughout history have attempted to establish architecture's taxonomies, as is the case of the ancient Vitruvius, the Renaissance men such as Alberti or Serlio, or the more recent Modern's such as de Quincy, Durand, Semper, Le Corbusier, Habraken or Frampton. Anyhow, regardless the approach and/or circumstances, the fact is that the efforts undertook by these and others apparently signal an ontological aspiration, that of giving architecture a discursive foundation where the archetypal stones or any dogmatic formulation cannot reach. A foundation amid the unraveling dynamic of the things of the world, for fugacious that may be.

3.2 Type and architecture

3.2.1 A KIN ORDER OF TYPE

In architectural discourse, the broadly used notion of *type* is what probably more vividly has been synthesizing the semantics of what is a seemingly more general notion of *system*. Indeed, although both are prone to multiple interpretations, the contribution of a *system*'s understanding of phenomena finds several analogies to that of the *type* in architecture, with both concepts often mistaken, which, depending on the scope or approach, it is not necessarily incorrect.

Our built environment is perceived through our sensory mechanisms and evaluated through our cultural background, via ideals, images, values, meanings, expectations, and so forth. What we experience is the outcome of many individual decisions of numerous people over time. The patterns arising from this environment are direct derivations of a society's culture over space-time, expressing shared preferences[238], and these can be classified in multiple ways.

In architecture things can be labelled in terms related with form (e.g. a box-like house), space (e.g. a patio house), and so forth. Architects, or other actors involved in the building processes, or any observer of such processes, can also use terms related with things such as the market (e.g. describing a house by the number of rooms, as T0, T1, T2), the style (e.g. *colonial house* or *neo-classicist house*), the location (e.g. *country house* or *beach house*), and so on. These classifications can be more or less questionable, and whereas some will be more prone to trends, others can have a deeper impact in the continuous process of analysis and production of the built environment. Modernly, in architectural thinking, particularly since the XVIII[th] century, with the contributions of Quatremère de Quincy (b.1755-d.1849) or Jean-Nicolas-Louis Durand (b.1760-d.1834), such classifications have frequently followed the terminology of *type*. Nonetheless, the notion of *type* had been around in architectural circles for quite some time, although with different connotations[239].

While seeking for the origins of the art of building, common traces can be found everywhere. For instance, creating a shelter from available materials, or devising a technology for it to provide the basic purpose of protection towards the weather conditions. As eloquently put from a vernacular perspective, as different materials are found, new uses are eventually enabled, old materials given different uses, or the knowledge to devise a different technology is adapted, and so forth, eventually evolving to a higher sophistication in materials, techniques, or processes[240]. Such can be regarded as an evolutionary view, and is one that has been broadly implied by several versions of the myth of the hut, as famously expounded in Laugier's *cabane*, set on the path of a Vitruvian-humanist tradition. In such an evolutionary perspective, forms are bound to arise from a timeless iteration between the observation of the real and its course in imagination, thus changing and adapting throughout.

Sprouting from the mythical notion of the hut, early reference books, such as Vitruvius's, or later, since the Renaissence, Alberti's, Serlio's or Palladio's books were embedded in the spirit of *type*. In such a Vitruvian lineage, the notion of *type* was essentially related to a *kin* idea of *form*, that is, on a certain predominantly *objectual* way of envisaging architecture. The case would particularly gain visibility with Serlio's, due to the groundbreaking illustrations accompanying the text, while contributing to a wider dissemination and audience awareness. The broad scope of the Vitruvian triad *firmitas*, *venustas* and *utilitas*, ascribes to a *kin* architectonic whole of an objectual, but too divine sense, since architecture is there regarded as a synthesis of these ideas in an undividable, perfect whole of interdependent parts materialized in a construction form. That has carried epistemological repercussions to these days.

The *Doric*, *Ionic* or *Corinthian* orders, rediscovered in the Renaissance, added to that objectual sense an emphasis on a somewhat mixed conceptual/aesthetical purpose. Conceptually, in the Renaissance, the faraway classical history provided a supposed ontological validation, which could not be thoroughly verified, but also could not be refuted—indeed the mythical hut model is based on non-particularly confirmable, yet plausible suppositions. The Roman or Greek remains, added by numerous inputs, such as those of remarkable Renaissance artists and architects, enhanced an aesthetical dimension to that ontological harbor, thus resulting in a *higher-architecture*—corresponding to a *high-culture*[241]—that readily became a model mimicked throughout. Remarkably illustrating the underlying validation process, a few centuries later, a comparable ontological harbor would be used to build the monumental, classicist inspired Washington DC, assumed as a both an architectural model and idealized as a solid, stable cornerstone of a liberal society[242], safe-haven of a national identity.

The classical orders are derived from a mythical inspiration—the hut or the like—each following more or less rigid rules and each with its particular issues, as illustrated by the classical corner alignment conflict of the *Doric*. Since seemingly directly binding conceptual and aesthetical purposes, the classical orders fundamentally reinforce an objectual, *kin* sense to architecture's episteme. Furthermore, they essentially constitute in themselves the idea of *system*, following its own laws, which can additionally be used in buildings in conjunction with other orders. Yet it can also be seen as a *type*, that is, each order can be distinguished from the others for the use of certain kinds of constructive or aesthetical motives related with more or less clear symbolic purposes, and so forth. From here, it matters to attempt to clarify the distinction between *system* and *type*, noting that the modern notion of *type* in architecture would extend far beyond the notions that could be interpreted from the classical orders, which in many cases has nonetheless blurred the difference in terms.

3.2.2 AN ENLIGHTENED TYPE

Etymologically, *type* derives from the Latin, *typus*, meaning figure, image, form, or kind. From the Greek, *typos*, it is associated with a blow, dent, impression, mark, effect of a blow; figure in relief, image, statue; anything wrought of metal or stone; general form, character; outline, sketch, and so on. From the XVIIth and XIXth century onwards, it has been used to symbolize, and to project, to foresee. Since ancient times, the knowledge of anatomy and physiology had been divided into *systems*—e.g. cardiovascular system, endocrine system, and so on[243]—which meanwhile have grown in specificity and clarification.

Carl Linnaeus, in his *Systema Naturae* (1735) and subsequent works, was the primary responsible for the 'invention' of modern *taxonomy*, or *systema* as he called it, by then dividing the natural world in three kingdoms, (*animalia*, *vegetalia*, *mineralia*), each of these into classes, (e.g. *animalia* into *mammalia*, *aves*, *amphibia*, *pisces*, *insecta*, *vermes*), and so forth. To these days, in biological terms, the notion of system follows a similar logic, regarded as a group of related (natural) objects or forces within a defined zone, an interdependent or regularly interacting group of items making a unified whole. In the same *Systema Naturae* and other works, Linnaeus also famously used the word *type* in the biological notion of *type specimen*[244] in his groundbreaking taxonomic classifications of the natural world. In biology, a *type specimen* is an example that serves to anchor or centralize the defining features of that particular taxon—i.e. it is a preserved specimen designated as a permanent reference for a new species, new *genus* or some other *taxon*. These *types* are usually physical specimens that are kept in a museum or herbarium research collection, but failing that, an image of an individual of that taxon has often been designated as a *type*.

Regarded immutably, *type* has thus the classificatory character of an encyclopedia—i.e. a referential source of knowledge made to withstand the times, much in the fashion of the Vitruvian triad or the Classical architectural orders. Anyhow, nature's classifications have evolved ever since Linnaeus, accompanying the findings of science, although in some cases early classifications have generally stood the test of time. In any case, directly or indirectly, *type* has most likely entered the architectural vocabulary based on Linnaeus' signification, not least, in our belief, because an important part of Linnaeus' *type specimen* characterizations followed a morphological insight. From there, as a modern conception of methodological breadth, the discourse of *type* definitely entered the architectural lexicon with the early encyclopedic definitions of de Quatremère de Quincy, or the collections of *types* of Jean-Nicolas Durand.

In the core of de Quincy's conception laid the distinction between *type* and *model*. In it, whereas *type* was located in the domain of the ideal, the abstraction, the *model* was located in a rendered set, used for practical purposes, repeated as it was[245]. According to de Quincy, fundamentally we should not mistake the idea of *type* with the idea of *model*. Whereas he regarded the idea of *type* as the original reason of the thing, which can neither command nor furnish the motif or the means of an exact likeness, the idea of the *model* was regarded as a complete thing, or an instance of the *type*, which was bond to a formal resemblance. The concepts do resemble the early biological taxonomic definitions, where *model* can somewhat be understood as *specimen*, and *type* as *type specimen*, although clearly following a free interpretation of their own, including some philosophical additions. Curiously, de Quincy's *type/model* distinction do resembles the *genotype/phenotype* biological distinction, which would only be introduced in taxonomic terms in 1908 by Wilhelm Johannsen[246]. Anyhow, on de Quincy's lineage, other distinctions have followed, as for instance the historically closer analogous distinction, proposed by Habraken, between *system* and *pattern*[247], which, regardless the divergence in terminology, in any case stands for the establishment of some kind of order, or replicable methodology, but not necessarily in stagnant mechanistic terms.

On the same epoch as de Quincy, the French architect Jean-Nicolas-Louis Durand developed a classification method to address architectural issues. Durand's approach was too tuned with an enlightened French post-Revolutionary spirit, which was additionally in line with the teaching philosophy of his *Polytechnique* school[248], where efficiency and economy were regarded as fundamental operators in architectural design and construction. By composing designs through modules on a squared grid, each depicting a scaled dimension, elements could be ordered: spacing of columns, wall locations, axis, openings, and so forth. Such approach expressed a generative understanding of the concept of *type*, since it was not limited by the mimicking of instances (*models*), but allowed a *free-flow* within a recognizable order.

Additionally, with Durand's *Recueil et parallèle des édifices de tout genre anciens et modernes (…)*, or *Le Grand Durand* as it also became known (1800), it was delivered the first extensive survey on major architectural monuments built since classical times, gathering a massive collection of examples. The book included plans of different buildings from different historical periods[249], and it was imbued with a true encyclopedic spirit. To ease comparison, the buildings were systematically classified, grouped by building *type*, drawn to a common scale and stripped off any context whatsoever. Indeed, in it, only plans and elevations were presented, and that in itself underlies an intention to depict universal architectural characteristics, regardless their location, cultural or historical setting. In a sense, through it, man does not inhabit a qualitative space, yet a universal geometric space, a notion that follows and stresses its very zeitgeist: method is everything.

3.2.3 CHARACTERISTICS AND LIMITATIONS

Our modern inheritance, allied to a practical communicational sense, makes us name the *spaces* of the house after their *functions*—the bedroom is where we sleep, the kitchen, where we cook, and so on. Although of utterly practical intentions, this explanation is insufficient, since the relation between a so-considered spatial sphere and the activities that take place within is more complex than what such a functionalist view conveys. The spatial sphere involves qualities that exceed a mere functional characterization, such as a particular system of settings and a context. For instance, sleeping may happen in places other than the bedroom, cooking normally takes place in the kitchen but different lifestyles or cultures may require different ways of using it, thus defying a usual functional correspondence. The spatial sphere certainly involves a particular location, with a particular environmental quality, which varies according to our socio-cultural perspective and/or background[250]. Therefore, to identify *types* of space, there must be an awareness of its inherent relativity, as well as of what potentially will be happening within those spaces. Moreover, it must be understood how these spaces are positioned within the *whole* system of which they are part of—e.g., a room in an apartment or an apartment in a building, and so forth. Not least, there must be an awareness of the transitional space between public and private, the open and the reserved, the self and the social and cultural milieu, and so forth, which will inevitably be reflected in the qualities and shape of the architectural ensemble.

Keeping that awareness in mind, anyhow, the concept of *type* can generally be defined as what is constant in terms of parts and relations among the innumerous different expressions, serving a dual purpose: making us share its particular values, and therefore a culture, while allowing us to express our individuality within that culture. Partly, it can be ascribed to a communicational need, that of transmitting ideas through recognizable concepts, or attempting to reach a wider audience. Yet, part is also necessarily related with a Platonic *Ideal*, that is, a projective perspective, where implicitly or explicitly, *type* can be regarded as a device in the creative process. From here, two distinct ways of observing the *type* can be noted, the *type* as *Ideal*, and the put in practice of the *type*, in a different context relatively to the original, mimicking and adapting—i.e. transforming from an abstract notion onto a sensible object in a different place. As an *Ideal*, the *type* is not immutable, yet subject to change, as the practical developments, or the variations it arises, are ought to question their very source of departure. In a way, it can be regarded as an essence, a soul, or as an internal form-structure, that unites the works based on a *type*. In this sense, between objects of the same *type* there is a principle of similarity given by the *type*. For instance, the graph theory illustrates a method for visually representing what may be read as an essence, or objects stripped off to their similarities, which can be regarded as an application of the concept of *type*. Nevertheless, since architecture results from a social construction, the similarities depicting what is the essence embedded in the concept of *type*, depend on the scope or viewpoint from where they are regarded. Moreover, some *types* are *naturally* more easily recognizable or communicable than others.

As a comparative instrument, *type* has long been used to analyze and discuss a design or multiple designs, and with it contributing to build further ones. Notwithstanding, when truly designing, the architect is not exactly or strictly concerned with the classifying principles, yet most likely to make use of those principles that are already neurologically embedded (or in the eminence of being embedded) in his own body-mind into a practical devising purpose in the creative process. In any case, we can recognize diverse possibilities to approach a notion of *type* in architecture, for instance through the notion of *archetype*, *prototype*, *typology*, *style*, *format*, or *pattern*, of which non-constructive or non-creative processes can also be included. Regardless the approach, or simply a divergence in terminology, *type* is most eloquently manifested in architecture by the architectural works themselves. For example, any seemingly coherent group of architectural works, like the *Greek temples*, the *Romanesque churches*, the *Palladian villas*, the *Prairie houses* of F. L. Wright, as well as cases of vernacular architecture such as the *Berber Moroccan houses* or the *Kasbah*'s, can be described as tangible manifestations of the notion of *type*[251].

Whether addressing spatial, physical, stylistic or other spheres, the notion of *type* intrinsically allows multiple interpretations, since *type* is implicitly an abstraction issue, and as so, its notion is *more or less vague*. Different buildings built in different locations, with different sizes and different programs may belong to the same *type*. That is the case when they share similar formal characteristics, similar kinds of details, similar colors, and so on. For instance, very different buildings painted in blue, can be said of belonging to the buildings *type blue*, although there are many different blues'. Indeed, methodologically *type* implies what can be described as an *inner coherence*, or more precisely, the sharing of at least one common element of similarity between two or more elements that hence form it—thus binary. In that sense, as in a *language/speech* distinction, an individual cannot form a *type*, although it may belong to the *type individual*. However, as in verbalizing the colors we see, given slight differences in hue or luminance, it is difficult to categorize certain entities in a single shelf as in many cases they are in an intermediate zone. For instance, we know that green is between blue and yellow, but bluish green or greenish blue are harder to differentiate, and we can only distinguish or describe them by comparison with others and, even then, the very limits of our perception mechanisms will disable a broader understanding. *Types* thus have a relative definition; they are partial, as it is always to some extent any generalization; and *type* is a generalization of a certain say *lower* level of things, in other words, a description of a limited (inferior) set of relations. Nonetheless, a *type* is also qualitative, and thus subjectivity can and will arise. Therefore, the scope and terminology of each as so-described *type* as to be set clear and its breadth acknowledged through its limited condition.

3.2.4 A RATIONALE OF TYPE

In an attempt to clarify the terminology of *type*, Duarte[252] confronted it with what he called *module*, which was not used in the exact same sense as de Quincy's notion of *model* (although there are resemblances) but more as a *component* of a *type*, hence in a constructive and somewhat mechanistic perspective. Following his reasoning, a simplified, but straightforward way to understand it is to portray such a *module* as a sub-*type* of a *type*, where a set of *modules* forms a *type*, and such *type* will be a *module* of a different *type*, and so forth. From here, it can be considered that there are different levels of *modules* and *types*, whose definition degree depends on the abstraction degree in use[253]. This idea is quite remarkably illustrated in the educational short movie *Powers of Ten* developed by Charles and Ray Eames in 1968, where the Universe is portrayed in and out successive scales of 10, from the human scale on to the entire universe and back to human scale down to the most elementary particles. Thus, the notion of *type* can also be regarded like a photograph, a frame in the continuum within which a certain *story* is told. Anyhow, from this understanding, the bonds between the concepts of *type* and *system* are reinforced, with no great observable difference between both concepts.

The *categories* branch or *set theory* in mathematics provides notions that can be brought for a methodological discussion of the *type*. It not only helps to clarify the terms, but also extends the rationale of *type* to a point that exceeds what the practical purposes of *type* can usually have in architecture, providing a comprehensive understanding of its mechanics. In brief, it states that to formulate *categories* (∴ *types*), it is essentially needed the *objects* (∴ *modules*) and the *morphisms* (∴ *relations*). Moreover, it postulates that more important than the *objects*, is their *relations* (here we opt for the terminology *type*, *object*, and *relation*). Without the *relations*, it is impossible for *types* to be recognized, therefore to exist[254]. Such as with the Russell's barber paradox, I exist insofar as one other recognizes me, without the other I am not. As such, in a practical sense *objects* only make sense when confronted (related) with other *objects*. In a simplified analogy, in architecture this can be illustrated by things such as the constructive joint (i.e. the *relational* element of two or more constructive elements), the hall space (i.e. the *relational* space between two or more spaces), or the door (i.e. the threshold between two different spaces), and so forth. That is, on how different *objects*—physical, virtual, abstract, and so on—may be brought together, connected constructively and/or spatially, and so forth. In any of these examples, the definition of the relating element constrains the very elements, their ability to face gravity, to flow, the ability for the user to see, hide, sense, cross, isolate, avoid, confront, … to exist.

Objects are thus independent entities that are going to be *related* within a sphere of a different hierarchical degree that we can call *type*. As in the structuralist *language* and *speech* distinction, if we consider the *objects* as letters of the western alphabet then, for example, English grammar could be their *type*. Another *type* for the exact same *objects* could also be Portuguese grammar, whereas Sanskrit grammar would be using different *objects* for also a different *type*, and so forth. *Relations* are the implicit invisible element that enables *objects*, and *types* along with *objects*, to interact and communicate—in a sense, music only exists in what is distinguished from silence, hence, methodologically, it can be regarded as a somewhat ordered relation between perceived vibration and non-vibration, or more generally between *vibration x* vs *vibration y*, and so forth. Following the same matrioska reasoning, ultimately *relations* can themselves be considered a *type* of *object*, and so forth. Finally, ontologically, *relations* have no tangible manifestation, they are strictly spatial, since they binomially accompany an *object* whose function is to *relate* other *objects*, and thus they have a pure methodological existence—

i.e. a standalone object is such in the extent that it relates with space-time, through which we observe it, object-subject ourselves in space-time.

Since the idea of *type* is intrinsically linked with the idea of *object*, the *types* of a given scale can be seen as the *objects* of a following scale—for example, the *types* of buildings can be considered as *objects* of the urban fabric[255]. For instance, consider the *object* 'room' (where 'room' is the *type* in *object-room*) and the *object* 'door' (where 'door' is the *type* in *object-door*). Via a certain relation, from both these objects we can obtain the *object* 'bedroom' (where 'bedroom' is the *type* in *object-bedroom*). Via a different *relation*, the same *object* could be instead a 'dining room', and so forth. Although belonging to different *types* through some scopes, both English, Portuguese and Sanskrit can be said of belonging to the same *type*—i.e. the *type language*. It is as imagining a world inside another, the universe in a nutshell[256].

In architectural terms, *types* and *objects* can be understood from different scales or degrees of observation, and, in each, the *type* can be defined with a bigger or smaller specificity, as it will also be analyzed through different levels of *relations*. Therefore, there can be *types* of urban spaces as a residential plaza, *types* of housing as a detached house, *types* of space as a kitchen, *types* of construction as a wall, and so forth. Also, a house can be a detached house, can have a court that can be a central court, a central square court, and so on; the degree of specificity can be increased until which each house has to be considered individually. More, an element can be set as belonging to a certain *type*, until a microscopic or macroscopic version of it is so far detached from the original observation point, that even the very object that was used as a starting point is unrecognizable in such analysis set. Evidently, there are more or less obvious degrees of reasonability, usefulness, or practicality in the observation and classification of phenomena—the degree of specificity of analysis of the house can extend as far as addressing each house individually, but, extremely, eventually also on to each individual texture on its walls, molecular composition, and so forth.

Anyhow, in architecture, the most useful notion of architectural *type* also seems to be the most abstract. That is, the one that does not rely on any rigid shape or any sort of physical attribute, but in the way spaces are related and the social behavior they suggest or imply. For instance, when referring the *type office building*, the *type open space*, or the *type supermarket*, the specific characteristics of these are not being mentioned. These can have all sorts of shapes and sizes, and be organized differently, yet by the implicit abstraction of the *type* we can easily have a closer sense of what we may be dealing with. That occurs because the architectural *type* is de facto no more than a socially engaging instrument, as it enables, or eases the transmission of what is said meant or done—where the limits are in imagination as well as in the linguistic ability to socially and/or culturally convey them.

To the *types, objects* and *relations* may be assigned different nomenclatures. As we have seen, in algebra they can be called, respectively, *categories*, *objects* and *morphisms*. In a *systems* terminology, they can be described as *things*, *attributes*, *relations*, (and *environment*). In architectural terms, eventually these too can be termed differently as long as serving their taxonomic purposes. Finally, it is worth noting that, from a mechanistic point of view, the similarity of the concept of *type* with the concept of *system* is notorious. Yet, from such a perspective, whereas *systems* can generally be synthetized in the set $S=\{t,a,r,e\}$, the concept of *type* in architecture can somewhat be regarded as a simplified version of this. In it, *things* and their *attributes* can be condensed to a unified notion of *object*, and the *environment*—i.e. the *place* or *topos* in diverse architectural acceptions—as in Durand's geometrical detachment, is released of the equation, or simply left to observe on a *type* of a different order of observation. Overall, such can bring a binary formalization to *type*, regardless eventual unfolding that may occur, where $T=\{o,r\}$, with 'o' for object and 'r' for relation, which provides it an enhanced operative sense, simplifying its communication, and that furthermore aligns with the psychological reductive (binary) needs to formulate thinking. From here, we could say that *type* can be considered as a simplified *system*, yet the value of such synthetized expressions is merely indicative, relative, and not to be seen in stagnant terms, and their unfolding can go as far as imagination may lead. Indeed, these synthetic expressions are ultimately no more than speculative. Their value can only reside in their use for a particular taxonomic frame.

3.2.5 USING AND UNDERSTANDING TYPES

To a certain extent, the idea that the unfolding of *types* can go as far as imagination may lead agrees with Durand's approach, which inspired architects to attain rational solutions for different *types* of architectural forms. His notion of *type* can be regarded as a directory of forms not referring to any particular context or use, but open to all their potential content. It could be regarded as if a manual of validated practices and, thereby, a target for reproduction. Indeed, many examples would be copied, and, in that sense, following de Quincy's rationale, the *type* was in many cases rendered *model*. Nonetheless, the approach entails a much more important notion, as to design under Durand's method is a matter of knowing the *types* and their possible combinations and, through it, finding further *types* and combinations. In this perspective, with it, immutability—or monotony—is there only if intended or allowed to. Added to a reenactment of *symbolic* values that Modernism had somewhat neglected, that is too a quest in which theorists and developers have engaged from a certain reenactment of the speech of the *type* in the 1960s and 1970s onwards.

The use of *types* is not a matter of originality (or lack of it), it is a condition imposed by the use of natural languages to describe phenomena. When using a *type*-like description we engage communication among the different intervenient. A common ground is formed. From a common base, the architect, facing specific problems, is engaged to devise a synthesis. In this sense, something is made by transformation of something that is familiar. When transforming a traditional *type*, decisions must be taken on what to keep and what to reject. Because the *type* mirrors common values, the choice process is engaged in the values of society. Therefore, a choice process is ought to reflect those shared values and not merely arbitrary choices. The *type* is not necessarily to be mimicked as a *model*, but to offer a frame of reference for problem discussion and ways of transforming, call it replication, originality, construction, deconstruction, or whatever label we may put to it. *Type* implies an analysis of a certain reality, which thereby recorded, belongs to a past tense. In a world flooded by (apparent) new things, it can turn out positive to follow a strategy of continuity with the past, as implied with *type*, without neglecting what is of our times. To do it, the circumstances and practical needs are ought to be let added to the modern spatial tradition, or any other tradition for that matter, and enrich it rather than replace what is still valued, that is, acknowledging our memes, building up on their shoulders. The originality of the architect, *Homo Significans*, lies in the ways as he, as too a *Homo Faber* interacting and working with the available reality, finds to assure this continuity in a particular way. In this sense, continuity is unfolded transformation, evolution, enrichment; it is not being stuck to the past nor ignoring it, and certainly not sterile repetition.

De Quincy's and Durand's *types* aroused in the context of the Enlightment, reflecting the developments in natural sciences. Their path would be followed by a lineage of authors ascribing to a rational perspective, such as Viollet-le-Duc's exaltation of rationality based on his admiration for Greek architecture, or his enthusiasm for the Gothic, expressed on the methods or materials of the first house, or on the analysis of the methods of construction of the Gothic builders. In *The Concept of Type in Architecture - An Inquiry into the Nature of Architectural Form* (1995), Agudin sums up a large extent of the tradition of the *type* discourse in architecture. Apropos the evolution of the concept during the XXth century he refers that "*In the transition from the nineteenth to the twentieth century, the psychology of form exerted a profound influence in art theory and history. About the same time, Le Corbusier came up with an interpretation of the origins of architecture that emphasized the mentalistic nature of the first architectural invention. For Le Corbusier the first house was a primitive thought, rather than a primitive construction. Finally, in this century, the field of cybernetics and computing has provided the framework within which notions like 'design process' emerged. Architects and theoreticians, like Alexander and Eisenman, rejected the idea that a design starts with a preconceived image or type. Instead, they proposed the consideration of design as a 'patterned design process', in which the initial image or type plays no significant role*"[257].

With Le Corbusier, van Doesburg[258] and other fellow moderns, in a way the *form* became preceded by *concept*, that of the space-time created by the mind, thereby separating the direct correspondence from myth to architectural form—e.g. a column serves a spatial intention, not a formal or stylistic aprioristic predicate. *Type* thus becomes more of an instrument of the mind, articulating with geometrical and/or perceptual[259] intentions (e.g. space or materiality) to deliver form, seemingly inverting the logic of the hut, setting it in terms of *process* instead of in terms of *form* as the former had engaged on, and with known analogies of the industrial world also implied.

Imbued of a certain dissatisfaction by the fading of the symbolic qualities in the architectural form that Modernism had proceeded, in the 1960s and 1970s, the concept of *type* had a resurgence. Together with the concept of *typology*, in a somewhat Durand's reminiscence, it aroused as a fundamental epistemological notion, attempting to relinquish analysis and synthesis, history and modernity, in the works of some prominent architectural theorists such as Carlo Aymonino, Aldo Rossi or Giorgio Grassi. Following the diverse theoretical trends, a considerable number of texts were published on *type* in architecture. Some developments, such as with Stiny's shape grammars, have also implied it with algorithmic processes of design, where from the assumption that architecture can be reduced to simple geometric shapes, and an interpretation of a coherent body of works, rules are devised in order to mechanistically reproduce or augment the body of works that originally made up its *type*[260]. In this manner, forms are to be scientifically validated, and thereby enabled for mechanization throughout. However, even if apparently accomplished, it remains a subjective, interpretational side of the original, which may jeopardize the validity of the scientific-like process—an issue that has seemingly been overcome in Duarte's *Malagueira grammar*[261].

Other authors, such as Christopher Alexander[262], have attempted to overcome the *type* as a constraining (aprioristic) image source, engaging in a transformative, organic sphere. However, even in those cases, again precedence lays even in the most hidden places, there, available, for subjectively be interpreted, and once again challenging the *type*. The variety of approaches to the notion of *type* in architecture throughout history has been remarkable, which confirms the richness of the discussion, and the danger of rushing into any sort of grand conclusions. As Agudin writes, "*Type, like Form, is eminently a philosophical question*"[263]. The real question, we would add, is engaging in the endless journey of finding out what architecture is all about, putting aside a logic of accomplished finale, maintaining a sense of openness towards the world.

3.3 A discrete view of architectural production

"When you buy furniture, you tell yourself, that's it. That's the last sofa I'll need. Whatever happens, that sofa problem is handled".

—Ed Norton's character's lament in the movie *Fight Club* (1999) after his condo gets blown up

Through the Vitruvian triad of *utilitas* (use, ergonomy, function, space), *firmitas* (solidity, construction, structure, matter) and *venustas* (beauty, plasticity, appearance, aesthetics) architecture arises as a unified ensemble, where each of these elements is interdependent and each is somewhat ought to have a similar relative importance—in a way, we can call it architecture understood as a *kin* form-structure. However, with certain interpretations of notions such as *systems* or *type* it can also be implied an enactment of what we can call a *discrete* understanding of the architectural form.

Although constructively highlighted in the least since the Gothic separation of wall and bearing structure, it is more clearly in a post-industrial world that a *discrete* acknowledgment of the reality of construction has found a fertile ground to evolve. In architectural thinking, the notion may primarily be ascribed to a distinction derived from Gottfried Sempers's studies of building artifacts that led him to break away from the Vitruvian triad, distinguishing the elements into classifications falling either into the tendentiously *heavy/stable stereotomics* of the *earthwork* or the tendentiously *lightweight tectonics* of the *frame*[264]. Similarly, it also finds bonds with the distinction between the *dry* and the *wet* (or *fluid*) methods of joining derived from the early crafts. In any case, the related notion of *tectonic*, as implied by Frampton in his own professed architectural triad—*topos*, *typos* and *tectonic*—but fundamentally the categories developed by authors such as John Habraken, Francis Duffy, Stewart Brand, or Bernard Leupen, have been valuable contributions for this discussion.

Overall, among these approaches it is noteworthy a compromise between both an abstract and/or representational sphere (*type*) and a material and/or sensorial sphere (*tectonic*) within an environmental setting (*topos*). Discursively, in architectural history and theory, these can be credited to an early acknowledgement of the architectural form from a rational perspective that can be traced back to the technical evolution comprising matter and craft. In a first stage, these would eventually lead to a space-time perspective typical of modernity, with rationalizing contours of a hierarchical order. However, with the posterior introduction of a timescale perspective of the architectural form in the discourse, eventually it too aroused a perspective crediting the relative, networked relations over hierarchical ones. With it, has also aroused a *discrete* understanding of the once *kin*-conceivable architectural form.

3.3.1 MATTER, CRAFT AND REASON

From an evolutionary perspective, the *primitive hut* still fundamentally stands as a believable ontological model of architecture, which finds one of its most famous expressions in the description of the XVIIIth century architect Marc-Antoine Laugier, in his *Essai sur l 'architecture* ["*An Essay on Architecture*"], published in 1753. In it, Laugier distinguished two main architectural elements that lay at the basis of all architecture, the supporting branches (*structure*) and the protecting leaves (*enclosure*, or protective layer)[265]. In such a raw technological state, materials have a direct correspondence in constructional function and do not require any particularly sophisticated craft. Although speculative, Laugier's model endured probably by the sake of its simplicity, from the belief that progressive simple transformations are the ultimate guide informing architectural design. He did it notwithstanding his underlying intents of legitimizing aesthetical tendencies through the seemingly rational logics of the origins, justifying an evolutional process towards the orders of the Greek temple, and thereby setting it apart of an arbitrary mimicking of ancient models.

To the model of the hut, Quatremère de Quincy would add the cave and the tent as further speculative original models, where the cave relates to hunters, the tent to the nomadic gatherers, and the hut to settled agricultural social milieus, thus adding a social co-relation to the technical sphere of matter and craft. The cave represents little or nothing of constructive intents and few remains in it of architectural or projective suggestion, aside its primal shelter purpose[266]. Nonetheless, the addition of a *rock solid cave* notion brings a new material insight to the architectural discourse, that of the *solidity*, *robustness*, or *weight*, that had been absent in the explanation of the original *lightweight* hut, made of relatively more fragile [or seemingly ephemeral] trunks, branches and leaf's.

As Kenneth Frampton pointed out, Karl Otfried Müller's *Hanbuch der Archäologie der Kunst* (*Handbook of the Archaeology of Art*) (1830), related the hut model to a series of applied art forms producing things such as "*utensils, vases, dwellings and meeting places of men*"[267], which imply both a more intricate technical knowledge and an artistic insight. With it, it is also remarked the implications of the *dry jointing* understanding of the term, noting that the specialized use of *tektones*, referring "*to people in construction or cabinet makers, not however, to clay and metal workers*". In a further clarification of the term, Frampton adds the contribution of Karl Bötticher in his *Die Tektonik der Hellen* ["*The Tectonic of the Hellenes*"], published in three volumes between 1843 and 1852. In it appears a key distinction between *Kernform* and *Kunstform*, that is, between the original wood elements in a Greek temple, and their artistic translation in stone through the trighlyphs or metopes of the classical entablature. From Bötticher *tectonic* hence emerges as "*signifying a complete system binding all the parts of the Greek temple into a single whole*"[268]. A representational sphere is thus added, where the original wood and leaf's are only present insofar as a reminder, a motive that no longer requires a correspondence in a material/craft sphere, but where the relational features are preserved in a rational domain.

Also building upon the primitive hut model, Gottfried Semper (b.1803–d.1879) in his *Four Elements of Architecture* (1852), distinguished four basic features of architecture: *Herd* (hearth), *Erdaufwurf* (earthwork), *Dach* (roofwork, including the roof's support structure), and *Umfriedigung* (enclosure, or covering membrane). Making use of an historic and ethnographic background, Semper ontologically related these elements with the ancient crafts—the hearth to ceramics and metalwork, the earthwork to masonry, the roofwork to carpentry, and the enclosure to the "*art of dressing (the walls), that is, weaving and wickerwork*". The focus is not exclusive on the crafts, acknowledging the elements in terms of production and materials. It also includes what, in our view, is the key concept of *Stoffwechsel*, referring to a process by which the outward appearance remains unchanged despite a change in the material and production mode—thus, it implies the notion that forms do not necessarily need to be attached to a material *truth* as they can somewhat free float in appearances as long as technique allows so. Moreover, Semper categorized the construction process into two key notions—the *tectonics* of the frame, with lightweight components (e.g. wood posts) assembled to form a spatial matrix; and the *stereotomics* of the earthwork, made of the repetitive assembly of heavyweight elements (e.g. brick).

For Semper's contemporary Eugène Viollet-le-Duc (b.1814–d.1879), architecture is definitely to be framed under a rationalizing way. Viollet-le-Duc saw a world in which there was no coherent approach to architecture, and thus urged for a rationalist way. It would primarily be from the Gothic architecture that he derived his lessons on structural and formal systems, to the point of applying them to modern materials such as cast iron. Concurrently, he examined organic structures from nature for inspiration, iconically applying the influences in his *Assembly Hall* design (1864). Nikolaus Pevsner stressed that Viollet-le-Duc's interest on reason towards the architectural form was an extension of a trend in France that extended back to the XVIth century, where "*Delorme, …, Derand, … Cordemoy and Frézier*"[269] were masters valuing rigorous stability principles and clear expression of structure[270].

The classical architecture also delivered Viollet-le-Duc key examples of such statement, with the Greek temple regarded as a rational representation of its own construction. In that sense, the development of a new architecture was also to be based on reason in the way that the classical orders had supported temple design. He believed that reason and method were key driving forces for quality architecture[271]. Viollet-le-Duc thus envisioned that architecture could be produced as long as the rationalizing spirit prevailed, even if its methods and materials were subjected to change. He would exemplify it, going as far as proposing the incorporation of the iron as building material under the logic of the Gothic, in what we may now observe as a kind of collage [or pastiche], but that made perfect sense given the context and an intrinsic exploratory character. Semper's *Stoffwechsel* is thus also implied, but only insofar as following fundamental rationalizing principles. Ideal forms would relate with specific materials, with their appearance reflecting a rational way of designing and building, but that not meaning different materials could not be applied, as long as they kept a sense of *rational truth*.

As a counterpoint, contradicting the methodic trends expressed by his contemporaries, for John Ruskin (b.1819–d.1900), quality architecture was tied not to a rationalizing or methodic spirit, but somewhat to the man behind architecture. The vision is stated in *The Seven Lamps of Architecture* (1849), where historically the logic of the structure had nothing to do with it, and although he appreciated the *truth* in materials, he saw it more in terms of *honesty* with oneself, with history, or the crafts, and not of reason. For Ruskin, the interpretation that the Gothic had been primarily the result of a rationalizing approach was a far too simple story, and thus the developments of the epoch signified a decline, a drift from the virtues of former architectures: "*We want no new style of architecture... The forms of architecture already known are good enough for us, and far better than any of us*"[272]. Architecture was thus not to be redefined as if everything was wrong with what had brought it to that point. Anyhow, despite Ruskin's plea, as we now know, the modernists that followed would be particularly keen of Viollet-le-Duc's rationalizing appeal.

3.3.2 SPACE, TIME AND NETWORK

Semper had left behind the Vitruvian archetypal view, instead relating architecture with an evolutionary view that relates with the materials and the crafts. However, he did not went so far as to distinguish the internal order, from an external order of the building elements. Some years later, Adolf Loos (b.1870–d.1933) would promote the internal space to a class of its own, addressing the elements that typically find their place within an architectural encasing: "*The architect's general task is to provide a warm and livable space. Carpets are warm and livable. He decides for this reason to spread out one carpet on the floor and to hang up four to form the walls. But you cannot build a house out of carpets. Both the carpet on the floor and the tapestry on the wall require a structural frame to hold them in the correct place. To invent his frame is the architect's second task*"[273]. Semper had referred to origins of the *tectonic* of the exterior through the covering membrane made of weaving and wickerwork. Loos used similar elements—the textiles and carpets—to imply an internal *tectonic*, thus also a spatial terminology in the discourse.

It would be from both a seemingly rationalizing spirit, and a spatial understanding of architecture, its motions and shapes, that Le Corbusier would establish his five points, the *pilotis*, *free plan*, *free façade*, *fenêtre en longueur* (horizontal window), and *roof gardens*. With it, he added both a spatial understanding of the architectural form, with the spirit of a machine age. Indeed, a free plan or façade, provided by an independence from the main structure, are only conceivable through an underlying abstract spatial understanding. Moreover, these ascribe to a mechanical sphere where, ideally, constructive parts have the freedom of a *modulor*-regulated grid or the like to find their place in architectural works, or where the roof gardens help providing fresh air and rest for the workers of a machine-enacted society.

Finally, these follow a rationalistic tone, where the functioning of the different elements implies a certain degree of independence in relation to the others, each following its own idiosyncrasies.

The posterior *supports theory*, by John Habraken[274] (1972), would clear possible formal misconceptions to which a literal understanding of Le Corbusier's five principles could lead on to, liberating it to a purely methodological sphere with no constraining aprioristic imagery, such as the *fenêtre en longueur*. Le Corbusier himself would implicitly make a self-critic in his later works as, for instance, *Ronchamp* had little or nothing to do with the five principles. Anyhow, Habraken sets a fundamental distinction between *support* (e.g. base building) and *infill* (e.g. interior fit-out), where on each are assigned different levels of expertise and responsibility on the different hierarchies and times of the elements composing the building. The distinction is fundamentally methodological, not constrained to any sort of aprioristic imagery, which although lacking a concretization, conversely contributes to its free interpretation, easing its adaptation to different contexts. Anyhow, the fundamental contribution of the *support* and *infill* perspective of the *supports theory* seems to be that of the introduction of a new temporal perspective. That is, a perspective of a timescale awareness on the understanding of the architectural form, regarding it not as a stagnant, crystalized entity, but as a process that has different parts to it, that can change in different moments, and so forth. Indeed, the categories that had been previously put forward by different authors did not suffice to frame, for instance, the countless technical apparatus required in contemporary buildings, and which often deeply constraint the architectural possibilities.

In that sense, the concept of *shearing layers*, coined by an English architect, Francis Duffy[275], in his *Measuring Building Performance*, first published in 1993, would bring a new insight. In brief, the concept of *shearing layers* entails a particular approach to a *discrete* idea of *systems* in architecture, referring to elements that are interrelated, but whose underlying idea is that they can be seamlessly detached. The space-time context, scale or modes in which this detachment occurs will vary in each considered *system*. The concept has since notoriously been further developed by Stewart Brand in his *How Buildings Learn: What Happens After they are Built* (1995)[276]. A more recent approach, conducted by the Dutch architect, Bernard Leupen[277], in his *Frame and Generic Space* (2006), expanded its scope. The underlying conceptualization finds a very close match in software development.

In architecture, the core idea in a *shearing layers* conception is that buildings are ought to be conceived bearing in mind that they are composed by different elements (or *layers*) that have different life spans. As in nature, there are processes operating in different timescales, and therefore the trades of energy, matter or information is meager, scarce or non-existent between them—a geological era has little or no relation with an ant colony, although both are part of the natural world. Adopting this concept that can be called of *hierarchical ecosystem*[278] to buildings, Brand demonstrated that traditional buildings were more adaptable because they allowed more freedom to its layers, for instance, with faster layers (e.g. *services*) not blocked by slower ones (e.g. *structure*). We could assume that the hierarchical positioning of these layers is straightforwardly definable with elements such as those of the *structure* preceding elements such as those of the *services* or *partitions*, and so forth. However, even if in material or constructive terms that aprioristically makes sense in most cases, that is not necessarily an absolute rule, not at least from a conceptual point of view, and hence it matters to understand how these categories can mingle.

For a start, the underlying principle of Habraken's *support/infill* terminology is generic, and implies a binary distinction that follows a reciprocity and complementarity logic rather than hierarchical, thus leaving plenty of room for interpretation. Habraken further develops the theme, decisively contributing to clarify how we may understand the placement (hierarchical or not) of the different spatial or constructive elements or components[279]. From an analysis of the house *type*, Habraken establishes three main categories which can be easily generalizable to other architectural *types*: as a *spatial organization*, as a *physical system*, or as a *stylistic way*. It could be argued that these categories resemble a certain Vitruvian inspiration, and accordingly we could relate the *spatial organization* with *utilitas*, the *physical system* with *firmitas*, or the *stylistic way* with *venustas*. However, on the core of Habraken's proposal stands that these categories can be discretely analyzed and developed, and that is fundamentally divergent from a Vitruvian way where is foremost stressed a kin—i.e. *sculptural* or *objectual*, *univocal* or *interdependent*—nature of the architectural form.

If setting these categories hierarchically, the *spatial organization* in most cases would likely be assumed as the most important, as it is more intimately related to our behavior. Indeed, we may observe technological evolution without it affecting much the main patterns in which we take hold of space. In second place, it would probably most commonly come the *physical system*. The *physical system* is not only about the materials being used, or how they are put together, but also as how *types* of physical parts are chosen (e.g. columns, walls, and furniture with certain characteristics) and how they are related and distributed in space, therefore on how the *types* of physical elements are prioritized. In third place, the *stylistic way*, which acts in a thinner level. It is about how certain characteristics can be inculcated (e.g. a certain color, material, texture) which are not depending of a spatial or of a physical organization, but nonetheless can affect the modes in which they can be thought of in the first place, as well as the perception of it.

However, if we observe cases such as the traditional Japanese house, in which spaces appear in succession, or are enclosed, then we realize that the main characteristics of a *physical system* or of a *stylistic system* can be kept while transforming the *spatial system*. In another known example, in classical Greece, the columns (a known *physical* architectural entity) were in marble, but as in what Semper describes as *Stoffwechsel*, mutatis mutandis, Palladio's classical columns were often made of brick and plaster. Here stand two physical entities, which are seemingly the same, with similar spatial and structural attributes and even with a similar appearance, but which are indeed different in their materials and technologies. Here, the *stylistic system* precedes the *physical system*, and thus we can call to evidence Semper's *Stoffwechsel*.

Thus, we can acknowledge that although a certain hierarchy may be established between elements of a *discrete* analysis, the same hierarchy, even if it typically fits, will not necessarily follow the same logic in different circumstances, and hence a *stylistic system* may instead precede a *spatial system*, and so forth. Therefore, that opens up room for an analytical understanding of the different systems where precedencies cannot be aprioristically set, since they are not absolute, yet relative to the object of analysis. Instead, they can be understood more from a horizontal perspective, which is not necessarily hierarchical, but more of a network kind. Hence, the intricacy of relations between different, discretized elements can acquire more complex contours than what could be assumed at first sight with a *slow* vs *fast* layer understanding, as proposed by Brand.

As of its application, a *discrete*, networked way of observing the architectural design provides a conceptual frame in which design no longer needs to be unique or repetitive. This can make even more sense when observing the modernist housing production, where typological repetition was often a means and uniformity was often a result. At least theoretically, that opens rooms to make use of the subtleties of the *types*, instead of limiting it to some sort of typological repetition. Accordingly, instead of uniformity, we can work with similarity and thus enact difference, avoiding rigidity or monotony when it is unwanted. When a large production is required, we may work first with the essential typological elements that are shared by every unit, leaving enough blank canvas for posterior decisions. As Habraken refers, *"the result of such an approach can be very rich and varied, and yet systematic and efficient to build. (…) It may be evident that this layering approach is only possible when a type is clearly understood and analyzed in its formal organization"*[280].

3.3.3 SYSTEMS AND SHEARING LAYERS

Semper referred to four elements, and introduced the key concept of *Stoffwechsel*. To this, Loos added an implied spatial consideration with an *internal* category. From the 1960's onwards the *supports theory*, by Habraken, stood out as a proposal for giving inhabitants a meaningful participative role in the design process. By the 1990's, Francis Duffy, developed a categorization system, dividing the building in three layers: *shell* (e.g. structure and enclosing), *services* (e.g. piping and wiring systems, elevators, and so on) and *scenery* (e.g. internal subdivision and finish)[281]. Stewart Brand, whose work broadly reveals a great concern in sustainability issues in building construction, developed a similar, yet expanded, system of categories, distinguishing building into *site*, *structure*, *skin*, *services*, *space plan* and *stuff* (i.e. non-architectural and/or decorative elements such as wallpaper or furniture)[282]. Bernard

Leupen, whose work reveals a great concern with spatial-constructive flexibility and adaptability issues (i.e. what he calls *changeability,* which comprises *alterability*, positive or negative *extendibility*, and *polyvalence*) devised a system, that included both Duffy's and Brand's concepts, using the categories of *structure*, *skin*, *scenery*, *services*, and *access*[283]. Broadly, all of these conceptualizations are implied in a *shearing layers* perspective, founded in a *discrete* acknowledgement of the architectural form.

As of the terminology, a *layer* can be regarded as a particular kind of *system*, which is autonomous in itself, that may or not be combined with others, which stands on its own or requires at least another to be conceivable. As a self-sustaining combined or standalone entity (i.e. needing no additional other to be conceivable) a *layer* can be considered as what Leupen calls a *frame*, which can also be considered as another kind of *system*. By acquiring the condition of *frame*, the elements that constitute it may acquire the ability to *relate* with others without losing their inner relations, which will be, in Leupen's terminology, via processes of *disconnection*, *excision* and *articulation*. The ways these can be handled depend not only on the philosophy that is thought of to be implemented, but also on the characteristics of the materials in use—e.g. whether if it is used fluid or dry processes of linking construction elements—the effort that their *morphing* requires, and so on. As had been subscribed in Habraken's non--hierarchical understanding of his *spatial*, *physical* and *stylistic* systems, in the essence of Leupen's approach, even the seemingly lowered ranked items, such as furniture—included in *scenery*—can constitute a *frame* for the remaining. Therefore, in architectural terms, the *frame* is related to the specific, encompassing elements that determine the building for a long time. The existence of a *frame* thus enables what Leupen calls of a *generic space*, which is an open-ended and unspecified kind of space. Nevertheless, implicitly or explicitly, in the ordinary practice it prevails a hierarchical approach that is typically closer to Stewart Brand's *shearing layers* division, from seemingly slower to faster, between *site*, *structure*, *skin*, *services*, *space plan* and *stuff*.

Leupen's approach can be particularly useful in the analysis of aspects related to *flexibility* and *changeability*, as its referred dialectics *determinism-changeability*, *dwelling-permanence*, are of relevance in the discussion of the housing problem and the sustainability problematics. As the author recalls *"ultimately the frame concept is about generating freedom"*. The column frees the wall, as the *scenery* can free the space, or the *skin* frees the *skeleton* and the *scenery*, each with its own potentials and freedoms within the *generic space* determined by the *frame*. This freedom is personified by the possibility of changeability, which can only be enabled if there is a disconnection between the *frame* and the *changeable*. In this sense, the *shearing layers* located in the *generic space* belong to the changeable[284].

An issue with *shearing layers* is that if it is misapprehended on which layer an element belongs, it may turn out that the building becomes very difficult to use. For instance, when applying a *service* layer within the *structure*, for instance in an HVAC, it may turn out that in case of air regulations change that it will become obsolete and the entire building would have to be remade. Indeed, *shearing layers* are difficult to get right and thus should not be addressed lightly. That was notoriously the case of the *Nakagin Capsule Tower* (1972), by Kisho Kurokawa, which was specifically designed to withstand the problem of varying rates of change by having replaceable living components attached to a permanent core. The capsules were to be updated as technology and style demanded, but in the end they never were. In the end, it stood out the conceptual value of the proposal, as well as its imagery, which although *fake* was nonetheless efficient in the transmission of its [conceptual] purpose.

The construction industry has long been using the notion of construction systems, which can somewhat be described as assortments of more or less intertwining material parts, which share common constructive purposes. The purpose may be specialized to a certain say *function*—e.g. kitchen modules—as a constructive occurrence independent of other constructive elements or can conversely be thought of as a more or less long chain of interdependent constructive occurrences, where the change in one may affect all the others. Likewise, most cars produced by the automotive industry can be described as the result of a collection of parts, each with a specific function—e.g. engine, clutch, transmission, suspension, differential, wheels, and so on—that can be as well used in the production of other cars, or as with a more or less intensive use of proprietary, single-of use of certain components in some other cars. With interdependence, the issue is that when changing a single element, the remaining elements of such a *kin* structure follow in cascade. Evidently, the specialization of production methods typically works in favor of discrete and not of continuity modes. As result, even if integrated, the *product* inescapably becomes the goal, and the notion of a purely *kin* architectural entity—where e.g. everything can be designed within the building—becomes economically impractical, no more than a romanticized idea.

With the thus unavoidable, *de-romanticized* notion of product, the difficult balance of the *shearing layers* is not only an issue of articulation between different layers or technology advancements, but also an issue that is intimately related with the theme of consumerism. It is undoubtful that a *discrete* approach, implied in a *shearing layers* perspective, brings a methodological insight on the *alterity* dimensions of architectural space, enabling a frame of though from where to develop flexibility, adaptability or polyvalence prospects in the architectural form. Moreover, it contributes to clarify potential bonds between the spatial and the physical spheres of architectural production in a context of a (post)industrial, digitally enacted, globalized world, seemingly immersed by the idea of product.

Anyhow, with the speed in which technology evolves in our world, effects such as product obsolescence must also be taken into account. A clear case occurs with the so-called *programmed obsolescence*, a strategy often applied (or implied) by companies in consumer products, which affects the way products may or may not be not developed and used, and that is propelled by factors that may be way beyond the technical knowledge, such as fashion or publicity in general. Treating buildings as mere consumptive products may prove non-viable economically. Certainly, their typical share in families' budget is not neglectable, and their effect on global resources consumption is certainly not ignorable.

To bypass or mitigate such sort of issues, at least in theory, it would be better to acquire things that last long, that are more durable, more reliable. However, the variables involved are more complex than that, often involving social, cultural or economical dynamics that are not straightforwardly generalizable[285]. In general, to acquire things that apparently may last longer could be assumed as a good principle. However, that is also often related to expensive items, those that most cannot afford. On the other hand, a consumerist perspective also tells us that the urge to consume, propelled by fashion, publicity and the like, eventually makes these things to be replaced not only because they reach the material end-of-life, but also because they reach their social/cultural end-of-life. This indicates that the personal *shearing layers* do not line up with the lifespan of the products. Furthermore, it is also likely that it suddenly comes up an improved version of that amazing object that was carefully selected to last a lifetime—in the end, programmed or not, obsolescence has many ways to show its presence. Moreover, if we try to keep things for the sake of simplicity of function, it is plausible for an unexpected development to occur, as seemingly coupled functions can become uncoupled in no time, or vice versa. On the other hand, if we try to keep functions completely separated all the time, the risk may be to spend too much time managing systems just to ensure basic work. Moreover, the more complex is the product and/or its components, the more likely will be for maintenance costs to rise up, and so forth. If in many consumer products these issues may fall under the radar, or are easily relativized, when we talk about buildings, they acquire completely different proportions, in the least because their relative financial weight in the consumers' pocket is typically much bigger. Pondering these factors altogether, from an architectural design perspective, there is no such thing as a best approach in this matter—whether more of *kin*, or more of *discrete*, more or less robust, more or less expensive, as in every other architectural approach, design options must be carefully considered and contextualized.

II (Pre)Fabricating Architecture

There was once a barber. Some say that he lived in Seville. Wherever he lived, all of the men in this town either shaved themselves or were shaved by the barber. And the barber only shaved the men who did not shave themselves. Did the barber shave himself? Some sets, such as the set of all teacups, are not members of themselves. Other sets, such as the set of all non-teacups, are members of themselves. Call the set of all sets that are not members of themselves 'R'. If R is a member of itself, then by definition it must not be a member of itself. Similarly, if R is not a member of itself, then by definition it must be a member of itself.

"*From this I conclude that under certain circumstances a definable collection does not form a totality*".

—Russell's paradox (following proposition by Bertrand Russell, 1901)

A forma é um mal da matéria. ["*Form is an evil of matter.*"]
—in *Falta (forma)*, album *Comum* (1998), *Três Tristes Tigres*,
lyrics by Regina Guimarães and Ana Deus

When you explain a 'why?', you have to be in some framework that you allow something to be true, otherwise you are perpetually asking why… If you try to follow anything up, you go deeper and deeper in various directions… You could either say, I am satisfied with the answer, you could go on asking questions… When explaining electromagnetism or gravity I can go thoroughly technical, but in an early level I just have to tell you is just one of the things that you have to take as an element in the world… I cannot explain it in terms of anything else that is familiar to you, otherwise when you would start making questions over it, then I would be in trouble; I would have to cheat, and eventually I would be cheating very badly… For a successful technology, reality must take precedence over public relations for nature cannot be fooled.

—Richard Feynman, apropos his participation on the *Challenger Disaster Committee*

Believe me, that was a happy age, before the days of architects, before the days of builders.
—Seneca (c. 5 BC – AD 65), *Ad Lucilium Epistulae Morales* (Volume 1) Epistle xc

1 A PREFABRICATION TERMINOLOGY

1.1 (Post)industrial architectural production

Architecture is *produced* on the bond of a design sphere (*mental*) with a physical sphere (*material*), established via a constructive sphere (*executive*). The *experience* of a space thus engaged, is apprehended by the senses, through aspects such as scale, contrast, color, texture, heat or cold, which result from spatial, constructive or material options taken during the design stage[286]. The construction bonds a represented spatial intention to a perceptible reality, as successive layers of structures bond the elements of form. Throughout, the option to use a material or component instead of another implies not only addressing certain *mental/executive* purposes (functional, aesthetical, structural, and so forth), which both unleash and confine the *experience* potential, but also to address certain *place* related constraints. In the latter, on a broader level, we can include aspects derived from social, cultural, economic, or environmental contexts, and on a stricter (*executive*) level the availability, or ease of deployment of construction elements, different durability or maintenance aspects in agreement with the materials in use, and so forth.

The modern materials and technologies contributed to enrich the vocabulary of constructive possibilities, while progressively detaching it from stricter *place* features. In pre-industrial times, the materiality, and its effect on form, had been more constrained to local idiosyncrasies. For instance, the dimensions of construction elements were in the least limited by their availability—in wood, limited to the available tree sizes, or in stone, by the availability of the intended batch in quarries, and so forth. Furthermore, size, weight, density, hardness or other properties had to be considered for handling, shaping, transport or, finally, the in-situ erection. In an industrialized world, many of these aspects could seemingly be eased or bypassed. Ever since, the path has been towards an apparent progress of the dematerialization of production relations, which has been further increased with the acceleration of the processes of globalization. With it, the tangibility of materials, and their implied production relations, can somewhat be reduced to an immaterial form of *capital*, of which in last resource a physical sphere may give place to a virtual, intangible sphere. With it, aspects of a *place* domain are no longer necessarily a constraint, yet it is the *capital* that symbolically becomes the limit for what and how architecture is produced. Nonetheless, the analogy of the *place* constraints remains largely valid to illustrate the intricacy of the multi-dimensional relations of architectural production, as denoted by the conventional materials and the archetypal forms in architectural history.

The archetypal Greek temple is plausibly based on a wood construction type translated to stone. However, stone's properties are different, with positive or negative yields which must be pondered. For instance, stone has the potential to last longer when exposed to the elements, but it does not support the beam's bending moment as flexibly as wood potentially does. Using a material instead of another can conduct to different construction principles, but also to different design philosophies. For instance, a stone beam may be able to support more weight for the same span than a wood beam, but, consequently, the supporting columns need to be more robust to support the added weight of the entire system. In the least, the resulting form will have a different appearance than if it had been made in wood. Anyhow, a comparison between different constructive systems extends beyond their spatial features and dimensioning in correlation to material or structural properties. In the least, these depend on a balance between intentionality and the possibilities to deliver it, between a purpose and a technological context. For instance, the columns of the Egyptian *Luxor Temple* (~1500-1200BC) have such a density that altogether seem like a solid mass. The effect is incomparably lighter in the *Parthenon* (~447BC), where, due to the visual density of its components, from far sight it seems like an impenetrable volume, whereas in a closer sight it becomes permeable, creating a transitional fluidity towards the interior.

If the constructive type derived from the Greek temple had known span limitations, with the constructive philosophy introduced through the *Rome Pantheon* (current building: 113-125 AD), spans could thereon be significantly expanded. The constructive principle lays in a dome geometry, where the iconic innovation is to mimic the compression principles of the arch onto a circular area, instead of a rectangular area in plan. From the top of the cylindrical wall base, an ingenious box-like formwork enabled the curvature of the dome to be built level by level, using a non-reinforced precursor ancestor of today's concrete. All compressive forces are discharged to the cylindrical base, which transmits the loads vertically to the ground. Yet, in a way, we could regard cylinder base and dome as two constructively independent elements. Indeed, the cylinder-shaped walls are self-supporting, which makes it structurally independent from the dome. Conversely, we can conjecture that the dome could have been laid in a different support, say in a column and architrave system, instead of a mass-like wall. Thus, in the *Rome Pantheon* it can be said that the dome and its support are structurally discrete.

In the Middle Ages, the archetypal *Gothic* mode of building would bring a different insight, with emphasis given to light and verticality. To achieve it, an ingenious use of its ogival arches, ribbed vaults and flying buttresses replaced the solid walls as structural elements. Unlike in the semi-circular *Roman* and *Romanesque* vaults, the archetypal *Gothic* vault channels the weight of the building elements onto bearing piers, or columns, at a steep angle, enabling it to be raised higher. In the structural schemata, supporting weight was channeled to bearing shafts with less outward thrust than what a semicircular vault would have required, hence resulting in less weighty walls. The flying buttresses contributed in an overall visual weight loss. Instead of a *mass* supporting directly gravity, a complex, ingenious skeleton of support and counter support enabled thinner, while higher elements. The *diet* also allowed walls to be freed from structure, letting more light to come in. All of it achieved with roughly the same materials that the Greeks or the Romans had available[287].

Throughout the ages, ingenuity alone successively increased the knowledge of construction materials and processes, thereby expanding the spectrum of architectural possibilities. When machines became a pervasive part of our world, the process acquired greater proportions. That was ignited in the early days of the Industrial Revolution, when high quality iron became widely available due to the devising of new techniques of ironwork in the foundries. Cast iron, then wrought iron, and finally steel introduced new possibilities, in an iterated improvement of machines and technologies, which, in time, would also impact the building construction. The technical characteristics of these materials, their production methods, size and weight, bolting, welding or other joining methods, and so forth, called for new ways of planning and erecting the constructions. For instance, the characteristics of steel lead to a very short tolerance for corrections in-situ, and in this sense, it was not as moldable as masonry or concrete (the typical fluid bonded materials), or even wood. Its use can comparably be as precise as wood construction, yet more difficult to handle manually, since simple adjustments of parts in-situ are a lot harder to make. It thus called for factory-precision methods, and hence the way towards *prefabrication* was wide open[288]. Its precision inherently demanded an improved calculus and dimensioning, which enabled the reduction of structural sections and increase of spans, thus contributing to establish new architectural quality standards. With the rise of reinforced concrete technology, the universe of possibilities would further increase.

Aside the exceptional architectural landmarks, in the history of building construction, most buildings have been erected with comparably less sophisticated materials or technologies, in wood, brick or stone, or also of earth or debris. Generally, these have followed an economic sense by using readily available materials and the like, making use of known technologies that have slowly, and solidly, evolved in time. Following gravity, the wall initially had both a structural and spatial function, and later would be freed from a supporting role. With the introduction of steel or reinforced concrete the material proportion of bearing elements significantly decreased, allowing increased possibilities as well as the potential for a more affordable approach, somewhat democratizing the principle. Anyhow, there seems to be a dynamic halt between an *instructed* architectural sphere and a *wise* vernacular sphere and/or an *advanced* industrial sphere. There are the needed, casual, ordinary, or evolutionary practices, but there is also the product, accounted, measured, predicted, automated or marketed, and finally, there is architecture in-between. The dialectics finds its first prescribers in modernism, but has been approached ever since. Indeed, the vernacular, as the industrial forms and methods have often been depicted as ideal for certain practices supposedly or in fact attempting to incorporate their spirit[289]. Le Corbusier and Pierre Jeanneret's praise to both the *machine* and the vernacular, testimonies it: "*We must find and apply new methods, clear methods, allowing us to work out useful plans for the home, lending themselves* *naturally to standardization, industrialization, Taylorization (mass production). If our diagnosis of the sheer inadequacy of traditional methods were not more than enough in itself to impel us to look for new solutions, the history of architecture (our own past, or sometimes even the present in other climates) would show us that other methods of house construction exist or have existed which are infinitely more flexible, more deeply and richly architectural than those made popular by what is taught in the schools*"[290]. A mechanistic ethos would nonetheless have a more visible impact.

Unlike in the *Parthenon*, whose technology only allowed compression strengths, with the evolution of construction technologies, architects have progressively been allowed more liberty. To an architecture liberated from the bearing wall, it added that technologies such as the reinforced concrete were relatively cheaper and easier to handle. Referencing to the *Dom-Ino* concept, formalizing it into a single-family house, Le Corbusier's *Maison Citrohan* (1920), a play of words with the car brand *Citroën*, was clearly stating that houses can be standardized as cars are—the "*machine à habiter*". In the referential *Toward a New Architecture* (1923), Le Corbusier writes: "*if we eliminate from our hearths and minds all dead concepts in regard to the house and look at the question from a critical and objective point of view, we shall arrive at the 'House-Machine', the mass production house, healthy (and morally so too) and beautiful in the same way that the working tools and instruments which accompany our existence are beautiful*"[291].

Following the *machine* narrative, later on, the *Villa Savoye* (1928-31) would arise as a modernist archetype, where, conceptually, the vertical elements—façade, stairs, *pilotis*, or the thin curved wall in the ground floor—are discretized from the plan. However, the *executive* application of the *mental* intents is not full-proof. In fact, although the elements are depicted as components of a machine, they are materially and formally bounded. The house is an autonomous object, just like a car, but the parallel of the machine stops there. Indeed, one cannot imagine replacing one of its parts by some different other, and so forth. In this perspective, the *Dom-Ino* was another incongruous example, which could not be industrially (re)producible as it was conceptualized[292]. Nevertheless, given its simplicity, it endured a great potential for replication or appropriation. In that sense, and in that sense only, it was in line with the epithet it proclaimed. Indeed, notwithstanding the historical value of the narrative per se, and circumstances in which these examples were produced, on today's standards the most resembling artifact to a machine in Le Corbusier's buildings was the automobiles he often (and strategically) placed in the photos of his buildings as a means for propaganda of his ideas.

With heavy, wall-based structural construction, historically the issue has largely been where to make the openings, and the Gothic proved that the wall could be liberated from the structure. With concrete, steel or other manufactured materials, appropriating and expanding some of the technological virtues of natural materials such as wood or stone, the issue shifts, as the structures become independent of the other material functions of the building. Filtering light or access becomes no longer a core concern, as such can be solved in latter stages, either passively (i.e. constructively), or actively (i.e. technologically), with wiring, piping, and so forth, giving the *services* or the like a relevance of its own. Complexity of buildings increases, opening room for different construction elements to gain a potential of excision, thus becoming more prone to be part of the design frame since early stages, and making design itself more and more a discrete matter, requiring numerous specialized fields. According to different discrete philosophies, for instance, façades can be regarded as screens, internal walls as movable elements, or even the main structure can be though-off to easy dismantling for when buildings end-up their useful life. Different discrete philosophies also endure different potential types of forms. With automation, buildings become more and more an assembly of discrete components and, with the aid of digital tools—helping to design and organize the constructions or to technologically enable the construction of once impossible forms—the idea of endless possibilities, as brought about by *capital* over *place*, is apparently reinforced.

1.2 An evolutionary view of lightweight dry construction practices

A certain story suggests that a Chicago carpenter, George W. Snow, invented the *balloon frame* in 1832, revolutionizing the construction practice in the USA. However, facts show that this was not exactly a revolutionary idea, nor that it was invented by Snow. Instead, it is more likely the result of a simplification of the *timber frame* principles throughout the years. It is part of a major arch of a continuous quest which contextually attempts to achieve economies in construction while delivering quality, accomplished by making use of interrelated principles such as reduction (e.g. of material, waste or labor), speed (e.g. through mechanization) or efficiency (e.g. through quality control). These come from an ancient lineage from where contemporary frame systems also find their roots.

Timber construction is an ancient mode of building whose records can be found since the Neolithic. It can generally be described as a method for creating structures typically using heavy, squared-off and fitted and joined timber. Such probably came from a handcrafted way of making things out of logs and tree trunks without the aid of mechanical means, but with all sorts of hand-powered tools such as axes, adzes, draw knives, or auger drill bits. With these, in the old days, woodwork was slowly and laboriously shaped by building artisans, which in the more isolated milieus were also often their very dwellers[293]. Unlike in wall-supported constructions, in such methods, since bearing forces are transmitted to posts, the interior can be spatially released. The number of posts ultimately depends on the available span dimensions, which is constrained by the characteristics of the available wood—type of wood, drying mode, length, section, and so forth.

A more sophisticated version of such methods is what would become known as *timber frame*—also known as *half-timber* or *post and beam*, among other regional variations. These are structures typically made of sawmilled wooden posts, beams and braces, connected through pins, wedges and grooves. The space between the wooden elements is filled by mortar and stone or brick, which are left visible or covered by materials such as plastered wattle and daub, weatherboarding, or tiles. Such infill has no structural function, is mostly weather proofing, hence alternatively it may be left empty and the structure can simply be covered with wood planks or boards.

Such sort of method was developed in many parts of the world, such as medieval Europe and ancient Japan. Because of its varied occurrence, crossing many different periods and places, there are many different labels naming historic framing styles. For instance, in Brazil, a famous example became known as *enxaimel*. In Portugal, a famous example is found in the *gaiola pombalina*[294]. Such labelling usually has to do with local specificities surrounding the system, such as climate or seismic conditions, informing the type of foundations, beam intersections, roof frame details, joints, decorative modes, and so on. In several of these cases, the outside of the structural wood elements is left exposed showing both frame and infill, becoming a distinctive decorative feature, leaving plaster, brick or stone visible. In a late Middle Ages example, such approach with the use of plaster became known in

Germany as *fachwerk*. In the same period, in England, a somewhat similar system became known as *Tudor style*.

It was used throughout Europe, tendentiously more in northern and/or rainier areas, with more abundance of wood supply, such as in Scandinavian countries, certain areas of France, Poland, Switzerland, and so on. In the southern and/or drier European areas, such raw material availability was not so profuse and whether conditions to allow a permanent outdoor use were not so favorable. In these areas, ordinary construction typically relayed more on the use of structural supporting walls, using robust walls of stone or of mixed stone, mortar, rumble and other aggregates, adobe construction, and so forth. To combine such mixes, and according to the type of constructive case, techniques using clay, lime or others in hydrated mixes were used as bonding elements. Exception in such systems could occur in roof structures, typically using wood elements and occasional large-section wood logs tying supporting walls and used as support for wood floors, and the like, resting on the large walls, or intermediate wood posts in the case of larger spans. In many of these, iron-cast elements were used where available to reinforce and provide enhanced lateral stability in the connections. In others, such as in the traditional Japanese wood construction, the intricacy of the joints would be the only elements bonding the different parts, allowing a greater flexibility to better withstand seismic motion.

The difference between the walls, using hydrated elements, and the remaining, using wood and steel elements would arguably contribute to the arousal of a popular distinction between what is commonly called *dry construction* and *wet construction*. The case of the Iberian Peninsula is peculiar, as historically there is a clear evidence of advanced knowledge of woodwork, which was applied in naval construction[295], but where the frame never became generalized in common construction, although used in some very specific cases—e.g. the vernacular fisherman's settlement of *Palheiros da Tocha*, in Cantanhede, Portugal. Such is expressive of the causalities of the raw material availability in the progress of common construction practices, their intrinsic implications in the formulation of a construction culture, and even of the formulation of an architectural culture, on the modes in which forms are understood and reformulated over and over.

American pioneers brought the know-how of ancient construction practices from their homelands into a land which had abundant forest resources. On the late 1500's, in Colonial America, and particularly New England, the abundance of wood and the English tradition of building made the *timber frame* house popular. Entire towns were built with such structure. During the colonial period (independence is declared in 1776) and onwards, carpenters would devise a simplification of the *timber frame* to allow for faster construction with materials of standardized dimensions. On the mid 1600's, carpenters in Virginia devised a method for rapid construction of their buildings, decisively developing the *timber frame* into a system using smaller sections and hence lighter wood parts[296].

The *balloon frame* evolved slowly over the course of the nineteenth century. It resulted from modest shifts in the practice of many carpenters over time. That resulted in a widespread typifying of construction elements, which would endure until the late 1940's as a common method in the USA. Typically, a 1×4in (2.5×10.2cm) board, called a ledger, was nailed into vertical timber members, called studs, which ran continuously to the height of the building. The studs, typically 2×4in (5.1×10.2cm) or 2×6in (5.1×15.3cm) and spaced in 16in (40.6cm) centers, were notched to accommodate the ledger. The second-floor joists were also notched and then hooked onto the ledger. The joists were then nailed to the studs. The studs extended from the base sill up to the top plate and support intermediate floor joists and the roof rafters or trusses to a height of up to two floors.

The idea was not original. As the carpenters in seventeenth-century Virginia had done, they employed a similar method when confronted with pressures to build rapidly. However, the *balloon frame* had the edge of having lightweight and compact studs, making the parts easier to transport and handle in the worksite, which also made houses more prone to be built without skilled labor. Additionally, with the industrialization of several skills and technologies, such as the industrially manufactured steel nails or a myriad of manufactured steel joints in the 19th century, alleviating the task of connecting wood members, the entire building process could increasingly be speeded up. By such characteristics, the *balloon frame* eloquently depicts the moment in which industrialization enters the domain of housing construction. The methods would evolve to other forms of structural wood construction, such as the *platform frame,* or even with a technological shift, by applying analogous principles in steel construction, as it is the case with the contemporary use of cold-formed steel (CFS) profiles[297].

Eventually, the old *balloon frame* developed in the USA would reveal disadvantages, such as the requirement for long wood members, making supply more difficult and expensive, or the tendency of inadequately treated wood to shrink and/or warp over time, making construction flaws to more easily arise over time when using long wood members. Nevertheless, the great disadvantage that has ultimately lead its usage to an end, was that the path of fire along the studs had to be obstructed with fire stoppers, otherwise making it an authentic box of matches, as the great Chicago fire in 1871 has dramatically exemplified. Consequently, in the late 1940's the early *balloon frame* method was banned by many building codes in the USA. In wood construction, this has lead the method to be largely replaced by the *platform frame*. More recently, with the replacement of wood with CFS profiles, with different fire safety issues, the *ballon frame* setup has been having a change to comeback in some circumstances.

Unlike in the *balloon frame*, in the *platform frame* the walls (or stud bays) are story-height. The floors (or joist bays) are laid independently. This non-dependency of elements sets a new construction philosophy, enabling different architectural possibilities. Since it is laid floor by floor, the total building height is no longer constrained by limitations in the material dimensions. Instead, the height becomes limited by the very material properties, cross-section or bracing methods. Yet it is not limitless. Given the intrinsic lightweight principles, which lead to a minimization of cross-sections, typically a platform frame can generate up to four levels, twice as much as with the *balloon frame*. The non-dependency of elements is also reflected in the roof structure, where the spans are freed, since no longer necessarily constrained by a bracing function to the building-height studs. Such often leads to a preference on the use of trusses, which are more prone to ex-situ works and by that ensuring better quality while reducing the typically longer and messier in-situ labor. As in *balloon frame*, the spatial gaps between the structural members usually allow space for placement of installations, and the window and door openings dispose of a great degree of freedom, if not coinciding with eventual toughened bracing areas which can often be used to improve lateral stability.

Whether in wood or steel, the *ballon frame* and the *platform frame* have become two widespread building techniques, making it now an aged-old tradition. In its inceptions, *timber frame* was grounded on a premise of local material availability, provided by abundance of wood from nearby forests, and *ballon frame* and *platform frame* followed. That explains why its use became so profuse in places where timber is plentifully available, such as Scandinavia, the USA or Canada. Technological development took it further, and as different methods and techniques evolved, so did the systems. These systems currently no longer depend on a particular availability of material or of its characteristics. With globalization, in a way these have become information and knowledge of construction possibilities. As this constructive knowledge is mastered and further defied by introducing new challenges, whether spatial, technological or material, architecture gains news possibilities. Besides, given the general characteristics that can be recognized in such systems, namely a great potential in ex-situ production, given the likely lightweight, which eases transportability and maneuverability, and the potential for dry connections, improving speed of works, these kinds of systems are often designated as prefabrication systems. However, such terminology may not be entirely accurate, raising the need for further clarification.

1.3 Towards a prefabrication definition

With the barber paradox, Bertrand Russell implies that no definition will ever be total. Yet, unlike in pure logics, in the case of linguistics, self-reference or a truth predicate is allowed, since, in it, representational principles are also implicitly valued. Addressing consistency is more a matter of logics than of linguistics, but there is a necessary presence of a certain generalization degree at each level of analysis for the handling of any matter to be possible[298]. Hence, in the least, an awareness of the implied weaknesses should be present when undertaking a definition. Added to these difficulties, the term *prefabrication* is surrounded of biases, making it harder to reach more consensual grounds.

As opposed to a general idea that the constructive practices are something that evolves in time, the notion of *prefabrication* has arguably aroused linked to a notion of providing fast, immediate solutions where a patient, evolving place transaction of materials and skills was not possible or not so economical. That is only conceivable in a post-industrial frame, when it became more feasible to produce some constructive elements away, in factory. Nevertheless, earlier related examples can be found far back. Laugier's mythical hut was made of trunks and leaves collected in nature which would be transported and/or prepared in a place that could differ from the final assembly location. Saudi-Arabian, Mongolian or American Indian hunter-gatherer societies made transportable huts[299]. Ancient romans had amazingly effective building systems. Anyhow, that does not necessarily mean these examples can be considered as *prefabrication*, not at least by our current technological state, which raises another difficulty in its definition, because it makes it context-dependent—i.e., a notion that changes, as technological state-of-the-art does.

For ages, man has built homes piece-by-piece, dealing with the irregularity of nature, labor quality, and so on. In such approach, as materials arrive to the construction site, they can often be stored out-doors, exposed to the elements, and that may present more vulnerability to delays, price fluctuations, and the like. The notion of *prefabrication* is often presented in contrast to these practices, in which in the very least is implied a transfer of a certain degree of the work from the final building site to a different location. Although many things have evolved since a pre-industrial era, in most places throughout the world, the construction industry currently still relies a lot on in-situ manual labor [complement with: **Annex, II.1 Outline and challenges of the housing and the construction sector in Europe**]. It adds that the construction industry is still often stated as backwards in relation with others, as the auto-motive, shipbuilding or aerospace industries, with which has classically been compared with, and which still is frequently referred as embedded in a sort of fascination on aspects of these[300]. The praise carries the promise of more efficient construction modes, with faster, easier, better controlled processes, where economies of scale may be more effectively attained, and so forth.

Although the term prefabrication is pervasive in the construction industry, it is often expressed in common language with a negative connotation[301]. Various factors contribute to such negativity, as it is still the case with a certain stigma in public opinion on post-war prefabs. However, such negativity is not generalized, nor it happens with the same presumptions in each of the main geographical groups where it recognizably has been having a more advanced implementation, namely in North America, Japan and some European countries [complement with: **Annex, II.2 Prefabrication of houses: A historical and socio-cultural survey**]. Nonetheless, the term is also often positively related with production features—e.g. mass-production, standardization, specialization or organization—interfering in construction processes—e.g. quality, time, cost, or building safety. With it, there can also be an assumption of generally improved production conditions that might be reflected in the speed (e.g. less days to completion), economy (e.g. overall gains in efficiency of construction processes and sub-processes reflected on the budget), social (e.g. improved working conditions) or environmental performances (e.g. less material waste). In that sense, plausibly there are gains in overall construction quality comparatively with solutions that are more dependent on in-situ works, although that may not be always true. Anyhow, architectural arguments can easily be relegated to a secondary plan, submerged by *overwhelming* technological apparatus or simply by mighty *business as usual* tendencies.

It matters to distinguish prefabrication from the industrialization of construction practices, although these can partially coincide. Industrialization is a reality in construction and such is of no exclusivity in what can be called *prefabrication*. With bigger or smaller component size and complexity when it comes to assembly in a building's final location, a great deal of the materials in use nowadays is industrially produced. Even in some of the so-called *traditional* methods, where archetypally materials are, unit by unit, prepared and/or assembled in-situ, age-old practices can be expanded, making use of by bigger components to speed up site assembly—e.g. the case of bricklaying, where the use of industrially panelized brick walls can occur instead of laying brick-by-brick. Worldwide exceptions to a conspicuous use of industrialized materials in building construction may only be found in those rare and special cases where age-old manual techniques still have some local impact—e.g. the case of Berber houses in some Moroccan zones, still built with ancient adobe technology. Nonetheless, these necessarily make use of tools or transport and deployment machinery that was not available in a pre-industrial world. Inevitably, the vast majority of the current practice must combine both industrially and/or remotely produced elements (ex-situ) with local works (in-situ)—Table 1 gives a general idea of the implementation of ex-situ works in different areas of the building industry.

Type of Building	**Level of** ex-situ **work (%)**
Rationalized housing	25-35
Industrial building site processes	20-30
Standard ready-built (reinforced concrete, steel, timber)	40-60
Ready-built housing (lightweight panel system)	50-80
Modular units/sanitary blocks (reinforced concrete, steel, timber)	60-90
Mobile modular units (steel, timber)	95-100
Automobiles (for purposes of comparison)	100

Table 1. Level of ex-situ work per type of building, adapted from Bock (2006)[302].

As industrial practices and, with it, transportation methods evolved, so did the notion of construction component, which can furthermore be related with a *discrete* understanding of the building construction processes. Not only it became possible to produce some elements more and better, it made more sense to assemble them in increasingly more sophisticated components. In cases, these components gather different elements brought (or not) from different manufacturing facilities. In other circumstances, these are single elements of incredible complexity, which are only possible to produce in factory-controlled environments. In many situations, components have grown so small and/or so pervasive, such as an electrical plug, a door handle, flushing toilet, or a gas boiler, that we may hardly realize them as components. In other cases, components have grown so big and complex that almost entire rooms or houses are produced ex-situ, sometimes requiring exceptional transportation methods to in-situ deployment or, as in the American *mobile homes*, built on their own chassis to be transported as such on the road.

It is hard to find coherent nomenclature in literature dealing with prefabrication. Although not necessarily with the same meaning, the use of terminology such as *offsite fabrication*, *industrialized construction*, *site assembly*, among others, is seldom used alternatively to *prefabrication*. There are probably good reasons for that, given that it is a term that can be associated with different types of construction, which often are mistakeable, such as construction using predominantly linear principles (e.g. *kit-of-parts*), planar principles (e.g. *panelized* construction), or volumetric principles (e.g. *modular* construction). Anyhow, these or other related distinctions are not straightforward to establish. For instance, in cases where some name *prefabrication*, others may call it of *systems construction*—in *prefabrication*, the linguistic association may easily be lain in a more direct bond between a design purpose and its construction; conversely, we can regard a *systems construction* as independent of the design (although necessarily influencing it), that is, the same system can be used for different constructions with different purposes and designs. What is clear though in a *prefabrication* terminology is that there is an unequivocal relation between the idea of industrial development and the notion of constructive component, which adds to a preexistent idea of constructive system. Moreover, these terminologies occur more in a constructive sphere and not so much on a social or spatial sphere of the built environment.

Thus, we believe that *prefabrication* must generally be accepted as a catchall term—i.e., adequate for a generic description, yet useless for a more precise development. On the plus side, due to its large possible scopes, its generalization can facilitate the communication processes surrounding it. However, in the least that raises the need to set its boundaries in relation to a subject or approach, but also to properly outline other terms that may be mistaken with it. For the latter, if we observe a few renowned dictionaries, a common lexical field arises from the diverse definitions[303], with a recurrence in words such as *construction*, *assembly*, *fabricate*, *manufacture*, *components*, *sections*, *parts*, *standardization*. That denotes there is an action occurring in space that is related with the idea of organizing and building something. Moreover, there is a recurrence in the idea that there is some sort of process preceding a deployment on a final location, that is, it is set through a temporal notion (e.g. in expressions such as *in advance*, *in factory*, *on site*). From here, some preliminary conclusions on a definition could be taken, but another question arises as to the up to date validity of the dictionary entries. For instance, in *Webster*'s case, the definition was first recorded in 1932 and has not been changed since. Meanwhile, technology has progressed, yet the word apparently has not, and in that sense, it may be reasonable to think it can mean something different today. Nevertheless, notwithstanding the evolving context, the meaning of the word has essentially been kept[304]. Besides, since the first dictionary entry has only been recorded in 1932, that indicates a relative historical novelty of the term, and thus of an increased potential difficulty in a clear-cut definition.

By word formation reasons, the closest word in its lexical relatives is *fabrication*[305], which is suggestive of some way of elaborating materials with desired properties by using different techniques[306]. *Assembling*[307], which is a closely related word, can easily be understood as means to join together[308]. *Fabrication* can also be defined as providing the elements that are to be *assembled* together. These definitions are obviously interrelated and precedence of one in relation to the other is often dubious. There is also the issue of hierarchy, that is, on how each stage of assembly can be defined and limit each sub-stage, which in turn leads to where fabrication and assembly start and end in relation to each other. The latter is a looping issue, as the boundaries between the means to fabricate and the means to assemble are not always clear. Anyhow, there is an implied subscription of a space-time notion, given if there is a certain stage, it implicitly means there is some other stage preceding or succeeding it—the prefix *pre*[309], agglutinated with *fabrication* is, if not more, a reminder of such. Therefore, *prefabrication*[310] places the activity of *fabrication* before some reference point in time[311]. Although not consensual, the term *prefabrication* indicates a space-time reference to the overall processes of fabrication and assembly, and thus can be described as *the putting together of all or part of an artifact in some place other than its final location*[312]. From here on it is a matter of degree, although not free of ambiguity, as if applied to every factory-made product the term would eventually lose its meaning[313]. Following a British terminological tradition, Gibb[314] apparently solves this question by naming it something different—i.e., *off-site fabrication*—but that also reduces its scope. For our purposes, in this regard we find suitable to distinguish between *in-situ* and *ex-situ* processes within a broader *prefabrication* terminology. As we will later observe, these also unambiguously fit the related conception of *modularity*. Another problem with this space-time definition is that it can seamlessly be adopted for different notions, as in *industrialized construction* or as in a definition of *component*, thus potentially generating other ambiguities.

The industrialization of construction products should not be mistaken with prefabrication, although the themes can often mingle. Construction industrialization results of a continuous progress made in the industry of intermediary construction products (i.e. those products that, when brought together, may or may not make part of a building). On the other hand, *prefabrication* can be regarded from the whole of the building and be thereon deconstructed into (or reconstructed through) its different systems and elements (components, sub-components, and so forth). *Prefabrication* should also not be mistaken as strictly the result of the hypothetical reduction of a *building* to a *manufactured product*. As far as we see it, it should be understood by the taking in action of the diversity of the building's morphology and its relations and for the comprehension of the conception processes that give it shape. A building process cannot be reduced to an assembly sequence, as if it was a mere and unequivocal spreadsheet—in the least, the building construction is intrinsically exposed to more imponderables when compared with finished products exiting a controlled industrial assembly line. Construction is ought to adapt, or to be though off in terms of a wider set of risks and constraints, such as technology, site, weather, transport, and so forth, not to mention legal or regulatory aspects that can be present since early stages in the design. Therefore, a typical industrial product cannot be strictly compared with a building *product*. For instance, there is no packaging for a house, the package is the house, which makes it a very different kind of *product*—nevertheless, in business terms it can be considered as so, as in a *real-estate product*. Foremost, there is necessarily an issue of scope and/or scale, but also of perception.

Indeed, technically, there is no possible consensus on a straightforward definition of *prefabrication*, and that in least indicates there is a relevant matter of [subjective] perception involved. If speaking, for instance, on *prefabrication of houses* or on *prefabrication of bridges*, it is a peaceful thing to say that different subjects are being mentioned, yet distinction might not be so easy in other cases. The two involve different scopes, notions, scales, skills, detailing levels, and so forth—in houses, we can commonly refer to *prefabrication of houses*; in bridges, the terminology can be, e.g., *prefabrication of elements for bridge construction*, instead of *prefabrication of bridges*, hence implying that prefabrication is assumed to be a part on a bigger process, not the whole process, as in houses. The same occurs in multi-story apartment buildings, where it is common to say that they have, e.g., *prefabricated façades*, or *prefabricated modular components*, although the building itself is not usually taken as prefabricated. Exceptions in specific literature are rare in this kind of buildings, nevertheless they can be found, as it is the case with the *Murray Groove* apartments in London (1999-2000), by Cartwright and Pickard.

It thus follows that *prefabrication* is not a technical or scientific notion, but more a notion dependable on a certain agenda, or on how a building product is set to be sold, that is, on a public perception and how that perception is built up, with what intents, and so forth. In a way, and only if it matters for its promoter, we would also add that the closer the building is to a bondable entity, such as a packaged consumer product, the more likely it is for it to be called *prefabricated*. Likewise, a analogous reasoning could inversely be applied to the multi-apartment, speculative real estate with no particularly perceptible use of construction components. Indeed, their essential difference in marketing terms is virtually inexistent. In any case, it is clear that architecture is not necessarily a *core business* in these specific perspectives.

In houses, and particularly often in detached houses, the term is typically assumed as describing a whole, even if it is known that it is not totally so. This notion of meaning attributed to a whole instead of a stage of it, as it occurs in the notion of *off-site fabrication*, gets higher relevance when we think that *prefabrication* is frequently denoted in opposition to the so-called *traditional* construction. However, when referring to *traditional* construction we may also be meaning many different things, e.g.: to a specific enrooted technique; designating a certain vernacular type; or generally to a process we take for long established or that simply we are somewhat used to. *Prefabrication* can too mean many different things[315]. If in some of its uses, the term *vernacular* can be evocative of *traditional*[316], analogously, *prefabrication* can be regarded as evocative of an architecture conveying a sort of feeling of vanguard related, cutting-edge (or so seeming) engineering or industrial practices. Regardless a greater or lesser propagandistic tone associated, the vanguard image it may convey can have a powerful appeal. However, that may well backfire, symptomatizing an enrooted social suspicion related with biased past examples. Anyhow, *prefabrication* also renders an appeal, derived from a certain functionalist discourse, to notions such as efficiency and economy, associated with a better work environment and qualitative control via enhanced planning in the design, construction, costs, and so forth. These do not necessarily need to be regarded as cutting-edge, or as if alien-like relatively to ordinary practices.

As palimpsest, knowledge and technology are iteratively devised, recursively summed and questioned in time. In the cases where its use is more reluctant, it should make sense to regard the potentials of prefabrication, incorporating it in current practices. Such does not occur overnight. It implies an entourage at the pervasive level of a constructive culture, and well-coordinated approaches from design to construction actors. At this level, *prefabrication* is already well established in the practices of places such as the USA, Japan or Scandinavian countries. In those places where such culture is not so vividly present, the approaches most likely require an extra effort in research, development and overall dialogue among players. In one case or the other, mitigation of social acceptability suspicion should likely be a major concern, as the low-quality examples throughout history have stigmatized the very term. In architectural practice, it is our belief that to overcome such suspicion, high-quality in design should interdependently correspond to high-quality in constructive solutions. Ethically in the least, both should in all cases be a permanent concern.

Trying to reach a consensus in a *prefabrication* terminology is a task that most likely will reveal unfruitful, as the methods to classify often seem to be as varied as the purposes of those making the classifications[317]. For instance, the client is probably interested in size and price, along with *style* or the like; the builder with productive quality, efficiency, revenues, and so on; and the architect will be concerned with design issues, such as the geometry of the building, functional organization, spatial qualities, and so forth. Being a general notion, *prefabrication* can be adjusted to the specific cases, with conventions of their own, in relation with the overall process that is under development.

2 FROM THE MODERNIST INDUSTRIAL PARADIGMS TO A NETWORKED REALITY

2.1 A business reality

Shipbuilding, aerospace and specially the automotive industry are perhaps the more direct inheritors of the coal and iron based Industrial Revolution times. Following mechanophiles such as the *motorized suburban* Frank Lloyd Wright, or the *functional urban* Le Corbusier, in the Modernist period these industries have often been discursively implied, whether symbolically/culturally or by their state-of-the-art production and management practices, as ways that architects should regard attentively. Hitherto, the literature related with prefabrication, and/or with systems construction, frequently borrows elements from these[318].

That hardly comes as a surprise, since the history of prefabricated construction, and generally, the technological evolution of construction processes has long been inextricably related with the development of other industries or businesses[319]. Attesting it, there are illustrious examples, such as the Portuguese *Gaiola Pombalina* building system, which was plausibly based in shipbuilding methods. In any case, it must not be forgotten that the building industry has its peculiarities that differ from those of other industries. That necessarily restricts attempts for a direct comparison, limiting the taking of early assumptions.

Several reasons contribute for the terminologies, processes or practices used in industrial production and management to be ahead of those of the construction industry[320]. As a general decisive factor, that can be credited to their tendency of concentration of capital, which results in more resources available for R&D, marketing, and so forth. Moreover, unlike what it often occurs in the construction industry, these commonly follow product-driven philosophies, where capital availability has a vital effect in the engagement of the entire productive fabric to converge towards the underlying goals.

Classically, this has led to conspicuous replication-engaged philosophies and methods. These arise as a natural consequence of unraveling efforts to attain economies of scale, by optimizing processes, reducing inefficiencies, self-regulating batch sizes, and so forth. Anyhow, currently the repetitive stereotypes of the production machine are very different from what they have been in the past. That can be illustrated by the IT's propelled tendencies towards the integration of a higher range of consumer choice, seemingly increasing variability of outputs through mass-customization strategies and the like. Anyway, notwithstanding the divergence in philosophy or the improved tools or technological state, the replication-engaged processes are still in the bare bone of most production processes around a globalized world.

The purpose of achieving more effective, scalable modes of production is deeply engaged in gradually attempt to achieve more with less, which corresponds to an idea of progress and development where economy is prime, often at expense of the social and/or environmental spheres of a sustainability equation. From the standpoint of the underlying economic processes, there certainly are many similarities between these industries. In any case, there are also differences worth noting between their sizes and characteristics.

As shown in Table 2, contemporarily the greatest of these is beyond doubt the automotive industry. Analyzing figures collected from the 2014 *Forbes Global 2000*[321] list, excluding the banking industry (in first place) and the oil industry (in second), the automotive industry had the most companies on top. Focusing in the more traditional hard industries' companies (i.e. construction, shipbuilding, aerospace or machinery), the sum of the auto industry top 10 companies' was head-to-head with the remaining top 10 combined. In other words, this means that 50 companies among these other *hard* industries moved a business that was roughly equivalent to the business moved by the top 10 companies in the automotive industry. This portrays the difference in the business scales, and not least gives an idea of the plausible difficulty in establishing a comparison, or extracting sound features on fair grounds.

Top 10 Companies' Summed	**Sales***	**Profits***	**Assets***	**Market Value***
Construction Services	596.9	17.653	751.8	256.3
Construction Materials	218.7	8.019	328.4	179.8
Aerospace and Defense	369.8	23.161	451.9	424.7
Shipbuilding**	152.074	1.962	126.7	32.7
Heavy Equipment***	231.1	15.17	326.8	246.5
Previous Combined****	**1568.57**	**65.965**	**1985.6**	**1140**
Auto and Truck Manufacturers	**1507.7**	**78.8**	**2101.3**	**859.6**

* In USA$ Billion. ** Including Conglomerates, which also include aerospace, defense, energy, and so on. Excluding the 'Profits', 'Assets' and 'Market' of the Forbes' 2000 unlisted - that is, the bottom 6 of Top 10 companies, anyhow of little relevance for the overall picture. *** Excluding Conglomerates that are included in Shipbuilding. **** For comparison purposes.

Table 2. Sum of Top 10 Companies by industry in 2014, based on *Forbes Global 2000* list.

Notwithstanding their differences, a bit all over, similar production features can be recognized among the diverse sectors. Henry Ford's iconic linear assembly has long been replaced by the production of integrated modules, each composed by innumerous parts provided by different suppliers. From the initial assembly line, companies have gradually begun to use third-party manufacturers, not just as source of parts, but also for fabrication of subassemblies. Managers, designers or process engineers began to realize the advantage of fragmenting products, and developing them in modules, or sets of parts, where each module can be composed of many parts, preassembled off the main assembly plant, in an adjoining or nearby facility, or at a remote location.

Although each case is a case, the general argument is that when these parts are fabricated into components before arrival at the point of final assembly, gains can be made in quality, features, or performance, while reductions can be achieved in cost and time of fabrication. The philosophy of the process of making, from design to production thus tends to follow a parallel, networked logic, instead of a linear, gravity-like process motion, where the collective intelligence is put at work in collaborative processes towards integrated component construction.

Our times are not those of the modernist age, when the comparison notably first arouse, and the production philosophies and methods have evolved to unprecedented sophistication. Notwithstanding, in many ways, it is our belief that the automotive, shipbuilding or aerospace industries are still largely valid as references for an assessment. Particularly, when comparing with other relevant industries such as the software, hardware, or services industries, the trio still seems to be the closest to establish a more useful evaluation. Surely, each with their own idiosyncrasies, surrounded of different challenges, and thus with potential of arising a variety of inputs towards the construction industry and/or the architectural production.

2.2 Notes from the automotive industry

In the modular and parallel assembly of car production, the supply chain is consolidated and hierarchically organized into a chain of *tier* suppliers, delivering modules for arrival at the OEM (*original equipment manufacturer*), the company that makes the final product for the consumer marketplace and thus bears a brand or multiple brand's name. For instance, *Volkswagen*, *Chrysler* and *Toyota* are OEM companies that manufacture cars, and *Apple*, *Sony* or *Samsung* can be regarded as consumer electronics OEMs. The OEMs are, so to say, the companies that are on top of the food chain, and straight below is the so-labelled *tier*-1 companies, which are the direct and major modules suppliers to the OEMs, followed by *tier*-2, *tier*-3, or even *tier*-4 companies[322].

This product-focused *ecosystem*, hardwired to build successfully higher (i.e. bigger and/or more complex) levels of components, until reaching the final product ready to deliver to the consumer, requires transversally fine-tuned processes. With a modular functioning of the production methods, and a clarification of the interfaces in the final installation (e.g. with use of fewer joints, or following strict, practical rules of assembly), more precise tolerances can be attained throughout. Moreover, there can be an improvement of working conditions, with less accumulation of parts in the final assembly area, thus easing the entire process and minimizing the risk of flaws.

Furthermore, with the fragmentation into modules build up by different tiers, there are more entities assuming primary responsibility for their quality and in-time delivery than in a classical command-and-control method of construction, thus contributing to streamline production and improve overall quality. Moreover, since production and accountability are spread across numerous players, focusing in design, engineering or systems' management (also known as product architecture) is key for a successful integration of the various contributions.

Following a fast-paced technological evolution, with the IT's of our information age, parallelism can be implemented and manageable up to scales unthinkable until just a very few years ago. The focus on process integration, through the adding or improvement of processes and/or technologies such as digital modelling, virtual testing, fast prototyping, supply-chain management, or corporate in-house connectivity with vehicle platforms and the like, have enabled this industry to reduce even more the concept-to-market period. In the mid-1990s, a concept-to-market period could typically take 52-58 months, whereas in the mid-2000s it was estimated easily taking 32-38 months (about 40% less in a decade)[323]. Speeding up the process has been a key focus for the automotive industry, and that means billions in savings. Henry Ford's linear paradigm, which we can symbolically ascribe to a motion of gravity and hierarchy, no longer dictates all processes. In a way, gravity has given place to the virtual, and its counterpart hierarchy has given place to the network.

From design to manufacture, every part, right down to the tiniest element, such as a screw, can be defined and digitally controlled on a process sheet that details all features and installation procedures. The entire process is poised to be controlled electronically through direct links among all participants, from the OEM to the suppliers (tier-1, tier-2, and so forth), and at last installed on the final assembly line. Quality control procedures help to insure minimization of flaws. For instance, discrete components are typically coded to enable instant tracking and to ensure that each is installed in correct positioning in the proper module or vehicle. Each module comes to the final assembly complete and ready to quickly be attached to the vehicle under construction. The various modules produced in parallel and trackable throughout the entire process, contribute to a drastic reduction of the overall time-to-market for the complete car. Moreover, these also enable client's customization options to be seamlessly integrated in the process, as well as ease of component tracking for future maintenance purposes of repair or replacement.

By optimizing the entire production chain, the time and total cost of labor required to install modules at the point of final assembly are poised to be dramatically reduced, as are the overall quantities and costs of material, and the total production time and cost of the final product. Additionally, from a suspension mechanism or an electrical socket, to a transmission or a differential system, an alternator, a chassis or an engine, or a set of several of these, through the concept of *platforms*, some modules are shared between different vehicle models of the same brand, or of different automotive brands or even brand holders, further contributing to the production economies[324].

These sharing processes also reflect a reality where, in a way and in many levels, the main differences between the end products may lay in what is more directly visible or tangible (e.g. bodywork, dashboard, alloy wheels), than in what lays beneath (e.g. chassis, engine, transmission, differential). Likewise, it is a reality where, aside the performance factors, a mix of aesthetics or tradition/meme carrying brand status plays a major role. Consciously or subconsciously this affects the *feel* of a car, aside its material quality or other more or less objective characteristics, with repercussions in the perception mechanisms forming the value, price-point, and so forth.

As we have mentioned, the codification procedures are key for a seamless integration of production processes in this industry. For that matter, aside following international standardization and/or certification schemes, the very companies often develop their own norms—from the material properties, to classification of construction elements, from screws fixation force or pistons tolerance specs to larger modules' joint tolerances, construction or management procedures, labor rules, and so forth. Additionally, regional or country specific aspects are also considered, from driver's seat on left or right, to CO_2 or NOx exhaustion norms, and so on, and thus though of to seamlessly be modularly integrated in the production. Management procedures, controlling and accounting, are thus key to keep these organizations well-oiled.

These procedures, engaged in the cogwheel of attaining ever-greater economic efficiency, reducing costs and increasing value to maximize revenues and the like, are obviously not exclusive of the automotive industry. For instance, in retail, companies such as *Amazon* or *IKEA* are well-known by the large public for their tight and detailed control. This are evident in *Amazon*'s logistic procedures, or in *IKEA*'s precise number of coded construction elements that are packed with their products.

2.3 Notes from the aerospace industry

As automobiles, commercial aircrafts are also the product of a highly efficient cooperation across a company's global supply and manufacturing chains, often built upon decades of innovation in the field. Design and production of a car or of a jetliner pretty much go through analogous steps in terms of modular fabrication. However, the jetliner's larger scale, added to the highly demanding air-safety requirements, make it a very different product, starting in the very organizational philosophy. Indeed, whereas in the automotive industry, the production and responsibility can more easily be fragmented into the different tier suppliers, in the aircraft industry, control typically stays closer to the hands of the main company, more in a command-and-control fashion.

In cars, tier-1 suppliers are typically specialized in a certain kind of component, thus following more of a performance approach, which is set by the OEM. That is, using their specialized expertise, the tier-1 supplier conforms its product to the OEM's design requirements, established in terms of performance goals, which include form factors (e.g. spatial/geometric characteristics, materials, joint locations, and so on) and function factors (e.g. structural, mechanical or electrical characteristics, and so on). In airplane production, given the nature and scale of the product, a performance approach cohabits with a detailing approach, where the different plants supplying the components for the entire airplane typically work in vertical integration under direct control of the main company, in constant dialogue with their design and engineering teams[325].

Thus, the concept of tier does not make so much sense here, since design and control is exerted throughout the entire line by the main company, without so much of fragmentation to third parties. Nonetheless, there are exceptions in particular dedicated components, such as jet engines, as it occurs with *General Electric* or *Rolls-Royce*, two well-known major aircraft engine manufacturers, with supply contracts with multiple aircraft manufacturing companies. Anyhow, the diverse individual plants under control of the main aircraft construction company, each typically specialize in certain parts of the aircraft and/or in the final assembly.

Companies such as the European *Airbus*, the American *Boeing* or *Lockheed Martin*, are the top players in the industry[326]. Within their own business, these companies follow a philosophy of global cooperation that begins in the very design and engineering. For instance, *Airbus*[327] relies on a network of facilities for design and engineering that spread throughout Europe, North America, India or China. Their headquarters in Toulouse, France, gathers competencies such as architecture integration, general design, structural design and computation, integration tests and systems, and propulsion, whereas, their facility in Filton, UK, produces and gathers design, engineering and support duties for wings, fuel systems and landing gear. To meet continued sturdy demand, and achieve high performance levels, in 2013, *Airbus* implemented a new production organization, focusing in further integration, full cross-functional alignment and even more teamwork in production activities. Structurally, the organization empowers each *Airbus* plant responsible for the corresponding components it manufactures, although there is a support by the overall design and engineering network to the day-to-day challenges. In the parallel assembly of airplanes, components sizes' create logistical issues that the automotive industry typically does not face[328]. Regional synergies seem to be of importance for the company's business strategy, both in terms of the economies of production costs, as of market implementation and visibility. Attesting it are the current final assembly line plants, which spread across several continents[329].

2.4 Notes from the shipbuilding industry

The shipbuilding industry has too been modernizing over the past years, aided by the incorporation of digital tools that help integrating different stages of design and production. Shipbuilding production has long been following modular principles of construction. However, the heavy weight and large dimension of its parts, potentially the most extreme of any of these three industries, makes it a special case. Shipbuilding greatly relies in the brute force of cutting and welding of heavy steel elements, with much of the work occurring manually (even if machine-aided), in-situ or in shop, although with some parts produced in more controlled environments with support of CAM methods. There are also some highly-specialized parts, such as engines, propellers, or control mechanisms, which are typically supplied by third parties.

Companies such as *Caterpillar* or *MAN* build heavy machinery and aside their own brand products, they also supply as third parties for ship construction[330]. This sort of companies is part of a grander ecosystem of businesses that we can relate with metal forgery and machining, spanning multiple areas, from auto or truck construction, to aircrafts or ships, as is the case of *Rolls Royce*, which produces cars, but also jet engines or maritime engines. The businesses of maritime building companies are also usually diversified, some of them moving through all sort of areas, in industrial conglomerate business structures, as is the case with the *Mitsubishi Heavy Industries* (*MHI*), the largest of its kind, which works in areas such as aerospace, defense, energy, shipbuilding, and so forth. Finally, their procurement is of a very different character than for instance that of the automotive industry.

The process of shipbuilding is very variable, facing all sorts of challenges, anyhow requiring robust production facilities. Indeed, ship construction can vary immensely according with the ship's dimensions and/or characteristics. Smaller ships can almost entirely be assembled in a welding shop, and subsequently moved to a paint section, and thereon to the water. In large vessels, a great deal of the building blocks can arrive fully furnished to the final assembly site, which can typically be an outdoor dry dock, facing weather conditions. Smaller or larger, a vessel construction is typically grounded. This, allied to the variability of construction cases, makes it an industry that in this sense resembles more a building construction, than a car or airplane construction.

Given the dimensions and the often-tight schedules, several specialized construction teams may be working simultaneously in different parts of the ship. Moreover, the dimensions and heavy weight of both the block modules, and the ships themselves, demands the brute force of the shipyards' gigantic cranes and, if required, a transportation of parts through large specialized ships or land carriers. Given these intrinsic logistic limitations in maneuverability and transportability, the implementation of motioned and/or automated production lines is pretty much inhibited from a certain component scale onwards, and parallel production has more implementation constrains.

Generally, the building parts in ship construction are bulkier than in car or airplane, which makes its production harder to delocalize to external suppliers. Nonetheless, parallel production can be made possible overseas, and not only within a single shipyard. That is the case with the twenty *Maersk*'s *Triple E* container ships contracted for construction in 2011 to the *Hyundai Heavy Industries - Daewoo Shipbuilding & Marine Engineering* (*HHI-DSME*). Despite the enormous size of the ship, the biggest of its kind, it is built with pinpoint precision, involving a massive international effort, from the design and engineering team, to the contractor teams and shipbuilding supervision[331].

South Korea has become the current world's leading nation in shipbuilding, with several major companies operating from their shores. As most of the companies in the industry, the *HHI*'s activities, the largest of its kind after *MHI* conglomerate, are not limited to ship construction, ranging to other areas of heavy machinery. Among other things, they too produce engines and propellers, as well as some of the equipment to move heavy stuff, such as forklifts, cranes, and so forth. As the world's biggest facility of its kind, with about 90 ships produced a year (one each 4 days), there are permanent concerns on the bottlenecks of the panel block assembly lines due to the limited facilities and equipment, the increase of construction demand or the simultaneous production of various types of ships.

Aiming at obtaining a continuous flow production system, they thus constantly seek ways to mitigate bottlenecks, for instance, by minimizing incompatibilities in the labor days required by different parts, aiming at related components to be produced just-in-time on the construction sequence. Even with a well-oiled IT's implementation, with automation, CNC cutting, CAD, CAM, and the like, the production process is nonetheless labor intensive. Therefore, a great effort must be set in addressing labor related issues, such as work safety or even in providing workers accommodation, for which they have even created a subsidiary housing division. Another major concern has to do with the integration of the diverse digital systems. Moreover, there is also concern set on the customers follow up, for which they have a maintenance and technical support division. Finally, there is an underlying synergetic philosophy pervading the company's initiatives.

As other companies in the field, *HHI* strives to increase their competitive edge in engineering, and they aim it through innovation. In 2015, a team of over 1,400 designers developed a more effective economical and eco-friendly ship design, responding to market changes and client demand, designing and engineering new ships for deep-sea environment in particular. In order to meet demanding quality and performance standards, they implemented a thoroughly quality management system for quality inspection of every manufacturing process. Apparently, the key to the performance improvement has been to aim towards a seamless, instantly updated information of the diverse concurring processes that directly or indirectly are implied in shipbuilding[332].

2.5 Comparison and challenges towards housing production

Modernist mass house production gave answers that soon would be criticized. The techno-optimistic posture of some prominent figures, lead to appeals for architecture to proceed along a path with a closer regard to the industrial way. Nonetheless, comparisons with *global* industries such as the automotive, shipbuilding and aerospace, regarding their benchmark practices, although long observed and revisited from time to time[333], have several aspects that can be questioned.

Mass produced housing systems, developed to satisfy urgent housing needs, such as some post-war entrepreneurships, was typically limited in terms of spatial flexibility and technical refinement. It testifies a core difference between the automotive mass production and the analogous application to produce dwelling units. As Kenneth Frampton wrote, "[*it has become clear*] *that the large amounts of capital necessary for the refinement of the automobile, from prototype to production stage, only becomes readily available because of the guaranteed marketability of the car as indispensable means of private transport. On the other hand unlike the automobile, that amortizes rapidly, the residential fabric, despite its seeming repetition, has a non-consumerist character*"[334]. Indeed, the aspects of the financial architecture and its derived manifestations, is a core issue that should be present when comparing both realities. Additionally, in housing there is an attachment to a specific location, which can raise questions when considering the house as a product, whether the comparison is established with products of a greater (e.g. automobiles) or lesser (e.g. ships) consumerism degree.

Indeed, the classical comparison, between house production and the industrial production paradigms, is not entirely fair thus it must be carefully considered. For instance, doing the exercise the other way around, it is difficult to imagine, for instance, how a car would be produced like a house[335]. For a start, there are issues related with the expected average lifespan, since it is hard to picture how a car can normally last more than 50 years as a house probably would. Typical house related questions, such as maintenance, how it could be altered and/or resized by the user, or easily expanded to take more people, are certainly very different.

There is also a design issue, since cars take over 30 months to design, which ordinarily is simply not a bearable practice to proceed with a house design. It is also difficult to imagine how a car could be repainted or redecorated inside when owners get bored with the color, or how it could accommodate a wheelchair without significant modification, or even how it could look totally different from the other cars on the market at the same type and budget level. Finally, how could its business logic be sustained without the benefit of a consumerist cogwheel of built-in obsolescence, which also feeds the automotive industry, starting in Henry Ford's philosophy of a car for everyone (beginning in its own workers), and ending in more sophisticated marketing schemes, from rentals to lease plans, fleet supply contracts to clientele companies, and so forth. Real-estate businesses can also be fiercely aggressive, anyhow the milieu is very different.

Buildings are made from many components, but these have different characteristics than those of other industries. Compared with others, most building industry components are relatively simple, not requiring a special technical sophistication in the in-situ works. Other industries are more likely to have complex components and sub-components, with specific differences in function and form, as it is the case of the engines in cars or airplanes. The organizational methods are too very different. It adds that the players in the automotive industry are typically much bigger when compared with most of the construction market players, with the bulk of the market composed of SMEs. The fact is that the automotive industry spends far more money on R&D than the building industry, which will inevitably reflect in the overall product quality and how that quality is managed and controlled, all the way from final assembly line to the diverse suppliers in the supply chain. Indeed, when producing units to the thousands, factors such as quality control acquire a determinant importance, since a flaw signifies tremendous losses to the OEM.

On the other hand, the building industry has completely different opportunities, because the relative simplicity of building components allows a much greater diversity of outputs, which can be reflected in the appearance of the final product. Such apparent simplicity is also what ultimately empowers what can be called the *culture of the home*, that is, of taking care of the matters with the own hands, adapting spaces to different uses, decorating and the like, or through the non-particularly complex technical services of others.

Although most components in building construction are relatively simple when compared with the complexity of others, the reality is that the supply of buildings can be more difficult. Moreover, for instance, in the automotive industry, although there are relatively complex components in different kinds of car models, of the same or of different brands, the essential parts can be pretty much the same. That, allied to a streamlined referencing of parts eases the ability to proceed with component substitution when needed, sometimes in a much more effective way than in housing. The numbered car parts are not only an effective mode for quality control, but also an invaluable source of tracking for replacement. Comparably, often when substitution of building components is required it is hard to find an exact replacer, although similar, but not exact ones may be available. Often product development or market trends render products obsolete in just a few years or, in other cases, companies simply cease to exist. For that matter, again, we need to recall that the bulk in the construction industry are SME's, more prone to financial risk, although even bigger ones are not at all immune. On the one hand, the general simplicity of building components makes it more prone for repairing purposes. On the other hand, it can make it harder for replacement purposes.

Alongside with more effective production methods, boosted by IT's or more effective transportation methods, we have also been witnessing a concordant decline of craft, with repercussions in quality and cost. It is clear that with a decline of craft, quality and quantity are going to be achieved by ever more rationalized and/or mechanized means, and where a focus must be put on systems' management. It also seems clear that no matter how these will evolve, that knowledge integration will increasingly become a core issue for architectural production[336].

Meanwhile, several aspects of the industrial production can be borrowed to the architectural house production. For instance, making use of a philosophy of costumer first, following notions of economy and value demand, or making use of a communal patchwork philosophy, sharing design and responsibilities among the different parts involved. Moreover, the disciplines integration, as in process engineering, is a crucial issue, to which IT's have a decisive say. Using new kinds of design regulating systems, through supply chain management, increased logistic performance, or segmented quality control, are possible successful ways to conquer such integration. Additionally, it can be relevant to implement information and simulation systems, such as online customer-oriented architectural survey to inform virtual simulation and general cost assessment. Finally, all this can benefit of integration with parametric design tools of *Building Information Modelling* (BIM), *Bill of Materials* (BOM) or *Manufacturing Bill of Materials* (MBOM), improving terrain integration, precise material definition, cost assessment, or generally the design workflow, while speeding up linkage to production. Furthermore, lean production, mass customization, digital fabrication, material advancements, or addressing sustainability issues, among others[337], can be looked as allies towards the evolution of the architectural production paradigms, where an awareness of technology should cohabit with an attention to the socio-cultural needs, redefining the quality of housing and living environment, locally and globally.

3 PREFABRICATION AND VARIABILITY

3.1 Logistics and output vectors

In prefabrication, it is primarily implied a distinction between locations where the building products are manufactured (i.e., ex-situ practices), and their assembly on the building site (i.e., in-situ practices). Logistics is the cement binding the two spheres, and is thus key for running any kind of building construction (prefab or not) smoothly and efficiently. Good logistic practices can bring positive impacts in several domains of architectural production, namely in aspects related with the output vectors of cost, time, quality and scope (Table 3). It is not only an issue of construction management, but an issue that should start with the very design.

Cost	Capital cost (administrative, project fees, construction, financing, marketing, etc.) Maintenance cost
Time	Designing and planning time Speed and duration of construction Speed of response to client's needs
Quality	Design reliability and durability Design innovation Subjective (aesthetical, spatial, impact in people, etc.)
Scope	Functionality (suitability for the intended needs, in program intents, subjective qualities, etc.) Sustainability (economic viability, socio-cultural integration, environmental adequacy, etc.) Life-cycle behavior (suitability for the intended lifespan, flexibility, adaptability, etc.)

Table 3. A selection of output vectors.

Factory quality control levels are extremely hard, if not impossible, to attain in-situ with the same standards, namely because of the effects that non-dry construction processes can have in a convenient solidarization, finishing or waterproofing of the parts. Conversely, certain craft-depending qualities cannot be met in factory with the same standard as in-situ practices. Higher or lesser industrialized construction environments have different qualities, but also pose different challenges.

In less industrialized construction environments, logistic pressure mainly occurs in the coordination of the integrated in-situ works, where things can get messy, often dealing simultaneously with raw materials, transportation, work coordination, besides weather conditions, and so forth. Compared to more industrialized environments, the management of the construction process has more dependencies, meaning that the mishandling of a single variable, can have downstream negative impacts in the output vectors. For instance, a delay in a craft can affect the integration of other works downstream, which may not be available for an alternative scheduling when ideally needed. On the other hand, more industrialized construction environments are more prone to alleviate in-situ logistic pressure, fragmenting it elsewhere, thus contributing to attain potential gains in the output vectors. As direct consequence, comparatively there is a reduction of dependencies which carries many potential benefits. For instance, if reducing construction to the closest as possible of an assembly process, in-situ works can almost entirely be conducted by the same group of people, specialized in assembly, since more demanding specific crafts would be circumscribed upstream.

Optimizing the separation of a building into its individual building elements, so that transportation can be optimized from ex-situ to in-situ, can be a decisive contribution to attain good logistic practices. Nonetheless logistic pressure will always be there, whether in higher or lesser industrialized environments, since components should anyway be delivered in the appropriate timings to avoid unnecessary time waste (e.g. arriving late, hence delaying the construction), or space waste (e.g. requiring unnecessary and expensive allocation of storage area). Especially on construction relaying on components in a greater degree, logistics must be precisely coordinated with the pace of the final assembly. Broadly, the higher degree of ex-situ work, the greater the influence of adequate logistics practices in what respects deployment aspects, i.e. in transportability and assembly. Furthermore, components can have all different kinds of sizes, shapes and/or complexity, the concurrent factors affecting construction logistics. For instance, in urban areas, particularly in the denser ones, additional constrains may arise due to traffic limitations, width of streets, or even trees, electrical or communication poles and cables, and so forth.

Indeed, transport optimization is one of the key aspects of good logistics practices and may even influence design options, if costs are to be kept tightly under control. The conditions under which the building elements are to be transported is a factor that can seriously restrict the units' size, as allowed transport dimensions should not be exceeded, otherwise requiring special transportation permit and/or more expensive transportation fees. Whatever the sort of transportation (e.g. truck, rail, boat, or even helicopter or airplane), it is imperative that the building elements are properly secured during transport and protected against possible damage *en route*, which may add some constraints to the transported unit characteristics. Normally, individual units can be combined to produce reasonable transport loads, optimizing the carrying[338]. For long-distance deliveries rail and sea transport can be economical solutions, but it should be remembered that the last stage of delivery to site must generally be made by truck. In that sense, multi-purposed carrying, such as containers or pallets are often a packaging device to consider, constraining dimensional considerations [complement with: **Annex, II.3 Logistic Notes**].

After transportation and arrival to site, to erect a building based on prefabricated elements, what mostly needs to be carried out on the building site is assembling and fitting. This includes hoisting, positioning, adjusting, connecting and waterproofing. Building work can thus become an assembly process, comparable with a factory production chain, although in different terms. For buildings made up of ex-situ built elements, the development of a jointing and connecting technique that guarantees fast and simple assembly is of primal importance, as it is its exact coordination in time. Following gravity, the in-situ assembly of a building is typically a story by story horizontal process. To make sure everything is in clockwork, the position of the individual building elements should ideally be included in the design process. Additionally, the position, size and weight of the building elements are decisive in selecting the hoisting equipment[339]. To simplify positioning and to avoid later adjustment on site, the building elements should have reference and fitting surfaces, and additional equipment such as assembly and fitting guides can be helpful.

Another major competitive issue in construction is the weight of labor hours. Moving labor from site to factory per se does not guarantee better overall output vectors. Construction requires labor hours, and these will occur whether in-situ or ex-situ. Nevertheless, it is clear that ex-situ work is more prone to labor replacement/assistance by machines, automation processes, and the like. However, to increase automation requires an investment that involves substantial risks, which the producer may not be ready to assume. Moreover, as complexity and/or volume of components increases, it fades the cost-benefit of the implementation of automation processes, or even from the transportability of the construction elements. For instance, in Japan, where there is a great implementation of automation in house producing factories, their implementation is nonetheless low when compared with the automotive industry. Additionally, logistical difficulties in transport and site deployment also indicate that there must be a pondered balance between the degrees of automation ex-situ, and components' complexity, which in business language is often described through the notion of batch-size[340]. Overall, this seems to point to potentially more gains in producing building elements that can feasibly be transported and require little finishing in-situ. However, some works are simply better done in-situ, namely water proofing or generally external finishing's, otherwise increasing the risk of appearance of future construction pathologies, and so forth.

In terms of production, broadly it seems reasonable to aspire replacing in-situ for ex-situ works, potentiating mechanization and/or releasing some types of logistic pressure. However, that may not suffice on its own. For instance, if variability is intended, tailor-made production cannot be entirely excluded. Partially manufactured products, or standardized manufactured products, require further processing in-situ, such as cutting, sawing or drilling, before they are ready to final assembly. To avoid it or reduce it, these ideally ought to be delivered in project-specific modes. Since stocking comes with a cost, the key is getting as close as possible to make *just-in-time* products. Thus, this will tend to pressure the delivering of project-specific elements and the accomplishing of a good logistical performance. Anyhow, there is no use to integrate efficient or economic construction practices if basic quality cannot be assured. Moving the construction process to a factory environment is not an end-in-itself. However, a conscious use of its potentialities can contribute towards a better overall behavior of the output vectors.

3.2 Mass-production and mass-customization

The well-known concept of mass-production (MP) marks an era in the modern age where machines indelibly settle in our lives, helping us to produce more with less human labor. In more recent times, it has been witnessed the arousal of the concept of mass-customization (MC). Industrial production processes, necessarily subjected to a business logic, traditionally have two main ways combinable to attain the desired profits: through economies of scale, producing large quantities at a relatively small price to maximize revenues; or through innovation, offering new products and thus creating new markets to obtain their revenues. With MC, is added a concomitant third way, which can essentially be described as attempting to address the client as directly as possible.

In a saturated market as it is the global market, competition is fierce, and an edge can only be achieved by setting difference from competitors. In that respect, it is worth observing the classical psychological theory of Abraham Maslow, which sets a hierarchy of human needs, often illustrated in a pyramidal form[341] (Figure 4).

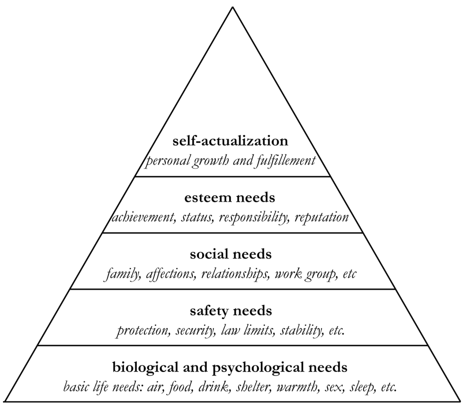


Figure 4. Maslow's hierarchy of human needs.

Early Henry Ford's assembly line followed a linear logic that was not limited to the production philosophy per se, but was subjected to a broader reflex of an understanding of the market as a linear system, exploiting the similarities between customers. However, people have different wishes and needs. Thus, at least theoretically, it makes sense to address the differences between people, instead of their similarities. Maslow's is a humanistic logic of stimuli and reinforcements, or of unconscious instinctual impulses, whereas the production logic is one of mechanical forces. In a way, the *market* is where both these spheres meet. Hence, following an analogous hierarchical logic, from a marketing and advertising perspective it is on the upper levels of the pyramid that it is more worth to target the consumer, because it is there that most differentiation will theoretically be obtained. To attain it, the logic of competitors can no longer single-handedly be that of MP's *product push*, where goods are produced in scale no matter what the end client is. Instead, a *market pull* strategy should be aspired, that is, ideally targeting consumers individually, from their seemingly needs and aspirations, which in practice will often work more in mixed *push/pull* way[342].

With the arousal of the informational age, the *pull* logic became possible to address on a larger scale, since handling control of complex networked systems became somewhat an easier task. With it, it has aroused the concept of MC, coined by B. J. Pine II, in 1993[343] [complement with: **Annex, II.4 Mass-customization notes**]. The MC, although settling on the same purposes of large production scales, is embedded of different purposes. Both MP and MC concepts are originally derived from the business language, aiming towards reducing production costs through the enactment of large production scales, yet the latter additionally seeks to answer the need that the industry has in delivering a diversified offer, targeting consumers in the most possibly direct fashion, enacting a seeming variety of outputs. Likewise, in the construction industry, the concept can be related with the purpose of delivering a range of formal or spatial outputs while ideally maintaining the same level of costs of large-scale production methods. However, business practice has shown that the implementation of a MC concept must be cautiously addressed and might not always be the best way forward.

A key issue among companies operating in saturated markets is whether their yields can be kept when supplying customized products. As in any basic business strategy, there is an immanent issue of costs and revenues. Although with different logics and logistics, both MP and MC can have an important weight in this equation. Apparently, in a traditional scaled production, logistic costs will be more dissipated than in a customized production. That inevitably pressures the efficiency of the production chain. On the other hand, the logic of the client can be hard to predict. The client is tuned with the product via a process where choices must be made. It is a process of psychological nature, where desires or aspirations can arise from authentic need, but also be (un)consciously inculcated, where marketing may have a decisive role, or where may arise related issues of fashion, consumerism, and the like.

When choice is engaged, and thus the production sphere meets the client sphere, from a production management perspective, we can translate it in terms of the *order penetration point* (OPP)[344]. As illustrated in Table 4, the OPP refers to the point in the production chain where the customer is engaged in his choice process, or equivalently, where customers' orders are accepted by the manufacturer, and can broadly be set in four different categories, *make-to-stock*[345] (broadly equivalent to MP), *assemble-to-order*[346], *make-to-order*[347], or *engineer-to-order*[348] (the highest MC rank), to which correspond different logistical frames and different customization potentials.

>>production scale >>

Postponement Strategy	Stage of Manufacture			
	Design	Fabrication	Final Assembly	Shipment
Make-to-stock	>> OPP >>>>>>>>>>>>>			
Assemble-to-Order	>>>>>>>>>>>>>>>>>>>>>>>>>> OPP >>>>>>>>>>>>>>>>>>>>>>>>>>>			
Make-to-Order	>>>>>>>>>>>>> OPP >>>			
Engineer-to-Order	OPP>>>			

Table 4. OPP postponement strategies.

Another essential issue facing companies is whether overall productive performance, including economy and quality criteria, can be maintained when the products are customized. Again, logistics plays a major role in costs, which in large-scale industries delivering customized products can be so high, that at first hand traditional products will always be more competitive. Thus, it is natural that businesses seek different approaches to reverse the hazardous trends of logistic complexity. Anyhow, inefficiencies are not exclusive of logistic practices, nor of companies that offer product customization. On the other hand, while a concern on the economies is paramount, competitiveness cannot be attained without a strong focus on quality, and certainly not disregarding the relationship with the client.

In management terms, it seems that the way to go from MP to MC must start by transversally eliminating inefficiencies and waste in the entire process from factory to delivery. Indeed, any MC strategy is necessarily ought to be settled on *lean thinking* (LT) approaches[349], a business jargon for strategies that aim at an optimization of the production and delivery processes, crossing the entire production chain to produce better and more with less. Built on the *Toyota Production System* (TPS) basis, LT[350] is a business methodology that fundamentally seeks to ways to mitigate *muda*[351], a Japanese word that roughly means *waste* and can refer to any human related process that absorbs resources without creating value. Thus, in a LT approach, every *muda* that uses resources for any objective other than the creation of value to the end-customer is targeted for elimination. LT thus settles on the continuous processes of improvement and is centered in the preservation of value with less work, by means of more efficient and optimized processes, waste reduction, empirical methods for decision making other than uncritical acceptance of pre-established ideas. This way, using LT processes, businesses can be set to provide ways to do more with less and less, with the aim of providing the clients what they want.

From an architectural point of view, the Miesian aesthetical statement of "*less is more*" can here be regarded under an economical flagship, transformed into *more with less*. The difference is far from subtle. Indeed, it can raise fundamental questions on production and on architectural design, as the natural, sustainable ways, of making *in the exact right measure* (of aspirations, needs, resources, and so forth) becomes a clearer understatement. We should not forget these concepts derive from a business language, and for that matter, *more with less* means more with less human effort, less equipment, less time, less space, or even less quality. To our belief, these aspects should not only be regarded only quantitatively, but also qualitatively. Moreover, we must not forget that in architecture there is a wider range of concerns involved, located beyond a typical business perspective.

The critical starting point for LT is value, which can only be defined by the client, and which is only meaningful when expressed in terms of a specific product which meets the client's needs at a certain price and time. The value is made by the producer, and from the client's perspective, in brief, *this is why producers exist.* However, often the investor pressure and the financial mind-set of the management and administration precede the basic realities of specifying and creating value for the client. Thus, there is the issue of the vectors of value, and of who specifies this and that for what, and so forth.

As in a LT philosophy, in MC continuous improvement is a requirement. However, unlike LT, in MC are also required quite different organizational structures, different values, management and systems roles, learning methods and especially ways of relating with the client. The product and its development are not commanding, but instead the client's desires and demands. Therefore, is not just about being better and working better as a team with a common purpose. From a developer's perspective, it is also about accepting the unpredictable nature of the client, considering him as an opportunity, not an obstacle. Thus, it is about getting the best possible method to relate every participant within the context and the circumstances of each case. In architecture, this should not be news, as most of the times the architect answers directly to the client's demands. However, given the nature of the architectural production, this is normally made case by case, without a methodology of the kind required by a large productive structure.

The additional requirements of MC in relation to LT have been illustrated in several circumstances, namely in the *Toyota* case. Indeed, despite the TPS success, and as any other competitive company on the path innovation and success, at a certain point, *Toyota* aspired for more, and thus attempted to follow a MC path. The company's vast experience, and the valuable, and acclaimed background, were indicators that the approach had everything to succeed. However, results would prove disappointing, and the obvious consequence was to remake the adopted MC philosophy[352]. In the least, this can be viewed as a warning sign on the difficulties to introduce MC in any business.

3.3 Notes towards variability in prefabrication of houses

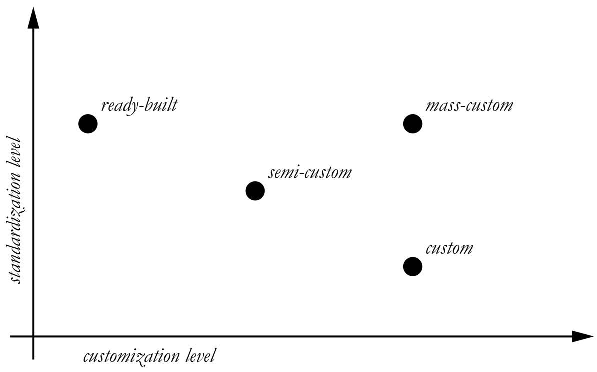


Figure 5. Customization vs standardization.

If we consider a simplified scheme as shown in Figure 5, moving from the less customized to the most customized product, and differentiating three stages of this movement onto the categories *production*, *semi-custom* and *custom*, then we would find these in the intersection of an inverse movement from more industrialized, to less industrialized approaches. Translating it to a typical house production approach, this means that as the industrialization level decreases in each of these, the customization level, design flexibility and, consequently the cost and overall construction time increase. In a MC implementation, we would ideally be able to invert this logic, thus increasing industrialization level while increasing the customization level.

We could also scale MC in terms of OPP, which in a traditional client-architect relation will be at its lowest level, with the least postponement occurring, and where everything is possible within the constraints (budget, location, and so forth). It follows an equivalent of an *engineer-to-order* fashion, where production concerns only arise afterward, typically with a contractor hired to follow the design specifications. Conversely, in a purely speculative design, the postponement reaches its highest degree, in a *make-to-stock* relation typical of MP.

Finally, we can also observe an MC process through the relations established by the main active forces participating in the construction, considering the client, the designer and producer. Depending on the sophistication, there would be other possible subdivisions, with intervenient acting in more specific roles, e.g. in the *designer* sphere, architects or engineers can be included, or in the *producer* sphere, we can name the developer, (sub)contractor, and perhaps it could also be included the marketing sphere, and so forth. From the point of view of architectural production, the client-architect relationship likely corresponds to the least design constraints and more production variables, whereas the client-producer possibly to the most design constraints coming both from design and production demands, and finally the architect-producer to a stronger focus in production optimization. When we

Actors	Client Producer Designer	
Constraints	General	Political Regulatory/Legal Bureaucratic Economical/Financial Socio-cultural Environmental
	Project	Urban Architectural Structural Thermal Services and their weight (Electrical, Plumbing, HVAC, etc.) Acoustic Sustainability
	Construction	Technological environment Availability and quality of builders Availability of materials, components or equipment, etc. Labor cost / Productivity
Project	Type Size Flexibility Adaptability Complexity Discreteness Integration of different design expertise Integration of design and construction Construction methods Degree of innovative technology involvement Aesthetics	

Table 5. A selection of factors with potential greater impact in the architectural production.

start mixing the actors, in a threefold client-designer-producer relationship, we get into a sort of grey area, where MC strategies may act and less *traditional* design modes of action take place.

Regardless the approach, several circumstances can arise from the timespan going from the client decision to build a house to the point where it is concluded, making it harder to establish a predictable outcome, for instance from the budget point of view. Among the changing factors, it can be included imponderables, such as natural hazards or political/regulatory changes, but not least important, the client may simply change opinion. The latter risk is perhaps the most difficult, if not virtually impossible to assess[353] (Table 5).

The purpose of variability in a more or less systematized, more or less prefabricated building conception is naturally related with a need to meet the clients' desires while maintaining a certain effectiveness of the building production methods. It is unlikely that clients ask for everything to change during construction. However, in a fiercely competitive market, where a prospective buyer has multiple options to choose from, the developer must be ready to implement changes when requested, and in this sense, a discrete approach to design and construction is mandatory.

Production in the building industry follows both ex-situ and in-situ practices. In a normal scenario in other industries, site works would correspond to the final assembly stage in an OPP chart. However, even in highly industrialized construction, final assembly in building construction typically has a great overall weight, with very particular dynamics, and with a site-related unpredictability that is necessarily greater than in a factory final assembly mode. Furthermore, clients often change decisions during the site construction. Thus, ultimately, it could even make sense to distinguish two related OPPs in the building construction process, one before and another during the site works.

At first hand, one may think that if the OPP would be exclusively conducted in factory, then the only change for the client to participate in the choice process would be in the design stage. However, many of the construction industry components have a remarkable degree of project independence, assuring greater freedom. In some, not only with the looks, but also with the very dimensions can be easily adaptable to a sudden change in requirements through relatively inexpensive processes of cutting, drilling, and so forth. Among the project independent components that in principle may allow a broader range of freedom, in different finishing and/or with adjustable sizes, we can find e.g. the windows (e.g. frames, glasses), kitchen equipment (e.g. furniture, appliances), door components (e.g. door, handles, hinges), sanitary equipment (e.g. in ceramic or plastic, taps), or electrical terminals (e.g. switches, sockets, sensors).

Anyhow, some systems will inevitably have a deeper constraining impact than others. We can even easily change the sanitary equipment, but normally it will be a lot harder to change the piping where the sanitary equipment connects, not to mention the primary structure or the foundations. To enable the shifting of options in-situ requires investment in discrete elements, and that depends on several factors, such as the cost, the state of technology, the willingness of developers to take risks, the strategy adopted by the different participants in the building process, the project size, or more or less clear aesthetical intentions/expectations. Moreover, the nature of the construction industry potentially allows the consumer a greater range of options than in ordinary industrially made products. Finally, the variability intents must take in consideration the client's options that are to be allowed to be produced ex-situ or in-situ.

To increase variability, certain OPP postponement strategies can be implemented, not necessarily requiring greatly sophisticated processes or techniques. Acting on a grander volumetric level, pressure is set on the design to meet eventual layout changes without burdening the production of construction parts. The morphological variability that acts on a larger volumetric level can be obtained with relative ease by hardwiring similarity principles in the design, which will act primarily at a typological level, but that necessarily will have implications in more detailed construction levels. For instance, by repeating a standardized product using straightforward geometric operations—e.g. rotating or translating—a considerable spatial variability can be attained with relative reduction of production impacts—by retaining an object's symmetry, production gains scale, while outputs can attain variability. Furthermore, the use of such operators eases the CAD generation of variants, with gains in design productivity, to which may be added the use of systematized detailing or even the handling of design libraries and the like. By hardwiring morphological variability through simple geometric operators, designers can act on a grander-scale postponement, enabling customers' decisions to a later-stage, while also theoretically enabling to comply with local regulations beforehand.

In lower levels of constructive action, both in new buildings and refurbishment market, variability range of outputs can also be increased without considerable extra efforts, by considering vectors of action such as the standardization of connections, while allowing dimensional flexibility, and the definition of the scope in which a layout can vary. In certain cases, stock products can themselves provide variability, serving postponement intents. For instance, in a façade, a catalogue of components with different dimensions can suffice to attain a reasonable number of variables by exclusively making use of standardized components, and thus can work on its own as an effective strategy. If to do this, we add flexible automated production (e.g. through CNC or 3D printing) or flexible dimension products (e.g. cutting window frame to desired size), we can drastically increase the overall variability without significant extra burden, while keeping the production postponement in later stages. If the plausibly more sophisticated (and likely more expensive) flexible automated production is not possible to implement, then variability intents can, in the least, be attained through a balanced mix of standard and custom-made components through the other previously referred strategies that essentially rely on principles of similarity.

Piping and wiring systems have increasingly become the major constraints of the design options. For aesthetical, technical or even legal reasons, the flexible solutions employed in the industrial or commercial buildings are typically less feasible and/or too expensive to implement in ordinary house construction. In industrial or commercial buildings, flexible solutions can typically be attained by the greater ceiling heights, which are normally both a legal requisite and an effective need. Moreover, depending on the requirements and/or design philosophy, these can go from fully visible—typically of easier maintenance—to concealed installations through suspended ceilings or raised floors. In house construction, these strategies are simply harder to attain.

It can also be added to this discussion the issue of the energy efficiency in buildings, particularly the unavoidable fact of the consequences that poor or non-existent passive design strategies can bring to the installations, increasing their spatial weight, further constraining the design options. Indeed, the growing energy efficiency requirements in buildings increases pressure in this particular, and it may not be easy to take properly informed design decisions. For instance, it is generally accepted that considerable energy savings can be achieved through airtight construction, using materials with good insulation characteristics. However, this can too have its inconveniences, which can be particularly more noticeable in low-thermal mass constructions, requiring temperature and ventilation control equipment. If applied in house construction, such equipment can too reach a remarkable complexity, comparable to what occurs in other building types (e.g. commercial or industrial). Although there are already quite remarkable advances in electronic and digital integration through domotic devices, with sophisticated protocols and the like, the fact is that the user is not always willing/financially capable to adopt them. These not only can have considerable associated costs that simply may not present visible yields, but also the user can be suspicious of more complex paraphernalia. A typical conscious user may likely want things to be kept ease, and the more complex piping or wiring becomes, the likely the customer will be suspicious that it will be harder to maintain or repair in the long run.

4 MODULARITY

4.1 A modularity context

Modules and modularity terminology has been profusely established[354], namely among production and manufacturing management[355] or mechanical engineering[356] circles, but we can also find some of its founding concepts developed in architectural literature[357]. Its generalization can be assigned to discrete mathematics[358], which deals with discontinuous objects, often characterized by integers (e.g. logic, set theory, combinatorics, probability, graph theory, Boolean algebra), in opposition to continuous processes, with objects that vary 'smoothly', dealing with real or complex numbers (e.g. calculus, analysis, linear algebra).

In its applied dimension in construction processes, modularity is often taken as key towards efficient, industrially-driven construction practices. In a broad sense, it reflects an aim to use resources efficiently when several tasks pend for a solution, or a series of products are to be produced. It can be regarded as a structuring principle in service of an enhanced clarity, complexity reduction, flexibility enablement, or by facilitating the implementation of parallel work and independent problem-solving. In a customization context, modularization thus comes as a requisite towards attaining variability while rationalizing production. In the design of complex products, it is a key concept, namely in mapping functional and physical components of a product, as well as its interactions and dependencies[359]. It can be applied in the areas of product design, in production management, or as a conceptual resource towards design.

Depending on the scope, a module can be referred to as many different things. In architecture, it has traditionally been associated with spatial coordination aspects, such as in so-called *modular coordination* or *modular grids*. In building construction, a *module* is also often referred to as *component*. In this field, the *component* terminology can be relevant insofar as it avoids eventual connotations with so-called *modular* construction, which has been typically associated with construction using larger volumetric units, often with the size of an entire room. In a broader sense of construction, from building cars or ships to mechatronics, and so forth, the word component is also commonly used.

For many of our arguments here, particularly those dealing with a physical notion of modules and modularity, we can regard *component* as a distinct region of a product, i.e., a discrete physical part or sub-assembly. In this sense, the use of a *component* terminology may help to disambiguate the notion of module, and we can use instead a *component modularity* terminology, where moreover it is implied that there can be different degrees of modularity. In non-physical notions, such as in software, modules are typically used from an unambiguously discrete perspective, thus the notion of module may probably be what best fits in those cases.

4.2 Defining modules and modularity

4.2.1 A SYSTEM'S PERSPECTIVE

Architecture's scope and architectural production modes are typically distinct in many ways from product manufacturing, which can raise difficulties when using concepts from this literature. Anyhow, some of the analogies occur in aspects such as those we have addressed in the taxonomical landscapes chapter, through notions such as *system*, *type* or by acknowledging *discrete* vs *kin* perspectives. Also from there, we have that notions comparable to *modularity*, such as *system* or *type*, are intrinsically relative. That is, they depend on the scope or scale of observation.

Furthermore, as we have earlier described, we can characterize a *system* by S={t, a, r, e}, with 'S' standing for *system*; 't' for *things*, 'a' for *attributes*; 'r' for *relations*; and 'e' for *environment*. This is also what essentially occurs in modularity, with exception for a few shifts in the terminology, where *things* are equivalent to *modules* (or *components*), *attributes* to *functional elements*, and *relations* portrayed in the notion of *interface*. Also from a systems perspective, we can regard modularity as a continuum describing the degree to which we can separate and rejoin the components of a system.

For clarity purposes (see Figure 6), here we can convention the scope as a *product*, which is set under a *production-chain*, and is the outcome of a *work* process within a given scope. In a different scope, a *product* can be regarded as a *module* of a different *product*, and so forth. Two or more *modules* combined form a *product*, which can be an outcome on its own or be a part of a *product set* (i.e. the *system*, which can be a *product/design system*). Finally, if we theoretically removed the scope pre-condition, we could say that a *module* or a *product* are conceptually equivalent, and thus tautological. In practice, the scope must always be there as a pre-condition, or primary constraint of the scrutiny.

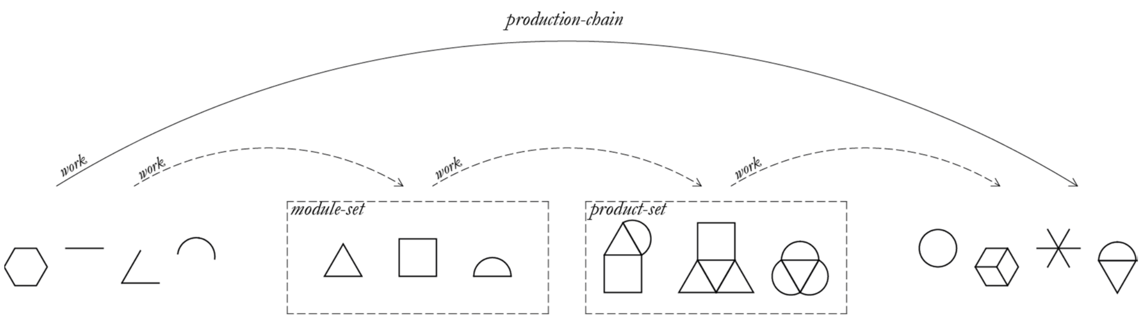


Figure 6. Modularity.

4.2.2 TYPES OF MODULARITY

Modularity has been typified in five different approaches:

(a) *Sectional*—when different components of a modular architecture can connect in any arbitrary way, as long as if connected to one another through standard interfaces. A classic example are the *Lego* blocks. In building construction, that can be the case with standardized office partitions, ranging from open-spaces to different configurations of partitioned spaces.

(b) *Component Swapping/Sharing*—the *component swapping* is when different product variants, within the same product-set, are created by combining a basic module with alternative components. A classic example can be an assortment of different cases (colored, textured, and so forth) that fit in a specific mobile-phone. In building construction, an example can be two houses distinguished only by their external coating. On the other hand, *component sharing* is when different product variants are created by sharing a basic component with different modules. It is thus complementary to component swapping, the difference standing in how a basic product, component or module are defined in a specific situation. A classic example can be automotive wheels, batteries or engines. In building construction, an example can be a standardized door used in different houses.

(c) *Cut-to-Fit*—when one or more standard components are used with a variety of additional components. A classic example can be when two standard connectors can be used in different cable lengths. In building construction, an example can be hinges and handles combined in cut-to-fit windows.

(d) *Bus*—it is when a module can be matched with a range of basic components, allowing their location and number to vary. A classic example is the computer hardware architecture, where motherboard slots allow the attachment of a range of different interface compatible components. In building construction, one example can be lowering the ceiling or elevating the floor, thus creating a *bus* where

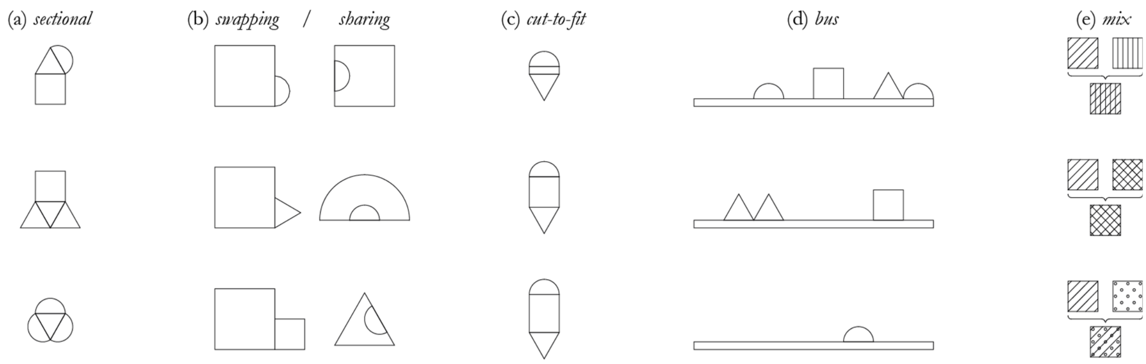


Figure 7. Types of modular architecture.

different infrastructures can be implemented and thus also easing the change/addition of different terminals (lights, HVAC equipment, sensors, and so forth).

(e) *Mix*—when a product results from different components that cannot be returned to their original state after being assembled together, that is, it occurs when there is a mix of substances. A typical example is color mixing. In non-dry building construction methods, it has a very common occurrence. It is in the extreme of what can be considered modularity, once assembled it is permanently coupled.

4.2.3 FUNCTIONAL MAPPING

As shown in Figure 8, modules can broadly be described by two main characteristics: a *self-contained functionality* and an *interface*. The *self-contained functionality* is what is in the component, what is it supposed to do within the considered scope. The *interface* is what enables interaction, or relational engagement between different modules. Both the *self-contained functionality* and *interface* require a certain degree of correspondence between a physical and a functional realm, as well as an establishment of interactions between modules. That is, a mapping must occur between these two spheres.

Figure 8. Module.

If we define a function as what describes what a product does[360], unlike what are its physical features, we can regard it in terms of *functional elements* and of a map (or set) of these in a *function element* of a higher degree (see Figure 9). For instance, at a most general level of abstraction the *function set* for a house might be a single *functional element*—e.g. provide a place to live. In more detail, the *function set* may be specified as consisting of a broader set of *functional elements*, such as: protect from the weather elements, provide thermal, air, light or visual comfort, but also establish an urban relation, and so forth. Each of these outcomes (the *functional elements*) in a scale, can be the starting point of a new *function set*. As we increase detail, the *function set* symbolizes more assumptions about the physical working principles on which the product is based. Because of it, two products that at a higher set level do the same, may have different *function elements* when detailed.

In the final step, we need to map the *functional elements* to the *physical components* of the product. Following a similar logic, we can observe a discrete physical product as a set of at least one *physical component*. The set of *physical components* is what implements the *functional elements* to the product. In other words, the set of *physical components*, corresponds to the last *functional set* stage within the considered

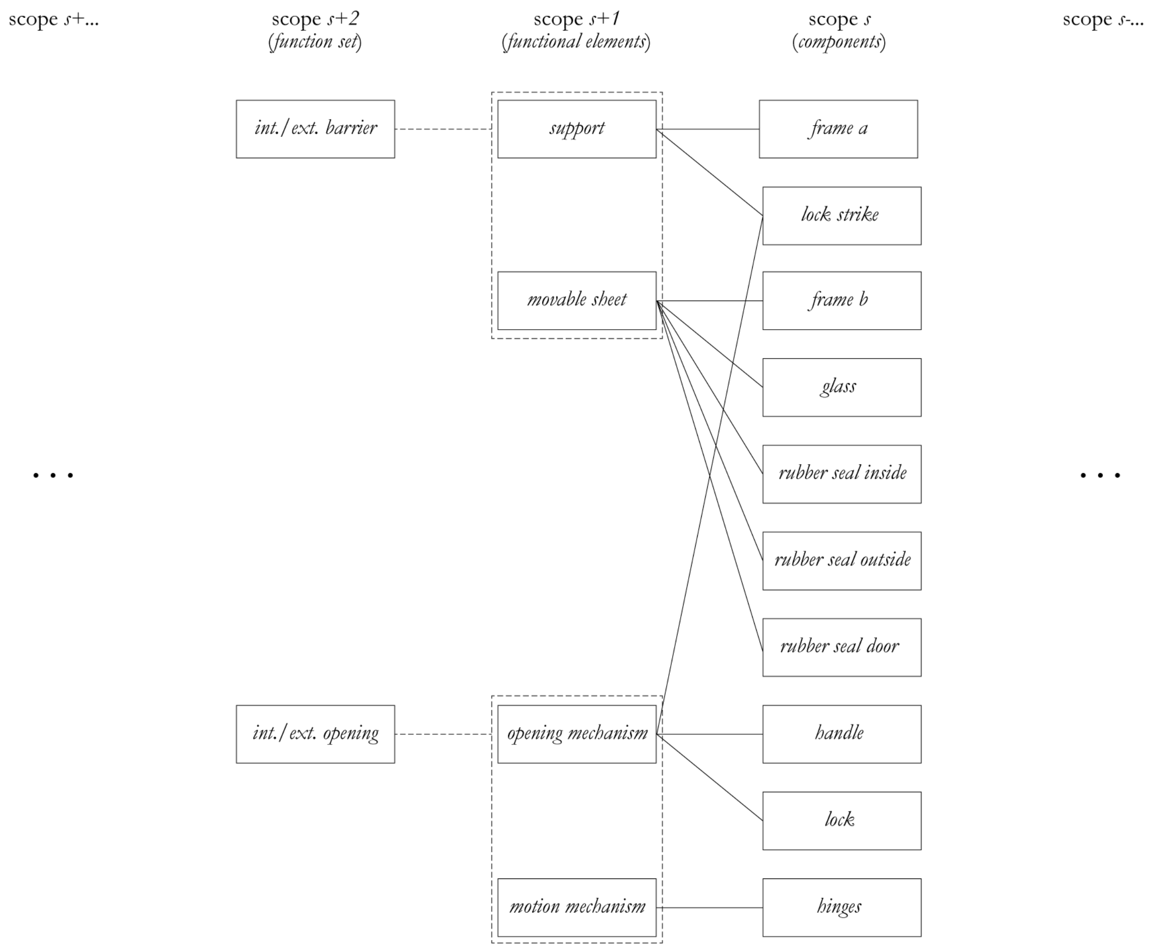


Figure 9. Example of a functional mapping of a window, from function set to a component mapping.

scope (see Figure 9). Throughout the process, we can map sets in a *one-to-one*, *one-to-many* or *many-to-one* fashion. A *one-to-one* means a direct correspondence, thus meaning a strict component modularity within the considered scope (e.g. *motion mechanism* on Figure 9). Conversely, a *one-to-many* or *many-to-one* (we can also name both together as *non-one-to-one*) indicates a certain dependency, making components non-strictly modular within the considered scope (e.g. *locking mechanism* on Figure 9). A *function set* can thus also be viewed as a *non-one-to-one* mapping process.

4.2.4 INTERFACES

In a physical module is not enough to consider geometrical, mechanical or material characteristics alone, as it typically occurs, particularly with the first two, in the field of modular coordination[361], or as observed in several traditions in the architectural field, as the Japanese *tatami*, based on the *ken* measure[362]. Indeed, generically the relations between modules can be described in terms of space (e.g. geometry, positioning), forces (e.g. mechanical, structural), material, energy (e.g. electrical current, heat) and/or information (e.g. radio waves), often with several of these simultaneously. An *interface* can thus be

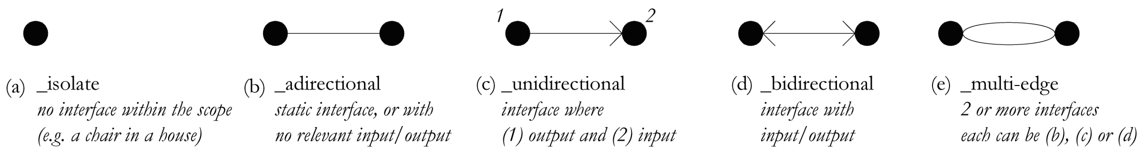


Figure 10. Interfaces in a graph representation.

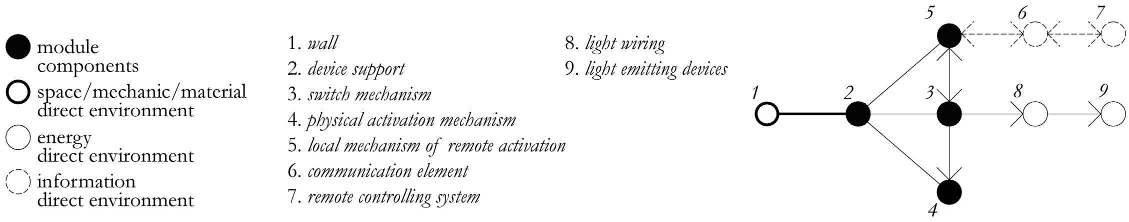


Figure 11. Example of a light switch modularity.

viewed as a set of at least one physical part that is integral to the module, where each physical part in the set establishes at least one of these relations. Moreover, depending on the characteristics, an *interface* can be described in terms of *input* and *output*, and these can have different degrees of activity.

For instance, a light switch establishes a spatial/mechanical relation with its physical support on the wall, but also an energy relation with the wires that connect with it, and eventually also an information relation if too connected to a home automation system. The *input* or *output* activities in relation to the spatial/mechanical support is of rare or irrelevant occurrence, hence of static *interface*. On the other hand, it is designed for switching on/off, which are relations of an *input/output* type. Indeed, within the scope of an analysis, the module's *interface* can be several physical and functional things simultaneously. In this sense, complex products can typically be regarded as a network of components that shares *interfaces* in order to function as a whole[363], which makes the handling of interfaces a key issue in the establishing of a modular architecture or in managing modularity.

As we have stated, *interfaces* may involve different kinds of connections. For instance, a wireless router does not establish a mechanical connection with a computer. Anyhow, it is essential to assure compatibility in the *interfaces* of the set of components that are to be related with one another. That can be achieved by establishing standard protocols, which may be developed with Universal intents, as in the ISO (*International Organization for Standardization*) standards cases, or for instance developed internally within a company product-line, although in that case it may not necessarily follow an external standard.

At first hand, many building construction components seem to have little or no relevant considerations to be made in regard to *input* or *output*, as they stand still in space, mechanically attached to one another, with *adirectional* (or *static*) relations. Anyway, external *inputs* such air for ventilation, or as solar light and heat can have a profound influence in design considerations. For instance, in deciding glass areas, or the use of architectural passive shading elements. At a services level, this becomes more evident, for instance in respect to the placement of air input for sanitary ventilation, or the *inputs/outputs* of a water heating cycle in a home, and so forth. In any case, regardless *input/output* features, even for bulkier parts of the construction, establishing clear *interfaces* is key to proactively solar light and heat can have a profound influence in design considerations. For instance, in deciding safeguard modularity implementation where intended.

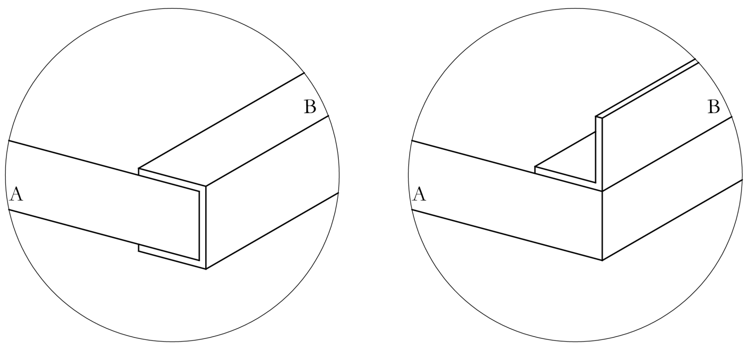
4.2.5 COUPLING AND DECOUPLING

A module (e.g. a door handle) can be described as a relative property of a product (e.g. a window), and this conversely as a module of another product (e.g. a house). In this sense, a module is opposed to an integral structure, meaning that in it, only a fraction of the entire functions of a product will be implemented. On the other hand, in the product, the functionality is integral regarding the product's scope as so-considered.

When a product results from a modular architecture, it is equivalent to say that it occurs a *one-to-one* mapping from *functional elements* in the *function set* to the physical elements of the product, and thus that *decoupled* interfaces are established between components—i.e. a *discrete* approach. Conversely, in an integral product architecture it is included a complex, *non one-to-one* mapping, where *coupled* interfaces are established—i.e. a *kin* (or continuous) approach. Finally, again, whether the mapping is more *kin* or more *discrete*, that is, whether *functional elements* map in one or more channels, ultimately depends on the scope of the approach.

Ultimately, considering the universe of manufactured parts, any component can be mapped to a *one-to-one* precision considering components stripped down to each individual part—call it *i* part. Broadly, of the *i* parts establishes a *one-to-one* mapping between these components and their *functional set*, then the product displays the *one-to-one* characteristic of modularity[364].

Two components are *coupled* if a change in one requires the other to change in order not to affect the product functionality. The mapping possibilities for this scenario are *non-one-to-one*. In a decoupled



(a) *coupled* (b) *decoupled*

Figure 12. Unlike in a decoupled interface (b), in a coupled interface (a) a change in A implies a change in B and vice-versa.

scenario, the mapping will be *one-to-one*. However, since components have an interface, theoretically they would always have to be *coupled* to a certain degree, since a change in one interface will imply a change in the other interface, thus in the components from where the interfaces emanate from in the first place. In practice, this may only become relevant as the interface gains complexity. As this complexity increases, the *coupling* vs *decoupling* distinction becomes useless, since there will always be some degree of dependency between the elements. Indeed, we can simply regard the *decoupling* as the special case of *coupling* where we can attain a strict modularity, as so considered from a given scope.

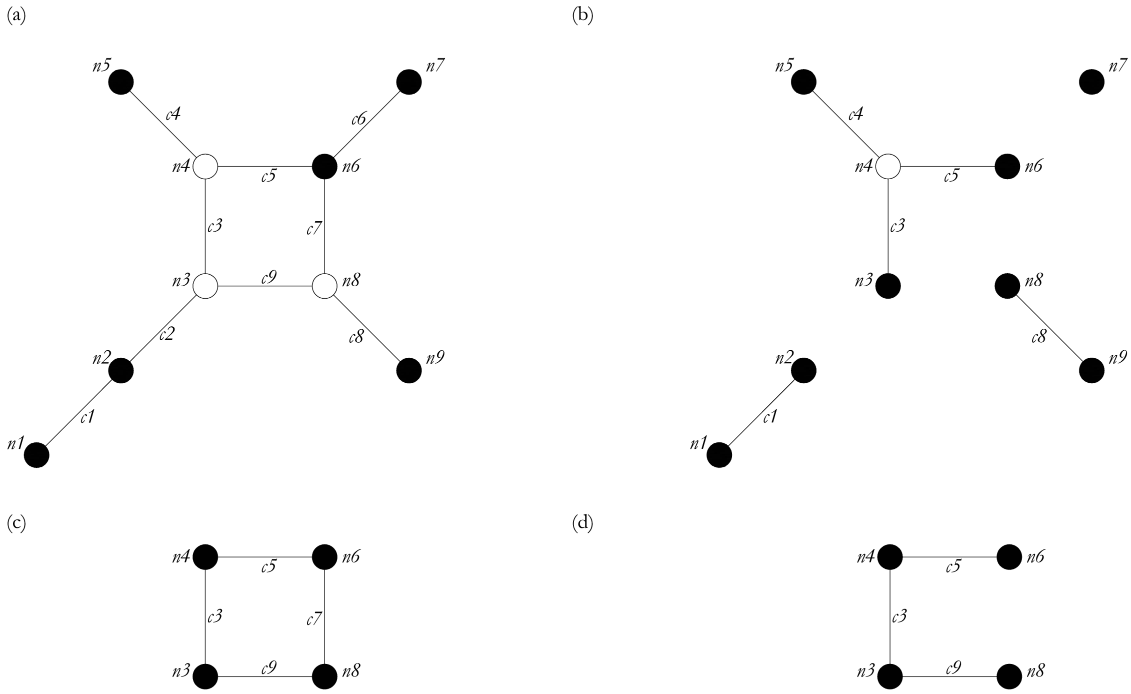
4.2.6 MEASURES OF MODULARITY

The modular architecture can be defined on how the combinations of different modules are set for a certain purpose in a modularity development context. In literature, the notion arguably starts with Alexander[365], in a description of the design process that involves the discretization of designs into minimally coupled groups. Meanwhile, the concept has been further developed to a perspective where complex systems can be viewed as hierarchical structures made up of quasi decomposable systems, such that strong interfaces occur within systems and weak interfaces occur across systems[366]. The latter seems to be consistent with the notions of mapping functional and physical structures, as with the underlying rationale in measuring modularity.

In general, products are hardly strictly modular or integral. Instead, it is more correct to say that they display more or less modularity than comparative ones. Likewise, some construction components are more clearly acknowledgeable as modules than others. It thus also matters to observe how modularity can be measured, capturing modular architecture in terms of components dependencies. The *decoupling* of components offers a preliminary insight, in which the more *decoupled* the component of a product or system, the more modular will be the product or system. This integrates the *one-to-one* or *non-one-to-one* mapping concepts. However, when developing complex products, this relatively simple and useful notions may fail short.

Literature in this particular has borrowed concepts from other fields, namely from *social networks theory* and *graph theory*. From it, it is essentially retained the concept of centrality, which aims to identify the most important actors in a social network based on their social interactions. Eventually the concept has converged in three types of centrality: *degree*, *closeness* and *betweeness*[367]. The graph theory has contributed towards a synthesis of the network aspects, providing a common ground to represent network attributes and mathematical structures with which these can be measured (Figure 13)[368].

Extending the graph rationale to a product decomposition, the component modularity can be defined as the level of independence of a component in relation to other components in a product. That is, we can assume that the more connected to other components, the more dependent, thus integral it is (Figure 14b). Conversely, the more disconnected a component is, the more modular it is



(1) degree
in (a), nodes degree are as follows:

node	*n1*	*n2*	*n3*	*n4*	*n5*	*n6*	*n7*	*n8*	*n9*
degree	*1*	*2*	*3*	*3*	*1*	*3*	*1*	*3*	*1*

(2) path lenght
in (a) consider e.g. going from n1 to n8 via the path:
n1, c1, n2, c2, n3, c3, n4, c5, n6, c7, n8
path lenght is: 5
(same as number of connections in the path)

(3) distance (or geodesic)
in (a) consider following a minimum path between
the same beginning and end nodes as previous (n1, n8):
n1, c1, n2, c2, n3, c9, n8
distance is: 3 (minimum path lenght between the two nodes)

(4) edge
in (a) edges are:
n1, n5, n7, n9

(5) bridge
in (a) bridges are: n2, n3, n4, n6, n8

(6) center
in (a) center is: set of nodes noted in white ◯
(n3, n4, n8)

(7) sub-graph
(b), (c) and (d) graphs are some sub-graphs of (a)

(8) star graph
e.g. of a star graph is:
n4 | *c3, n3*
c5, n6
c4, n5

(9) isolate
e.g. of an isolate is n7

(10) cycle
a cycle is e.g. graph (3):
n3, c3, n4, c5, n6, c7, n8, c9

(11) path graph
a path graph is e.g. graph (d):
n8, c9, n3, c3, n4, c5, n6

Figure 13. Graph fundamentals.

(Figure 14c). This is fundamentally consistent with the notion of functional mapping. We can further generalize it through a *star graph* (e.g. Figure 14b), where we can assume that the more connected and/or central the components are, (1) the more *direct connectivity* to all others, (2) the *closest* to all others, and (3) the more *in between* to any two others it will be. This generalization has been useful because components are not only directly connected to others, but their dependencies may propagate (via *unidirectional* or *bidirectional* bonds) to other distant components via intermediary components, or they can serve as intermediaries connecting others.

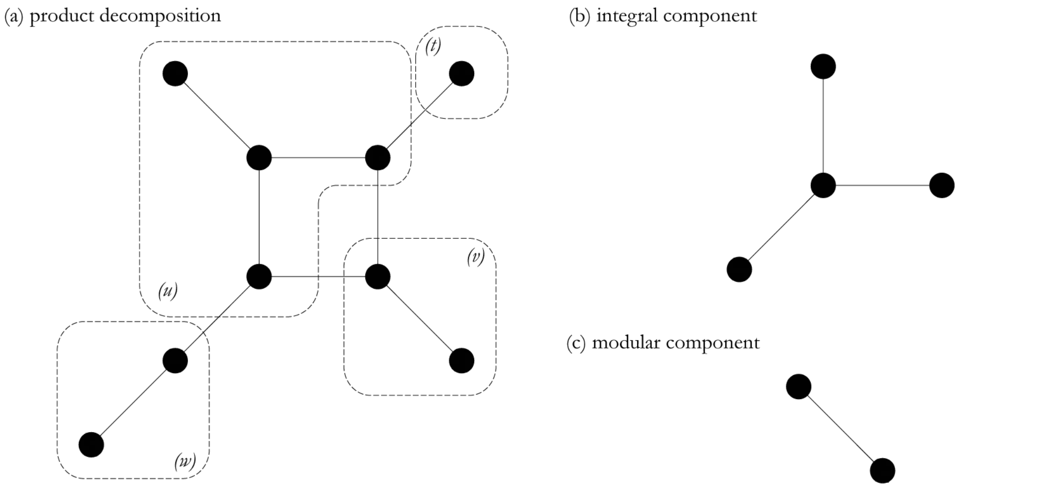


Figure 14. Graph representation of a hypothetical product decomposition and isolated observation of two of its sub-components.

Building up on these concepts, literature has defined component modularity threefold, in terms of: *design dependencies*, *degree modularity* and *bridge modularity*[369]. The *design dependencies* have been defined in terms of types (spatial, structural, material, energy, and information), and in terms of strength, that is, the direct bonds intermediating a component *i* and a component *j*, on which *i* depends on for functionality. The correlated *degree modularity* of a component is established by its dependencies, considering both direction and strength. The *degree modularity* in a component *i*, will be a normalized measure, based on the inverse of the sum of the number of other components that *i* depends on for functionality (*in-degree*), with the number of other components that depend on the *i* component for functioning (*out-degree*). The minimum value will occur when a component has strong dependencies with all other components in the product. The maximum when it is not connected with any other.

The *distance modularity* has been defined in relation to the distance a component *i* is from all other components in the product, where the more distant a component is from the others, the more its design dependencies must propagate, and thus the more modular the component is. Formally, it is proportional to the sum of the geodesics of the component with all the other components. Thus, in its simplest form depends on the direction but not the strength of the dependencies. A high value means that the component is far from the others, thus more modular.

As to the *bridge modularity*, it has been defined in terms of the integral degree of a component in relation to the connections it establishes with other integral components. The greater the number of links to other integral components, the likely more integral the component is, thus less modular, and vice-versa. Therefore, even if a component has few links to other components, if the others have a very low modularity, the component modularity is also expected to be low.

These are complementary approaches, which require different insights, and can help analyze different issues. Nonetheless, both share an underlying argument that components are more modular, the more independent they are from other components and vice-versa.

4.2.7 AN EXAMPLE

As we have seen, when analyzing component modularity, we have to observe not only the types of bonds (spatial, structural, material, energy, information) but also their relative strengths. Analytically, we can start by addressing the product-scope needs as potential constraints on all product components, thus assuring these are found in the functional mapping definitions. In design terms, we can not only depart from previously known constraints, but also embed eventual new product-scope needs within a virtual mapping, thus establishing different constraints towards design and development of the product.

The first step in a modular analysis is to attain a functional description of the elements within the scope. In our main example, a product *window* (Figure 15), we can begin by describing what are its main functions, from where we could conclude: (1) separating interior from exterior, while letting light through, and (2) may open/close. This means that, to some degree, it must somewhat be a water/air/thermal/acoustic barrier, while facilitating light exchange. Moreover, it means it should imply a motion and a motion locking device.

The first is a consideration that emanates from spatial aspects, namely from the interior/exterior distinction, whereas the second is essentially mechanical. The first kind inevitably leads to a multidimensional description of the module abilities to meet some physical and material properties. However, since those considerations affect all components, it would be inconclusive, thus irrelevant for a modular analysis. Thus, the approach should not be posed as on what components can do, because they intrinsically may do many things simultaneously, but on what are the truly structing functions of each component, stripped of all other functions that could not be assigned without these. That is, the approach should start by hierarchizing the possible functions of each component within the module, through a functional mapping (Figure 9).

In the next step, we can begin to describe how the relations between components are established (Figure 16). The first thing we can observe in a higher scope is that in the components of our product follow a cycle pattern, thus indicating a chain dependency of the diverse parts. We can also observe that the window is physically linked with its *close environment* (a11-*wall* and a12-*floor*), and has variable environment conditions (*inputs*) in the actions that can lead to the opening or closing of the window (rotate the a8-*handle*, push pull the a8-*handle* or push/pull the b2-*movable sheet*). The relations that the

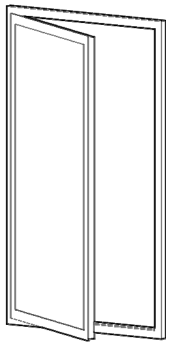


Figure 15. The module window example-case.

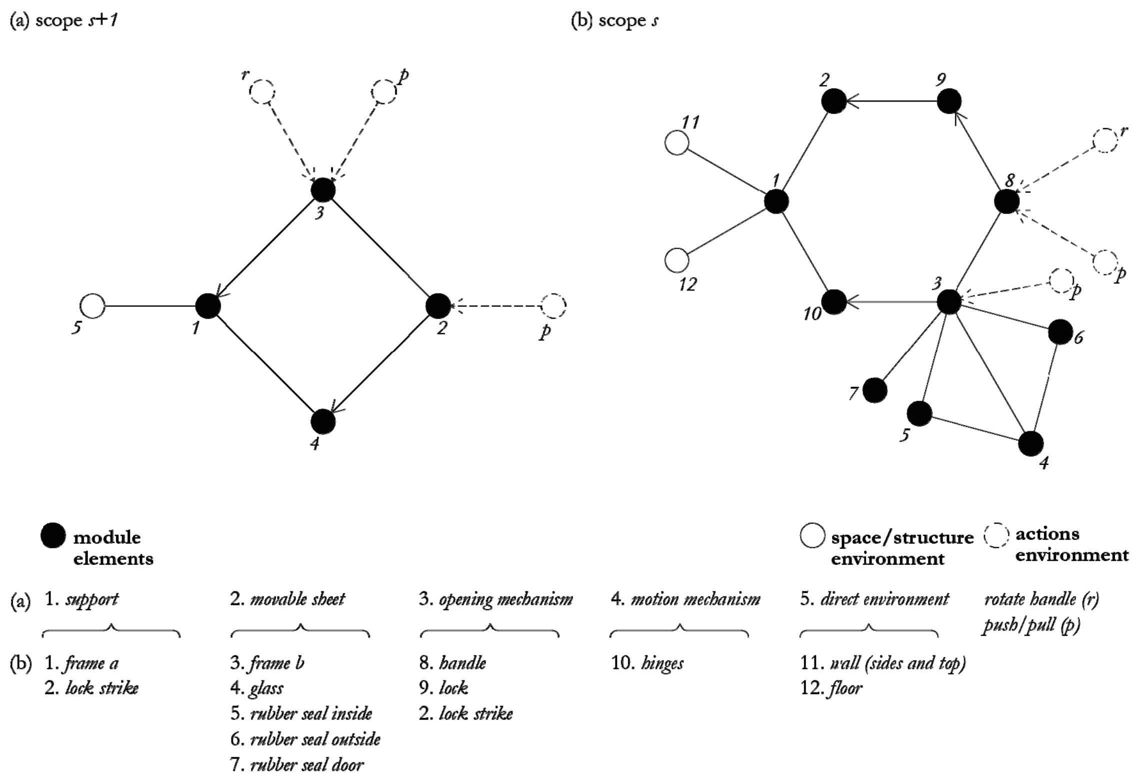


Figure 16. A graph representation of two different levels of functional components of a window.

window establishes with these two environment sets is what primarily defines its *interface* features as a module within a higher product-scope (e.g. a house).

When we zoom in, lowering the scope, we see that the a3-*frame b* in the b2-*movable sheet* establishes numerous connections in a kind of separate island, aside the main cycle. The island indicates an independence of the other b2-*movable sheet* components in relation to the main function of the module—indeed, the window could open/close just with the frame and nothing more. On the other hand, the numerous connections established with a3-*frame b* indicates a certain integrality of this component and/or a higher relevance within the overall system-*window*.

Anyhow, regarding the window from a product perspective, we see that we can reduce its observation to a main relation with its direct physical environment, thus making it strictly modular. In the previous example of the light switch (Figure 11), regarding its direct environment, we could observe that it was modular from a spatial/mechanical/material point of view, but integral from an energy and from an information point of view.

4.3 Notes on modularity and architectural production

4.3.1 MODULAR KNOWLEDGEABILITY

The evolution of non-physical modules, namely in software, has contributed to expand the horizons of the conceptions of modularity in physical elements. In software architecture, modularization is key for program development, since each program is typically made up of one or more modules, written in a certain language. Each may contain several routines, and may be developed independently, easing testing, debugging, and so forth. As modules, these can be assembled in the final program, but may also be re-assembled in other programs.

This dematerialization of the concept pushes forward the physical notion of modularity as self-contained functional units, their mapping and so forth. Indeed, the setting of a physical module can lay in its knowledgeability, rather than in its physical concretion[370]. This is, for instance, what occurs when reusing or recycling specifications from a former module, or, as in software development, when the known functionality of a certain module is used towards a different purpose or product than the original. On a broader perspective, thinking of a *production-chain*, in a way, this intellectual reuse blurs the limits between knowledgeability and a 'traditional' conception of module as a physical thing, rendering it closer to an evolutionary view of the technological development, built of successive incremental improvements.

On a stricter perspective of knowledgeability, we can consider a *knowledge module* as a precedency of a *physical module*. That is the case with CAD, numerical or any other specification or representation of a constructive component. These abstract representations can be reused if the component is reused in the product (e.g. a building), or eventually in a different product of the product-set—e.g. a *virtual* module in a mass-customization product development. Additionally, the knowledge of the product-set can be seen as module itself, in which specifications are products made by combinations of self-contained functional units. That can be the case of structural, thermal, acoustic or other projects within an architectural coordination.

4.3.2 MODULARITY AND VARIABILITY

As we have implied, modularization is driven by an aim to create variety (customize) while rationalizing production. Variety ought to be an output of customer choice, not an end in itself. However, there are numerous aspects to take into consideration. The customer will certainly want the best constructive quality and desired aesthetics that the available money can buy. However, choice processes often enter a gray area which can be hard to keep track. As demonstrated by the paradox of choice, having too many options to choose from can be highly counterproductive.

Some of the potential inefficiencies may be proactively avoided by following an insightful modular approach. For instance, it makes sense to discard right from the start useless *external variety*, that is, the choices in which the customer will not likely be interested in. Moreover, it also makes sense to tackle *internal variety*, that is, cost generating variations (e.g. materials, processes, solutions) with no added value to the customer. In the least, this is necessary because as components grow in diversity, logistics can get complex, harder to manage efficiently, and eventually causing more losses than benefits.

Too much or unnecessary information make harder any choice process. Thus, in a context of offering product variability, the modular architecture should take in consideration the client's requirements, grouping them in sets of variety with simplified information. In each set the variants can then be detailed. Finally, the information that is made available should be clear and concise, and focusing on the variety that can be useful to the client.

Within the context of variability in a rationalized production, some rule-of-thumb tools can be used to minimize potential logistic complexity derived of choice processes. One way to do this is by implementing principles of *similarity* across the entire process—e.g. by standardizing, reusing resources, or simply implement geometrical symmetries[371] whenever possible. In this perspective, it also makes sense to integrate previous modular knowledgeability, thus not only avoiding unnecessary work, starting over and over from scratch, but also making work potentially faster, more productive and with better quality. Moreover, by opting for departing from proven solutions, the associated risks can be reduced.

Another effective way to attain rationalized solutions in this context is to transversally implement *complexity reduction* strategies in the overall process. That includes breaking down elements in independent units, enabling parallel work, distributing tasks, enhancing planning, or separate testing. Moreover, since discretized elements are more easily grasped, that will improve the handling and overall understanding of the elements by the people participating in the process. Architecture requires a knowledge of a wide variety of solutions, with often too much information to reliably be handled via cognition. Thus, attaining a greater clarity should be a permanent concern. Discretization, classification, hierarchization or decomposition are all aspects prone for incorporation in a modular sphere, contributing to reduce complexity while keeping up with the client's requirements.

4.3.3 CHANGE AND OBSOLESCENCE

One of the main aspects the modular architecture is closely bounded with is to the ease in which change can be implemented. In modular terms, the least change in a product means a change in at least one component. Modular architecture specifies which functional elements within a product are constrained by a certain component, and which component should change in order to alter a functional element of the product in an intended way. In that sense, strict modularity entails a discrete perspective in which change can occur with independence. Conversely, integrality entails a kin perspective in which a change in an element can produce effects in every element.

Within the life-cycle of a product, we can recognize various types of change motives:

(a) *Obsolescence*, which can include *upgrade* (as technology and/or the user needs change, e.g. replace incandescent by LED lights) and *wear* (when features deteriorate, e.g. a broken hinge).

(c) *Adaptation*, when products are subjected to an environment change (e.g. converting an old house to be fully accessible when occupants have special needs).

(b) *Add-ons*, when products are featured as a base unit for user adding components (e.g. desktop computers).

(e) *Consumption*, when products use consumables (e.g. a water filter).

(f) *Flexibility/Adaptability in use*, when products exhibit diverse competences (e.g. hardwired flexible partitioning in office spaces), or have a though-of potentiality to convert towards accommodating diverse competences (e.g. an open-space).

Most of these can simply be related with designed product characteristics (*add-ons*, *consumption*, *flexibility/adaptability in use*). Unlike *adaptability*, which implies design considerations, the case of *adaptation* refers no non-previously though-of environmental changes which normally occur on larger time-spans, corresponding to unknown or unpredictable circumstances at the time the product was developed. Therefore, *adaptation* is out of a design or product management scope. Finally, we have the *obsolescence*, which is somewhere in between. Indeed, although some *obsolescence* aspects may be out the design or management prediction ability or competences, others are foreseeable, thus requiring action to be taken, otherwise potentially incurring in several risk factors.

Indeed, among these, obsolescence is perhaps the case that raises the most questions related with the designer and producer responsibility. Certainly, it can have a major impact on firms of all sizes and sectors, affecting all sorts of products, and eventually upon various stages of the product's lifecycle. It thus may lead to potential high-costs, such as expensive replacement of parts or repair works, or even the need to redesign or requalify. This can harm not only profitability, but also firm's competitive edge or reputation. In a perfect storm, it can even affect firm's very survival. Nevertheless, obsolescence is unavoidable, the producer knows it, and the client also does.

To attain a successful new product development two critical goals must be accomplished, that is, to meet customer needs and minimize time-to-market. However, strategies to accommodate both can often be conflictual, often clashing in obsolescence-related issues[372]. Indeed, more than the awareness of obsolescence by both the producer and the client, the issues arise mostly in function of falling in meeting certain expectations. That is true about performance, as it is about obsolescence expectations.

Downstream, there are several reactive ways to manage and mitigate obsolescence. Namely, cannibalizing parts from product returns, getting alternate (form, function and fit) replacement from the original or a different manufacturer, finding the closest equivalent replacement part or procuring in the after-market. Also, mainly for those parts with expected shorter lifespan, it can be useful to make a lifetime stock, or buy parts in bulk and stock them in inventory for future needs, particularly when knowing that products or parts may be discontinued. There are also more sophisticated reactive strategies, such as reverse engineering, which may not always be possible to implement.

Upstream, prior to a market stage, it should be established a pro-active and/or tactical management of obsolescence as a key way to mitigate associated risks. Among these, in one extreme, particularly in relative lower value products, it can be included a so-called programmed obsolescence, particularly in those products where a higher pace of technological development is verified or in those products more depending on trends, which makes them more likely disposable in a relatively short term. On the other extreme, particularly in relative higher value products, it can be included product follow up strategies, customer assistance, and so forth.

Obviously, company's business plans differ, as they target markets, and thus their obsolescence strategies. For instance, a consumer hardware OEM will likely be more prone to consider obsolescence as a *business as usual* strategy. Conversely, an electronic hardware supplier for aerospace systems will certainly regard obsolescence from a longer-term perspective. In that sense, it is worth mentioning a sentence attributed to Bill Gates, where he states: "*The only big companies that succeed will be those that obsolete their own products before someone else does*"[373]. Regardless a debatable liberalist ideology, the statement is nonetheless enlightening.

In a management context, obsolescence can also be seen as a way to make modularly conscious sourcing decisions. In OEM's, in those components with a high-modularity/high-obsolescence profile it can make more sense to focus on outsourcing, particularly if the technology is not completely aligned with the business core development. On the other extreme, in a low-modularity/low-obsolescence profile, components are weak outsourcing candidates, and simultaneously may be critical for service and warranty issues. In a low-modularity/high-obsolescence component profile, it can be positive to keep a technological edge in these parts, as well as making in-house production and/or establishing strong supplier relations. Finally, in a high-modularity/low-obsolescence component profile, it is when parts are the strongest candidates for outsourcing, and are not likely relevant for warranty or service issues[374].

When we cross different degrees of modularity with different degrees of expected obsolescence, we can get a panorama of what a business focus should be in each circumstance. We can thus retain what the design efforts should concentrate on to maximize overall performance. Although not always wise or feasible, keeping products with a high degree of modularity enables the designers to test on components that may have greater potential for influencing the performance, and thus the value of the system.

4.3.4 IMPLEMENTING A MODULAR ARCHITECTURE

In design terms, the idea of going modular can be appealing, but in practice there are essential limitations to the design that should be overcome. Making a modular product is extremely difficult, because modularity adds a new series of requirements and constraints. The interface can take up space and resources that otherwise would not be there, at least not so prominently. Every component must be tested with every other in every possible configuration to ensure that they all function together. Although some testing can be done virtually, with the aid of IT's, nonetheless this means that testing and eventual certification are onerous, with a significant weight in development costs.

Moreover, to be market competitive, products must offer comparable output vectors (cost, time, quality, scope) at comparable price points. In the least, eventual design gains must acceptably trade--off with eventual losses, such as with pondering in adding flexibility for replacement of parts, or considering end-of-life or upgrade scenarios. The case of *Google*'s failed *Project Ara*, set to develop a modular phone, showcased many of these issues. For companies, ultimately the difficulty is to meet an attractive price point while they remain solvent throughout the process. In the worst-case scenario, the danger is to end up with a monstrous and expensive Frankenstein that, despite the qualities, no one wants to love.

Products may be designed and fabricated without ever explicitly considering many of modularity's notions. However, if the modular architecture is integrated during development, that does not typically occur in early stages. Indeed, it usually happens after the design and the basic technological principles are established. However, while it is of key relevance, there is no such thing as an optimum modular architecture in all cases.

The task of bringing together a modular system is immense and likely very difficult. It is commonly hard to devise modules that are satisfactorily universal to be applied in a system and not only in one single product. Thus, some advantages of modularity can fade, namely when variability is introduced. Thus, in some cases, best option can be not to modularize, but instead to make dedicated, integral products.

Table 6 synthesizes some of these concerns, advancing possible strategies in product development to implement modular or integral architectures.

Concept Development >	Design >	Detailed Design >	Test and Refinement >
Choose technological working principles Set performance targets Define desired features and variety Choose architectural approach			
	Discrete Approach		
	System Architect as Team Leader Map functional elements to components Define interface standards and protocols	Component design proceeds in parallel Monitoring of components relative to interface standards and performance targets Design performed by 'supplier-like' entities Component testing can be done independently	Effort focused on checking for unanticipated coupling and interactions Required performance changes localized to a few components
	Kin Approach		
	System Integrator as Team Leader Emphasis on overall system-level performance targets Division of product into a few integrated systems Assignment of subsystems to multi-disciplinary teams	Constant interaction required to evaluate performance and to manage implications of design changes Component designers are all 'on the core team' Component tests must be done simultaneously	Effort focused on tuning the overall system Required performance changes propagate to many components

Table 6. Differences in product development according to architectural approach, based on K. Ulrich (1995).

At a design level, pursuing modularity may be simply pursuing its knowledgeability, integrating it in thought processes. With the progressive use of its concepts, modularity can well become intuitive, informing design decisions on whether following one direction instead of the other. A simple example illustrates this idea (Figure 17). In the development processes of the modular AHP house design that we will later be detailing, architects had though-of an underlying grid for structural purposes. However, when it became the moment to build a prototype, decisions were taken in order to make some exceptions to the grid's inherent rigidity. Namely, that occurred in establishing openings in the façade that could enter in conflict with the most sensitive structural points of the modules' structure as envisioned in the design conception, that is, in their corners. The idea beneath was to prove that the constructive system could endure to go off rule if ever required. In the end, it proved feasible constructively, but not without evident structural exceptions which naturally redound in increased costs.

Within a structural scope, both modules departed from a structural independence standpoint in relation to the other. The action of opening *m1* or *m2* would cause no change in that condition. However, the action of making an opening that occurs in the two simultaneously implies a change in their initial modular terms within a structural scope. This meant adding dependencies, rendering integral an otherwise discrete structural approach. It is quite a simple case, and its more sophisticated

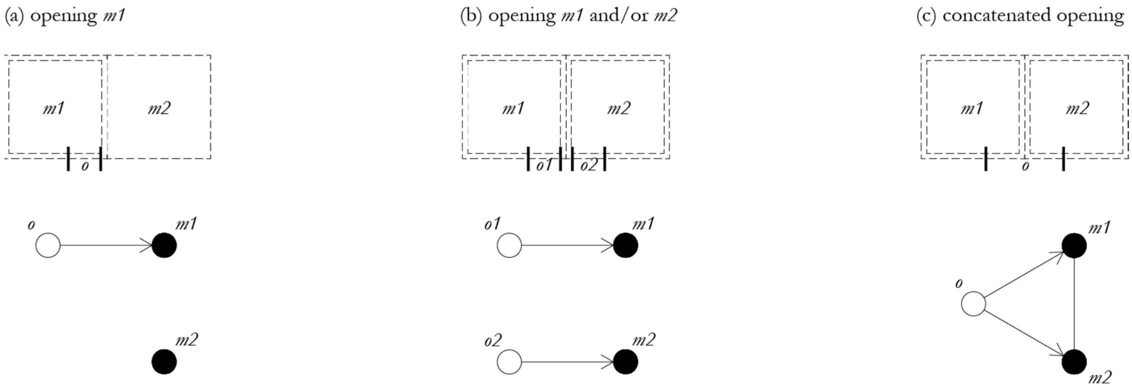


Figure 17. A simple case of modular application.

representation in a graph was not required to take a design decision ahead. However, here it serves the methodological purpose of explaining what is occurring in modular terms.

In the multi-dimensional decision process of a design development often decisions are analogously simple. On its own, more than using more or less sophisticated tools to assess each problem as moving ahead in the design, modular knowledgeability may help in making design decisions. It is not a matter of getting it right or wrong, as options on the table may all be correct from a design point of view. It is a matter of making design decisions more consciously.

A certain tendency or architectural authorship, can inhibit architects to regard their buildings as products, and more like works of art. However, the fact is that the reality of architectural production is rarely able to exclude the usage of manufactured products in their works. Certainly, not everyone has to go modular. However, a modular insight may benefit professionals and architectural production down the way.

4.3.5 MODULARITY AND ARCHITECTURAL FORM

Architects may typically desire to have the possibility of disposing of a diversified array of solutions. However, modularity often falls in the accusation of restricting the possibilities that are at an architect's disposal. Nonetheless, it is also known that highly complex shapes may be defined by modular arrangements. Mies van der Rohe employed a module of 24x33in for the *Farnsworth* house. Alvar Aalto reportedly said: "*my module is the millimeter*". Indeed, ultimately it is all a matter of degree.

In the shapes found in nature, say a rock shaped by the elements, the form devising processes can be described from a mathematical continuity perspective, meaning that the possibilities of arrangements given an initial condition are infinite. The generalization[375] can straightforwardly be given by laying out a line segment with a given length l, where $l \neq 0$, and figuring out how many possibilities there are of dividing that line in smaller segments (Figure 18a). Then, repeating the process with one of the remaining two segments, and subsequently the same with one of the remaining three, and so

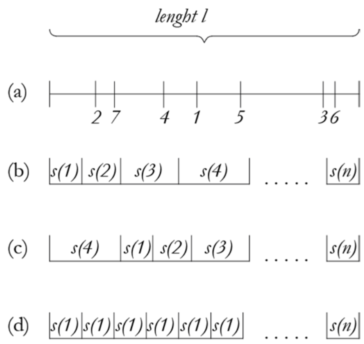


Figure 18. A one-dimensional generalization of form processes: (a) continuous (kin), i.e. dividing the length *l* sequentially, starting in one; (b,c,d) discontinuous (discrete), assembling segments given by s(*i*) to form length *l*, in (b) *i* goes from *1* to *n*, in (c) a case of arrangements of (b), and in (d) with *i* always equal to *1*.

forth. In each step, there is an infinite number of possibilities. The original segment can analogously be of any scale and/or dimension, thus corresponding to a certain shape, for instance describing what happens to the stone when exposed to the elements.

However, in artificial forms, or even in some living forms found in nature where patterns can be grasped, we can aspire to a description from a discontinuous perspective. We can also straightforwardly generalize it, but now instead of dividing a segment, we will be assembling one. Meaning, that instead of dividing, using real numbers, we will be adding positive integers. Thus, consider any arbitrary segment given by $s(i)$, where i is the label of any given segment s in a finite universe of n segments, where i is never repeated, and that the sum of all the segments considered equals the length l, where $l \neq 0$ (Figure 18b). In these circumstances, the possible arrangements that we have can be given by $n!=1*2*3*\ldots*(n-1)*n$ (Figure 18c). For instance, when we have 6 distinct segments, then the possible outputs are $6!=720$. If i was always the same, then the possible arrangements would be only 1, since $1!=1$ (Figure 18d). Moreover, since all segments would be equal, the way to assemble them would be irrelevant.

In practice, as we shrink in modules size, increasing the n number of modules, in the limit we can approach a continuous form devising process. However, there is a substantial difference between both approaches. In one case, we are devising a form, shaping it as we move on, as a sculptor casts a form. On the other, we are assuming a pre-existing form, and we can approach it with more detail as we move on. The first we can relate with an abstract design sense. The latter has much more to do with a practical design sense, underlyingly constrained by the ability of a physical construction. Although also dealing with the first in early stages, the architectural production primarily depends on the latter. Indeed, a millimeter is nonetheless a module.

For instance, we could also characterize great historical architectures, such as the Classical or Gothic, within a certain sense of modularly, given the repetition of elements such as columns, windows or bays. These have internal substructures, with decorative elements such as fluting or triglyphs.

Even in flatter zones, we can observe these qualities, for instance by the stereotomic given by the joints of even the smaller building elements. The appearance perceptually results from a balance between various layers and scales of substructures. The greatest the number of discontinuities, the higher the visual density, the lesser, the flatter. Finally, one can argue that this may seem dubious when we recall a classic distinction between dry and fluid bonded construction. However, fluid bonds can too be scrutinized modularly in respect to their properties and relative weight and properties for a mix modularity. It all comes down to the scope.

5 A PRACTICAL CASE: THE *AFFORDABLE HOUSES PROJECT*

5.1 Background

The housing problem is a permanent and transversal issue that has been crossing mankind's history. Its continuous reappearance is signaled from multiple sources, varying on socio-cultural, economic or environmental conditions, and of which the related constructive or architectural aspects are just a small part. Contemporarily, the housing problem can be easily identifiable in those places where endemic misery is a reality. It is also straightforwardly detectable in those developing countries where the rapid economic growth, coupled with a significant demographic pressure in urban areas, among other aspects, ostensibly calls for housing to meet adequate quality levels [complement with: **Annex, IV.4 Housing, a global issue**].

With different shades, the problem is also resilient in wealthier nations. For instance, in some European countries there is a huge demand for the replacement of ageing housing stock not meeting minimum standards. In consolidated urban areas, these typically fall on renewal or refurbishment practices, but in places where there is more land availability, as typically are the urban outskirts, or in rural areas, new construction also often takes place. In parallel, as the built environment processes unfold, the generality of the construction sector, with few exceptions, remains one of the least industrialized activities. Moreover, as history has been demonstrating, factors such as economic constraints, or a fast pace culture of consumption, increasingly demand more efficient construction practices while keeping up with quality-delivery standards.

Stirred up from the Portuguese reality, this sort of concerns was at the core of a housing concept focusing in affordable and efficient steel-based construction methods. The concept was developed under the *Affordable Houses Project* (AHP)[376], a research and design initiative launched in January 2009, which came up in the context of an international taskforce, promoted by the *ArcelorMittal* company and under the *International Scientific Networks in Steel Construction* (ISNSC). The origins of the current thesis can be traced back to the research undertaken within the scope of the AHP, and has largely evolved around some of the perplexities which it arose.

Following the ISNSC scope, the project primary involved civil engineering expertise in the field of steel structures. Altogether there were eight participating universities, coming from Brazil (*São Paulo University*), China (*Tongji University*), Czech Republic (*Czech Technical University in Prague*), India (*IIT Bombay*), Poland (*Rzeszow University of Technology*), Portugal (*University of Coimbra*), Romania (*The 'Politehnica' University of Timisoara*) and Sweden (*Lulea University*). As set by the promoter, the purpose was to develop innovative affordable houses, adapted to each of the different national contexts of the participants. Each national group developed its work independently and results were presented and discussed in two general meetings.

With investigators primarily linked to the *University of Coimbra* (UC) and/or the *Institute for Sustainability and Innovation in Structural Engineering* (ISISE) research unit, the Portuguese group was formed with cross-disciplinary concerns. It gathered mostly architects and engineers, the latter with diverse expertise (structural, thermal, acoustic, fire safety, sustainability assessment, and so forth)[377]. Despite the diversified contributions, architectural research would assume a key role in the group, as the approach primarily focused in establishing a solid conceptual ground over spatial and constructive issues, thus anchoring the subsequent developments of the different specialized domains[378].

Concordant to the initiative's scope, the main lines of AHP's preliminary brief can be summed up to the idea of affordability, while making an intensive use of steel. The remaining typical features outlining a design development, namely target market, building typology, house program, architectural solution, constructive technology, and so forth, had to be formulated by each of the national design teams from an analysis of their local realities. Providing an answer to these was scheduled for delivery on two project phases, each culminating in a general meeting joining the various national representatives. In the first stage of the project, what was called for was a portrait of the country's socio-economic and construction contexts, as well as a preliminary design proposal. In the second stage, the debate took place mostly over a detailed design, with its components thoroughly described. The main elements mapping the two stages can be summed up in the topics presented in Table 7.

As the work progressed, eventually some of these topics acquired more relevance, and some others were further added to complement the findings. The info retrieved from the first group of topics would be key to set the design foundations. Regarding the contribution towards the design proposal, such info can be divided in to two main areas. Firstly, a statistical analysis broadly characterizing the Portuguese territory in terms of its geographic, economic, or demographic dimensions, contributing to set the target market and the house program formulation. Secondly, a technical analysis, assessing structural, thermal or regulation issues, added by an observation of state of the art practices, contributing to establish a framework for the architectural and constructive features.

The second meeting, which fundamentally was set to discuss the thoroughly detailed designs, signaled the conclusion of the international project, with its final call held in 2010. In the aftermath of the AHP, the Portuguese prefab company *Coolhaven* was created in that same year. The company took its first steps out of the AHP legacy, but in due time it would also develop its own designs, following business' opportunities. However, the symbolism of the AHP remained, as *Coolhaven*'s first job was the construction of a full-scale AHP prototype. The prototype was a true proof-of-concept, since it enabled a real-world testing of the typological and constructive ideas.

STAGE 1 – DELIVERABLE 1	**Socio-economic evaluation**	General description of the country General description of the socio-geographic-economic conditions Statistical data about the country, population, construction market Description of the construction market
	Traditional housing concept	Geographical, geotechnical, structural, architectonical constrains Overview of legislations and of the boundaries Description of the traditional housing concept Advantages and disadvantages of the traditional solutions Cost of traditional housing concept
	Innovative concept	Technological state of the art General description of the innovative process, solution, choices, etc. Advantages and disadvantages Innovative aspects Review of the selected technical solutions Preliminary architectural project Preliminary structural project and other design features
	Follow up	General planning Critical points and risk analysis
STAGE 2 – DELIVERABLE 2	**Final design and detailed description of the technical solutions**	General description Innovative aspects Advantage, disadvantage, feasibility study Detailed design Architectural project Structural, Thermal, Acoustics, Plumbing, and Electrical project Quantity survey and bill of materials Sustainability and life-cycle valuation Achieved quality and performance assessment
	Socio-economic assessment	Economical evaluation Comparison with traditional housing concept and material Social advantages Possible deployment, possibility for demonstration, etc.

Table 7. AHP main topics.

Meanwhile, the research work progressed on a further fine-tuning of the concepts, with new research lines arising, and with the findings published in diverse scientific media. All in all, these would contribute for the development and registration of a European patent on a *modular construction method for constructing dwellings*—PE10792013(A1) 2013-10-25.

Hereon we will be describing the main features of the AHP design and its progression up to the prototype construction. Additionally, we will be including related research that has since been developed apropos. More than a plain description, this is a critical observation over a process that is now possible to analyze with greater detachment, and by it favoring a better acknowledgement of the eventual methodological implications that can be extracted. Although there is a concern in presenting the themes in a sequential and logical way, the description does not strictly follow the chronological path of the findings in all its extension, but instead favors a conceptual clarification.

5.2 Preliminary remarks on the affordability concept

Affordability is a relative concept, depending not only on a certain cost or value, but also on if and how such cost can be met. The latter depends on factors such as capital availability, credit access or financing mechanisms in general. In a prospective house buyer or tenant, these can be ultimately linked to the subject's income, the stability of such income, and so forth. Furthermore, affordability is a context-sensitive concept, and hence there are different conceivable approaches towards it[379]. Despite the intrinsic ambiguity, it may generally be acknowledged as aiming to somewhere in between a low-end and a high-end market.

For a given territory, the analysis of the available statistical data can contribute to establish the price point that an average family may pay for a house, and from there derive construction cost benchmarks, potential target markets, or other relevant economic factors that have an upstream influence on the design. Informing the design with these boundaries is a critical task, as that is what ultimately sets what can and cannot be done. Surely, the designer's concerns will differ from those of a real-estate promoter, contractor, or prospective buyer. Anyhow, at the least ethically, it should be the designer's duty to assure the envisioned design can be made with the available resources.

Notwithstanding, the final price tag of a building depends on multiple factors that far extend architectural options, such as those concerning spatial-constructive features. To start with, it will be depending in the variable land cost—i.e. the location[380]—which can directly or indirectly include marketing mechanisms, publicity effects, social status, and the like. There are also commissions, interests, additional speculative values, and so forth, that can be included. In the end, both the architectural and the location conditions are not dissociable.

When introducing innovative construction practices, such as in the AHP case, a hands-on way to look at affordability from a designer's perspective, is to make it comparatively, via construction area cost. In this case, that means establishing an area cost benchmark (e.g. cost/m^2) of an ordinary house construction method, and from that reference working to attain spatial and material comparable purposes. Given the social suspicion which undermines the public opinion on some innovative constructive practices—as is utterly the case in a *prefab*—staying below such a threshold potentially also works favorably in terms of the attractiveness of the design solution towards the public, and hence in its potential marketability, salability, and so forth. In many ways, the cost/m^2 is a much more practical approach from a design standpoint, since it fundamentally focuses on construction cost, discarding variables that can often be subjective or in the least harder to measure, adding unnecessary complexity to the design problem, and typically often out of the designer's control.

There is little that the designer can do within its deontological scope to lower the impact of the variable land/location in the affordability equation, except optimizing the available space within the given constraints. For such, strategies such as minimizing circulation areas or instigating to concepts such as flexibility or adaptability can be used. On the other hand, since affordability is a relative concept, whoever may afford more expensive land will also likely afford more expensive construction, which again makes it hard to take useful generalizations in this matter. However, in those cases where a design is developed from a speculative basis, as in the AHP, statistics should contribute to inform the design[381]. This can lead to potentially more scalable solutions, helping to accomplish less onerous costs, and benefiting marketability prospects, the first gate for the product's success.

Statistically, in Portugal there is an oversupply of housing, with plentiful offer of multi-story apartment buildings. Therefore, the AHP focused in the residential sector, which is more likely located in suburban or rural areas, where land is typically cheaper. Figures disclosed that the dominant type in the residential sector in Portugal was the three-bedroom house, and that this type is also quite often intended as secondary or holidays' house. Thus, adding to the affordability and marketability focuses, this explains why, in an initial stage, the design program was targeted to a two-story, three-bedroom residential house. In the Portuguese context, given the typical family structures and its evolution, as well as a propensity for a second house market, this could then be regarded as a versatile typology.

Meanwhile, a severe economic crisis stroke the country, as well as the world economy. Some of the data collected at AHP's early stages may now be outdated. However, it is our belief that the general principles are still sustainable, as they are laying in a relativist approach, grounded in abstract design principles, which conceptually encompass different needs and requirements, as well as their change over time. To a degree, this contradicts one of the initial purposes of the AHP promoter, which was to find specificities in the regional contexts of each of the participant countries. Although the design development took a different course in relation to these intents, these specificities indeed exist, and decisively contributed for the research to follow this direction, and not another.

5.3 The *AHP* design system

5.3.1 MAIN CONCEPTUAL LINES

In a first approach, the design was thought of in terms of a residential house design exploring the potential of cold-formed steel structures[382]. Constructively, the preliminary goals were set in achieving a better, or at least comparable building performance with what would typically be attained with ordinary construction methods, and at a competitive construction speed and cost.

To attain good output vectors, the constructive goals had to be inexorably linked with the spatial goals. The latter were essentially set in answering to different contemporary lifestyles. That meant designing homes for different kinds of families and their evolution, and as places that could congregate different uses, such as permanent or temporary work of the family members. Partly, this meant questioning the rigidity of functionalist models, instead appealing to notions such as flexibility or adaptability. To accomplish it, strategies such as endorsing typological variability, maintaining a certain open-endedness in the allocation of uses, or enabling future expansion/retraction of the construction, were thought of as beneficial to incorporate in the design.

The analysis of the collected data initially led to set the housing program in a three-bedroom, two-floor residential house. However, given the goals that had been established, it became obvious that there could be more to the design than a limited one-of case. Instead, there could be multiple possible dimensions and formalizations. As result, in coexistence with constructive principles, the design came to be conceptualized as what can be called of a *design system*.

Central to the idea of a *design system* was the purpose to achieve variability within a limited set of spatial-constructive components in a kind of rule-based system, grounded in modular principles. Thus, the design would be provided with a potential scalability, quality and cost controlled production, while enabling formal, material, size or cost variability to a prospective buyer. Instead of simple box-like houses or the like, the purpose was to make it possible to devise a myriad of shapes and configurations from a clear set of design components.

Additionally, to address the flexibility or adaptability aspects, the *design system* also came to be conceptualized in terms of enabling ease of interior changes during building's lifetime, as well as in terms of an evolutionary matrix to allow eventual future volumetric growth or reduction. In time, the *design system* also came to be thought of in terms of being adaptable to the multiple urban requirements of residential dwellings—i.e. attached, semi-attached, semi-detached and detached scenarios (Figure 23). Finally, in a later stage, the *design system* was also considered in more generic terms so to also include multistory buildings within its scope. Throughout the process different methodological conclusions have been extracted, which serve not only the purpose of the *design system*, but can be generalized to diverse other realities.

Since there can be strong fluctuations in land cost according with the location, and that may be a strong constraint in a final building cost, several options were taken to lessen its weight in the design. Straightforwardly, that meant that the design should be conceived to occupy the least possible plot of land. To attain it, it made sense to implement as a core measure the minimization of the main circulation space, to maximize useful areas, optimizing their ratio[383]. Thus, main circulation space was designed to have a central location in the plan layout, starting with centralizing the entrance area and, in the case of a second floor, locate the stairs within it. Finally, to minimize waste in vertical circulation space, the system, as thought of for the residential sector, would be limited to a two-floor height, plus an eventual basement. Nonetheless, if the two floors would not be required by a prospective buyer, the system was also feasible in a single floor. The basement, which could be used as a garage and/or storage, would be justifiable in those cases where terrain had a steeper, non-flat configuration. It could thus work as a sort of foundation plateau, assuring a flat, dry and solid grounding, on top of which the *design system* could seamlessly be implemented.

5.3.2 SETTING INITIAL MODULAR CONSTRAINTS

The construction was to be made of a steel structure. Given the higher prices of rolled steel, option was to think the design in terms of the constructive potential offered by the relatively cheaper *cold-formed steel* (CFS). Comparatively, CFS also has the edge of its lightweight, making it more prone to handle and maneuver without requiring heavy machinery—theoretically, if provided with precut parts, a two-man team with not much more than a screwdriver can do the job. When compared with ordinary masonry or concrete construction, CFS is also more prone to production automation, and likely has an edge in terms of reduction of environmental impact, lowering construction waste and increasing recycling potential in a building's *life-cycle end* (LCE) scenario. It also potentially simplifies repair and maintenance—e.g. in infrastructures, for piping or wiring replacement, or in changing interior materials.

In theory, CFS can also offer greater potential in terms of spatial flexibility, making it easier to change internal walls, and eventually with the same occurring with the external walls, in a future case of expansion/reduction of the building. Summing it all up, if properly devised, these factors may contribute to assure an overall greater sustainable performance. Finally, since CFS enables construction up to four floors with ease, or even five floors in special cases, it was plentiful for the original aim of two-floor residential typologies. In any case, given that in a great part of the Portuguese territory buildings do not exceed four or five floors height, such also did not exclude an eventual possibility of devising multi-story from similar typological principles.

From the technological CFS choice, a preliminary structural study assessed optimized span distances of the structural elements. At this stage, it mattered to understand what would be a reasonable maximum span without compromising the structural behavior. One of the goals in mind was to minimize the amount of steel in use to achieve a cost-effective solution, while enabling a sound constructive solution. Thus, whatever the structural outcome, it was also important for it to be a practical, round figure, to simplify the assignment of standardized components to the construction. Thereby, the structural basis was settled in a 60cm grid, with the entire design regulated from that basis.

The 60cm grid theoretically allowed a wide range of potentially useful discrete subdivisions or multiplications, which was conceptually a key intention so to avoid as much waste as possible in the construction, thus improving its environmental performance. Its integer subdivisions can start from 1cm or 2cm (e.g. for tiny-sized materials), 5cm (e.g. for small-sized materials), 10cm (e.g. for materials and the bulk of internal walls), 15cm (e.g. for materials and some special internal walls), 20cm (e.g. for materials and some special internal walls) or 30cm (e.g. for materials, some dividing walls and external walls).

Furthermore, if adding composed and/or multiple figures of 60cm, options increase. For instance, it can swiftly be attained measures of 40cm (e.g. 3×40cm=120cm=2×60cm) or 50cm (e.g. 6×50cm=300cm=5×60cm). With 90cm (3×½60cm) it is for instance possible to fit kitchen bench tops height. With 120cm (2×60cm) it was possible to attain the Portuguese legal minimum 110cm for corridor width, plus enabling a 10cm tolerance for a wall or other, and fitting the 240×120cm plasterboards' or be close enough to the *oriented stranded boards*' (OSB) of 244×122cm, thus theoretically minimizing potential waste in left overs after cutting the parts. With 240cm (4×60cm) it is attained a typical room-height, and fit for the plasterboards' or OSB's.

This meant that the *design system* became supported in a dimensional coordination scheme. That also included the heights for windows and façades (which followed a ½60cm regulation). In terms of heights, the modules were also ruled by an economy principle, with the ceiling height established at the Portuguese legal minimum of 2.4m, to which added 30cm slabs to a total of 2.7m between floors. The windows were thought of to function at 30cm (½60cm) height increments, starting from the maximum 2.4m case (Figure 19).

From these preliminary considerations, at least in theory, the construction could benefit of a greater potential of economies of scale in production. Concomitantly, the option to use modular dimensional principles assured an overall minimization of waste in construction materials, since it eased the compliance of standardized, industrially produced materials and components to the design instances casted from the *design system*.

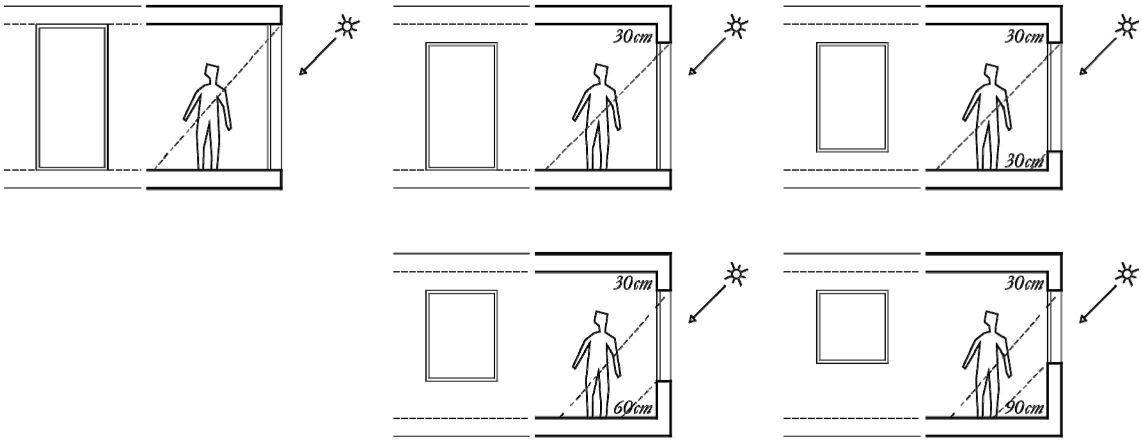


Figure 19. Example of initial section constraints.

5.3.3 THE ORIGINAL *AHP* DESIGN SYSTEM

The initial idea for the *design system* was to define a configuration that enabled a good functional organization, over one/two floors, and with the possibility of changes over time. Resembling pieces in the well-known *tetris* game, the proposal envisioned possible combinations within a limited number of shapes. A 0.60m×0.60m dimensional unit (**u**) defined the minimum modular framework. A module (**m**) of order **u**:(8, 7) (i.e. 4.8×4.2m), acted on the **u** grid, and a master-grid of order **m**:(2, 3) (i.e. 9.6×12.6m) on the **m** grid—where in any **x**:(*v*, *u*) the **x** denotes the grid order, described by the *v* and *u* values, which are positive integers, respectively denoting the grid's rows and columns. All alternatives were compelled to this **m**:(2, 3) perimeter, including the possibility of expansion. Thus, the maximum area of ground occupation considered for a single dwelling was limited to the total of the six modules per floor (*level*) in a **m**:(2, 3) (Figure 20a).

Modules' horizontal combinations defined each of the possible shapes formed under the **m**:(2, 3) boundaries. Vertical combinations were anchored to a central module. For structural economy, vertical combinations were limited to structural precedencies, meaning that a *level 1* (i.e. first floor) shape in its fullest occupation would be at most coincident with a *level 0* (i.e. ground floor) shape. Exceptions would require a different structural philosophy (e.g. cantilevering), or additional structural support—which would be equivalent to more foundations in the *level 0* (e.g. I_2, L_2, in Figure 20b–*level 0*). Constructively that meant having an extra module in *level 0*, even if not fully occupied. Within these shapes, there could be layout variations, resulting in thousands of arrangements (Figure 21). To allocate functions, each module within a shape bared a main space that was either a kitchen, a bedroom, a living or a dining room. Exceptions occurred in central modules, assigned for entrance/staircase/toilet space. Secondary spaces, such as toilets or storages, were placed within the main spaces, establishing a hierarchy of functional allocation. These principles guaranteed a balanced use of the functional areas.

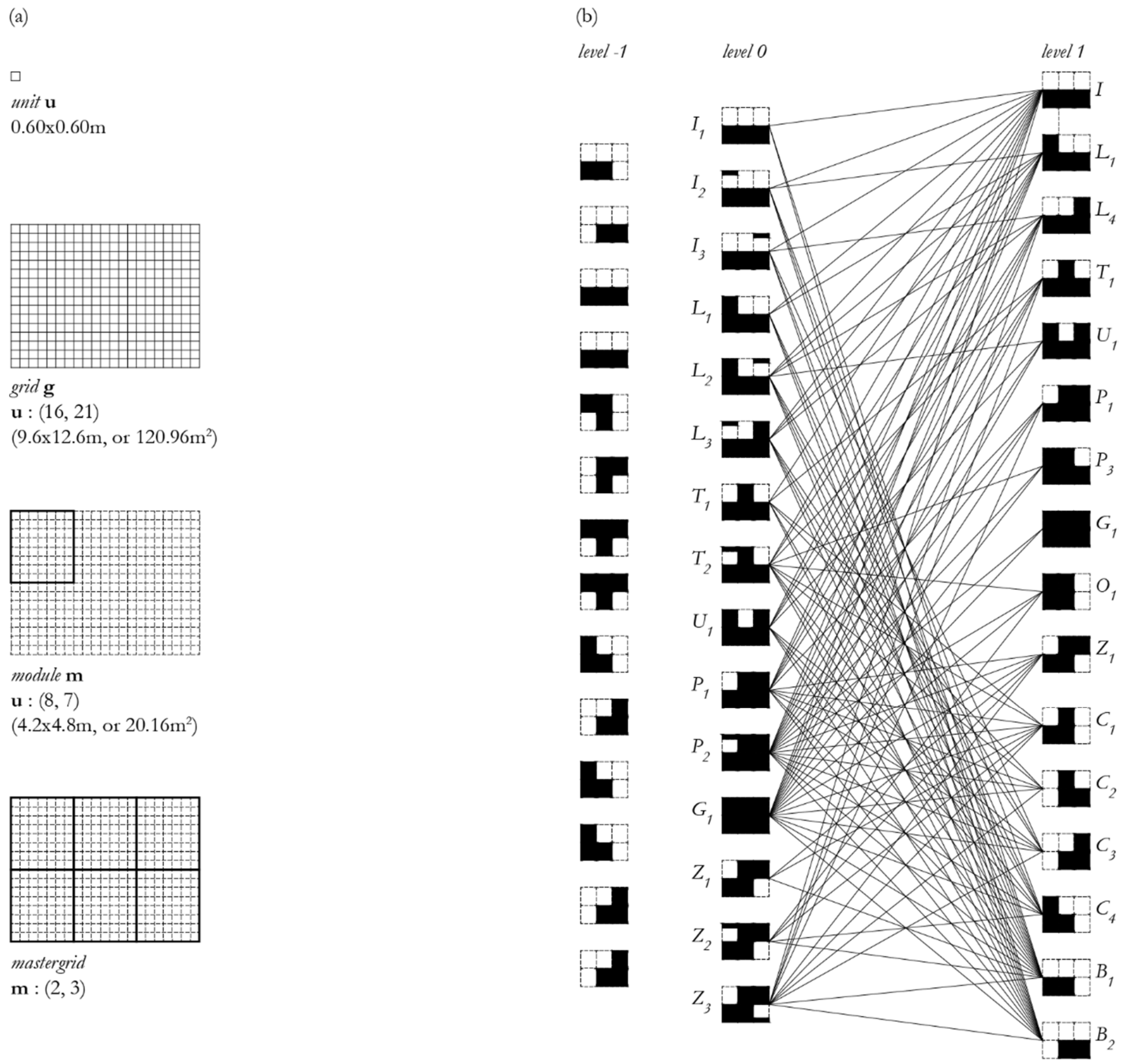


Figure 20. Grid (a) and combinations (b).

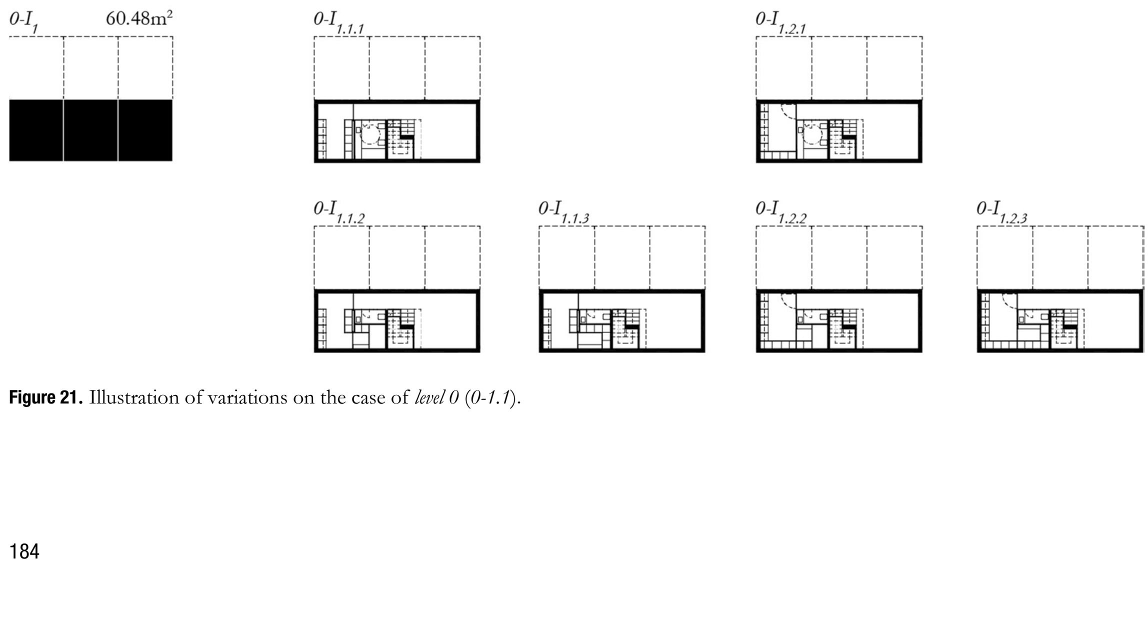


Figure 21. Illustration of variations on the case of *level 0* (*0-1.1*).

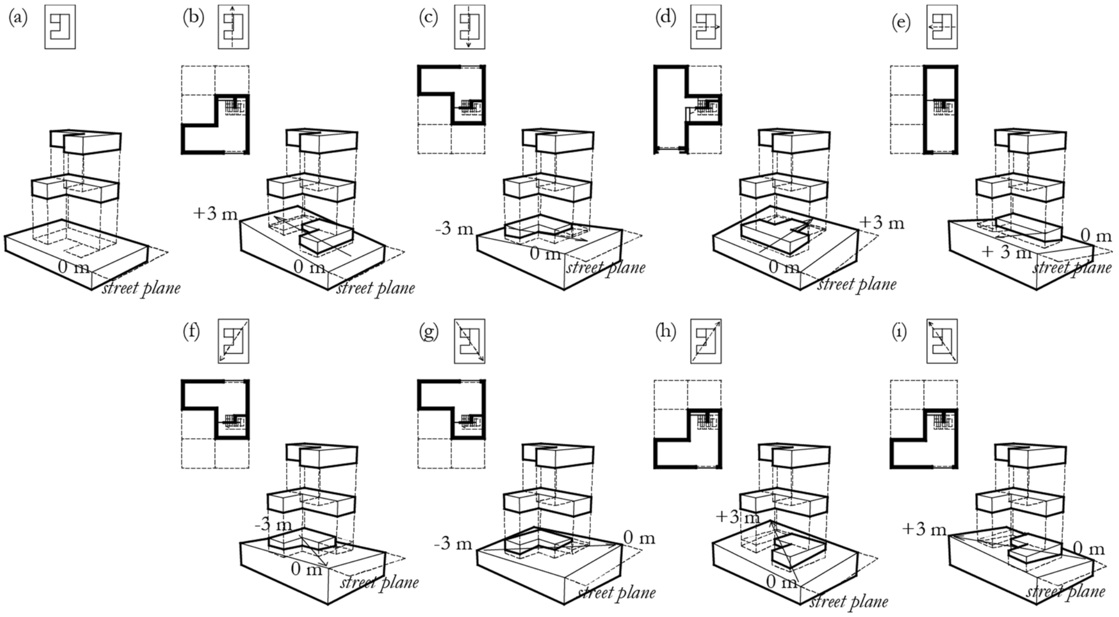


Figure 22. Illustration of *level -1* variations according to terrain adaptation scenarios.

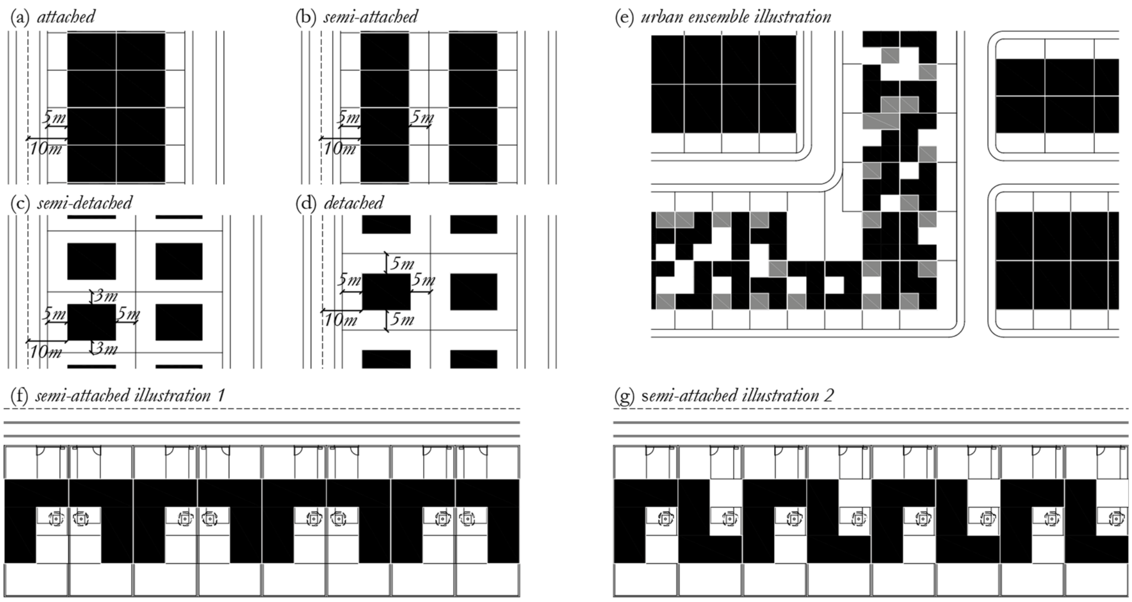


Figure 23. Illustration of urban adaptation scenarios (a, b, c, d), example case (e), and developed cases (f, g).

Figure 24. Illustration of an urban ensemble in detached scenarios, and showing different overhangs hypothesis.

A catalogue of layouts sharing similar principles was produced for each of the shapes, regarding a two-floor scenario (e.g. in Figure 21). Topographical issues that could arise were depicted in a catalogue of distinct basement configurations that absorb the several possible types of land differences (Figure 22). Diverse urban and soil occupancy situations, namely, (a) attached, (b) semi-attached, (c) semi-detached, and (d) detached, were also addressed (Figure 23). In the first case, the suppression of at least one of the modules per *level* (such as in the shape of an internal patio) was imperative to ensure proper natural light and ventilation to every inhabited space. In a preliminary test case, the typological variants were also induced to a collective house scenario, in which a simple case of a four-story apartment building was designed. Finally, given a preliminary thermal behavior assessment, different architectural solutions, including diverse sized window heights and overhangs hypothesis were tested (Figure 24).

Overall, the typological rationale endured the added constraints, which could be understood as a validation of the translation of the conceptual framework onto the *design system*. That was further supported with the development of a more detailed design case[384].

5.3.4 AN ILLUSTRATIVE DESIGN CASE

Considering the **m**:(2, 3) limits, a volumetric simulation was conducted to assess the validation of the design in a more detailed version (Figure 25). Following the initial research, it was developed a two-story, three-bedroom house typology. To optimize urban infrastructures and land plots, the smaller dimension of the parcel is parallel to the street, and the major dimension is perpendicular. Each floor has an *L-shape*, with the top shape superposing the bottom shape in a mirrored position.

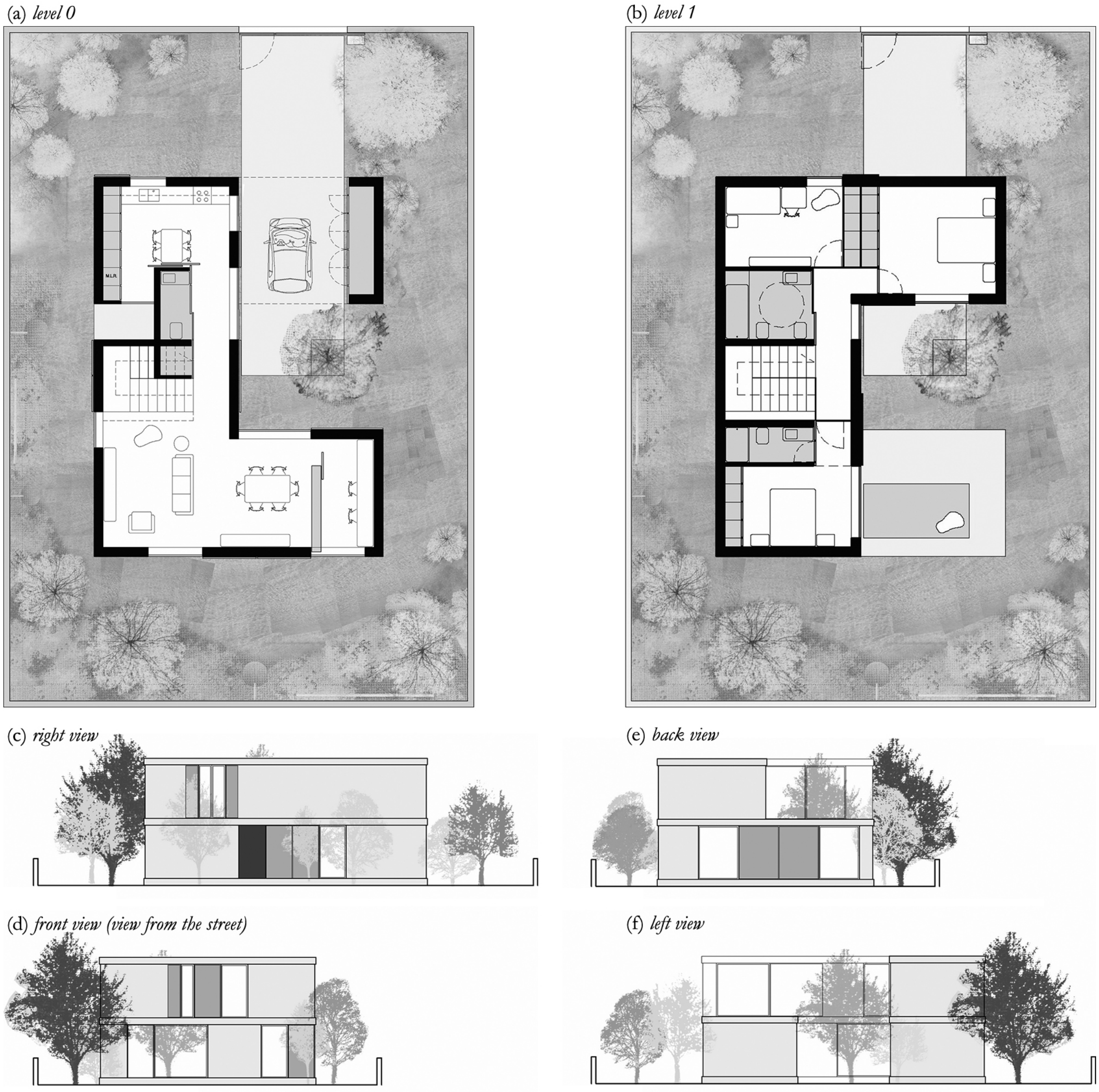


Figure 25. Illustrative design case.

The house program includes a living and/or dining room, a kitchen, three toilets, a storage area and a covered parking place. Social and private areas are vertically segregated. The *level 0* contains the social areas, while the *level 1* has the bedrooms and other private areas. The program is suitable for a family of four—e.g. a couple with two children—but it is also easily adaptable to other occupations.

The kitchen was placed closer to the street front, and designed to allow meals to be held within it. In the central module is located the core distribution zone, where an entrance hall gives access to the kitchen, a toilet, the staircase and the living/dining room. Adjacent to the living room, there is the ability to set a small working space. Given the overlap of the two mirrored *L-shapes*, the *level 1* provides a roof in the *level 0* for car parking. Arriving to the *level 1*, there is a direct distribution to the spaces, minimizing circulation area, giving access to the bedrooms, toilet, and a master-bedroom with private toilet.

To assess the adaptability, a few variations were tested over the same illustrative case. In *level 0*, next to the living room, it is feasible to add/remove a small, informal office space, just by adding or removing a wall (or shelf) and a door. In *level 1*, the two contiguous rooms can be transformed in a single master bedroom by changing the door placement, resulting in a 3-room bedroom, with a toilet, a primary space for the bed and a secondary space for either closet room or small home office. From a similar design base, it was also tested if typologically the design could endure a growth in length, increasing the area of the living room and of a bedroom, and if it could endure a different plot orientation, with both hypothesis proven feasible[385].

5.4 Optimizing the design system

5.4.1 EXPANDING THE GRID

In this part of the work we aim at further clarifying the *design system*, instilling a deeper methodological insight. In that sense, we have further developed the initial object towards an optimization of its modularity. By doing it, we have also expanded it to other domains, aiming at multi-dwelling housing that could share similar principles. The latter necessarily incites to an expansion of the initial grid. Indeed, considering the **m**:(2, 3) derived shapes, we could only achieve it in a limited number of cases within the initial boundaries. However, with no further criteria, grid expansion can be limitless (Figure 26), and thus more constraints are required than those that have initially been set forth.

We started by simplifying the rationale, discarding shape instances with shared similarities. For example, in Figure 20, shapes C_1, C_2, C_3 and C_4 were condensed to a single *C* reference from where the others derive. The **m**:(2, 3) shapes are thus released from their initial referential. Thus, excluding isometries—i.e. geometric transformations that maintain the inner congruence of shape elements, as are translation, mirror or rotation—the total number of horizontal combinations is in fact less (Figure 27) than what was considered in the AHP. Whereas in a real case the additional possibilities may be relevant, given different solar positioning, views, and the like, in an isometric/topological sense these are essentially equivalent.

The next simplification step was to reenact the modular essence of the shapes. The AHP limited module's combinations within a **m**:(2, 3) and to a single dwelling over a maximum of two levels. Yet, a typology can exist in a shape that is different from these. For it to occur the modular order must be bigger (i.e. the grid size must increase). With the same topology, for the **m**:(2, 3) it was initially considered 10 possible derived shapes (Figure 27b), but many more are conceivable. For instance, if it was a **m**:(4, 2), the number would boost to 24 possible shapes, in a **m**:(3, 3), it would be 36, and so

Figure 26. Illustration of a virtually limitless expansion (no added constraints) of **m**:(2, 3) derived shapes.

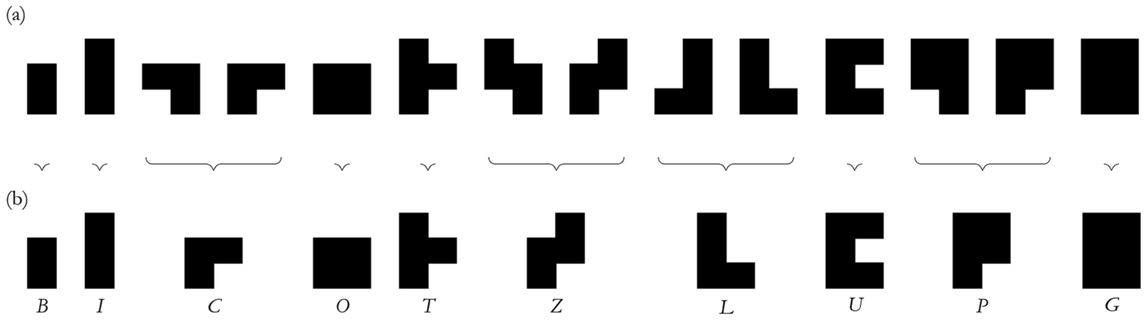


Figure 27. Initial **m**:(2, 3) derived shapes (a) and their essential members (b).

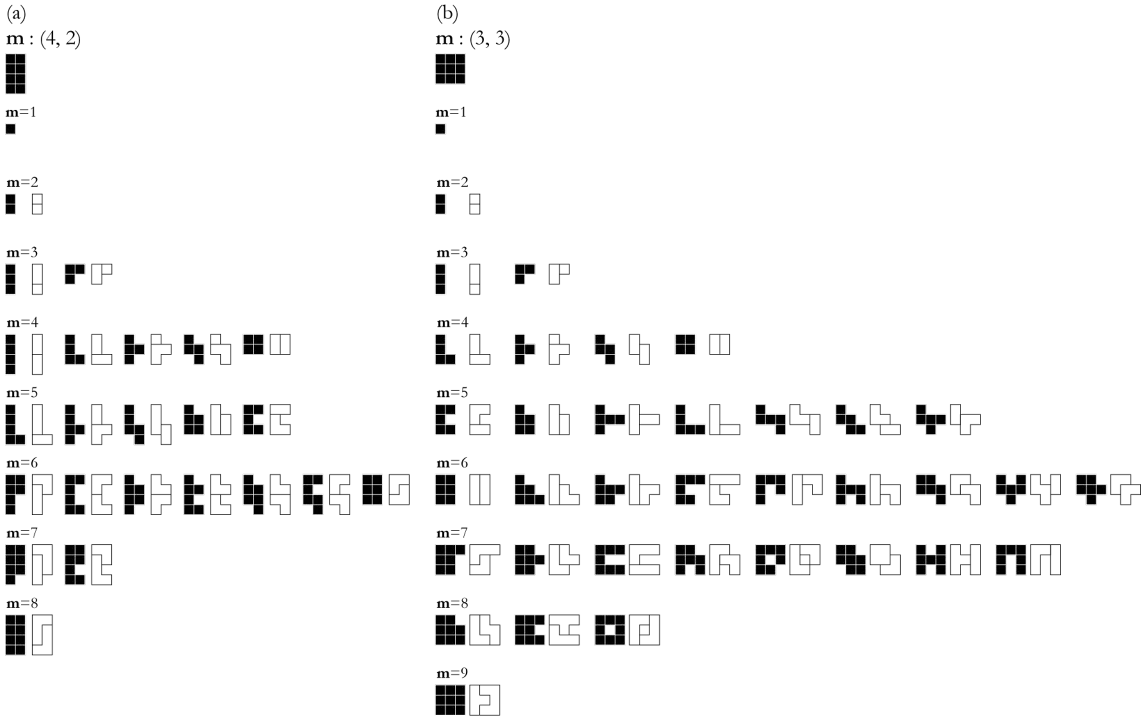


Figure 28. Arrangements in (a) **m**:(4, 2) and (b) **m**:(3, 3) (left, in black), and some of their possible bi-part subdivisions using elements from a **m**:(2, 3) (right, in white).

forth. Nevertheless, any of these 24 or 36 possibilities could be composed by combinations of the previous **m**:(2, 3)—ultimately, if given no further limitations, any **m**:(*v*, *u*) could be reduced to a combination of a single module (Figure 28).

To assure a comparable, equitable principle, which would not significantly distort the *design system* principles, typological tests primarily focused in assessing the limits of combining **m**:(2, 3) shapes, and variations within relatable constraints. If limiting the possible shapes to these (10 in total, or 11 if including a single module shape), but using a larger **m**:(*v*, *u*), theoretically we can maintain the same typological principles. Yet, as we will later observe, different constraints arise—typological, constructive, legal, and so forth—as well as new possibilities of juxtaposing and/or connecting the different shapes.

Given that with bigger grids, shapes are more diverse (e.g. Figure 28), methodologically it can be useful to establish a shape notation to unambiguously clarify descriptions. Indeed, when increasing grid sizes, it is no longer feasible to label them in a shape suggestive fashion, as we have done under a **m**:(2, 3), with *L-shape*, *U-shape*, *T-shape*, and so forth. Indeed, when grid size increases, and shapes within get more complex, it is hard to keep track of what kind of shape is being addressed with this method, and it can easily be equivocal. Thus, for some purposes, it is necessary to have a shape notation, or codification procedure of some sort.

5.4.2 DEFINITIONS AND FORMALISMS OF MODULAR SHAPES

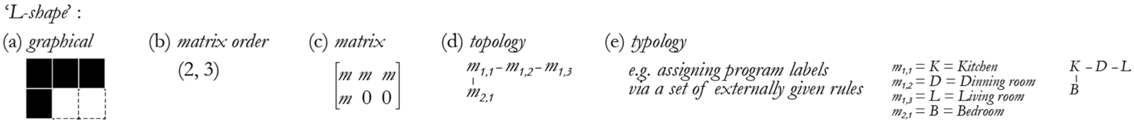


Figure 29. Illustrating a matrix formalism through the description of a *L-shape*, and unfolding to topological and typological values, where in (d) are added connections to establish a topological path, and in (e) topology is labeled with typological values via a set of externally given base program rules. The subscript notation for *m*—in (d) and (e)— follows the conventional matrix notation, where in the comma separated values the first indicates row and the second the column position in the matrix.

Existing mathematical notation provides the tools to disambiguate shape labelling (Figure 29). With it, we could describe an *L-shape* through a matrix of order (2, 3), with the values and criteria of the matrix order corresponding to what we have been describing for grid purposes—i.e. comma separated values first indicating the number of rows and then of columns using positive integer values. Following this formalism, the matrix order can be extended as far as necessary, and in it straightforwardly acknowledge the module's positions. From there, we may establish a direct bond between the topology and the typology, that is, in assigning label values to each module, which establish the guidelines or rules of their devising intents, for instance in functional or programmatic description, and so forth. Although of far greater range, the method can be regarded as essentially analogous to the graphical representation. It thus shares some of its qualities, but also some of its limitations, particularly when attempting to denote it compactly, such as we do with an *L-shape*. Thus, a different descriptive method may be necessary to complement the matrix description.

As in any modular construction, we must start by defining the modular scope. In our devised descriptive method, a *shape* is a discrete set of one or more modules within a tridimensional grid of a modular scope **s**, respectively with (u, v, w) relative coordinates, and through which is possible to establish at least one continuous path, using orthogonal (i.e. horizontally/vertically through *uv*, *uw* or *vw*) connections (Figure 30). In the higher **s+1** scope, the coordinates will be absolute in respect to a modular multi-shape assembly referential, that we can name (x, y, z). Alternatively, for the benefit of congruence, we can name each respectively (u_s, v_s, w_s) and (u_{s+1}, v_{s+1}, w_{s+1}), or any of these generically

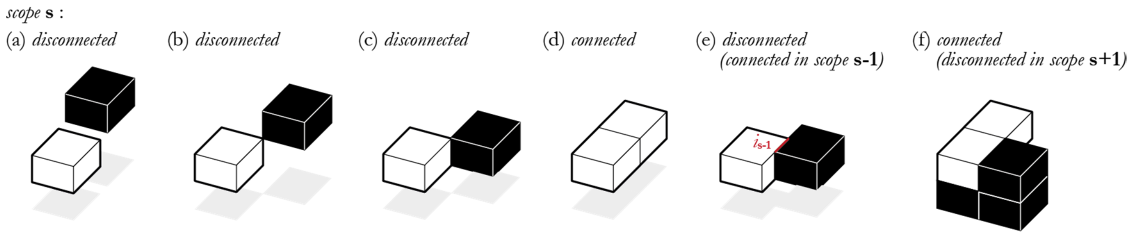


Figure 30. Illustration of a modular shape definition via connectedness, in which in each case a discrete shape is defined by a continuous color in a given modular rank. In (e), the expression i_{s-1} stands for a modularly incremented distance (i) of a **s-1** scope, which is thus analogous with connectedness features in (f). In the AHP, the i_{s-1} would be a modular denominator, corresponding to a dimension of the modular unit **u** of 0,60×0,60m.

by (u_{s+i}, v_{s+i}, w_{s+i}), with **i** corresponding to any integer value (positive, negative or null), with the higher scope corresponding to the absolute referential in the considered modular system. In our design, the **m** description equivalates to an **s**, and the **u** to an **s-1**.

As shown in Table 8, and illustrated in Figure 31, we have devised a compact shape descriptive formalism which can be used complementarily to the powerful matrix description. In it, from left to right, we can first read the row, i.e. the position on the *v* axis. Then, in subscript, the columns that occur in that row, i.e. the positions in the *u* axis. Finally, in superscript, the *level* (*w*) in which these are contained, i.e. the positions on the *w* axis. All *u*, *v* or *w* values are integers, but with a difference regarding *w*. The starting *w* is conventionally 0 (as for *level 0*) and can go either negative or positive. Conversely, *u* or *v* are positive integers, since they refer to countable objects (there are no negative or null modules). The full notation criteria are shown in Table 8 and illustrated in Figure 31.

To simplify, when there is only one *level* (i.e. one *w* unit) considered, or when it is irrelevant for the analysis on whether *w* is implied, the corresponding notation can be suppressed (e.g. Figure 31d). When there is more than one option to make the shape notation, it may be best to privilege the most economical way—e.g. in Figure 31d, the $[1{:}2_{1:2}]$ notation could have been written longer in $[1_{1:2}2_{1:2}]$ or as an array of a single module, i.e. $^{A}2_{2}{:}[1_{1}]$. Anyhow, formal option should be to use what is most convenient in each case, which can also be privileging consistency, rather than economy. There are several ways this notation could be presented without loss of content. For instance, instead of using subscripts and superscripts, we could have used parenthesis, slashes, or other forms to distinguish the different elements—e.g. writing [(1/1:2)(2/1)]w instead of $[1_{1:2}2_{1}]^{w}$. However, we found this way economical, both in terms of the number of characters and line length used, and that it provided a relatively better readability, particularly if making use of larger expressions, (e.g. Figure 31c in the *b•c* description).

With this formalism, we can describe multiple modular shape stages: (a) a shape relatively, i.e. through its inner modular-grid features based on its *u*, *v* coordinates, distributed in one or more *w* levels of a modular scope **s** system; (b) a shape absolutely, e.g. through *x*, *y* and *z* coordinates of a multi-shape, higher scope **s+1** modular-grid system; (c) a shape relatively plus a translation operation (*T*) from

(a) shape-modules cases	(b) notation e.g.	(c) description of notation e.g.
Isolated	$s_a=[v_u]^w$	*row* v, *column* u, *level* w
pair of isolated columns' value	$s_b=[v_{g,h}]^w$	*row* v, *columns* g *and* h, *level* w
interval of consecutive columns' value	$[v_{g:h}]^w$	*row* v, *columns from* g *to* h, *level* w
interval of consecutive and isolated columns' value	$[v_{g:h,u}]^w$	*row* v, *columns from* g *to* h *and column* u, *level* w
in two rows	$[v_u p_{g:u}]^w$	*row* v, *column* u, *and row* p, *columns from* g *to* u, *level* w
isolated equal rows' value	$[v,p_u]^w$	*row* v and p, *column* u, *level* w
interval of consecutive equal rows' value	$[v{:}z_u]^w$	*from row* v *to* z, *column* u, *level* w
multi-level shape	$[v_u p_{g:u}]^w,[v_u]^{w+1}, \ldots$	*row* v, *column* u, *and row* p, *columns from* g *to* u, *level* w, *and row* v, *columns from* a *to* u, *level* w+1
isolated equal levels' value	$[v_u]^{w,w+i}$	*row* v, *column* u, *in levels w and w+i*
interval of consecutive equal levels' value	$[v_u]^{w:w+i}$	*row* v, *column* u, *in levels w and w+i*
translation T *from a referential* x, y, z	$T_a{:}s_a={}^{T}y_x{}^{z}{:}[v_u]^w$	*shape* a, *translated* T *from a higher scope* x, y, z *referential*
translation T *in vector form*	$T_a{:}s_a=\mathbf{v}{:}[v_u]^w$	*shape* a, *translated with a vector* **v**
array distribution m, n, o *of a shape*	$A_a{:}s_a={}^{A}m_n{}^{o}{:}[v_u]^w$	*shape* a, *repeated in array* A *with* m, n, o *instances*
two combined shapes	$s_a \bullet s_b= [v_u]^w \bullet [v_{r,u}]^w$	*shape* a *and shape* b

Table 8. Shape notation.

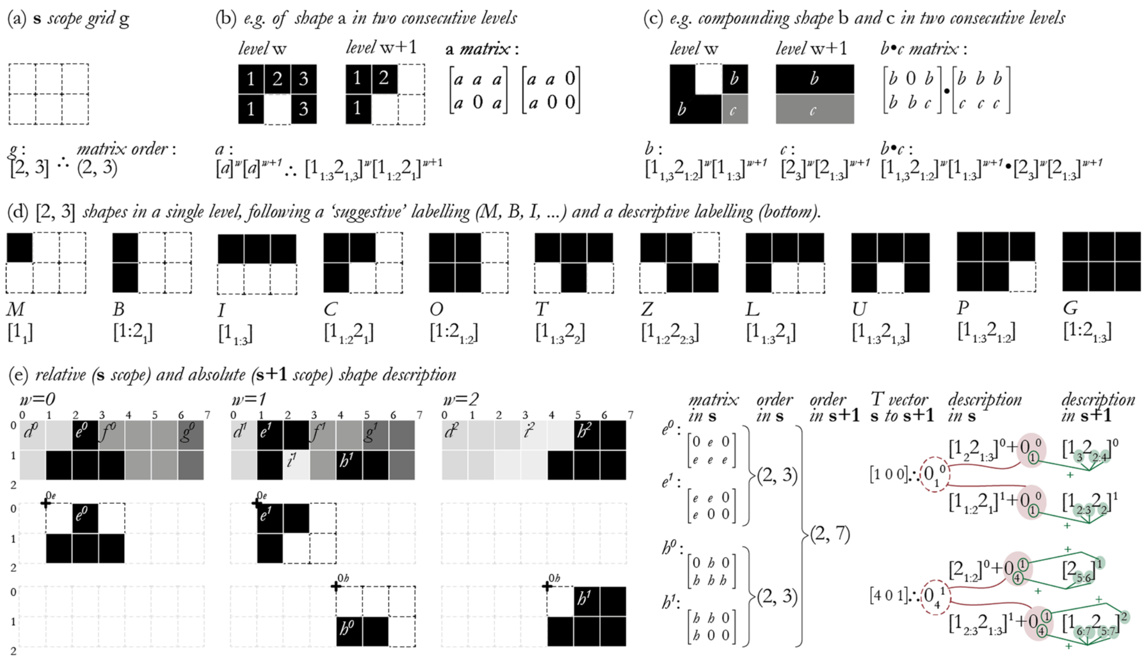


Figure 31. Notation application examples in a **s**:(2, 3) grid (a, b, c, and d) and in an expanded **s+1**:(2, 7) grid.

a given origin $o_{\mathbf{s+1}}$ of a multi-shape system; (d) higher/lower-scope shape-compounding of any of the former in any **s+i** (with **i** as any positive or negative integer), algebraically enabling modularly parametrized grids and/or an array of multi-shapes with different modular scales.

To complete the picture of operators, aside a *T* and an *A*, we could include a mirror (*M*) or rotation (*R*) operator (Figure 32). Anyhow, for this we could generalize *T* as special displacement cases of *R*, either as a theoretical *R* where the axis of rotation recedes to infinity, or as two consecutive *R* operations over axis of rotation at finite distances and with 60º magnitude and inverse directions each (Figure 32b). Moreover, as implied in our modular rationale, *M* can simply be the result of swapping the locations of one or more modules within a shape, i.e. making exclusive use of *T* operations.

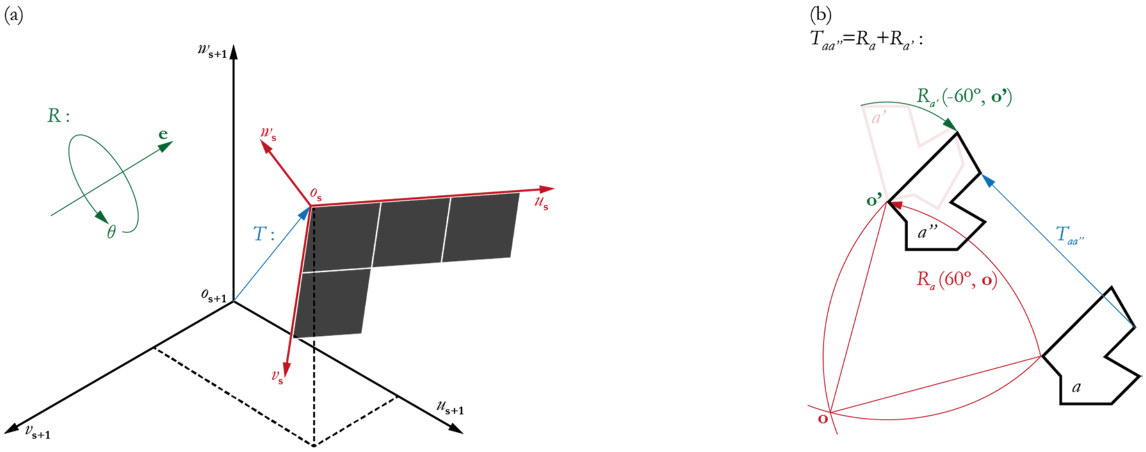


Figure 32. Illustration of a R (rotation) and T (translation) operations. In (a) R uses a simplified $\theta\mathbf{e}$ formalism, describing a unit vector **e** (indicating the direction of an axis of rotation) and an angle θ (describing the magnitude of the rotation about the axis) to be applied in the relative origin o_s of a shape. In (b) is shown T as a special case of R.

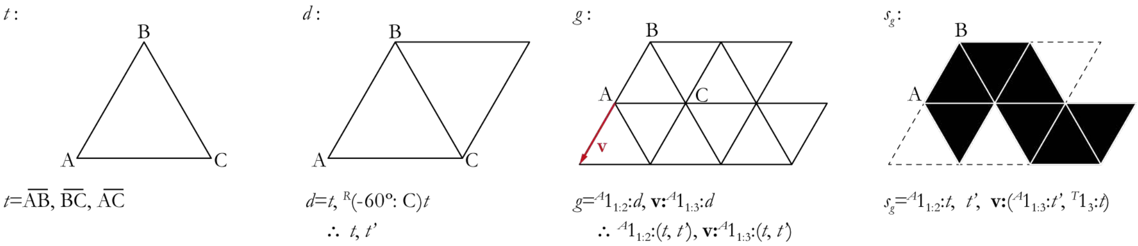


Figure 33. Illustration of a simultaneous use of R, T and A (array) operators to form a triangle-based grid (g) and a triangle-based shape (s_g).

Although not developed in our case, R enables the tridimensional description of non-modular relations between different modular sets, or of modular elements that do not follow orthogonal connections as it occurs with triangular modules with tridimensional relations.

This notation may not be as intuitive as when describing shapes by labelling each with a resembling letter. It certainly is not as intuitive as simply illustrating them, as is notorious in the example of a triangular grid. Yet, it gains in clarity and precision, disambiguating the relative description of shapes, whether they are simpler, or more intricate or complex, as well as their positioning within a considered multi-shape referential. Whether using this formalism, or any other method, any clarification can be a positive contribute to an applicability, for instance to keep track, compare and account modular shape formations in digital aided developments. The latter are outside the direct scope of our work. To our concern, this is essentially a methodological insight on the potential of modular shape formation, and a resource to apply in the remaining descriptions that follow.

5.4.3 TACKLING DEPENDENCIES

The approach that was followed in the initial AHP design presents a considerable amount of different layout possibilities. This occurs both volumetrically, with the different shape combinations, but also internally, given that the structure and external envelope can be understood altogether as a sort of free void to be filled, with the internal walls able to cross different modules. While the latter entails a world of possibilities, it also hosts more spatial or constructive dependencies regarding a modular perspective. This can be a limitation for the potential of adaptability of a design, as well as for its ex-situ production potential.

We have thus addressed endogenous adaptability (internal changes) and exogenous adaptability (volumetric changes) aspects of the *design system*. We concluded that any main functional allocation should be discretized within a module, namely kitchen (*K*), bedroom (*B*), living room (*L*), and dining room (*D*). Thus, each would have to roughly correspond to a module, regardless any secondary functional allocation that could fit within, namely the toilets, stairs or storage spaces. Also, internal partitions defining secondary functional areas were no longer allowed to spatially belong to more than one module, and instead be clearly discretized within each module, as in Figure 35a, thus reducing dependencies. At most, these were tolerated in the modular threshold offset zone within certain conditions.

For this, the self-imposed offset criteria envisioned that it either must be added area to one functional space or to the other. The underlying principle is to avoid wasted interior space, by avoiding redundant internal walls that had been dimensionally calibrated as external walls given the structural constraints. Anyhow, in more detailed design stages, these considerations must consider needs for infrastructural space. It should in all cases be present the concern in keeping the integrity of the modular design, that is, insofar as maintaining the original alignments as much as possible (Figure 34). In a modularity context, whether with this or other criteria, this is a core matter since it addresses the interface component of the modular design.

The modular optimization conducted to internal partitions to be contained within modules, or at most to occur with variations within in their threshold offset limits, maximizing their constructive independence. Moreover, since the most demanding spaces in terms of area allocation (e.g. a living room), could, in their least, be contained within the modules' dimensions, such meant that, in principle, the idea would be typologically feasible in every case. Alongside with restricting the constructive dependencies between different modules, clarifying their interfaces via offset criteria, it rose a related idea of establishing the vertical circulation areas to occupy approximately half module width. The symmetrical layout meant that the staircase could be placed in equal terms on two different positions in a module, and with it any functional space that shared the same module, such as a fully accessible toilet if required (Figure 35).

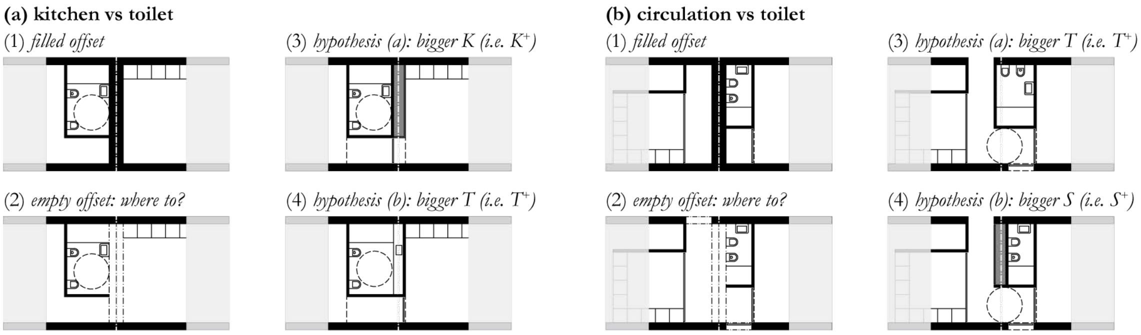


Figure 34. Two examples of addressing modules' interface, with application of threshold offset criteria, including some possible variations.

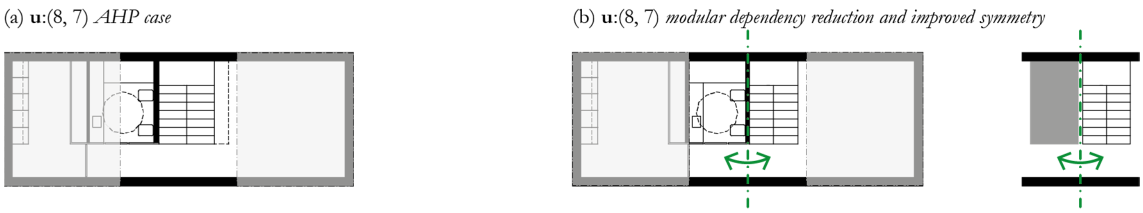


Figure 35. Modular dependency reduction and improved symmetry in relation to the initial AHP design.

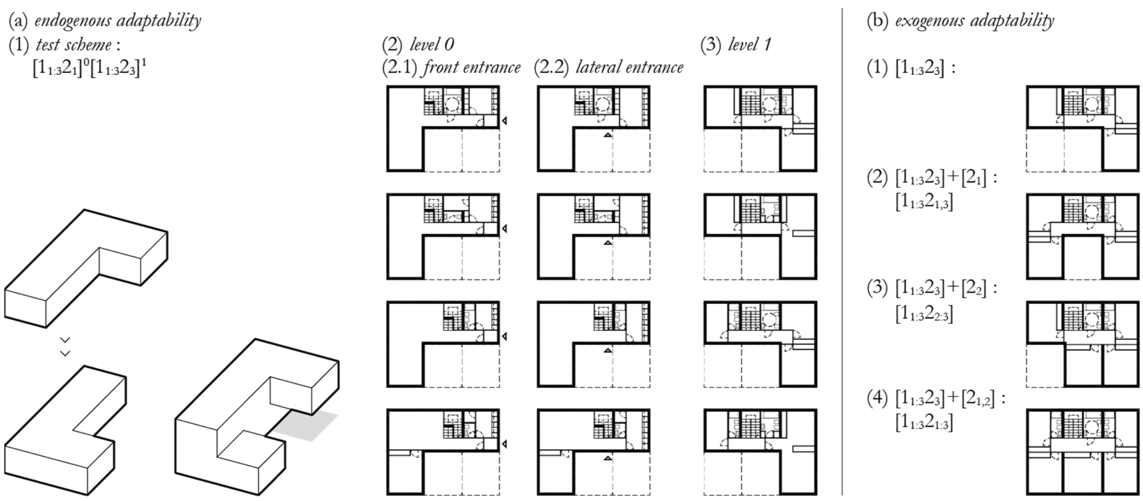


Figure 36. Examples of (a) endogenous adaptability with typological variations from two symmetrical $[1_{1:3}2_1]$ shapes, and (b) exogenous adaptability from a $[1_{1:3}2_1]$ base shape.

This simple tweaking has increased the module's combinatorial possibilities, while it entailed a simplification of the constructive principles. Concurrently, it contributed to enhance the endogenous and the exogenous adaptability potential of the *design system*, as it can be verified with the examples in Figure 36.

To validate the endogenous adaptability (Figure 36a), as a case-study, we used the most common 3-bedroom typology, set in two symmetrical [$1_{1:3}2_1$] shapes in both levels. In it was observed that it could be feasibly implemented an internal functional reorganization. In *level 1*, a bedroom can change into a private zone of a new enlarged suite, with plenty of closet area or with a private reading room. The space reserved for a fully accessible toilet in *level 0*, can be easily transformed into a smaller toilet with a contiguous closet/storage area or into an enlarged hall zone with an informal function. Also in *level 0*, an office/bedroom zone contiguous to the living room can easily be created by reserving a part of it, without significant loss to the living room area. The zone of the toilet/kitchen can also be easily changed into a smaller toilet plus storage space, or as an enlarged kitchen with plenty of dinning space, and so forth. That is, it can easily evolve from t_3 to t_2 or even t_3 to t_4 and vice-versa, with plenty possible configurations and without affecting the exterior of the building or its infrastructures. Additionally, there is a polyvalent quality to some of the house spaces, which easily allows interchangeability on functional allocation.

It can be argued that some of this potential endogenous adaptability occurs because areas are generous. Indeed, they are if compared with the legal minimum in Portugal. Nevertheless, these areas are not over the average that can be found in the Portuguese real-estate market[386]. Anyhow, if it can be true that it is harder to transform a smaller area, the issue does not end with the area argument alone, since other constraints also must be considered, namely the form factor, which interferes in the internal fit-out transformation potential, as well as its furnishing, not mentioning the infrastructural philosophy adopted, and so forth.

As to the exogenous adaptability (Figure 36b), again what was tested was primarily about the typological potential, and not so much the constructive aspects. Nonetheless, it should be technically feasible, contingent on the constructive principles in use, namely on the size/complexity of the components. As a matter of simplification, and easier comparison and explanation, a [$1_{1:3}2_1$] shape was again considered with a stabilized internal program. If one module of the **m**:(2, 3) is exclusively dedicated to entrance and/or vertical circulation and/or toilet area, it can be generically said that each added module conceptually corresponds to a bedroom unit. In that sense, two modules correspond to t_1, three to t_2, four to t_3, five to t_4, six to t_5. This is valid for a building in an isolated a plot, otherwise one of the modules must be kept free. Hence, from this assumption, and to ensure that every compartment would have contact with at least one facade wall to have proper light and ventilation, the maximum typology considered within this case was a t_4.

5.4.4 OUTLINING A MINIMUM COMBINABLE UNIT

The purpose of exploring junctions between two or more shapes follows the need of assessing how multi-shapes may behave, having in mind its modular optimization. By combining shapes, we set a spatial/formal frame where to allocate functional elements. This means that junctions cannot be made blindfolded and/or merely formally. Instead, they follow constraints that are both external, such as those derived from regulations, or internal/self-imposed, such as those resulting from a certain design philosophy, or from functional requirements. When conducting a new design exploration, the internal constraints will likely have to adapt to accommodate new developments, and new constraints may arise, all-in-all contributing to clarify the optimal limits of the study object.

As opposed to an independent **m**:(2, 3) derived shape, as it had occurred in the AHP, here we have begun to explore how many functioning shapes we could fit into this grid. In this case, it is primarily mandatory for the location of the vertical circulation within the grid to become flexible, as opposed to be locked in a central location of the **m**:(2, 3), as it was in the AHP. That may not necessarily be required in the least constrained detached scenario, where there is freedom of access to any module from every direction. However, in more constrained settings, this can be harder, or even impossible to achieve.

We have tested several scenarios for two level shapes within a **m**:(2, 3), starting by a combination of two, then three, and finally of four shapes. Eventually combinations with more elements would be possible. However, if growing in number of shapes within this or any other limited **m**:(*v*, *u*), they necessarily decrease in size, and thus the ratio between horizontal/vertical circulation areas and useful areas may lose efficiency. Moreover, if we have shapes formed by a one-to-one (i.e. 1-1) vertical correspondence—as it occurs when we have six shapes over two floors in a **m**:(2, 3), where each shape can only develop vertically—then we will have typologies which will be mostly dedicated to vertical circulation, with little room for anything else. Thus, for area economy purposes, as a minimum vertically developed shape, it makes sense to consider that, when a *level* has just one module, on the other *level* there must be at least two modules—i.e. a 1-2 configuration. In the latter, we can have a t_0 typology as shown in Figure 37, which thus illustrates a minimum two-*level* dwelling unit.

Observing the examples of minimum shapes in Figure 37, it is noticeable that, despite (d) and (e) cases are possible, they have much less available area for functional allocation since more is wasted in circulation due to the stairs positioning. From the same base module (a), entrance points can occur in all four orientations (*Left*, *Right*, *Front*, and *Back*), as long as a full accessible toilet is not required next to the stairs on the base module (4), given it is not possible to deploy it in all cases in the other level.

Despite some faults, if we would have further *levels* to develop vertically, using two modules in every *level* except for the base module, we could plausibly consider this scheme as viable in most cases. Nonetheless, any such application would be constrained by the feasibility of an access path to the

Figure 37. Example of four possible minimum shapes—(a)•(b), (a)•(c), (a)•(d), and (a)•(e)—over two levels, using the two different orientations, **m**:(2, 1) and **m**:(1, 2) given by the module's asymmetry by the **u**:(7, 8).

base module, which would be depending on the design of the multistory building in which the shape would be contained. Anyhow, since there are four possible entry directions and four possible development directions on a subsequent *level*, this kind of layout can be extremely versatile.

For illustration purposes, following the full occupation case in a two-*level* configuration, we have tested several combinations. We did not start directly by the arrangement of shapes, but by the arrangements of numbers of modules between any two *levels* (Table 9). These have in the least a base module, plus two on the other floor, or 1-2 configuration. From here we can derive multiple shape variants, of which we have illustrated only a part (Figure 38).

In the simplest case, of which there was no point to illustrate, to fill two **m**:(2, 3) levels we would have the entire space filled by a single shape, with a single arrangement possibility (i.e. a 6-6). Likewise, on the opposite end, reducing shapes to a 1-1, we would also have a single possibility, which nonetheless would be non-efficient given that half of the internal space would be occupied with circulation. However, as we have said, our minimum has been defined in a 1-2, and that is in fact the core conclusion, given that it is what enables the diversity of arrangements within this grid as well as it would in many other setups (Figure 39). However, we would have to use another configuration if modules' junction required to use direct stairs instead of 180º stairs. In that case the minimum configuration would have to be a 2-2 (Figure 40 (d) and (e)).

(1) number of shapes	(2) arrangements of numbers of modules between two *levels* (in left and right)						
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
2	{1-5 5-1}	{2-4 4-2}	{3-3 3-3}				
3	{2-2 2-2 2-2}	{2-4 2-1 2-1}	{2-3 2-2 2-1}	{3-1 2-2 1-3}	{3-2 2-1 1-3}	{3-1 2-3 1-2}	{3-3 2-1 1-2}
4	{1-2 1-2 1-2 1-2}	{1-2 1-2 1-2 2-1}	{1-2 1-2 2-1 2-1}				

Table 9. Possible arrangements of numbers of modules (base arrangements) in a **m**:(2,3), excluding the non-viable both extremes, the 6-6 and the 1-1 case. In each case left and right-hand sides of the hyphen separator are swappable without loss of generalization.

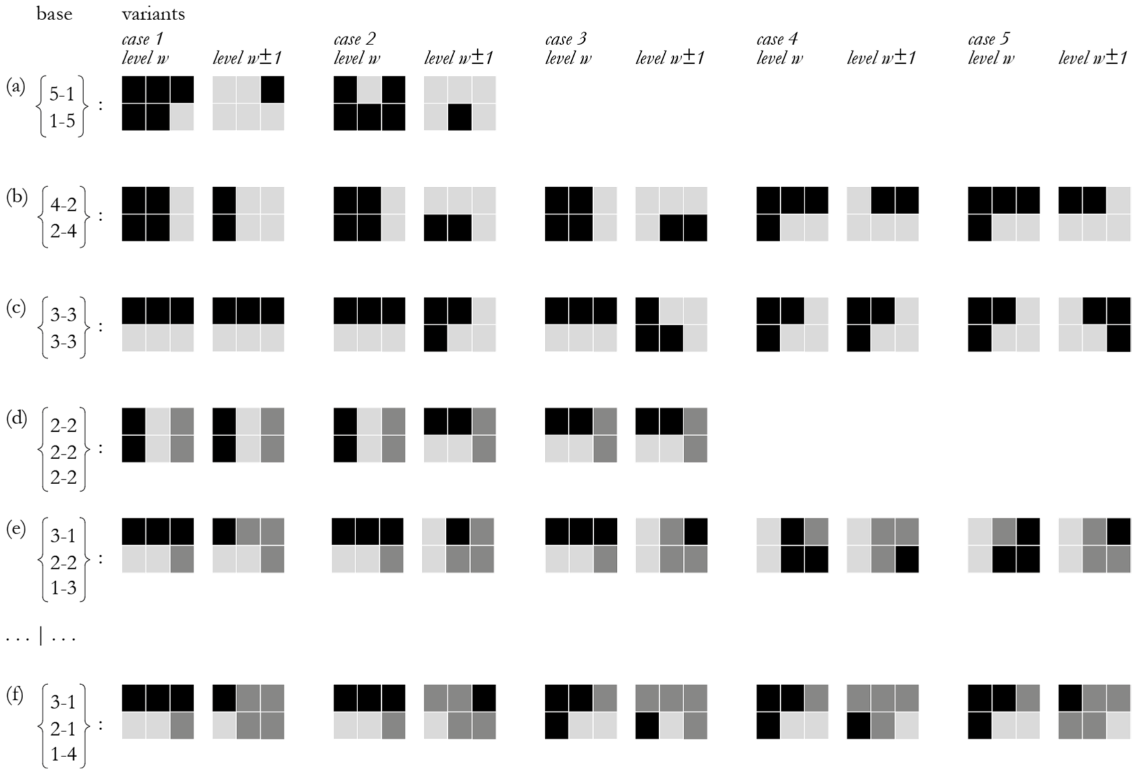


Figure 38. Illustration of all of the different combinations within a **m:**(2,3), in which shapes have the same total number of modules in each case, considering both *levels*—except (f), for comparison purposes. In (a), (b) and (c) are represented the two-shape cases, and in (d) and (e) the three-shape cases.

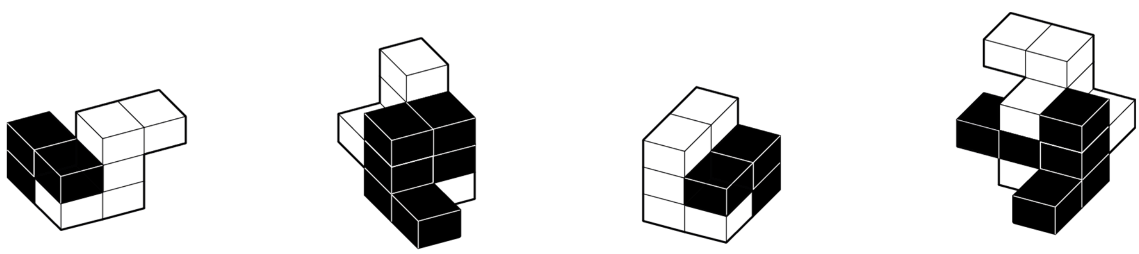


Figure 39. Examples of other formal possibilities using the 1-2 as core principle.

5.4.5 IMPROVING SYMMETRY AND BEYOND

We concluded that we could have significant gains in terms of combinatorial potential when making the vertical circulation module symmetrical. Without loss of generalization of shape formation and functional allocation on a **m** scope, we can further improve symmetry if instead of basing **m** on a **u**:(8, 7), we base it on a **u**:(8, 8). As consequence, the potential for different junctions between shapes is increased (Figure 40).

As we have seen earlier, we can substantially upgrade the original modules of a **u**:(8, 7) base by inputting a symmetrical configuration to the staircase positioning. However, as shown on Figure 40b, if we need to rotate the direction through which the 180º stairs are launched, we can no longer maintain the same principles. In the original design, these were oriented through the longer side. To allow modules to rotate while keeping the same design principles, we would have to change stairs' construction. That would imply losses on both economies of scale in modular construction, but most importantly, it would severely limit the stairs comfort and potential use, namely in terms of adaptability to disabled users' accessibility. Another vertical circulation alternative could be the direct stairs (Figure 40d and Figure 40e). Anyhow, this is a far less versatile solution, given that it implies more spatial dependencies—e.g. in Figure 41c and Figure 41d there is no other possible direction to launch it.

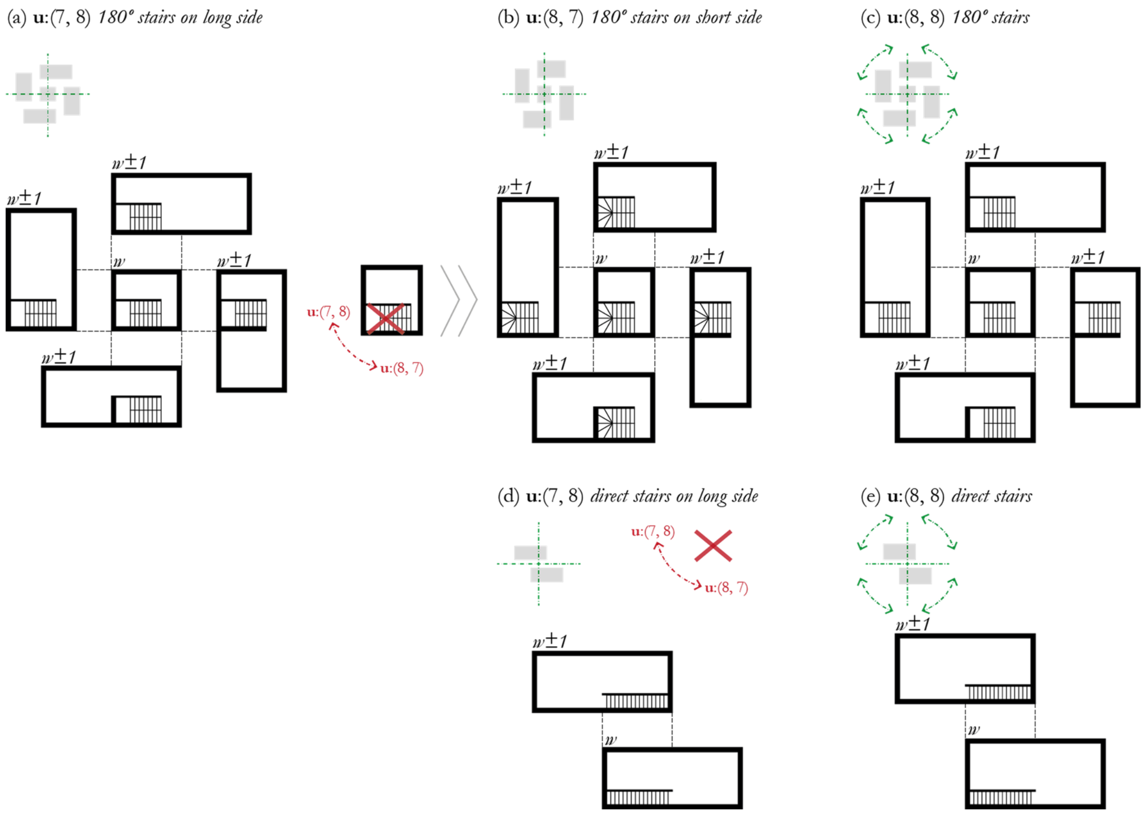


Figure 40. Increased symmetry by using **u**:(8, 8) modules.

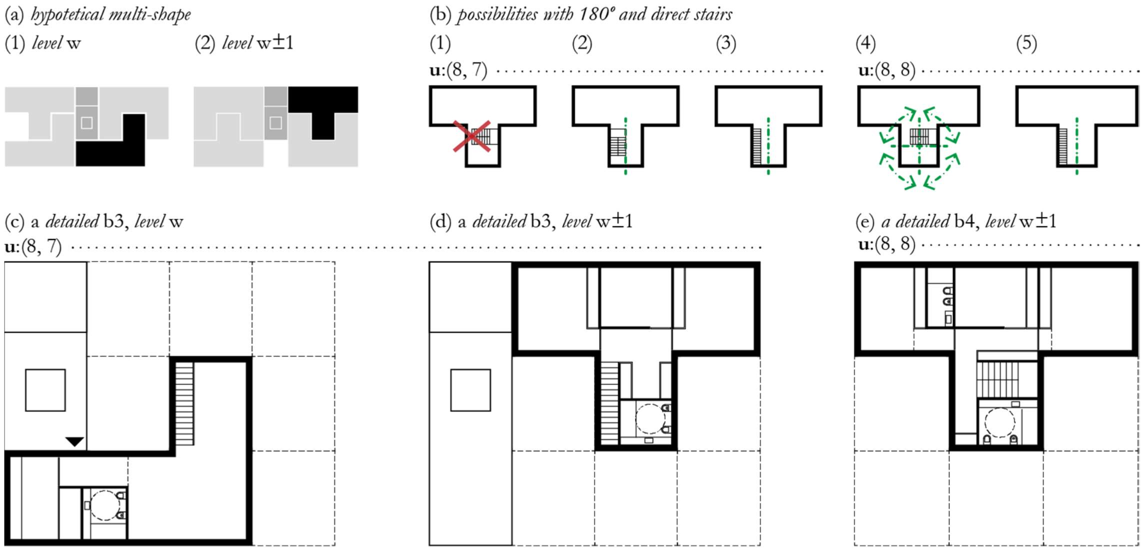


Figure 41. Detailed example of the increased symmetry implications.

By improving symmetry, using square modules with **u**:(8, 8) dimensions, we are also implicitly increasing modules' areas. However, that extra area can also be decisive to assure minimum spatial quality, particularly in more constrained cases, such as the allocation of a bedroom within a module that is simultaneously used for circulation purposes (Figure 41e). Indeed, if we compare bedrooms, in Figure 41d and Figure 41e, we observe that the added space enables a central bedroom with higher standards and also that it is possible to even have another toilet allocated if necessary. Indeed, the use of more area per module does not mean per se that area is being wasted. Instead, it can decisively contribute to improve spatial standards.

For future development of the modular design, we think that it makes sense to evolve towards compoundable smaller modules that may enable more varied outputs. As an example of how that might occur, in Figure 42 we show modules of three interrelated sizes. The smaller is what we can call of minimum functional unit, where we can allocate with ease most of the required functions in a house. When we double its size, we can either have a second function allocated under similar constraints, or we can extend the area of a functional space, which can particularly make sense in the case of a kitchen (*K*). We can extend the logic to when we triplicate the minimum unit size. As shown in Figure 42d, the threshold offset criteria clearly arises as an essential modular design device. Apparently, from what is shown in Figure 42e, this kind of three-module solution can lead to very diversified solutions. Intuitively, in the least it seems to have potential for a successful applicability in residential housing. This is ultimately due to its smaller grid. As we decrease modules' size, we increasingly may leave a 'block' appearance, and come closer to a continuum: an 8-bit *space-invader* will never be as refined as it would in 32-bit.

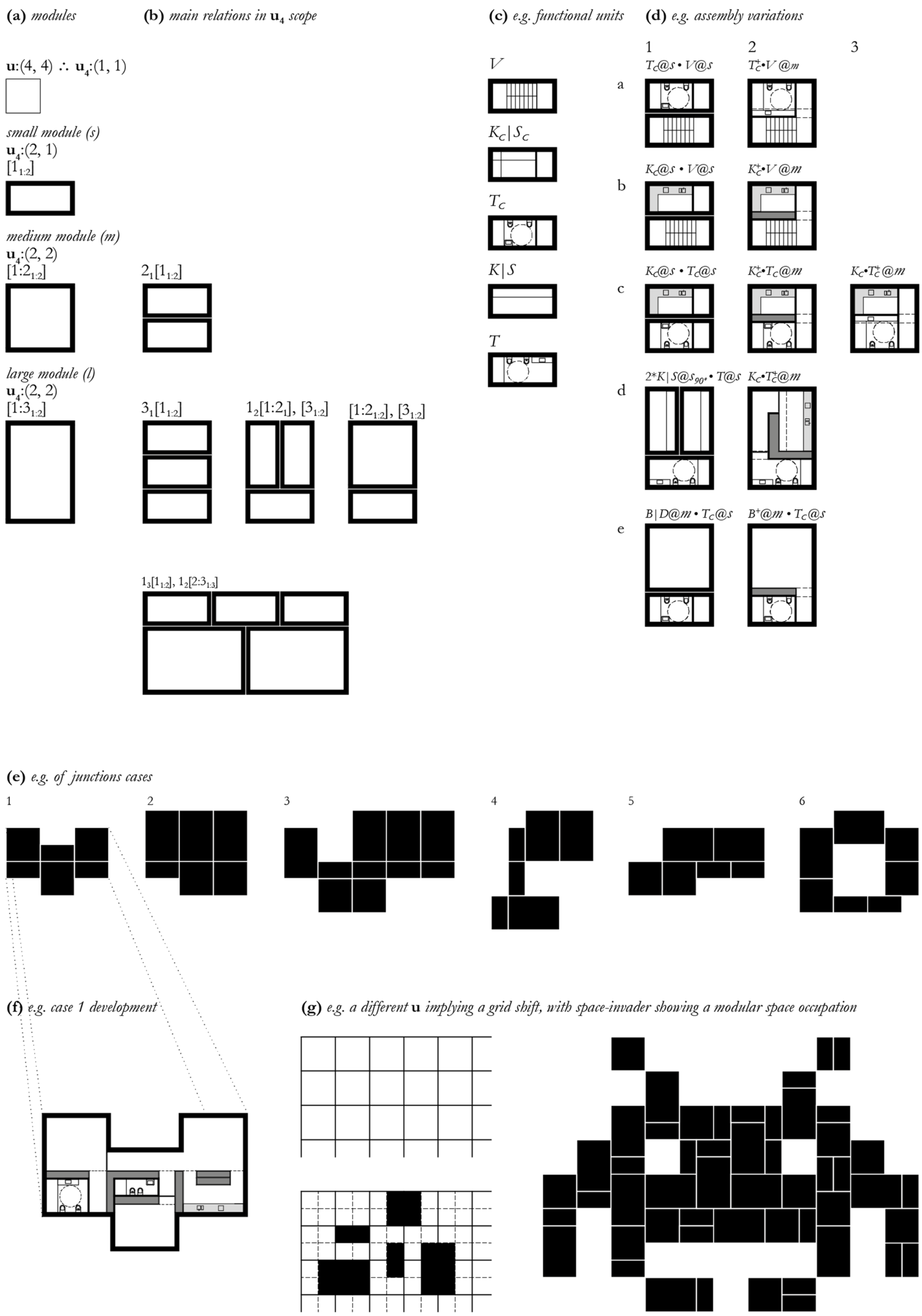


Figure 42. Illustration of what future developments may look like, using smaller modules as modular compounding base for more intricate and varied outputs.

5.4.6 LIGHT AND VENTILATION CONSTRAINTS

In the original AHP design, shape junctions formed a single dwelling unit. Its **m**:(2, 3) grid was strategically devised for all modules to benefit of at least a façade with direct contact with the exterior for light and ventilation (*d*). However, when expanding grid dimensions, some modules will no longer be able to have *d*, except in roof openings when no other modules are positioned above. Disregarding the latter, and restricting to horizontal junctions, when using single row shapes, such as the $[1_{1:3}]$, we can combine more than a dwelling unit within a **m**:(2, 3) grid. However, there are only three of those single row shapes derived from this grid—the $[1_1]$, $[1_{1:2}]$, and $[1_{1:3}]$—which limits potential horizontal arrangements. Nevertheless, as we have earlier elaborated, working from limited scenarios can also provide a useful insight in the formulation of the design's modularity principles. On the other hand, to do it with two-row shapes or bigger, such as the $[1_{1:3}2_1]$, the initial grid needs to be extended to at least **m**:(3, 3) dimensions.

As depicted in Figure 43, using an **m**:(3, 3) configuration, we tested the fullest occupation scenario in diverse urban settings. Working from a full occupation scenario, it can be assured that less intensive setups, with shapes with less modules, can too function if given similar constraints. Finally, following the purpose of testing junctions, the shapes should overlap somehow, that is, they could not be discretized in relation to one another in terms of their grid positioning, otherwise that would be equivalent of considering them autonomously with no junction function. As a secondary consequence, the combination of these rules implied a symmetrical configuration of the typologies in tridimensional space. The exercise eventually allowed to extract some previously unnoticed aspects, that are related with the maximum number of feasible consecutive modules and their spatial relations regarding *d*.

In these **m**:(3, 3) grid circumstances, the most limited scenario (Figure 43c) is where the double dwelling blocks are in an attached urban setting, meaning there is only one free façade facing the exterior where it is possible for d_1 or d_2 to occur. In this case, it was verified that a void must be left open in the center of the **m**:(3, 3) grid, functioning as an interior patio, allowing *d*. In this circumstances, where only the center modules are left free, there are only two possible **m**:(3, 3) arrangements. One uses a $[1_{1:3}]$ and a $[1_{1:3}2_{1,3}]$ combined, while the other uses $[1_{1:3}2_1]$ shapes with different rotations ((4) and (5) in Figure 43c).

As to the second most constrained case (Figure 43b), the modules can be feasibly distributed to occupy the entire grid space. Unlike in the previous scenario, in this case, with full occupation there was no need to release the center module of the equation. In this circumstances, the feasible junctions are the $[1_{1:3}2_{2:3}]$•$[1_{1:3}2_3]$ and the $[1_{1:3}2_{1:3}]$•$[1_{1:3}]$. Finally, as to the least constrained scenario, in a detached setup (Figure 43a), it is possible to combine both the $[1_{1:3}2_{1,3}]$•$[1_{1:3}2_2]$, the $[1_{1:3}2_{2:3}]$•$[1_{1:3}2_3]$ and the $[1_{1:3}2_{1:3}]$•$[1_{1:3}]$.

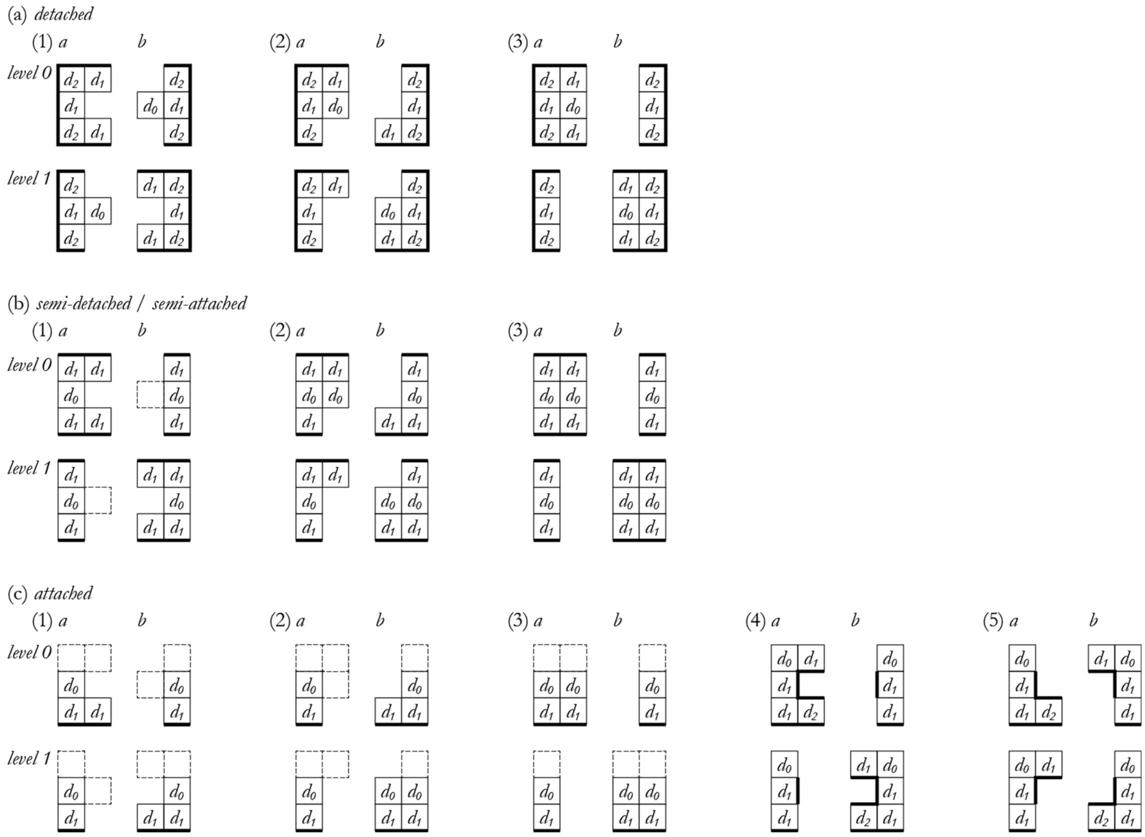


Figure 43. Maximum occupation cases of simple junctions in a double dwelling scenario (dwelling *a* and *b*) of **m**:(2, 3) shapes under different urban constraints: (a) detached, (b) semi-detached and/or semi-attached and (c) attached—d_0, d_1 and d_2 correspond to the number of walls with possible direct contact with exterior, dashed lines represent unfeasible modules and thick lines the d_n walls. Without loss of generalization, in this case we illustrate only examples with equal areas, and thus with symmetrical shapes. Numbers (1), (2) and (3) depart from the same base illustrated in the (a) respective cases. In (c), numbers (4) and (5) are illustrate the ways out of the *d* induced constraints with a void central module. In thick lines are eventual façades with *d* and in dashed line are impossibilities due to *d* constraints.

We can move to a generalization of the previous observations when questioning the limits of joining consecutive modules in terms of their least as possible relation with their d_1 or d_2 conditions. The rationale thus must leave the **m**:(2, 3) derived shapes and consider the modules in a more abstract sense. For this, considerations must depart from external constraints, namely in legal aspects determining the minimum salubrity conditions. In that respect, we based our developments on the Portuguese legislation, that defines that when a room area is greater than or equal to 15m², the depth must be smaller than twice the width, except when the two opposite walls further apart have openings, notwithstanding that it must be possible to inscribe within a circle of diameter with no less than 2,70m. From here, the maximum feasible linear shape—i.e. of a **m**:(1, *u*) kind—satisfying our modular conditions is a four-module shape (Figure 44).

Disregarding legal considerations, it would still make sense to integrate this kind of proportion constraints in practical terms, since it becomes a very difficult exercise to allocate main functional areas requiring *d* when too many modules do not have a single *d*. The principle is sustained in a **m**:(1, *u*) grid, but we can generalize it to other grids. So, consider a **m**:(*v*, *u*) grid, where both *u* and *v* are positive

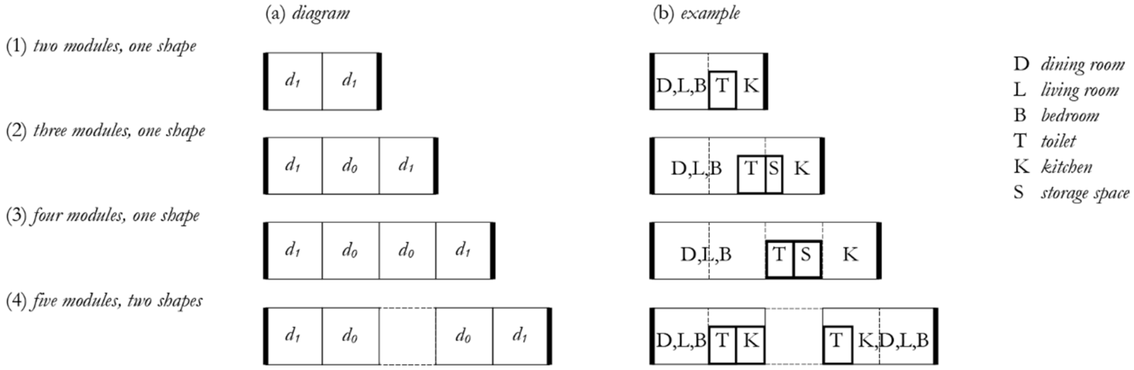


Figure 44. Linear limits given *d* constraints.

integers, and $u \geq v$, and that we incrementally increase u and v a unitary step at a time. In these conditions, we conclude that when both values are simultaneously bigger than 4, that it becomes extremely hard (most likely impossible), to attribute a functionality to certain spaces within a dwelling, since these cannot benefit from at least a d_1. In this respect, we could eventually overcome this proportion constraint if we considered aggregation of pairs of modules. However, in practice this would mean that spaces were being set off scale, perhaps solving a problem, but creating spatial imbalances. Particularly, we would be going against the spatial-dimensional characteristics of the *design system* as it was conceived, and probably we would have to reconsider it deeply. From here we conclude that the maximum feasible grid for a single dwelling theoretically is **m**:(4, u), with $u \leq 4$.

Most modern housing examples rarely, if ever, reach these theoretical limits. Indeed, we conjecture that in general most grids, as so considered from the observation of spaces of primary functional attribution, present a **m**:(2, u) configuration, or at most a **m**:(3, u) configuration. In older examples, we can find deeper typologies, particularly in dense urban scenarios, that may attain **m**:(4, u) dimensions, but rarely more, and if so with skylights included, and anyhow not fulfilling modern requirements.

From a sustainability point of view, the relation between external surface areas and internal volume/area must not be overlooked when combining different shapes. As this relation increases, it also augments the potential for *d* exchanges. These may be desirable from certain perspectives, e.g. aesthetically or by contributing for a saner spatial environment. However, these may also pose more constructive issues—e.g. water-tightness, breathability/air-tightness, and so forth. Thus, they potentially have more construction risk factors and more costs associated—e.g. internal partitions within a larger volume are cheaper than building an equivalent number of external walls. Moreover, energetically it is a known fact that the more compactness in a building—understood as the least degree of external surface in relation to interior volume, which is optimal in a sphere—the more the interior volume will theoretically be protected from unwanted energy transfers.

5.4.7 THEORETICAL GRID CONSTRAINTS

There are infinite possibilities to establish grids and shapes within these, as starting from just one shape-module $[1_1]$ in a **m**:(1, 1) grid, we could reach a shape such as $[1{:}v_{1:u}]^{0:w}$ in a **m**:(*v*, *u*) grid. Nonetheless, there are limitations that are related with factors such as *d*, as well as economy or feasibility, that constrain the maximum acceptable volume dimensions.

In a $[1_1]$ shape, the four façades and the roof can be opened. When it gets to a $[1_{1:2}]$, only 6 facades out of 8 possible sides are available, and in a $[1_{1:3}]$ there are 8 out of 12, and so forth. In the most basic case, where we have a shape (*s*) of the size of the module (*m*) there are 4 total (*t*) façades, each corresponding to a possibility of direct light or ventilation (*d*). However, when growing in grid size and dimensions it may be useful to assess these figures in a clarified form, as presented in the expressions bellow (Figure 45).

	expression for 3D (*u*, *v*, *w*), 2D (*u*, *v*, 1), or 1D (*u*, 1, 1; if *u*≥2)
(a) modules (*m*)	$m_{uvw}=uvw$
(b) total sides (*t*)	$t_{uvw}=w(2uv+u+v)$
(c) *t* with 5th façade (t^5)	$t^5_{uvw}= w(2uv+u+v)+uv$
(d) *d* modules	$d_{uvw}=2w(u+v-2)$
(e) *d* sides	$d^s_{uvw}=2w(u+v)$
(f) *d* sides with 5th façade (d^5)	$d^{s5}_{uvw}=2w(u+v)+uv$
(g) side connections (*c*)	$c=t-d$
(h) side connections with 5th façade (c^5)	$c^5= t^5-d^5$

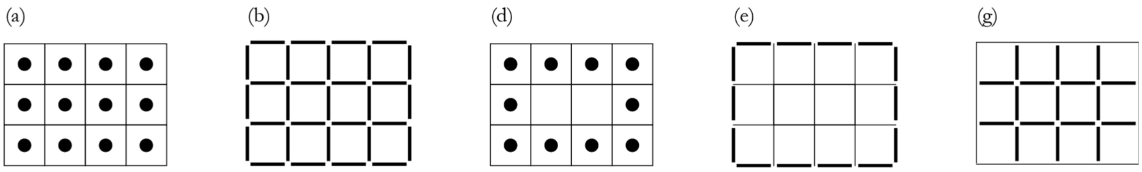


Figure 45. Expressions for assessment of different grid scenarios.

5.4.8 ESTABLISHING A MINIMUM CIRCULATION

In the first typological test of the system into a multi-story housing building, we have implied an expansion of the grid. In the example (Figure 46), we can observe a building design that uses a **m**:(3, 4), formed by **u**:(8, 7), analogous to dimensions used in the AHP. The expansion to a **m**:(3, 4) is due to a self-imposed constraint of trying to keep as much as possible the **m**:(2, 3) derived shapes, to which it must be added further modules to address common circulation functions within the building.

In the example, the two center modules are allocated to common circulation, and in *level 0* there is even a third module to provide access from the exterior to the central circulation area. All the shapes are wrapped around it, which means that all their modules can have a *d* connection. The exercise led to the $[1_{1:3}2_13_{1:2}]^0$ shape (orange diagram) that already differed from the **m**:(2, 3) derived shapes, using instead a **m**:(3, 3) grid. That could have been overcome by dividing that shape in two smaller

Figure 46. Illustration of a basic case of multi-story adaptation, where it was necessary to add an exception to the **m:**(2,3) shapes in *level 0*.

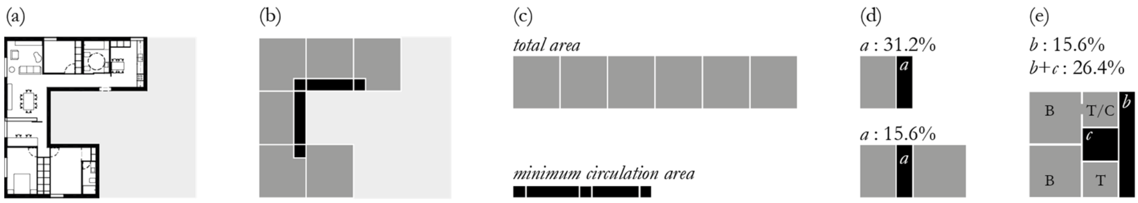


Figure 47. Unwrapping minimum circulation area in (a), (b) and (c), and circulation schematics in (d) and (e).

ones, in a $[1_{1:3}2_1]^0 \bullet [3_{1:2}]^0$, $[1_{2:3}]^0 \bullet [1_1 2_1 3_{1:2}]^0$ or $[1_{1:3}]^0 \bullet [2_1 3_{1:2}]^0$, but option was to assume a bigger typology so to test additional circulation issues.

Given the characteristics of this case, in each level the shapes could be, so to say, unwrapped to form a linear shape with the same topological characteristics in terms of their relation with the main circulation areas within (Figure 47). If we generalize the procedure, we can say that the main circulation areas correspond to the minimum circulation area, that is, the least area that allows access all main functional areas within a dwelling shape (kitchen, living room, dining room, bedrooms). This does not need to be explicitly established, such as in a corridor space. Instead, it can be implicit within a space, such as when crossing a living room to access a bedroom, just as in the second row of the shape in the example (Figure 47a). Whether or not explicit, a minimum circulation can be defined as a derivative of the minimum legal width established for corridor space developed across a definable length. In the actual design development, we have considered two types of horizontal circulation. One with net width of 1.1m, and the other, for hall areas, with a net width of 1.5m to allow wheelchair accessibility. However, for these methodological observations, to simplify area measurement purposes, we considered a gross area, with the measure from the external side of a module's 0.3m thick external wall, to the internal side of a 0.1m thick partition wall defining a corridor, for a total gross width of 1.5m and a net corridor width of 1.1m.

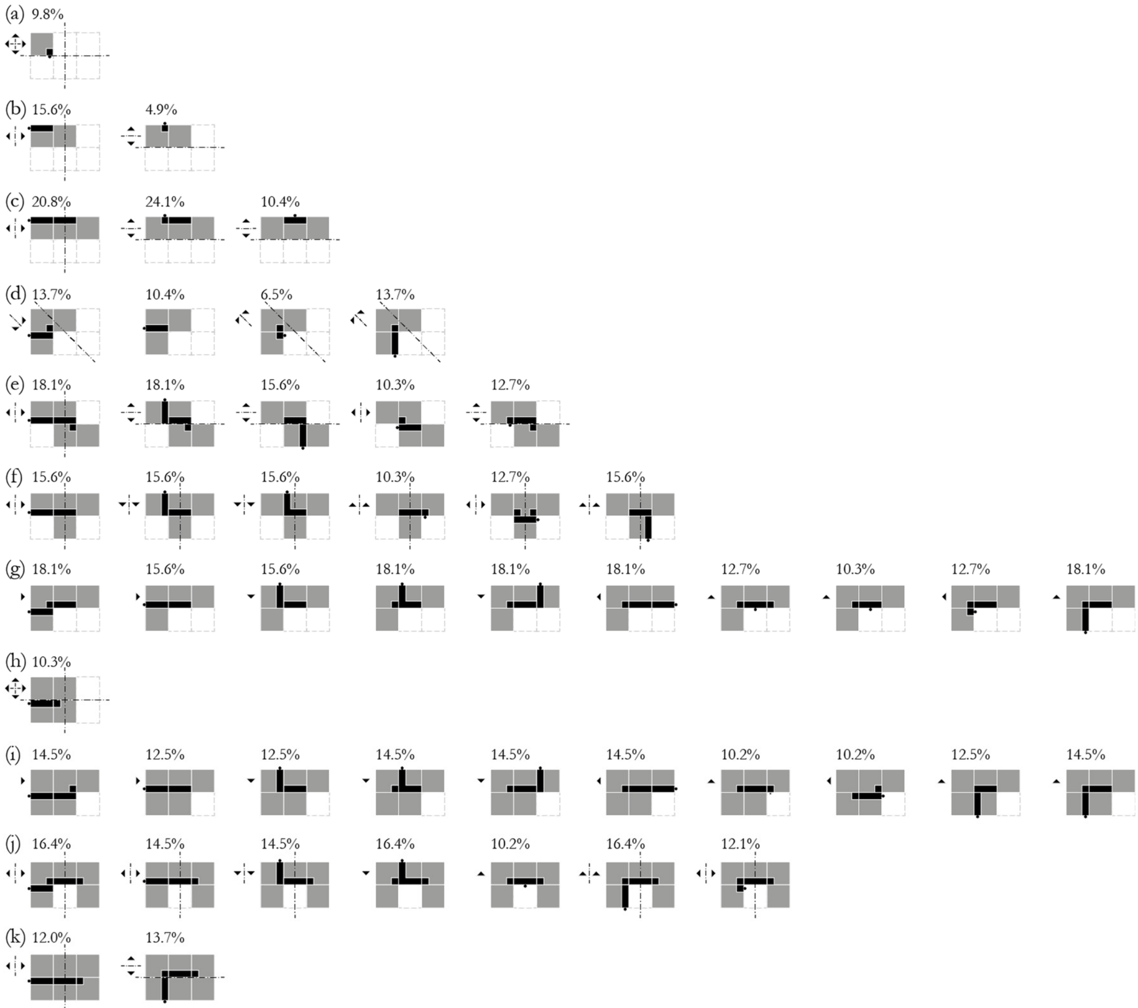


Figure 48. Minimum circulation in the enhanced AHP shapes.

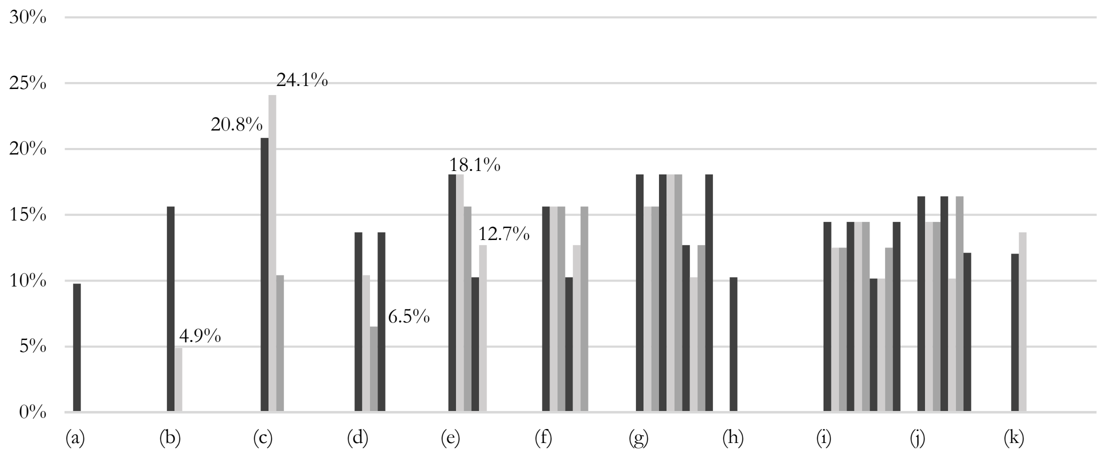


Figure 49. Percentages relation of the minimum circulation areas depicted in Figure 48.

As modules increase in size, the percentage of minimum circulation area decreases in proportion. However, if module's get bigger, as in Figure 47e, this may signify that the main circulation areas must unfold further to assure functionality, thus partially losing what would be the eventual gains. In our case, since each module roughly corresponds to a main functional area (one-to-one), this is not an issue (Figure 47d). Instead, from the one-to-one main functional allocation criteria, we can assume that in an optimized solution, each strip of minimum circulation area can serve two main function areas, thus reducing a theoretical 31.2% circulation percentage of the total area, to half (i.e. 15.6%) (Figure 47d).

If we apply the same methodology to **m**:(2, 3) shapes with **u**:(8, 8), we can observe some patterns that enlighten on what an acceptable minimum circulation area can be in relation with the total area of the modules (Figure 48). To assess it, we have tested every **m**:(2, 3) shapes in every possible entrance point, and distributed circulation zones across the diverse modules so that, from that point, a minimum path could be established to every module in each of the considered shapes. For simplification purposes, we have discarded the redundant shapes resulting from rotation or reflection, and instead opted for representing their reflection axis and notating their unfolding possibilities. In these circumstances, the results indicate that the minimum circulation mostly varies between around 10% and 18%. Of these, the largest share is located between around 12.5% and 15%. Further detailing may lower these values. Nonetheless, it can be conjectured their reasonability as a benchmark for reference of future developments (Figure 49).

5.4.9 FUNCTIONAL MAPPING STRATEGIES

As we increasingly clarify a design, we also become closer to a way of describing it algorithmically, that is, through a set of rules that given an input can produce an output. In the AHP, we have distributed the housing program upon a shape or combination of shapes, over which finer adjustments followed, in a roughly intuitive process. The starting point of that kind of approach is a formal desire. However, the underlying logic of an algorithmic description works inversely, that is, form is raised from the specification of an elementary structure of relations. These are ought to speak a logical language, which may be far from intuitive.

This raises the need to use a different approach. The way to do it seems to be from an architectural program starting point[387], in this case, a housing program, that is emanated from a brief. By defining a set of needs, transcribed in a system-constrained housing program, one can start on building the functional relations, independently of how intricate the design is. Final shape will be accomplished by successively building up these relations and will be terminated when all the housing program ele ments are fitted and specific formal issues are met. The logic is analogous to establishing a functional mapping to assess a product modularity. That is, we can outline the topological relations between different functional zones of a design but only insofar as they are in a scope that we can define, i.e. in the measure of the detailing we need or want to achieve.

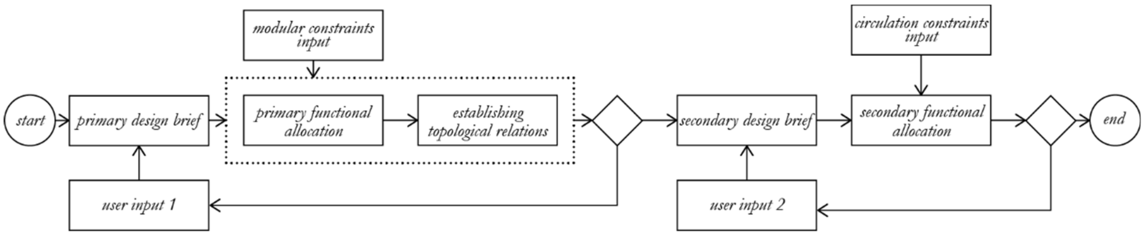


Figure 50. Algorithm development flowchart.

(a)		(b)		(c)	
primary allocation	**label**	**secondary allocation**	**label**	**circulation**	**label**
base module	*O*	supplement (storage, pantry, etc.)	*S*	horizontal circulation	*C*
kitchen	*K*	toilet	*T*	entrance hall space	*H*
bedroom	*B*	vertical circulation (stairs)	*V*		
living room	*L*	kitchen	*I*		
dining room	*D*				

Table 10. Functional labelling, to note that, given its specificity and range of different sizes (from full module to half module) the *Kitchen* is here considered both for primary (as *K*) and secondary (as *I*) allocation.

Our housing program constrains were developed to define the total number of admissible house compartments corresponding to a typology. We had previously clarified the modular scope, thus setting the *modular constraints input*. Then, from a user inputted brief, we can inform a two-fold *primary functional allocation* stage, with a part specifically for allocation and the other to establish *topological relations*. The output of this part is what informs shape assembly at a modular scope. If we want to detail it further, we need to proceed to the *secondary functional allocation*. The primary, secondary and circulation spaces that are considered for a housing program requirement within our *design system*, as well as their corresponding labels, are shown in Table 10.

Following a principle of modularity, we have defined that at a primary level we allocate a main functional space to each module *m* of an **m**:(2, 3) scope. In a subsequent step, secondary functional spaces are to be allocated within each of these main functional spaces. The secondary spaces *S* and *T*, are admissible within any primary space; *I* only admissible in *K*; and *V* only within *O* and only if a second level is required. The circulation spaces are not assignable, as they can be functionally defined by exclusion of the remaining primary and secondary functional allocation. Nevertheless, these have a key role in the definition of dimensional constraints that integrate both the primary and secondary functional spheres.

The total number of modules (*m*) required by a housing brief are defined with function to bedrooms in the house, here named with the expression t_b—standing for typology and number of bedrooms within. Following the methodology, rules for primary functional assignment can thus be defined (Table 11). With this set of rules, and given an inputted housing brief, it becomes possible to compute a primary *housing program* for functional assignment. Without loss of generalization, based on the previous set of rules, we have manually computed the results only for the simpler one level case house in a **m**:(2, 3) grid (Table 12).

1: For each *B* in t_B (except t_0), *m* must be at least

per *B*: *m*=1

per *K*: *m*=1

per *L*: *m*=1 except if *L* and *D* are not differentiated, then *m*(*L*+*D*)=1

per *D*: *m*=1 except if *L* and *D* are not differentiated, then *m*(*L*+*D*)=1

2: In terms of t_b definition, maximum number of *m* for each *B* in t_B comprehends a maximum of (except in t_0)

per *B*: *m*=2 meaning that for a certain of t_b there is only one master-bedroom considered (i.e. a *B* with *m*=2). If there is more than one master-bedroom with *m*=2, then t_b increases level to t_{b+1}, meaning there is only one master-bedroom for the *B* value of a t_b considered

per *K*: *m*=1

per *L*: *m*=1

per *L*: *m*=1

3: Minimum number of levels per house is 1

4: Maximum number of levels per house is 2

5: Per level, minimum *m*=2

6: Per level, maximum *m*=6

Table 11. Primary design brief assignment rules.

typology		number of modules	base program
t_0	t_0 *min*	2	(*O, K*)
	t_0	-	-
	t_0 *max*	3	(*O, K, B*)
t_1	t_1 *min*	3	(*O, K, B*)
	t_1	4	(*O, K, B, L*)
	t_1 *max*	5	(*O, K, B, L, D*)
t_2	t_2 *min*	4	(*O, K, B, B*)
	t_2	5	(*O, K, B, B, L*)
	t_2 *max*	6	(*O, K, B, B, L, D*)
t_3	t_3 *min*	5	(*O, K, B, B, B*)
	t_3	-	-
	t_3 *max*	6	(*O, K, B, B, B, L*)
t_4	t_4 *min*	6	(*O, K, B, B, B, B*)
	t_4	-	-
	t_4 *max*	-	-

Table 12. Primary housing program for a simple one level house, given Table 11 rules and a **m**:(2, 3) grid.

The subsequent step of program assignment is to use this information (Table 12) as input to its placement within modules, which calls for further rules defining the relative positioning of each functionally allocated module. The minimum t_b, the t_0 *min*, is also the base for allocation of further modules. Since modules will be positioned in a **m**:(2, 3) grid, the *O* is placed centrally in a [1_2] position, and the *K* contiguously in a [1_1] position. Remaining rules for this stage are shown in Figure 51. More than the specific rules that are being portrayed, the formalism that is applied serves the methodological purpose of showing how this kind rationale can be further implemented.

The formalism we have used is not associated with any specific programming language. Instead, it simply describes what would be the main lines for primary functional allocation purposes in modularly defined shapes under the devised design system. Using a similar formalism, we can transform an outputted matrix of this algorithm into a set of topological relations between main functions, which define the general circulation flows in the typology.

(a) operation	(b) rules			(c) notes
>>>start allocation				
K and O allocation	**1:**		$\varnothing \rightarrow \begin{bmatrix} K & O & m_1 \\ m_1 & m_1 & m_1 \end{bmatrix}$	create **m**:(2, 3) matrix with K and O assigned and the remaing positions are free
B(1) allocation	**2:**	if total B=1,	$\begin{bmatrix} & & \\ & & m_1 \end{bmatrix} \rightarrow \begin{bmatrix} & & \\ & & m_2 \end{bmatrix}$	skip *B(1) allocation* in the [2_3] position
	3:	in a random m_1,	$m_1 \rightarrow B$	pick up a random m_1 and convert into a B
	4:	if total $B \geq 2$,	$m_1 \rightarrow m_2$	skip m_1 to *B(2) allocation*
	5:	else if L=1,	$m_1 \rightarrow m_L$	skip m_1 to *L allocation*
	6:	and	$m_2 \rightarrow m_L$	skip m_2 to *L allocation*
	7:	else,	$m_1 \rightarrow 0$	end
B(2) allocation	**8:**	if $\begin{bmatrix} & & \\ B & & \end{bmatrix}$,	$\begin{bmatrix} & & \\ & & m_2 \end{bmatrix} \rightarrow \begin{bmatrix} & & \\ & & m_3 \end{bmatrix}$	when there is a B in the [2_1] position, skip *B(2) allocation* in the [2_3] position
	9:	in a random m_2,	$m_2 \rightarrow B$	pick up a random m_2 and convert into a B
	10:	if total $B \geq 3$,	$m_2 \rightarrow m_3$	skip to *B(3) allocation*
	11:	else if L=1,	$m_2 \rightarrow m_L$	skip to *L allocation*
	12:	else,	$m_2 \rightarrow 0$	end
B(3) allocation	**13:**	in a random m_3,	$m_3 \rightarrow B$	pick up a random m_3 and convert into a B
B(4) allocation	**14:**	if total B=4,	$m_3 \rightarrow B$	*B(4) allocation* in the remaining m_3 positions
	15:	else if L=1,	$m_3 \rightarrow m_L$	skip to *L allocation*
	16:	else ,	$m_3 \rightarrow 0$	end
L allocation	**17:**	if $\begin{bmatrix} & & m_L \\ B & m_L & m_L \end{bmatrix}$,	$\begin{bmatrix} & & \\ & & m_L \end{bmatrix} \rightarrow \begin{bmatrix} & & \\ & & 0 \end{bmatrix}$	when B is in [2_3] position and remaining m positions are free, skip *L allocation* in the [2_3] position
	18:		$\begin{bmatrix} & & \\ m_L & & \end{bmatrix} \rightarrow \begin{bmatrix} & & \\ m_D & & \end{bmatrix}$	skip L in the [2_1] position
	19:	in a random m_L,	$m_L \rightarrow L$	pick up a random m_L and convert into a L
	20:	if D=1,	$m_L \rightarrow m_D$	skip m_L to *D allocation*
	21:	else,	$m_L \rightarrow 0$	end
D allocation	**22:**		$\begin{bmatrix} & & \\ & & m_D \end{bmatrix} \rightarrow \begin{bmatrix} & & \\ & & 0 \end{bmatrix}$	skip D in the [2_3] position
	23:	in a random m_D,	$m_D \rightarrow D$	pick up a random m_D and convert into a D
	24:		$m_D \rightarrow 0$	end
>>>end allocation				

Figure 51. Algorithm structure to generate a random primary functional allocation from a given brief, for a generic case of a single level typology of an **m**:(2, 3) scope.

(a) operation	(b) rules		(c) notes
>>>start topology *connect all*	1:	$\begin{bmatrix} O \end{bmatrix} \rightarrow \begin{bmatrix} -O- \end{bmatrix}$	connect all elements of the first row and all the columns
connect D L	2:	$D\ L \rightarrow D\text{–}L$	horizontally connect D and L where laterally contiguous
remove useless connections	3:	$0- \rightarrow \varnothing$	remove connection established in *connect all* with a non allocated position on the left
	4:	$0 \rightarrow \varnothing$	remove connection established in *connect all* with a non allocated position on the front
	5:	$-0 \rightarrow \varnothing$	remove connection established in *connect all* with a non allocated position on the right
	6:	$0 \rightarrow \varnothing$	remove connection established in *connect all* with a non allocated position on the back
	7:	$\begin{bmatrix} \ \end{bmatrix} \rightarrow \varnothing$	remove brackets to end conversion to topological relations
>>>end topology			

Figure 52. Algorithm structure for conversion of functional allocation into topological relations for a simple case of a single level typology.

(a) allocation test case given the house program input (*O, K, B, B, L, D*)

$$\varnothing \overset{1:}{\Rightarrow} \begin{bmatrix} K & O & m_1 \\ m_1 & m_1 & m_1 \end{bmatrix} \overset{3:}{\Rightarrow} \begin{bmatrix} K & O & m_1 \\ m_1 & m_1 & B \end{bmatrix} \overset{4:}{\Rightarrow} \begin{bmatrix} K & O & m_2 \\ m_2 & m_2 & B \end{bmatrix} \overset{9:}{\Rightarrow} \begin{bmatrix} K & O & m_2 \\ m_2 & B & B \end{bmatrix} \overset{11:}{\Rightarrow} \begin{bmatrix} K & O & m_L \\ m_L & B & B \end{bmatrix} \overset{18:}{\Rightarrow} \begin{bmatrix} K & O & m_L \\ m_D & B & B \end{bmatrix} \overset{19:}{\Rightarrow} \begin{bmatrix} K & O & L \\ m_D & B & B \end{bmatrix} \overset{23:}{\Rightarrow} \begin{bmatrix} K & O & L \\ D & B & B \end{bmatrix}$$

(b) topology test case given the input described in *0:*

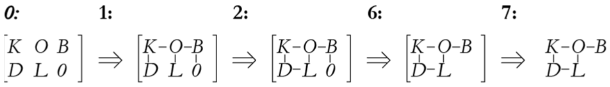


Figure 53. Example of derivation the set of rules for allocation (a) and topology (b), for a case given a *O, K, B, B, L, D* brief input.

Since shapes and sub-shapes are clarified in the modular design, we would not have to develop a full algorithm for shape creation, as it would have to be, for instance, in a shape grammar fashion[388]. Instead, shapes will be a consequence of a clarified functional mapping acting on the previously defined modules' physical and dimensional features, i.e. a *primary functional allocation*. This will define the shape's broad volumetric features, over which we can further detail the internal elements, i.e. a *secondary functional allocation*.

Secondary spaces are describable as subsets of the primary spaces. These must follow their own dedicated brief, and obey a hierarchy of allocation. Each house requires an *I*, a *T* and an *S* as minimum secondary spaces. Given its specificity, the kitchen is considered both as a primary (labelled *K*) and a secondary (labelled *I*) space. The number of *I* (i.e. the i_I) thus comes in first and is always i_I=1. It follows the number of *T*, that can be defined it in relation to the number of *B*, where $i_{Tmax}=i_B$, $i_{Tmin}=(i_B-1)$ for $2 \leq i_B \leq 3$ or $i_{Tmin}=(i_B-2)$ for $i_B \geq 3$, and finally in a t_0 typology, i_T=1. As to the number of *S*, every typology has an i_{Smin}=1. For further cases, we can define it in relation to *T*, where $1 \leq i_S \leq (1+i_{Tmax}-i_{Tmin})$. The output conjunction of these elements is the brief of the secondary functional spaces.

Finally, the spatial integration of the primary and secondary elements follows the dimensional constraints imposed by the circulation spaces (*H* and *C*). The distinction *H* and *C* is due to the different minimum dimensional requirements of each—1.5×1.5m for *H*, and a 1.1m width for *C*. Both can be defined either implicitly or explicitly. Implicitly means that they can occur integrated in a wider space than its own minimum dimensional requirements, for instance they occur via an *L* space—e.g. the *L* in Figure 41c when moving from the entrance to the stairs. In this sense, *H* or *C* will be implicit within any primary functional space. Explicitly means they go from a module to another through a third module, thus having to physically separate the functional space from *C*—e.g. in Figure 41d or Figure 41e. This is also what occurs between a primary and a secondary space. Thus, explicit circulation is defined as from a secondary space, whereas the implicit circulation is non-definable. Finally, in terms of housing brief, *H* has the specificity of occurring only once, and thus has to be associated with a module or a pair of modules which are closer to a certain requested entrance direction, definable through a precedent input.

5.4.10 THE MULTISTORY BUILDING

Throughout the work, we have already been showing some of the tested multi-story buildings and their implications. The system proved to have a wide variety of possible applications. In a rural context, the terrain dimensions may not constitute a major problem. Conversely, in urban spaces, this is typically a core issue. Indeed, given the higher land prices in urban settings, it matters to explore architectural solutions enhancing spatial and aesthetical qualities, and that at the same time look out with versatility for an optimized use of land. The initial structural technology, using CFS elements, roughly withstands 4 or 5 *levels*, and thus the multistory typological studies targeted it[389].

In the first studied cases, the focus was on the single-family housing units with a maximum of two floors. A solution was developed that started from a maximum implantation polygon that allowed an elevated number of associations, both as isolated building and a compact urban solution. While in the first cases a direct connection from the street to the interior of the house was possible, in the case of the multi-story collective dwellings it is necessary to use complementary modules, such as common staircases and elevators, to assure this connection from the street to the dwelling interior. In this case, a few variations of some classical building distributions were developed, namely option with direct entrance from a common hall (i.e. left right apartment building type) and gallery type.

As expected, given the modular characteristics, the typological explorations of direct entrance cases proved to be feasible with minor adaptations. In the first case (Figure 54b), a central core is used to make the vertical connections within the building. Here all the living modules are directly facing the exterior, and so can benefit of *d*. The implementation is possible both with **u**:(8, 8) as with

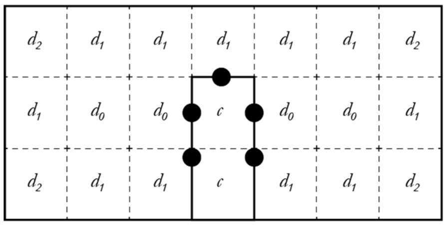
u:(8, 7) modules. However, the latter requires some adjustments to assure a sound functional allocation. The ideal scenario is nonetheless the **u**:(8, 8), which as we knew assures symmetry at an optimum degree. At an urban level, since this type of building only allows facade superposition in the external corners of the building—where the modules are of a d_2 kind, thus when superposed reducing to a still feasible d_1 kind—its use with contiguous buildings would be limited, therefore requiring some degree of plot isolation.

The second tested case of direct entrance (Figure 54a) was a symmetrical arrangement of two **m**:(3, 3) zones, intermediated by a core of **m**:(2, 1) set for common areas plus, a third module which can be freely attached to any of the main blocks of modules. The first verification was that of the five modules that can potentially connect with the vertical core, only a maximum of four simultaneous direct entrances from the same common hall are possible. The main differences with the first case are that not every module can connect directly with the exterior. Moreover, a wider spectrum of shapes is allowed, with more possible combinations. Finally, using either a **u:**(8, 8) or a **u:**(8, 7) does not imply significant layout changes. Anyhow, as in the previous case, some adaptations were needed. Namely, there is a shape junction that may be particularly prone to use direct stairs. As in the previous building, the urban use of this solution is limited to isolated plots.

Finally, two solutions of gallery distribution were studied, the first using an external type of gallery (Figure 54c1), the second implementing a mirrored variation of the first in terms of common circulation areas (Figure 54c2). Aside this difference, both are essentially analogous solutions. The detailed gallery solution (Figure 55 and Figure 56), proved to have quite a direct application of the **m**:(2, 3) shapes, working either with an **u**:(8, 7) or a **u**:(8, 8). It allows parallel junctions, both horizontally and vertically, as well as misaligned junctions between floors within the same dwelling fraction. Moreover, it is quite easy to create excavated verandas in every floor and/or patios in the top floors. It is quite reasonable to think of an endless expansion of the length of this building, making it extremely feasible for urban implementation either if is in isolated or laterally closed plots.

(a) left/right

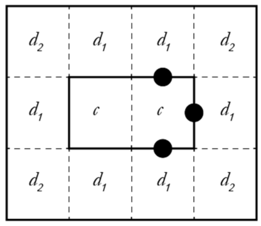
u:(8, 7)
m:(3, 7)
m=21
c : 2m 9.52%
d_1 : 11m 52.38%
d_2 : 4m 19.05%
d_0 : 4m 19.05%



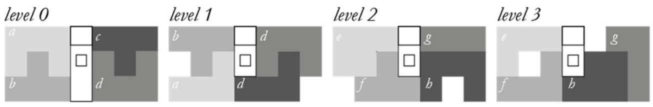
_5 possible access points per floor
_max. 4 simultaneous entrances per level because of d_0 *location*
_great typological flexibility

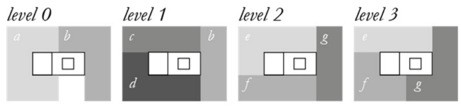
(b) left/right of central circulation

u:(8, 7)
m:(3, 4)
m=12
c : 2m 16.67%
d_1 : 6m 50%
d_2 : 4m 33.33%

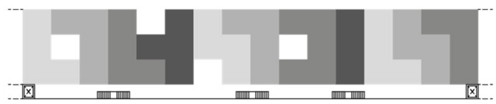


_max. 3 simultaneous entrances per level
_no d_0, *thus greater transmutability*
_only prone for linearly developed typologies





(c1) gallery



_common circulation optimized when using duplex typologies
_gallery is optimized if placing bigger shapes in the extremities
_some typological variability

(c2) internal gallery

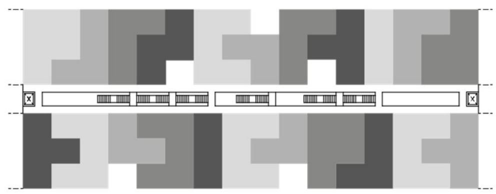


Figure 54. Multi-story diagrams.

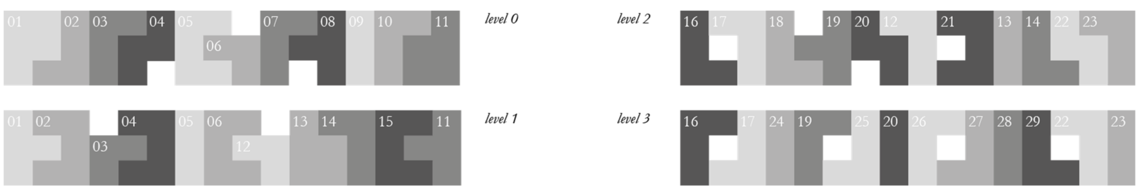


Figure 55. External gallery solution diagram.

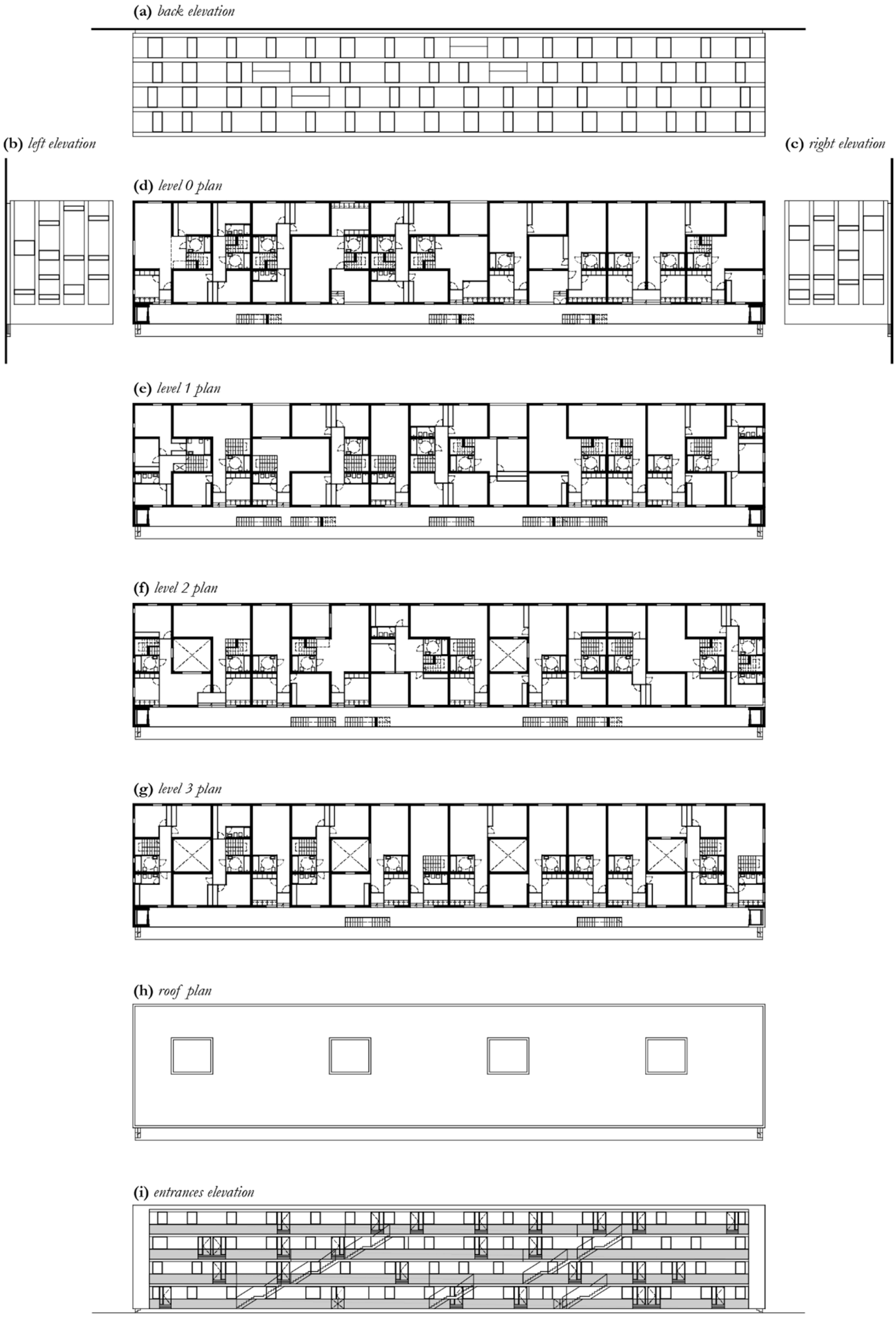


Figure 56. Detailed gallery solution.

5.5 The prototype

5.5.1 MODULARITY, CONSTRUCTION AND SUSTAINABILITY

The array of hypotheses within a modular system underlays a dimensional regulation which has production control purposes, while still enabling a great deal of exploratory latitude. These principles are, to a great extent, lined up with the 1960's much in vogue modular research and standards creation, or even earlier research. However, these principles do not necessarily make sense today. Indeed, current technologies, such as CNC, automation, or 3D printing, enable a more feasible production of non-standard material dimensions than it used to in the past.

Nonetheless, normalized sizes are still cheaper in most cases due to their larger production scales. For instance, in the case of OSB boards used in the prototype construction, these are provided in standardized dimensions by the manufacturer. Depending on the intents, the boards can be used in their original sizes, or be cut-to-fit the specifications. However, cutting can hardly occur without producing some sort of material waste, and not without energy consumption in the cutting, trimming or screwing machines, or not without involving labor time. The same analogously applies for most materials used in the construction. Whereas some materials have a greater reuse or recycling potential than others, waste production in result of the construction process is nonetheless unavoidable.

Furthermore, given multiple factors and even if best intended so, deconstruction for repair and maintenance or after life-cycle end of a building is hardly a clean-cut process. Among other reasons, this contributes for a non-correspondence between the reuse and/or recycling potential of a certain material (if used by itself or combined with other) and the verifiable reuse and/or recycling rate. The case of steel is a good example in this domain, since it has a nearly 100% recycling potential.

Downstream a likely more optimized, large-scale production plant, any of these operations will have their cost increased. As we have verified during the prototype development, under the current technological stage, even if attempting to follow these modular principles to the extreme, construction without these sort of costs is but a utopia. Indeed, one of the initial goals set for the construction was to make it with the least waste as possible. To some extent, that can be achieved in a design stage, attempting to exhaustively predict it. However, when facing some construction issues, the exercise is not always easy to put in practice. Furthermore, when adding further criteria such as for the construction components to be easily transportable, including considering their fitting into ship containers, and thereby further limiting the maximum dimension of the components, the number of variables necessarily increase and it becomes harder to keep track of waste.

Nonetheless, mitigation measures in this respect, such as those embodied by lean production principles, can be implemented. There is a break-even threshold between what may be useful practices to improve the design or the construction, and the time or money investment it takes to get to it. The design process is a dynamic process, and such break-even is often hard to understand on the go. Furthermore, in some contexts it is just better to keep on using ordinary, time validated procedures, and not rushing in implement cutting-edge innovations. As history tells us, good tools and practices are typically the result of a slow evolutionary path, where social or technical assessment and recognition takes its time to test and eventually settle.

The **u** grid was theoretically optimized for a cold-formed steel structure, and though of in terms of an easy adaptation to a multitude of standardized materials to use inside or outside the house. Nonetheless, the typological architectural principles it gave birth to could have also been feasibly used with different structural elements, i.e., the same *design system* can be used with a different kind of structure. Such is certainly in debt to the abstract character of the design exercise, which in turn ascribes to a topological nature of the modular device. Divergences between the exercise level, and some of the technological peculiarities of the construction, would only arise in a late stage, during the prototype construction. Some of these would contradict the initial constraints, and if had been previously known, the initial design principles would likely had been devised differently. Anyhow, at some point, the approach inevitably became independent of constructive constraints.

5.5.2 BUILDING THE PROTOTYPE

A proof-of-concept building, full-scale prototype was built out of the AHP design. The development of more detailed building drawings went through several stages, with natural advances and setbacks. Built by the *Coolhaven* company, the prototype solution was based on the most requested typology (3 bedroom detached house), like the illustrated case in Figure 25, yet using **u**:(8, 8) dimensions.

A multidisciplinary team worked together for this purpose. A close work had to be developed with the architecture and the different specialized contributions, as well as with the industry. The greatest transversal concern among all the participants was to confer the best possible sustainability to the project, which included energy efficiency simulations, lifecycle assessments, fire and stability tests. This included meetings with several suppliers set to develop innovative solutions, from special semi-transparent solar panels to eventually use in the façades, to the consideration of different domotic systems, efficient water heating systems, or the use of phase-changing materials to improve the buildings' thermal behavior.

For several reasons, not all solutions ended up being applied. Moreover, inherent difficulties and incongruences were found during the final planning and construction process. These were mainly due to the prototypical and experimental character of the design and to the need to present visible results within a tight schedule, in which the typically slower pace of research has a hard time to follow.

Besides the aspects which are normally taken in consideration in any building, such as orientation and spatial qualities, several principles guided the concerns from the start. Aside implementing environmentally sound technologies, the building was to show the potential of different spatial layout arrangements. These had to be coordinated with a proof of ease of installations maintenance handling. To attain it, the kind of materials considered were to be apt for both construction and partial deconstruction to enable access to dedicated piping and wiring.

Another concern was for the building parts to be optimized for containerization, that is, considering a virtual 2D deconstruction of the building parts. Finally, the building had to meet the expectations that the technology and processes in use, comparatively with current construction methods, would not only significantly reduce the total construction period, but evidently also turn it cost-competitive. Overall, the prototype served not only as proof of the set targets, but as test the very limits of what conceptually had been defined, going beyond them as it was feasibly possible.

The devised principles established that, structurally, the construction would be made of independent, cube-like modules, like a tridimensional cube made of post and beam set side-by-side. The structure it is as if a tridimensional frame, made of composed post and beams, whose corners are laid in a rammed steel piles foundation and can be staked upon each other. Since such foundation only leaves a few visible spots in the ground, it dramatically minimizes the building's footprint, allowing a total ground reestablishment in case of future deconstruction (better only if mobile). Cold-formed steel parts are used to make the composed posts and beams. Since steel is priced by weight, arguably, these have a competitive cost over hot-rolled steel profiles, since they are lightweight comparatively. Yet in the end, these also require a higher processing, which in non-automated manufacturing environments may, in the end, result costlier. Being also an experimental structure, the initially proposed structural design ended up requiring additional bracing on the corner junctions, to better withstand lateral forces. Initially, one of the ideas for the column design, besides keeping it a minimum to maximize free wall space, was to make it somehow has a hollow and accessible shape in order to fit required installations within it. In the end, although applied, given a higher amount of installations than initially expected, its effectiveness was more reduced than anticipated.

Despite the difficulties, and of some degree of constructive experimentalism, which ultimately lead to solutions that could only be optimized in subsequent projects, it took only three months to complete the construction, which can be regarded as a great improvement, considering the rough average estimates for the Portuguese reality. If compared with other approaches worldwide, it is our belief that, in optimized circumstances, the design potentially would take just two or three weeks to be fully built since design completion.

Figure 57. Prototype construction, (a,d) ground floor structure, (b,c) infrastructure through structure, (e) vapor barrier, (f) exhaustion through structure, (g,i,j) stairs, (h) first floor structure (cont.)

(a)

(b)

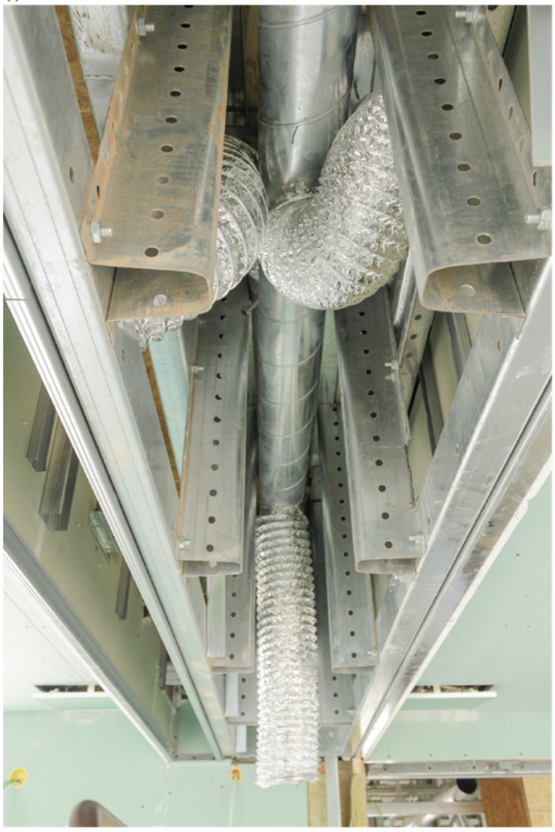
(d)

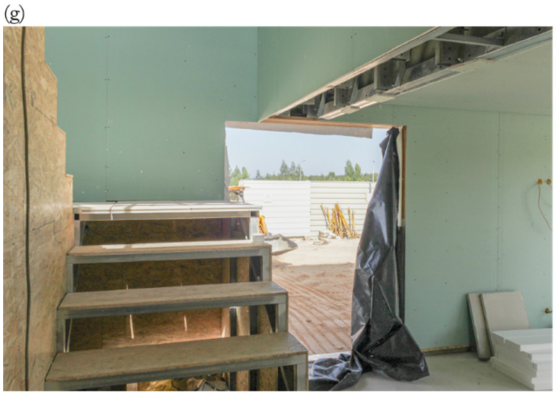
(e)

(c)

(h)


(i)


(f)


(g)


(j)


(k)

(l)

(m)

(n)

Figure 57 (cont). Prototype construction, (k) OSB over structure, (m) finishing external layer (l,n) concluded raw elements.

5.6 Revisiting the prototype

5.6.1 THE COMPANY

The business structure of the company created after the AHP project, has gone through several changes since its inceptions. This results from many factors, but with economics in the lead. The core activity output has changed in concordance with a new market focus.

The company has been moving away from a turnkey concept, which was its initial business focus. The CEO's words sum it up: "*the turnkey is a nightmare... its logistics is a nightmare… the customer is a nightmare*". On the one hand, old, enrooted constructive habits, more or less artisanal, are part of a constructive culture that ends up being a great source of inertia to the realization of the projects. Furthermore, residential house client's indecisions, change of mind, or lack of assertiveness, meant too much resources can be entropically lost, diverged to activities that add no value to the outputs, and thus to the business itself.

Another important change that took place is the moving away from an environmental sustainability focus, particularly in the field of energy and life-cycle R&D. At one point, it became clear that the investment to obtain competitive solutions in this domain was out of the scale that the company could support. There would still be left the 'green' marketing, which, however, proved to have limited effectiveness. In a business perspective, in the first instance, this may even be appealing, connecting the customer. However, when the critical moment comes for client decision-making, it all seems to fall on the economic component. Sustainable practices are nonetheless hardwired in the company's backbone, at least in its continuous search for optimizing constructive solutions.

Given that "*the sustainability that matters first is that of the company*", as referred by the CEO, they ended up looking for a focus on the skills and markets that could bring greatest benefits. In agreement, it is their belief that those in Portugal looking for prefab solutions are mainly looking to economize in relation to more ordinary constructive solutions. In fact, for better or worse, the price-point is the typical focus marketing strategies of prefab companies in Portugal. Anyhow, that is not a guaranty for the customer, since the final cost has many other aspects to take in consideration besides the *design system* or the structural philosophy.

The company is currently focusing on the R&D of modular components for a business-oriented clientele, thus now positioned more as industry suppliers than as contractors. As consequence, the national market plays a secondary role now. Instead, they are exporting to European countries with stronger economies, particularly for France. The focus is on 2D constructive solutions (panel construction or the like) and no longer 3D (volumetric) as they had equated at a certain point. The latter, which they tested, essentially posed logistical difficulties that drastically reduced the competitiveness potential of such solutions.

Figure 58. Robot manufacturing modular panels. Robot #1: (a) loading substructure; (b) deploying substructure to place; (c) loading board; (d), (e) deploying board. Robot #2: (f) fastening board to substructure.

Anyhow, at the core of the company subsists an idea of modularity. However, they also note the difficulty of implementing modularity in some contexts. That has particularly occurred when they had to adapt their modular solutions to projects that had been developed independently and without any though in that perspective.

They affirm that the cost of their products is not necessarily higher nor lower than ordinary solutions. Nonetheless they believe they can attain high standards while delivering within demanding production scales. The highly adaptable modular 2D solutions they develop are able to be incorporated into different architectural programs—they have built houses, but also schools and nursing homes. Moreover, these are also highly prone to industrialize, attested by development of an experimental robot technology for panel manufacturing (Figure 58).

Nevertheless, investment plays a huge role in industrializing practices, and financing not always goes as desired. For instance, they intend to acquire a steel profiling machine, so they could be more independent from suppliers, but they have not managed to do it yet because of the high financial engagement required. Ironically, since they are mostly working with markets with stronger economies, one of their current competitive advantages seems to be the comparatively lower labor cost.

5.6.2 THE PROTOTYPE

Aside being in and of itself a showroom of the company's products and services—a house-in-display—the building also became the firm's headquarters. It is from there that both management and design teams have their main base to workout decisions. There have been some minor changes in the layout, with a partial glass enclosing of the space corresponding to a living room in the ground floor, making it more sound-proof to have meetings and the like. In the exterior, there has also been some minor changes, namely in the pavements connecting to the entrance. Anyhow, the building has withstood both program and physical changes with ease. On its own, this validates the intentions of flexibility and adaptability that had been set forth since early design stages.

Overall, in its daily use, space distribution and area proportions seem to satisfy its users. Denoting it, an unscheduled visit showed that although it is clearly a busy workspace, particularly in the *level 1*, seemingly fitting the needs comfortably. The *level 0* areas, with more of a social character, also seems to satisfy for a coffee or lunch break, or for informal meetings. The kitchen space has notoriously been appropriated, with some domestic appliances included—a coffee machine, a microwave and a fridge—as well as a table and chairs, and some other objects, such as cups, magnets or a plant, overall giving it a domestic, personalized character.

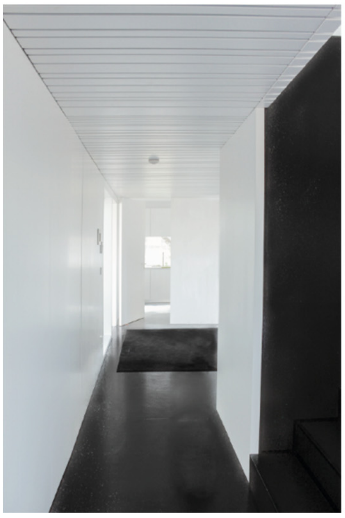
From a constructive point of view, there are few things to point out. The foundations solution (point by point piles, that had been opted to minimize the use of concrete and to favor LCE deconstruction) have had a slight give way. Nevertheless, that has been swiftly solved, and did not carry relevant consequences, given the relative flexibility of the structure and the main materials. With this exception, at the level of constructive pathologies, there is nothing to point out, demonstrating the resilience of the constructive solutions adopted.

From the thermal behavior point of view, the prototype seems to satisfy its users, both in winter and summer. The feature taken as key in this domain are the efficiency of the window frames, allied with the air renovation system that uses underground stable temperature to deliver a controlled, energy efficient, air circulation. In a summer context, the effectiveness of outdoor shading is the point mentioned. However, there are complaints about the fragility of the screens that do it from the exterior, because they seem to easily escape from their guides, and must be collected when stronger winds occur—in fact, in the north façade they are permanently raised. The use of higher thermal inertia materials in some strategic places, namely as a surface plate laying over the floor structure, right beneath the pavement, is also perceived as having a positive role. Anyhow, overall, fears associated with negative impacts of a construction making mostly use of low thermal inertia materials so far have been proven wrong.

The acoustics also seems to satisfy, both from external noises, as from internal propagation. The materials, with a high thickness of thermal/acoustic insulation both from the outside, as in between floors and main partitions, are certainly contributors to this aspect.

The issue of floor vibration due to the use more flexible materials, which is often taken as a negative aspect in this kind of construction, does not seem to bother users much. In fact, we only feel it if we are standing still and someone jumps somewhere. Users are used to the normal vibrations of walking, and thus they do not notice it. Moreover, there are no noises attached, no scrapping or squeaking sounds, which minimizes eventual negative impacts in this matter.

Figure 59. Finalized prototype.



III Practical Conclusions on a (Pre)Fabricated Architecture

Here we will sum up aspects that we consider to likely have an impact in the development and implementation of house prefabrication practices. Whereas some of these can be directly discernable from the elements described throughout the thesis, others derive from historical and socio-cultural related aspects[390] that are only referred in the Annex Volume, or from conclusions arising from the development and construction of the house prototype. The concern was to depict stricter aspects of prefabrication and modular construction related with housing purposes, but also to reflect aspects of a broader scope of the building and architectural activity that hopefully contribute to a better and more holistic understanding of the problematics.

1 ON AN IDEA OF PREFABRICATION

A broad-term. Throughout history, there is a wide diversity of house prefabrication examples, making it a rich field of exploration, but also making it harder to extract unequivocal assumptions on a definition or a corpus of knowledge on the subject[391]. As any building practice, different options in the diverse stages must be considered.

Prefabrication scope must be defined in each case. As a broad-term, prefabrication can be mistaken with terms such as systems construction, rationalized construction, standardization, industrialized construction, and so forth. Although generally embedding the spirit of these, when making use of the term, it primarily matters to specify the scope of the respective approach.

Prefabrication has been associated both with positive and negative aspects. Positive aspects are often related with state-of-the-art construction practices and/or a techno optimist attitude. Negative connotations are normally related with socially stigmatized examples, arising from low-standard practices, associated construction pathologies, and so forth.

2 TERRITORIAL CONSIDERATIONS

Construction environments. There are different construction cultures at a country and/or regional level, with roots usually traceable to natural conditions, vernacular built forms, or socio-cultural practices in the respective territories.

Socially recognizable archetypes. Likewise, the use and acceptability of different materials and forms can have territorial variations based on socially recognizable archetypes, or on more or less clarified ideas of *tradition*. This affects aspects such as quality perception, and eventually undermines the development of new or innovative solutions at an aesthetical or constructive level.

Political frames. The political conditions can too vary country and/or regionally wise. This affects aspects such as the potential risks and benefits of construction investment, namely in political/fiscal uncertainty, attitude towards investment, enforceability of contracts, or eventual incentives.

Administrative issues. Bureaucracy, communication and transportation networks, legal aspects, administrative machines, social and work conditions, or general economic environment, are also aspects to address when considering different territorial realities.

Building regulations. Technically, attention is required in exporting or adopting imported systems, namely in some regulations specificities, such as fire and earthquake, and so forth.

3 ECONOMY AND VALUE

Main variables of the economy/value equation. The competitiveness of any economic activity is subjected to an economy and value relation, which can be measured in the intersection of the output vectors of quality and scope, cost and time. Likewise, the overall architectural equation is subjected to a ponderation of both its delivered quality—which can be understood as value for client—and economy related factors, in order to deliver the envisioned design/constructive purposes in a satisfying manner.

Output vectors: quality and scope, cost and time. Quality and scope are interrelated elements that can generally be defined as desirable aspects of a product. Things well made can be said of having quality. Their features, or what they may induce, such as intrinsic characteristics and/or, eventually, their optional aspects, can be referred as scope. Cost and time are also bounded elements that can be defined as non-desirable aspects, thus constraining the quality and scope. Typically, there is a direct correspondence between quality/scope and cost/time. The million-dollar question is how to increase quality/scope in a greater degree than the cost/time.

Contextualizing variables. No single factor in the overall building equation should be considered independently. For instance, material cost does not correspond to final cost after the building is concluded—e.g. bricklaying can be expensive from a labor perspective, although bricks themselves can be relatively inexpensive. Indeed, aside direct costs, labor or time related factors, such as workers income, safety, building site management, or overall production logistics, are also to take in consideration, influencing in the economy, and consequently in the quality of the building product.

Competitiveness factors. Satisfactory answers to attain an economically competitive edge in construction processes must address aspects such as labor replacement, logistics and quality issues. In labor replacement, it must essentially be pondered which method will allow a faster final assembly time, and thus it is least voluminous/complex and/or requires least in-situ finishing. In logistics, it must essentially be pondered the in-situ storage space requirement versus just-in-time delivery capability. In quality, it matters to assure the greatest degree of finished product as possible (or OPP postponement), attaining a greater quality control on the components of the building assembly, but also knowing that the greater the postponement, the more constrained options will be.

4 COMMERCIAL CONSIDERATIONS

General reasons for commercial success. General reasons for success seem to be associated with aspects such as innovative selling schemes, knowledge of the market, or availability of choice. Business timing and opportunity can also be a decisive driver for commercial success—e.g. the mass-produced, all similar, *Quonset Huts* (1941-present)—or conversely the main reason for its failure—e.g. *Packaged House* (Wachsmann & Gropius, 1941-1952).

Technical factors for commercial success. The most successful cases in terms of built units generally do not denote particularly remarkable architectural qualities or even concern for that matter (e.g. *Sears Catalogue Homes,* 1908-40). Anyhow, business success seems to overall be related with reliable constructive methods, and aesthetical or spatial flexibility—e.g. an open prefab system allowing different architectural design languages, or a flexible system of partitions allowing different architectural layouts, adding/removing volumetric parts, and so forth.

Broad social support. Looking to places such as the USA, Japan or Scandinavia, where prefab technologies are of common use, and even considered *traditional* to a large extent, it is verifiable the existence of a strong social support. In the lack of such, risk of unsuccessful outcomes can increase. A sudden attempt to implement *alien* technologies, even if these are proven to be extremely good, will struggle to succeed.

Commitment and persistence from multiples actors in the building industry. Steady, continuous efforts are required to achieve design and construction quality standards, but also involving considerable investment in marketing strategies. The XIXth century pattern books are a good example on the introduction of technologies to the masses, while highlighting the relevance of publicity, showing that a broad range of skills and expertise must be involved, and that technical quality of the outputs per se is not enough.

Integrated innovation and financial robustness. New technological developments in construction need to be properly framed within the existing constructive methods and construction businesses ecosystem, i.e. to be understood and accepted so to successfully be put into use. Overall, these factors put a financial pressure on prefab businesses, which will inevitably require a substantial financial support to withstand wait for an investment return. In principle, this means that the bulk of companies within the construction industry (mostly SME's), are likely unfit to single-handedly support innovative developments in this field on a medium/long run.

5 CLIENTS' BIAS, RESISTANCES AND PRECONCEPTIONS

Low-quality bias. Prefab biases are typically related with low-quality examples of the past, such as post-war prefabs, or concrete panel systems, which have been widely associated with construction pathologies. These occur without the knowledge of good quality examples, helping to build an uninformed negativity towards it.

Aesthetical bias. Likewise, a prefab terminology associated with aesthetical features of these past examples, such as visible joints, flat roofs and the like can be suspiciously regarded.

Lifestyle bias. There can also be lifestyle-related prejudice and preconceptions, as in the case of the *mobile homes* in the USA.

Conservative spirit. There is empirical evidence of an attachment to an idea of *tradition* and/or a conservative spirit in housing, related with both material and aesthetical preconceptions, as illustrated through the *three little pigs* tale. Technically this can translate to seemingly robust materials, proper weather adequacy, fire resistance, good structural stability, and so forth. Formal preconceptions may result from how a material form fits a certain local or regional context, but also from inculcated socio-cultural bias, and reflects a certain nostalgia of the past, as well as a sense of ontological security that is inevitably bonded in an idea of *home*. Likewise, a conservative attitude can also be related with what can be called the *fear of the unknown*, or simply a legitimate intention to express oneself within a social milieu, or not least as of making sure that a lifetime investment is proceeded satisfactorily.

Resistance to innovative solutions. There is thus a likelihood of bias over less conventional housing forms or seemingly more radical types of design, e.g. (*hyper*)modern aesthetics, unfamiliar constructive solutions. Some of it has to do with inculcated aspects, but it can also be explained by the perception that it can affect value and mortgageability. Nevertheless, the acceptability of less ordinary forms may vary with age and/or with socio-cultural background, generally with younger people and first-time buyers more open to different forms and materials.

Maintenance costs expectancy. A newly built or extensively renovated house may induce a wrong expectancy that maintenance costs will not be required for many years. On the medium/long run, at a social level, this potentially causes distrust and/or lack of predisposition to engage in less ordinary solutions as they are proposed.

6 CLIENTS' ATTRACTIVENESS FACTORS

Financing and Costs. Financing aspects (e.g. mortgageability) are typically the primal concern among clients, comparatively setting a minor relevance to design issues (e.g. aesthetics, plan layout), or technological features (e.g. construction materials, maintenance). The perspective of a lower direct capital cost, energy savings, or low investment risk due to technological features, can be persuasive arguments.

Avoiding reference to past, biased examples. Generally, to attain attractive solutions, seems to be important to avoid visual reference to the examples perceived as bad in the past. Therefore, it may often be best to *disguise* prefabs as conventional solutions, or at least not make them explicitly like known biased types. Particularly in countries where there is no *prefabrication* tradition, an acceptable prefab house may be one that does not look like it is prefabricated.

Location, location, location. In one way or another the adage *location is everything* can generally be applied as a key argument for attractiveness.

Design and Space. Architectural quality, larger areas and/or more rooms are generally persuasive arguments if not meaning comparably significant extra costs.

Diversity of houses and living environments. Diversity of houses, subscribing exclusivity, or of living environments, may potentially be attractive factors. Without significant loss of productive efficiency, these can be attained by providing a reasonable range of finishing's material, enabling layout flexibility, or providing external areas in which inhabitants can adapt to their needs and wishes and so forth.

Flexibility/Adaptability. There is thus eminently a demand for open, flexible and/or adaptable spaces. For instance, additional bedrooms or reasonable storage spaces may be given unplanned uses such as for office, children's playroom, or other activities. Depending on the constraints set forth by the design this can be achieved through a dimensional provision that allows ease of change overtime, through ease of dematerialization of partition walls, or by hardwiring movable elements such as partitions or furniture.

Mobility/Acessibility. Further stressing flexibility/adaptability aspects, are the requirements for ease of mobility/accessibility, particularly in what concerns elderly users, or people with different sorts and degrees of handicaps.

Material preferences. The material preferences are not universal. Some people may prefer solid appearance, with brick or uniform coating, others a rustic cladding with timber or stone, or instead clean looks with concrete or glass, and so forth. Generally, the young might be more amenable to unconventional solutions.

Ontological security. In brief, a prefabricated house must be able to retain a feeling of ontological security, and a dwelling sense, which by no means should be inferior to other construction methods for comparable outputs.

7 PEOPLE AND THE CONSTRUCTION INDUSTRY

Resistance to prefabrication. Whether using prefabrication or other methods, there is a general notion that construction processes must follow a continuous evolutive path. Nevertheless, there is a latent resistance to prefabrication related practices involving both rational and irrational biases among all the groups involved—developers, professionals, clients, purchasers, and so on. Concerns are generally based on a sense of a bad historical experience, more than with any real present evidence. Among the professionals, it can be found in those whose vision on prefabrication is not properly informed. Developers often fear compromising image and long-term value. The financial and/or insurance sectors still tend to penalize prefabrication methods over others, due to claims of greater fire risk, more susceptibility to the arousal of construction pathologies, and so forth. Despite the facts, there is no particular evidence that people share antipathy towards prefabrication per se, meaning opportunities are out there for developers to shape their businesses more like other industries, developing innovative solutions, as long as improvements can be demonstrated and backed up by suitable guarantees.

Direct capital and maintenance costs perception. To a prospective house buyer the direct capital cost is typically more highly prioritized than the avoidance of future costs, since those are less visible or harder to assess when formulating a subjective notion of a good deal. Among these, the maintenance costs are particularly not greatly considered, with the general view being that a new house should have no maintenance costs unless there is something wrong with it.

Product/Process. Generally, the public focuses on the house primarily as a product, and the construction industry focuses on the house primarily as a process. However, there are signals of some developers seeing prefabrication as relating to the notion of product rather than process. That can be worrisome if achieved through bypassing some key development stages, related with design, the role of the client, and so forth.

Reducing in-situ labor weight. There is a general notion that is necessary to reduce in-situ skilled labor weight and/or wet construction processes to improve output vectors.

High-standards and reality. The generality of developers publicly claim they achieve high-standards, although commitment to innovation can be very partial among individual developers.

Political drivers. In Europe, the effects of political targets, such as the *2020 Directive* on the construction market, is generally regarded as an important driver for change.

Hearsay truths. Developers' assertions about the optimum house and its marketability are largely based on hearsay information that is not challenged, as time or funds lack to try alternative models. That can be particularly noticeable in some *eco-friendly*, or *sustainable* trends, which can often be more the result of marketing, than of deeply addressing the issues.

8 THE PUBLIC AND THE ARCHITECT

Aesthetical bias. More or less subjective, more or less born out of a lack of knowledge or architectural culture, architects are often biased as those that design *extravagant* or *radical* shapes, or use *modern* lines that have no emotional value, and so forth.

Technical bias. Other biases, follow preconceptions of an eminently (pseudo)technical tone. That can be denoted in common expressions such as *house with no roof is no good*, or *visible joints make it seem like postwar prefabs, thus probably water leaks inside*, which nonetheless typically work as prosaic justifications for opting for a *traditional* type instead of a *modern* type. Anyhow, when *modern* forms become known by the public, they too can become objects of desire.

Architectural fees myths. There is a common perception that recurring to architect's services can be expensive or even a luxury. However, in many cases, that preconception can backfire on the very customers that opt not to use the architectural services, reflected either on the overall bill, or by qualifying buildings below acceptable standards.

Subjectivity of the architectural profession. To some extent, the architectural profession is guided by intersubjective knowledge, reflected in aesthetic or stylist memes and the like, which the public not always follows (and does not have to). The prefab examples regarded positively among pairs are often related with a strongly recognizable authorship (e.g. *Case Study No. 8*, Charles and Ray Eames, 1945-1949) or iconic architectural projects (e.g. *Habitat '67*, Moshe

Safdie, 1962-67). Those likely constitute a reflex of the typical architectural education of the professionals, recognition among professional pairs, or in the modes the architecture is rendered visible, mediated to the public. On the other hand, prefab that is architecturally regarded for its lack of success tends to be more socially recognizable, hence more visible among a wider audience (e.g. *Khrushchovkas*, 1947-61). It adds what it seems to be an *absolute truth*: if it is a failure, it is the architect's fault.

Professional aspirations to higher creative grounds. Most architects, if so empowered, would concentrate exclusively on the top end of the market, in *higher* cultural grounds that potentially provides more freedom to put ideas on the stand. Paradoxically, it seems to be in the middle sector of the market that most opportunities are available.

Use of design visualization methods. Aspects dealing with spatial or use environment visualization in new or interventioned spaces are currently widespread in architectural practices, constituting an important dialogue device between client and architect, increasing the client's perception of the proposed solutions. However, some digital ways to endorse designs still have great unexplored potential, particularly in what concerns virtual interactive environments.

9 TECHNICAL CONSIDERATIONS

New technologies, old construction methods. Overall, aside some new materials and a certainly not neglectable implementation of digital technologies, aiding in design, production and final assembly management, for the bulk of built environment construction technologies are pretty much the same as in the post-WWII.

Acknowledging long-term vs short-term technical impacts. Technical success in prefab can be determined by the degree in which a technology has seen its use spread and solidified along the years. However, it is important to acknowledge that a technological breakthrough is always a sum of different inheritances, making it difficult to trace the boundaries of an achievement, but also the extent of the influence of a certain technical improvement. Whether de facto or not so much, so-advertised *technical breakthroughs*[392] can have positive effects in marketability, but may also be a cause of undermining the buyer's trust, given the risks that can be associated with what is new and relatively unknown. They thus need to be regarded and proposed cautiously.

General reasons for technical success. Construction-wise, overall reasons for success seem to be associated with aspects such as: constructive simplicity; low-tech; availability of materials; or use of *safe* technologies, i.e. meaning there is a general knowledge of building technologies in use. On the other hand, overall reasons for lack of success can be related with aspects such as:

constructive complexity; misuse of new, *unsafe*, technologies; design with little concern for the building lifecycle (for instance, on maintenance costs); lack of communication between commercial and/or contractor and design author aspects; top-down, speculative design, with little or no consideration for flexibility/adaptability issues; and so forth.

10 LIGHTWEIGHT PREFAB ISSUES

Building faster and lighter, but possibly with higher risks attached. The growing prevalence in the use of modern, lightweight methods of construction, such as timber or steel frames, over older, heavier techniques as with bricklaying or concrete blocks, generally enables to build quicker, cheaper and more efficiently. However, some of the materials involved in these methods may carry substantially greater risk projections, which are used by insurance companies or banks, and thus can have a direct impact in financial factors such as insurance fees or mortgageability.

Fire safety issues. Fire safety typically has a more demanding regulation in lightweight prefab, typically requiring a greater concern in the enclosure of vulnerable structural components with approved fire-resistant assemblies and/or involving expensive automatic fire sprinkler systems. In-situ quality control must be a strong concern, since with speed requirements workmanship can often negligently rush an adequate jointing of elements, contributing to increase the risk of structural integrity in case of fire. Among the risk factors, the major concern is driven from greater fire spread risk assumptions, due to the use of lightweight and/or combustible materials.

Weather risks. Possible hidden gaps in prefab construction may become a gateway to wind and water. These can lead to small incidents, or if developing under the radar, to severe pathologies and disproportional high losses. Weather damage in the materials from wear and tear over time, or from storms and/or flooding, are also to be considered.

The new/unknown risks. On top of the previously enumerated risks, it can be added an unknown resilience of many new and innovative materials, as well the contractors' lack of experience with these and the assembly techniques required.

Repair flow risks. Given the nature of the construction business, and the typical profile of construction companies, it can also be a concern the problems of obtaining replacement components in the future, especially if a particular manufacturer goes out of business.

Acoustic insulation issues. Acoustic insulation makes it harder to build than in concrete slab methods. General concern should address impact and noise insulation from other houses and in between floors, and integration with other building elements. Particular concern must be addressed in the floor surfaces, insulation between floor/ceiling, ceiling material and thickness, and in a resilient isolation of components such as the light fittings.

Vibration issues. Although without the creak noises of old wood floors, lightweight constructions are likewise more prone to undesirable, perceptible vibrations of floors or walls. Mitigation measures may include use of heavier material overlay over structural elements and assuring a tight solidarity between different floor or wall components.

Low thermal mass related issues. In lightweight construction, the typically low thermal mass of buildings can be an issue in terms of the overall energy efficiency of buildings[393]. Conversely, higher thermal mass can have a positive effect, particularly in climates where there is a higher diurnal temperature range[394]. In cold or cool climates, where heating systems are often used, high thermal mass construction is positive regardless of diurnal range. A very thick mass is not necessarily more effective in the direct gains, since larger elements have a negative dispersion effect[395]. Anyhow, any solution should have in mind the overall climate conditions, and be used in conjunction with appropriate passive or active solutions and design strategies. Options must consider energy requirements (varying on climate, design, and program), as well as the solar income (varying on climate, orientation and surroundings).

On breathability of buildings. Breathability of buildings is key to understand building performance, but also how design should be conducted. The term can be misleading in building construction, since it is not only about air, but on the biological and chemical processes that occur between the inside and the outside of the building capsule. In particular, it is about the effects of water interaction with the building materials (condensation, evaporation, hygroscopicity, capillarity, absorption, permeability, and so on), thus affecting the building's health and performance. The issue has become increasingly relevant with an air-tightness trend, with effects on a more intensive use of house climate control equipment.

Compliance of construction elements. When assembled in-situ, OSB or other sub-final-coating board elements in lightweight construction can be hard to deploy seamlessly aligned, and the very expansion/contraction of materials can occur unevenly in different parts of the building, often making it hard to predict tolerances. This can have implications on the final coating, particularly if it is intended, for it to be smoothly continuous. As a possible mitigation strategy, final coating layers need to be adjustable to disguise eventual sub-layers' imperfections.

11 ARCHITECTURAL PRODUCTION AND INDUSTRIAL PARADIGMS

Prefab and industrial paradigms. Prefabrication, in particular house prefabrication, often comes in comparison to the industrial state-of-the-art practices highlighted in the classical examples of car, ship or airplane construction. However, its constraints and entourage are of a different nature. In any case, there are aspects of these that make sense to integrate when thinking in prefabrication terms, e.g. a broad economical thinking, integrated production, supply chain management, quality control procedures, standardization and/or dimensional coordination, and a generalized and integrated use of digital tools for designing, producing and/or customer interface.

Detailing vs performance approaches. Performance specification, as typical of OEM's, is an alternative to detailed specification, with the architect designing according to the performance required, instead of thoroughly detailing the design. In theory, with a performance-based approach, the design can attain a greater freedom to market forces in the supply, thus contributing to keep controlled costs.

Architect's resistance to performance approaches. Due to the nature of the profession, set to imagine and design spatial/constructive solutions, architects are typically not very fond of performance-based approaches, preferring detailing approaches. Typically, architects consider the implementation of their firm's detailing to be indispensable for the buildings image and/or construction quality. Anyhow, architects will unlikely use in exclusive a detailing approach for all specifications, particularly in less expensive housing, making also use of the market's standardized and certified components, or of previously in-house developed and implemented details.

Costs and value of a detailing approach. Detailed specifications can be a major cause for increased costs if set at a very early stage in the design, due to all kinds of changes that can arise during the entire process. Even if developing a detailing portfolio, with previously tested solutions, and combining it with new detailing specifications, the budget risks are still potentially higher. The value of detailing specifications can be highly esteemed among peers, but for customers that does do not necessarily provide great added value for money. Moreover, the detailing specifications and the concurrent production of drawings are responsible for a significant share of the architectural fees.

Quality equation. Faced with both performance and detailing approaches, the architect's dilemma can often be put on whether to provide good detailing at the risk of overrunning the budget or use standard detailing thus risking losing architectural quality. In a customer-driven building, to assure client's wishes are suitably incorporated can highly increase the number of working drawings and overall specifications.

Errors, omissions and accountability. Directly or indirectly, the architect will be held accountable for errors or omissions in the written or drawn specifications for the construction, which often occur due to a high time pressure, that makes it hard to double check every element of the specifications. Even when the error is not the architect's fault, he will have to either adapt the design to new circumstances (with added working hours), or to assume those faults, risking the envisioned quality aesthetic/constructive intents and in last resource his own professional image by a not so accomplished design. Faced with unexpected costs, contractors will attempt to turn these events to their favor. This makes the architect an easy target, and thus a weak bond in the construction industry ecosystem. With the use of non-standard and/or non-certified components, risks are potentially more expressive.

Knowledge of the market. For different reasons, a broad knowledge of a fast-pace evolving market is not always possible, and thus some design solutions end up being somewhat a reinvention of the wheel. Anyhow, there are aspects of the design that just have to be detailed from scratch since there are no existing and/or adaptable solutions available in the market.

Performance approach benefits and inefficiencies. Specifications and detailing are increasingly produced and made publicly available by the suppliers in physical or digital formats, through technical documentation, drawings, and so forth. If the systems or components are compatible (materials, connections, and so forth), they can easily be assembled to complete the construction using the separate specifications provided by the suppliers, which can hence be held individually responsible. The previous factors may contribute to ease pressure on relatively complex detailing and specifications, yet can create workflow issues, related with compatibility of digital formats, or a seamless integration of the diverse elements in any of the possible interchange scenarios (i.e. office-to-office, office-to-construction, construction-to-construction, or construction-to-office).

12 MODULARITY, CHANGE AND VARIABILITY

General modularity aspects. Buildings do not necessarily shout out loud *I am modular*, nor its design intents have to explicitly consider it. Nevertheless, the knowledge of different aspects of modularity can contribute to improve decision-making processes in the complex, multi-dimensional decisions that are required during architectural creation, namely having in mind aspects such as: interfaces; observing dependencies; or addressing similarities.

Dependency reduction. Modularity is all about reducing dependencies, starting from a clearly established functional map. Indeed, dependencies can be observed more obviously in physical or constructive terms, but in fact these are essentially emanated from to the ability or intention to discretize spatially attributed functionalities.

Symmetry boosting. Symmetry related aspects must be a design concern if aiming to attain constructive cost-efficiency while keeping up with quality standards. The eventual idea that this may result in monotonous environments is wrong. Indeed, if devised accordingly, symmetry features can also enact a wide and varied range of solutions.

Modular threshold offset (interfaces). Modules are not simply virtual squares or boxes, they are to be built in real space, and thus their boundaries have a structure, external and internal coating, and so forth. The latter has a body or a thickness, that we can call the modular threshold offset, that should be carefully addressed. Indeed, if in diagram the junction of modules can work seamlessly, when further detailed it will often arise contiguously duplicate elements. This can be less of an issue when these walls separate different dwellings, yet it adds unnecessary elements when within the same dwelling. When removing them in a drafting stage, particularly in the case of more complex connections between modules', often unexpected blank areas come up, disrupting previous formal alignments, and so forth. Broadly, there are two main options in this respect, which are to either repeat structural elements or not doing it. The first, privileges discreteness, and thus has potential gains in terms of simplicity of production and assembly processes, although it might incur in material losses given the unnecessary repetition of construction elements. The second option, is released of these issues, but will likely have more dependencies attached.

Faster, but not so fast. Potentially, one of the great advantages of prefabricated components over traditional make-to-order products is a faster in-situ assembly. However, components can have all sorts of different characteristics (sizes, shapes and/or complexity), the concurrent factors defining their greater or lesser potential batch size, but also implying different deployment difficulties.

Logistic constrains. For reasons that are fundamentally related with logistic processes of transportability, maneuverability and consequent final in-situ deployment, in urban areas, particularly the denser ones, it generally makes more sense to use components where size, weight and form factors are least bothersome.

Minimizing eventual constrains. To ensure a smooth, more sustainable, eventual future replacement of some components, or even their partial or total dismantling, care must be taken in assuring that interfaces are discretizable or excisable, whether dry or fluid connections are involved.

Dimensional coordination. With mass-production strategies, the effectiveness in the implementation of construction systems is highly dependable on a proper dimensional coordination in order for standardized components to fit, which benefits production scale but will likely make variability in components harder to attain, although there are exceptions (e.g. window frames, kitchen modules).

Parallel production and digital tools. When variability of outputs is intended, the use of CAD-CAM in non-linear production methods can be a valuable contributor, with more recent techniques such as 3D printing with high potential in this domain.

Prioritizing from a slow vs fast distinction. If variability is intended, constructively, it must be kept in mind that the relatively *slower* layers (e.g. *slow* concrete structure vs *fast* partition wall) will more likely have a deeper constraining impact, determining the performance of the other systems, and thus the ability to accommodate variations.

Prioritizing from components' connections. Generally, the simpler the connections' characteristics between discrete components, the better in terms of the in-situ construction time and quality. For instance, typically the bigger components are more difficult to handle, thus particular concern should be put on these or others whose characteristics (size, complexity, fragility, and so forth) can be regarded as priority in comparison with the remaining building elements surrounding it.

Keeping it open. An open building principle is supported on a philosophy that makes substitution possible between several suppliers. Why would a wall panel producer develop a complete wall system with no finishing required, if a similar result can be attained when supplied by different producers at a lower price? While gaining in labor replacement, removing finishing work from in-situ works can raise several issues. For instance, it raises connection issues (dimensional or material compatibility, and so forth), which depend on aspects such as agreements with other suppliers, compliance to certain norms or procedures, and so on.

Construction speed issues. Whereas main structure can be ready relatively quickly, finishing layers can often take comparably much more time. The bottleneck seems to be more related with the compatibility of the different assembly procedures in the limited space available in-situ, than with the time they take per se, resulting in time waste between the diverse steps. It is hard to make the logistic control, since it is not easy to force sub-contractors or suppliers to follow an optimal logistic plan. Given the limitations, it is often hard to implement parallel methods, making more sense to spread them over time and space. As variability options increase, the problem only grows bigger.

Getting around logistic bottlenecks. Only larger building companies, with considerable building volumes can have the strength to tie down sub-contractors, thus the only ones being able to aspire control over the logistic constraints underlying the compatibility of individual contractors in a project. However, in most other cases, the best option is to remove as many in-situ activities as possible from the supply chain.

Moving finishing and furnishing upstream. To remove the most labor out of in-situ, typically focus must primarily be held in finishing and furnishing activities, moving them as upstream the production chain as possible. To attain it, efforts must continuously proceed towards the convergence of the connections between different building systems (external connections), as well as of the compatibility between different elements of each building system (internal connections).

Boosting ex-situ production and visualization methods. To increase the degree of ex-situ production, having a previous knowledge of both the buyers and of the options they want is key. However, people often change opinion. In a systematized, prefabricated construction method, changing options after the building process has started raises even more risks and difficulties than in other building methods. Therefore, to minimize the risks, visualization methods can be key for customers' choice process.

13 IMPACTING DESIGN PERFORMANCE

Performance constrains due to services' weight in construction. The increase of services' weight due to comfort (e.g. thermal, acoustical), fire risk mitigation, overall sustainable requirements, and so forth, has become one of the major constraints in the spatial design, being pervasive to all construction methods.

Performance limitations due to the (un)knowledgeability of systems. Architects are not necessarily attached to conventional or ordinary construction methods, but are also far from being able to deal with all building systems, lesser even if these are relatively new and/or unknown.

Improving design performance by working from existing systems. Individual efforts by architects to adapt existing building systems (typically subjected to certification methods and the like) to their designs may prove to have little chance of success. Instead, it may be more feasible to constrain the designs from a prior knowledge of the systems.

Performance and design subtleties. Prefabricated building methods may even have a better technical performance, but that does not necessarily mean they are more feasible to tackle architecture's subtleties and complexities. Prefab methods have intrinsic potentials and limitations, which have to be understood and worked out accordingly, otherwise risking adding inefficiencies to the construction, with effects on output vectors. That is not a problem on its own, since working around limitations can work as a positive way for improvement. Nonetheless it is important to be aware of the risks.

Changing and/or developing a system. Changes on systems by individual architects may have a greater influence through publishing about architectural or technical performance in appropriate publications, than through single-handedly developing systems. The effort (time, financial) to proceed in the R&D and marketing stages is just too big to have likelihood of success if single-handedly doing it, unless perhaps if framed within a dedicated business structure.

Integration towards improved performance. Producers' impact will increase on the measure of the integration of both the *constructive performance* (certification schemes and the like) and the *design performance* (enabling differentiation, discretizing different building elements while enacting standardization of interfaces, and so forth).

14 FUTURE WORK

Test direct the design's light/ventilation and circulation conjectures against real cases. Assess the assumptions of the design case against a broad batch of historical and/or contemporary built cases, namely in respect to direct light/ventilation derived grids and to circulation optimization.

Extensive development of a global house prefab history. Develop in greater extent a global history of house prefabrication, further expanding some the sub-themes addressed (e.g. Japanese wood construction, patented designs).

Design a new residential house prototype. Design a new prototype, but this time with the accumulated knowledge since the first.

IV Epistemological Notes [A Global Epilogue]

"*It is no longer a question of either maps or territories. Something has disappeared: the sovereign difference, between one and the other, that constituted the charm of abstraction. Because it is difference that constitutes the poetry of the map and the charm of the territory, the magic of the concept and the charm of the real. This imaginary of representation, which simultaneously culminates in and is engulfed by the cartographer's mad project of the ideal coextensivity of map and territory, disappears in the simulation. It is all of metaphysics that is lost. No more mirror of being and appearances, of the real and its concept. No more imaginary coextensivity: it is genetic miniaturization that is the dimension of simulation. The real no longer needs to be rational, because it no longer measures itself against either an ideal or negative instance. It is no longer anything but operational. In fact, it is no longer really the real, because no imaginary envelops it anymore. It is a hyperreal, produced from a radiating synthesis of combinatory models in a hyperspace without atmosphere. Never again will the real have the chance to produce itself—such is the vital function of the model in a system of death. A hyperreal henceforth sheltered from the imaginary and from any distinction between the real and the imaginary, leaving room only for the orbital recurrence of models and for the simulated generation of differences*"

— Jean Baudrillard (1994) *Simulacra and simulation* : 2-3[396]

"*They say men lived in trees one time. Somebody had to get dissatisfied with a high limb or your feet would not be touching flat ground now. (…) Someone's got to do these things… Else Fate would not ever get nose-thumbed and mankind would still be clinging to the top branches of a tree*".

— Samuel Hamilton character in John Steinbeck's *East of Eden*

1 GLOBALIZATION'S SEMIOTIC PARADOX

In many senses, our world has become a globalized world[397]. Multiple events and conditions such as the dissemination of neoliberal though and economic orthodoxy worldwide, or how knowledge is produced and diffused, have been having major impacts upon processes of development, designing a global landscape, and deeply influencing our lives. Not surprisingly, the theme of globalization and its relationship with the built environment and with the territory in general, has fetched important concepts for architects, social scientists, geographers or economists, analyzing the shifts that have been occurring in the world's economic, social, or environmental sceneries [complement with: **Annex, IV.1 The phenomenon of globalization**].

In a structuralist sense, what can be called a *global culture* is as much a rhetorical construction as a *local culture*. Their critical construction is based on processes conveyed by signs, structured and organized in diverse ways, anchored in socio-cultural contexts, and to which language remains metaphor par excellence. Structures work dynamically, that is, it seems that neither their syntactic, nor semantic levels can be traced back to an ultimate *Ontology*. Instead, structures seem to have multiple traces depending on ever-shifting contexts and processes. In Umberto Eco's words: "*the code is presumably neither a natural prerequisite of the Global Semantic Universe, nor a structure that firmly and unalterably underlies the complex of bonds and ramifications that accounts for the functioning of every association of signs (…) i.e., that a semiotics of the code is an operative instrument that serves a semiotics of the message*"[398].

Generically, on the architectonic code, a *structure* can be synthesized as a relational and referential organism determined by processes of successive simplifications regarding the devising of an effective (formal) purpose. From an architect point of view this means that a code remains valid for the actions emanating from the architectural code-in-use, regardless the code's eventual evolution. But this is not necessarily valid for other codes, with the analogy also valid for codes used in different languages—e.g. the musician, the geologist, the economist, and so on. Such raises multiple questions, where are included, e.g., the role of technique, how can boundaries be set for a certain domain, the translation of thinking form to physical form, what differentiates the conceptual from the action, and so on.

Lévi-Strauss expressed that the ontological universalism of an elemental code stands above the languages in which is expressed, from where, ultimately different languages can be regarded as translation aspects[399]. Ferdinand de Saussure's structural linguistics indicates that *language is a form, not a substance*. However, if considering, as Eco did, that there is no *Ontology*, then substance and form are primitively equivalent. Thus, if substance is what emanates from difference (of form), then attempting to get to a primitive instance, where difference has not occurred, in the least seems to be logically incongruent. The mere observation of such original fragment would imply a difference roughly equivalent to the least required space-time conditions for form *to be*. In a way, in logical terms, this means form is all there is. But then logic is also a language. There is a circularity in all this. The mere existence in the space-time of forms does not require an architectonic (i.e. an organizational apparatus). Yet the architectonic is there, implied, when acknowledging form. Therefore, the architectonic is of a global tendency by definition, i.e. gathering otherwise fragmented entities in a language, going beyond the fragments to critically handle them, blending difference in a *fragment-plus*.

The existing and conventional structures of the architectonic code in architectural design and production are largely fixed by means of technical, orthodox, and traditional rules and laws[400]. Brazilia's ambitious planners and architects considered the principles of functionalism and cultural symbolism, which has nonetheless resulted in a reality where the lives of inhabitants and users, their changing behaviors and lifestyles, were greatly bypassed, so that what was left was a monument to (hollow) architectural rhetoric. Indeed, to make *global* is necessarily also to make on a univocal, and therefore insufficient, or partial perspective, and the same is valid for its *local* complement.

Adolf Loos once conceived architecture from triadic understanding of the architectural production: *craft* (action), *draft* (representation), and *critique* (rhetoric)[401]. In a modern industrialized world, from rhetoric, representation and action on a physical reality, the put in practice of a certain architectonic into a built environment is inextricably commanded by financial mechanisms, energizing the different unfolding plots from where forms arise. To a *capital* order adds that any one-sided attempt, such as e.g. a uniquely architectural approach, disregarding political, economic or technical realities, is insufficient to address the problems of the built environment. In this respect, Tafuri's lesson is unequivocal: "*It is useless to propose purely architectural alternatives. The search for an alternative within the structures that condition the very character of architectural design is indeed an obvious contradiction of terms*"[402].

Structural linguistics tells us that to make a language anew, it is in the least required a binary sender-receiver, i.e. requires the previous knowledge of a different, departing language—and it will primarily be the departing language which will be enriched. Analogously, the knowledge of local circumstances is key to the success of implementing global methodologies—e.g. architecture cannot take the place of the vernacular (the local's utterance) and vice versa, as this would mean a global language to destructively conflict with a local language. Local and global are mutual processes and, thereby, any *genius loci* or the like, is not but an idealization of a *genius loci*[403], their interdependence occurring analogously to the Vitruvian ethos of *house* and *city*. In such inescapability, the bonds of architecture and capital are a reminder of a freedom and fulfillment which architecture cannot but to aspire, trapped by the elements lost in translation in a global which is also local.

2 SPACE-TIME SHIFTS

Raised from a sort of cartographic need of control imposed by the efficiency required by capital, globalization became a ubiquitous issue in our everyday life, affecting aspects such as the products we consume, how we communicate, work and relate with others, affecting the modes in which we understand and experience space-time. The prodigious improvements in the field of communication, IT's and transportation, have been establishing new kinds of relationships in human history, reshaping the condition of place under a global-local dialectic.

As space-time perception is acutely altered by instantly available information[404], ease of commodity availability and people mobility, so the experience of the territory, or the concepts of nationality, citizenship, or authorship, are profoundly altered[405]. An instantly accessible *world on steroids* results in an image of support to the most private spaces, subjected to the openness and intimacy of online, pocket-fit and all-around available networks and the like. Such need for speed, or speed as need, is also responsible for a homogenization, or trivialization of a variety of public spaces that were once referential in an imaginary of local identities. The tendency is confirmed in many contemporary neoliberal discourses, powerfully expressing a representation of the globe as an increasingly integrated, homogenized, seamless whole, which settles in the prevalence of time over space, where synchronization overpowers location, clockwise efficiency crushes difference. As Paul Virilio wrote: "*in the realm of territorial development, time prevails from now on to space*". It is no longer a chronological local time, but a *"universal world time, opposed not only to the local space of a region's organization of land, but to the world space of a planet in the process of homogenization*"[406].

An adaptive (or evolutionary) development of construction practices had molded the physical elements of the human habitat until the Industrial Revolution. Since then, for the first time in history, and at a planetary scale, the fast pace of the modern architectural methods has in a way been homogenizing cities and architecture in a rapid and once unthinkable manner. In a sense, modern architecture and urbanism has not only given us flat roofs and sanitized streets, it has also contributed to a homogenization of our cities. As Frampton wrote: "*the phenomenon of universalization, while being an advancement of mankind, at the same time constitutes a sort of subtle destruction, not only of traditional cultures, which might not be an irreparable wrong, but also of what I shall call for the time being the creative nucleus of great cultures, that nucleus on the basis of which we interpret life, what I shall call in advance the ethical and mythical nucleus of mankind. The conflict springs up from there*"[407]. What is currently left from a mythical, slowly evolving vernacular world, is no more than a detached insight. In the great majority of the remaining cases, the archaic vernacular has turned into a sort of touristic theme park, where the original motives are barely recognizable, conserved in a form which no longer finds a correspondence from within. That can be noticed in the famous examples of Ait Benhaddou in Morocco, Mykonos in Greece, Cappadocia in Turkey, Piódão in Portugal, and many others. These are somewhat artificially preserved and there is barely any trace left of the socio-cultural systems that originally gave it shape. As result, in a way, these forms have become mere caricatures of a nostalgic and romanticized past time, while their surrounding territorial remains are left to an unprivileged chance.

In contrast, what we see in some extreme contemporary ordinary vernacular forms are miserable dumps where many would not even consider living in. These are no longer wrapped up of an old detached romanticism, and that is probably why they are often also called *ordinary forms*, instead of the (new) vernacular they too are. Famous [and astoundingly huge] examples sprang, from the *Favelas* in Rio de Janeiro or São Paulo, the Vietnamese *Nhaa ven song* river slums, the *Neza-Chalco-Izta* slum in Mexico City (the world's largest mega-slum also known as *Ciudad Perdida*), or the slums in Manila, Lagos, Mumbai, Caracas, and many others around the world. Yet, perhaps in a part of our imaginary, we would like these to keep modelling the built landscape, since regardless their evident issues, they too are compact, bounded, complex, lively, intense, bursting with problems but filled with life. Additionally, as in the archaic vernacular, they keep a certain photogenic quality, which can be so treasured in an isolated touristic visit or the-like[408]. Henry Cartier-Bresson used to say something like *what we photographers don't capture immediately, is lost forever*, and perhaps sometimes it is just easier to forget what happens outside the embellished frame. In a certain way, deeply we would like the vernacular's (ordinary) best qualities to keep characterizing the villages and regions of a coming-to-be time. Certainly, some of the empty historical urban centers, as found in some old-Europe towns, praise for the return of a lost density of life—the life that escaped, motorized, to the suburbs. It adds that, in many circumstances, we would prefer something else than the legal but speculative, [more or less] planned but diffuse recent territories, which can be found on the outskirts of many world cities, where rapidly the urban fabric is squandered in discontinuous, fragmented [and *ugly*] spaces which many would prefer to ignore.

Le Corbusier's tour, described in *Le Voyage d'Orient*[409], went so far as the Balkans and somewhere near Istanbul. Nowadays his journalistic notes on that voyage would probably never have that title, since for today's standards he barely left Europe, which makes what could be a kind of *exoticism of orientalism* account indeed sound rather common. Exoticism, if there is any left anywhere, has been belittled. In a world of revisited and easily available all sort of trivialized *seven wonders*, phenomena such as tourism in all its variants becomes a *global* experience. Every major city has, in its touristic guides, the art history or the contemporary art or natural history museum, the parks to visit, the opera, the busy bars and night-clubs area or even the two-story buses or panoramic boats; spaces above all dedicated to the needs of an erratic lifestyle that seeks everywhere the same facilities; spaces of temporary inhabiting that put a homogenizing veneer to localities. Nonetheless, as the unsuspected Lévi-Strauss points out, "*differences are extremely fecund*"[410], and it is unlikely that any sort of process, no matter how powerful, will ever completely shred difference.

We can see globalization as generating increasing homogeneity, while giving death to the fabric of diversity through a sort of *westernization* of the world. But we can also see it as generating heterogeneity and diversity, e.g., through hybridization. These can be observed in phenomena such as fusion of food, of music, of iconography, and so on. Inescapably, since industrialization took its pace in most of the world's territories, it is difficult, if not impossible, to speak about pure locally-driven difference. There are many signal inputs, observable at a socio-cultural level, of growingly hybridized societies shaped by a diverse subcultural fabric. For instance, great world cities are largely multicultural cities, with multiple ethnic groups composing them: from Indian or Polish living in London[411], to Chinese or Puerto Rican in New York City[412], Algerian or Portuguese in Paris[413], and so on. In many of these, it is perceptible an attachment of the migrant communities to delocalized traditions reminiscent of their places of origin, as noticeable by their nostalgic cafés, restaurants, shops, or in the neighborhoods referenced to these communities—in NYC alone there is China Town, Little Italy, Little Brazil, Koreatown, Little Germany or Le Petit Senegal.

The power of IT's boosts these *displacements* into truly heterotopic[414] manifestations, enabling that, in a fragmented panorama, phenomenon's such as immigration can be lived both in the origin and the destination. The place of arrival used to be set to be the only place in the immigrant's real life, but that is no longer necessarily the case. The vivid realities, which IT's are poised to create, can apparently make forget what the real looks like, embedding it in a sort of heterotopic illusion of proximity. This, in turn, can be deceiving, as it cannot replace the subtleties of a physicality achievable by a full presence with the original.

Likewise, the space-time shifts driven by IT's also make it easier to dissociate the work place and the dwelling place with the place of emotions, imaginary or of belonging. This affects fundamental aspects of our lives, such as the way we work or use leisure time, the way we move or rest… the way we dwell the world. That is particularly observable in a tendency of expansion of types of family structures comparatively to the traditional family patterns, consequence of different aspirations, different role of women, acceptance of different kinds of sexuality, different lifestyles, secularization, and so forth. The fast-paced arousal of the now pervasive social media has made it clearer than ever before.

Many of the changes in our perceptive notions of space-time can also be linked a certain loss of place identity. The *non-places*[415], a notion originally proposed by Marc Augé, describes some of these *lost*, universalized places such as a sauna, a hotel, or a shopping-mall, all non-permanent to their inhabitants, and all different but all similar everywhere: simultaneously homogenizing and hybridizing. For instance, tourism on high scales powered by low-cost flights, that make travelling easier and relativize length of travel into duration, is accommodated by a wide range of non-places, as are airports, railway stations, major chain hotels, or trade fairs[416]. Added to the physical, psychological or memory dimensions of a place, the ease to communicate to virtually anywhere in the globe, makes linkages to *place* to last and develop in different ways. The meaning of a place thus becomes more the product of the mounting sequence of perceptual experiences of life, than a simple juxtaposition of an individual meaning and personal space[417].

The nature of many of the places of contemporary society is given from its capacity to accommodate within a given frame, within material needs and geographical ties, within a multiplicity of meanings and projections. It is a nature open to multiple interpretations while still localized; it is vague and amorphous, but too static and rooted in survival needs. The *instant world* is a major source of the rhetoric conveying that with little effort and a little attention we can do *everything everywhere*: work in the most unsuspected places, socializing at our desk or on our phone, while creating increasing dependency with machines, changing the psycho-social ways to relate with the *Other*. Instant connecting means new significance to domestic and to private space, but also to open a breach to let in an unpredictable and not fully non-referential stream of signs and requests.

3 A GLOBAL ARCHITECTURE FACTORY

The space-time shifts involved in globalization processes empower the conception of a planetary factory, visible in multiple levels of the production chain, from design and production to purchase. From the mining of raw materials, to the multi-component devices designed, manufactured and assembled in many different locations, even in products we may not suspect at first sight, the log is truly global. Things can be produced and sold almost anywhere, be available almost everywhere, to almost everyone. Its epiphenomena in architectural production can eloquently be observed in a material sphere of the construction practices, with IT's as primary catalyzers of new ways of doing in design. Construction material availability is wider than ever, and material suppliers reach more places than ever. Moreover, the implementation of construction practices is ever-more transnational, with builders, designers, consultants, and so forth, circulating between borders [complement with: **Annex, IV.2 Three cases of global collaborative work**].

The subject uplifts an old epistemological debate in architecture, where *place-form* and *product-form* are key components[418]. There are the canonical arguments of *place*, of an architecture which relates with a certain local reality. But then, there is also the notion of architectural commodification, which springs from the culture of consumption, with readily available materials and technologies. Some seek the safeguarding and development of time-honored local architectural traditions, forms, decorative motifs and technologies, often defending historical continuity, cultural diversity, and preservation of identity. Others promote invention and diffusion of innovative forms, using technologies and materials in response to changing functional needs and sensibilities, often focusing on systemization, flexibility, adaptability or interchangeability. Apropos, Montaner observed that "*one of the basic features of the twentieth century was the triumph of abstraction over the mimesis, a triumph based on the prestige that reason and science had at the beginning of the century. Since then, a part of art and architecture took the machine and advances in scientific technology as a reference, and began to rely more on reason and systematization than in the irrational forces of imagination and creativity. It is an attitude of technological optimism that has reached our days and we can analyze it using two visions: the consolidation of abstraction as a renewing method to generate forms and rationalism as the basic discipline used by a part of architecture, art and thought*"[419].

Regarding an industrial sphere, on the one hand, architectural design can be a positive driver for change and product development. On the other hand, in many ways, state-of-the-art industrial methods seem far ahead from the construction methods used in architectural production. The different ways architects may approach the context, materials or technology at their disposal is subject to different interpretations. Theories asserting that architecture depends on where the building is to be located, the intended program to which it must respond, the material conditions in which it must be conducted, or the way the user may or not be enacted to participate in the design decisions, have been profusely disserted[420]. Rational methodologies, reflecting these and other concerns, are certainly a legacy that is to be kept alive and contextually fed. Nevertheless, the architectural artifact has also been conspicuously bonded with a subjective notion of *authorship/artistry*, which is in many cases adverse to certain rationalizing ways, as can also be to a stricter sense of *place*. On the other hand, the architectural perspective can too be disruptive, thus propelling breakthroughs and evolution, or even have long-lasting cultural or social impacts, acting as civilizational symbol.

Aside quality, the vectors of economy and efficiency have always been an architectural task, in the sense that architecture is ought to deliver the best of the available resources, whether they are provided plentifully or not. Anyhow, there is always an adjustment between the expectations of the different actors involved (architects, clients, builders, and so forth) and the eventually available resources. Additionally, the technical apparatus, necessary for a building to be, is ever increasing, requiring a growing wider knowledge of subjects such as heating, ventilation, or other applied mechanics, as well of the materials, their characteristics, certifications, regulations, and so on. Therefore, building structures and technologies are becoming more and more dependent on the appropriate intersection of ever-more varied and specialized skills and expertise, and the building's artistic imprint (or *authorship*) becomes more of a socially acknowledged trademark, rather than a fact. Anyhow, the reality of a building as the result of a collaborative work is not at all recent, as the XIXth century *Pre-Raphaelites* made sure to make a point. Nonetheless, if already more of a reality in the ancient builders of the great architectural landmarks, the issue has become pervasive to the most ordinary kinds of contemporary constructions.

The developments in building construction that rouse from an industrialized world have contributed to keep a juvenile excitement about the material and technological possibilities and a resolute belief in progress, changing architecture's entourage. A serious reevaluation of the design disciplines took its course in the burst of the XXth century, with a plea to bring a new insight to the architectural artifact. Architects, urban planners or theorists nurtured the ideal of a rational understanding of the built environment, developing methodologies to attain a maximum yield of resources, and so forth, epitomized in buzzwords such as function and economy, and stressed by the housing demand. Standardization ideas brought about by the rational functionalism were a major research front, as was the mechanized production of the architectural object. If that brought about new possibilities, by doing so, architecture was also moved away from an artistic character, towards an uncharted territory of *mechanical reproduction*[421].

Since the early stages of mass production, architects had to begin considering the tendencies towards individualistic and fashionable consumption, the need to market inventions and the devaluation of objects. For the craftsman, the pleasure in work used to lie in the relation to the object being produced. For the user, the pleasure of the production of the object arguably lays in the consciousness of its human origin, in its ontological singularity. In the work of art, it is not the form that is cherished, but the truthfulness of its originality or, as long put in evidence by photography, the authenticity of its underlying story. With an era of *mechanical reproduction*, it emerged a different satisfaction in a society of consumption, as it was notably stressed with the *pop-art*, that is, a hedonism laying not merely in the sense of a truthful story, but as a commodity fetish. On the other hand, if in some circumstances an original is the most valued, a sudden cognizance of a fake, in a once supposed original, drastically depreciates its capital value. Similarly, the collector cherishes the rare, authenticated object. But the artist and the collector act on different interests. The artist produces a synthesis which adds something more to a cultural heritage, enriching it, while the collector has foremost a conservative concern.

Housing has long been in the center of the reproducibility debate. Regardless its type, serialized house production always departs from a speculative standpoint, an attempt to satisfy the requirements of a market sector, or of an emergency. A customer of a house may have special requirements, but these will be accommodated by adjustments to pre-established designs, whose architect may no longer be involved. In architectural terms, the issue can be put on how can the practice adapt to the requests of a factory-based and market-oriented construction industry. The answer may be to simply follow a speculative path, designing first and consulting the final client later. However, this is an anathema to most architects, who become active only when the client requires a solution to a problem.

Moreover, there is the reluctance to abandon a certain notion that a building should be designed for a specific location—i.e. a unique building for a unique site, the building as an expression of the uniqueness of the *place*, or simply the designer's aspiration to design and/or to be acknowledged. Nonetheless, a speculative and reproducible path has historically been followed for a long time, of which the persistence of the notion of *type* is an obvious example. Indeed, the history of architecture is largely the story of adaptation and recombination of existing types and/or styles. A certain rhetoric of resistance to design buildings speculatively and without reference to a specific site is even more surprising as it has been a perfectly normal practice, at least to the dawn of the modern movement.

As current online social networks display, the more an object is reproduced, the more it can increase its value, which, in a way, contradicts the idea of the old law of supply and demand, as the object becomes more valuable and hence desired as it is increasingly more visible: it is instead the logic of publicity working. In a way, in our post-industrial society, things no longer need to be produced, they just need to be reproduced, with the idea enhanced in the immateriality or apparent innocuity of the digital artifacts. In fact, since products are subjected to the commandments of trends and the like, the value is established much in function of the visibility laid by the innumerous forms of publicity, with marketing becoming a ruler of social behavior—semiotics all around.

With the increase in sophistication in the production processes, upgrading the once only repetitive mass-production, questions regarding the actual difference between fashion and style, the patent or copyright problematics, educating consumers, the role of brand names, trademarks or display surfaces inevitably arose in architecture. It was as if the magic of culture, that had been lost with the loss of reciprocity between people and their handcrafted and inherited artifacts and the resultant loss of enchantment in the environment, was regained with the promise of an immediate, live, contact, where we all are apparently connected and possibilities seem limitless, although in fact they are not. In this sense, the modes by which architecture is produced and what architecture produces has been destabilized. In a way, if ever, architecture no longer seems to *afford* a patient transaction between cultures and possibilities, between investment and return, between the building and its experience—between seeding and cropping. In some cases, it mutates to the virtual instead of real buildings, freshness instead of slow, digestible, time. These are not *deviated* architectural approaches, yet once again signal of an inevitable epistemological transformation, following the motion of the world, and anyhow affecting the ways architecture is made and delivered.

The global design factory is punctuated by brands, the semiotic backbone of the social visibility of things, the main driver of the consumption requirements of our economic *reality*. But if that is evident for consumer products, from *Coca-Cola's* to *iPhone's*, it may not be so clear in architectural design. Business agendas, consumer expectations, or market opportunities drive a ubiquitous culture of commerce which is too manifested in the built space. Architecture is thus also an instrument of power and capital, with representations set to endorse the symbolism and image of states, governments or companies, used for product identification or corporate purposes, branding space-time. It is thus not difficult to imagine cities not as skylines but as *brandscapes*, and buildings not as objects but as advertisements and destinations, again and still *complex and contradictory*. Times Square buzzing screens is a remarkable example, with its powerful electronic ambience. But the phenomena can also be more ordinarily observed in the glossy façades of mega-capital buildings punctuating the built landscapes of cities around the world, housing corporations, banks, hotels or offices. Likewise, *branding* in architecture can mean the expression of identity amidst a complex social fabric, whether by a company or by a city: *Prada's* attachment to *starchitectural* design or *Apple's* designing iconic *iStores*, where the very architectural design is patented, ready to replication, but foremost to corporate-protect an envisioned *total consumer experience*; New York, London, Dubai, Lisbon using architecture to propel their images, in order to generate economic growth, and elevate their visibility worldwide.

As experiences become increasingly commoditized, and the global landscape seemingly more homogenized, it is also the role of architects to input meaningful transformations in a growingly aseptic language, of complex and mesmerizing but somewhat void shapes, where even difference is often addressed equally[422]. There are international brands, from junk-food to fashion, implemented a bit everywhere, with typified products, typified spaces, such as hotel rooms looking the same whether located in Nairobi or the Soho, and so on: *non-places* all around. There are too the local brands, which will inevitably copy successful design formulas that come and go with the trends, and the affordability of massified design products—from an *IKEA* chair and desk, to a state-of-the art *Apple* desktop computer [complement with: **Annex, IV.3 The *Bo-Klok*, or architecture as branded product**].

There are also all sorts of practices of consumption and incitement to consumption, from museums or concerts to organized tourist tours, which share common economic, cultural and social processes worldwide. In many cases, and sometimes contradictory with some of these very practices, these been made at the expense of regional or local identities. For instance, catalyzing the destruction of older or consolidated urban fabrics, reducing investment (and potential for investment) in those, by instead opting to direct investment towards speculative schemes sprawling on the cities fringes and beyond, or its inverse, creating speculative bubbles which force people to move away. In some cases, this was at the expense of a suitable concern on the needs of the inhabitants, with reflex in the urban landscape, for instance by only making affordable housing schemes of doubtful quality and/or meager floor areas in exhaustively repeated typologies. In many cases, these were the result of a sort of deficient or limited long-term views by decision-makers, caused by economies following their own profit-driven ways, to which may be added, for instance, some lack of critical judgment or political short perspective.

The shifts inducted by a global design factory can also be signaled at the level of design conception. The so-labelled architectural postmodernism offered numerous of such examples. For instance, Michael Graves has designed all sorts contemporary interpretations of classical shapes, doing it systematically regardless buildings' sizes, contexts, functional programs or locations: "*mimetic devices for a culture unfamiliar with the initial sources, belated signs of a public domain they never had, and never will have. Rome imported via New Jersey to Japan, the literal collapse of time and place*"[423], as Rem Koolhaas described. In a certain sense, these are in the least conceptually familiar with what occurs in places such as the *Paris Las Vegas Casino* in Las Vegas (1999), extravagances in the middle of the Dubai desert, such as the *Burj Khalifa* skyscraper (2004-10), the real-estate *Palm Islands* (2002-08), or the indoor ski track of *Dubai Snow Park* (2005), or other flaunting displays as a swimming pool connecting the rooftops of Singapore's three-tower *Marina Bay Sands* (2010). All in all, heterotopic architectural dimensions of more or less anachronic glimpses, capitalist symbols, global as can be. The long-praised notion of place, or even of architectural artistry or authorship seems irrelevant in these places. What is depicted in these postmodern landmarks is true capitalist ideology in the extremity of the *artifact-artifice*: an architecture as symbol of man's delusional power over space, over time, and finally over nature.

4 ARCHITECTURE, MEDIA AND THE MASSES

Architecture has been acquiring a global character which is inextricably linked with a conspicuous media sphere in which it is more and more involved with. The idea of a media affair is deeply historically rooted. We can notice it, for instance, by the spirit of the so-called architectural *styles*, as are the cases of the *Romanesque* or the *Islamic* architecture, both conveying a globalizing spirit[424] and embodying a dissemination device. These are examples of an ancient, but still common mode of diffusing architecture, which can be related with information processes, but also to a critical sphere of the profession.

Fed by the crafts, but also fed by the critique, architecture has always sought ways to communicate itself, even to the point of becoming mostly a representational métier, more of a draftsman thing than of a craftsman. As Loos wrote: "*Books meant little to the craftsmen. The architect took everything from books. (…) And there was no end to the abomination. Everyone was desperate to see their things perpetuated in new publications and a large number of architectural periodicals appeared to satisfy the vanity of architects. And so it has remained to the present day. There is another reason why the architect has ousted the craftsman. He has learned draftsmanship, and since that is all he has learnt, he is good at it. The craftsman is not. (…) The architect has reduced the noble art of building to a graphic art. The one who receives the most commissions is not the one who can build best but the one whose work looks best on paper. There is a world of difference between the two. (…) The graphic arts and architecture are polar opposites, at either end of the row. The best draftsman can be a poor architect, the best architect a poor draftsman. Nowadays those entering architecture are expected to show a talent for graphic art. (…) But for the old master builders the drawing was merely a means of communicating with the craftsmen who carried out the work*"[425].

From mouth to mouth of master apprentice, to a contemporary communication to a wider audience, the choice of certain labels or critical statements aids to spread the architectural knowledge[426]. For instance, the word *style* is often used in architecture to reference a certain period, or certain characteristics, to convey a certain type of approach, a mood, an aesthetic, a recognizable type of form, or of construction, or of conceiving, or of building. It thus conveys a bond to craft, although it extends way beyond. This or other labelling is embedded of a universalizing character, which serves for its more or less arguable characteristics, but fundamentally for the purpose of communicating it, to make it understandable. Thus, it is ultimately a critic's, historian's or theorist's construction, and inevitability, we must enter a taxonomic domain to observe, analyze, describe, or finally re-conform space-time in architectural terms[427]. For instance, modernist architecture, portrayed as a movement to produce a universal language has been critically called the *International Style*[428], or in the bonds of architecture with capital, a notion of personality cult has contributed establish a *starchitectural* label over a self-referential, global constellation of architects[429].

Loos stated that on the opposite end of craft is draft. Perhaps he was not accurate, and on the opposite end of craft is critique, as craft is enriched by draft, enriched by critique, and recursively so forth; or perhaps there are no opposites in this story. As signaled by a *Tate Britain* exhibition in September 2012, the late XIX^th^ century *Pre-Raphaelites* left an important legacy regarding the preservation of the values of craft while criticizing an establishment of a mechanist perspective and somewhat appraising sense of a non-authorial centered, communal work. On our times, the drift away from craft is more and more accentuated, but no longer because of a mechanist apprehension, as machines are already embedded in our realities, but because of a growing visibility of critique propelled by a conspicuous media.

Vitruvius' *Ten Books of Architecture* was, for the romans, a sort of universalization of good practices, as the books conveyed a certain generalization of ways of building. The principles have endured the centuries, being occasionally revived—as was the case of Leone Battista Alberti's (1404-1472) reformulation in *De Re Aedificatoria* (1486)—but architectural knowledge has benefited from different ways of transmission. The ancient master-disciple knowledge transmission evolved, information availability increased, and more perceptive modes of accessing were developed[430]. In architecture, as in all areas of knowledge, that would be boosted by signal developments in printing or information systems—from Guttenberg's printing system, the Morse code or the telegraph, to current digital systems. All in all, these contributed to the development of a broader intuition on the underlying processes of architectural production.

Vitruvius' books had no figures, but modern books soon were illustrated, providing architectural diffusion a richer visual sense[431]. The new endorsement was arguably inaugurated in 1537, by Sebastiano Serlio's publication of the *Tutte l'opere d'architettura, et prospetiva* treatise, the first book of a series of eight—the last two were actually only published in the XX^th^ century after his manuscripts. It is the first of its kind to be though for a wider audience as it is written in Italian—some were even published using alongside text in French—and made use of high quality illustrations, unlike Alberti's *De Re Aedificatoria*, written in Latin and with no illustrations. Serlio's ambitious publications were the first to present architectural theory in the form of a professional manual. It contained illustrations of similar series variations on a theme, such as the *palace* or the *private house*, none of which is derived from Classical buildings.

In 1570, *I Quattro libri dell'architectura,* by Andrea Palladio (1508-1580), was first published in Venice, and remains one of the most influential treatises in the history of architecture. It provided systematic rules and plans for buildings drew from Roman buildings and authors (namely Vitruvius), as from Italian Renaissance architects. It included plans and elevations of twenty villas, not all executed or with that intention in mind. The plans were also ideal types in which the principles of Renaissance composition and theories of harmony were presented. The conventions of composition and construction governing correct building practice are there established by prescription and example, as Palladio combined historical precedent with his own work, significantly innovating the genre of the architectural treatise. It is notable for its vivid language, striking images, the ease with which historical examples sits alongside the designs they inspired, and by its accessibility. It was widely disseminated outside Italy as it was translated into several languages. The published translations increased the popularity of Palladio's designs internationally, and helped their imitation and interpretation regionally. They left their mark on pattern books and trade publications, and so Palladio's ideas became accessible beyond the upper-class owners and book collectors[432].

Alberti's, Serlio's or Palladio's treatises are some the most influent of its kind made in the Renaissance, yet are only some between the astonishing body of work that was produced in that period[433], reflecting an interest in recovering history and transform it into a new path for knowledge through the sciences and the arts[434]. These treatises would inspire countless imitations that would eventually develop into forms such as architectural manuals and pattern books. For instance, through English translations of his publication, the influence of Andrea Palladio would eventually reach colonial America, becoming highly influential. Also significantly, a flood of more than 100 luxuriously illustrated pattern books were published in England during the XVII[th] century to be broadly distributed in America[435], although that many variations were not only due to Palladio's. In any case, a *high* architecture could thereon reach almost everywhere, although many would degenerate to interpretative, down-graded developments of the originals.

As Davies writes, "*by the mid-nineteenth century in England the pattern book was being eclipsed by the rise of the architectural magazine. In the USA, however, it was spreading and beginning to mutate in interesting ways*"[436]. A remarkable mutation would be that of the house catalogs, which started being published in the late XIX[th] century onwards in countries such as the USA or Sweden. Although not particularly known for notable design qualities, the development of pattern books or house catalogues nonetheless contributed to spread architecture to the masses. In the least, these typically assured quality construction, and inspired buildings made to the thousands. The developments also point out for what it can be interpreted as an inevitable association between architecture and publicity, and of bringing to the table an architecture that may not necessarily depend directly on a client, or of a direct relation with a client, or of a place, of a context. That is, to an architecture in the process of finding new and different ways of acquaintance, which envisions a more generic, global character. A vision of an architecture of validated constructive systems which are poised to different sorts of combinations to produce different designs, while deeply entangled with a business language, as with intrinsic bonds with prefabrication methods.

Architectural treatises, paired with manuals, have always been linked to the day-to-day *high* architectural practices. The late XIX[th] century catalogs offered a dream to the masses, with their considerable variety of plans, regardless being a depiction of certain idealized tastes, or styles. The prominent Frank Lloyd Wright himself would issue pamphlets, advertising a popular, stylized architecture with controlled costs. For the most part, architects were unnecessary for these catalogs, once they were offered as a complete package. In the early XXth century the *Aladin* or *Sears Roebuck and Co* catalogs were well-known in the USA, among dozens of other books that had homes ready to build. It is famous Buster Keaton's (1920) surreal comic satire to this type of houses in the short film *One Week*, in which the character attempts to mount, following an instruction book and without great success, a wood catalog house received by mail from a fictitious company name *Portable House Company*. The example denotes the socio-cultural relevance of these catalog houses and is an eloquent metaphor for the difficulties inherent of the prefabrication of housing construction.

The businesses of houses received by mail would not survive the Wall Street crash of 1929 but the catalog method persists today, accounting for much of the American suburban landscape. Current software-packaged house catalogues are much more sophisticated. These may include pre-designed house in certain styles, as well options for the intended number of bedrooms or the price range, and so forth. It is also possible to set houses in a tridimensional environment using diagrams which are later translated to real plan by the software in use, opting for the variety of forms of roof, windows, doors, materials and others. After opting, software may translate the design to plans and other visualizations, making instant bills of materials. As in the catalog method, options are obviously limited.

In a different perspective, some of the developments of architectural publications also evolved to an idea of brand, embedding the notions of trend or fashion, thus more restricted to a specific time and range. Contemporarily, we can associate the phenomena with certain fashion magazines, coffee-table books, or the like, showing the ultimate trends of living, and mixing it with design furniture and objects, presented in carefully selected photographs. The social media, blogs or other web phenomena have given it a different twist. The examples are plentiful, from more generical design media—e.g. *Wallpaper*, *Dezeen*, *The Cool Hunter*, *Evolo*, *Icon*, *Mondo*—to more arguably more specific architectural media—e.g. *ArchDaily*, *Architizer*, *Architonic*. Bounding it with a certain trend, via a mix with design or art objects and the like, makes it more appealing to a wider audience, but such is also a double-edge sword. As people are supposedly more informed, the speed of trends may often set little or no room to a suitable scrutiny of information, to which adds effects such as the repetition or circularity of content between the different media and publications. There is more information available, but also more noise disrupting the message.

As argued by Colomina, in an early reflection on the theme, architecture only becomes modern in its engagement with the mass media, and in so doing so, it radically displaces the traditional sense of space and subjectivity[437]. Where conventional criticism may portray architecture as a *high* artistic practice in opposition to a mass culture, an informational paradigm has come to define our culture as the true *place* within which architecture is produced. The architectural discourse has thus become an intersection of a number of systems of representation such as drawings, models, photographs, books, films, and advertisements. Such does not mean abandoning the archetypal architectural object—i.e. the building—but rather looking at it differently. In that sense, the building can be understood in the same way as all the media framing it, as a mechanism of representation in its own right. It is again Loos' triad of *craft*, *draft* and *critique*, with an increased emphasis on the latter, certainly a reflex of a post-industrial detachment from craft.

With modernity, the site of architectural production moved from the street into photographs, films, publications, and exhibitions—a displacement that presupposes a new sense of space; a space defined by (moving) images rather than by walls. Today's architecture renegotiates the traditional relationship between a communal and a domestic sphere in a way that profoundly alters the experience of space. The (built) landscape is affected by fashion, war, sexuality, art, show, religion, TV, or social media. Finally, it is distilled on the interiority that constructs the (post)modern subject: its dwelling[438]. We have been witnessing an increasing projection of architecture in processes and displays of media representation, through brands, advertisements and the like. That can be traced back to the advent of a modern approach, as noticeable through Loos' or Le Corbusier's writings. Architecture and media representations are now entangled more than ever before, and that is in a good part due to the ubiquitous nature of the media we currently have at our disposal worldwide twenty-four seven.

5 SHIFTS IN THE PROFESSION

The media entanglement is linked with an important aspect surrounding the architectural profession, which is social notoriety. Visibility begets attention, attention begets discussion, discussion begets notoriety, and finally, perhaps work to feed the architectural office. Work begets visibility and so on, in what appears to be a natural cycle. The tradition of architects' visibility is straightforward: trained as professionals, architects acquire work through both their contacts and the skills they demonstrate in making buildings. Built work gradually ensures wider circles of attention for the practices, and correspondingly more work, increasing in volume and in complexity as a reflection of the growing contacts and expertise. This tradition certainly may broadly true for most architects exerting the profession in a conventional way.

There are others, perhaps more intellectually inclined, whose ambitions may lay in having more direct impact on the environment, following more of a political path. In this case, the connections must be pursued more aggressively, the level of achievement is set higher, the cultural pretensions of the work are similarly high. In the past, quite often such architects became the heads of academies (Walter Gropius or Hannes Meyer) in order to be part of the political system, to be closer to the nexus of decisive political power. Another route to visibility for the ambitious architect was the radical group, the exhibition, the competition scheme, the private publication, the manifesto (Le Corbusier or Mies van der Rohe)—the building as a means was not always available to such architects, whose connections to, or influence over private individuals or corporations willing to spend money on building, were very often limited.

The majority of the acknowledged Modern masters (in Europe, anyhow) and members of the avant-garde had these *qualifications* in common, forming a tradition of their own and providing a template for future generations of architects. It is worth stressing that these were referred to by both the public and peers alike as *masters*. It is also worth noting that this tradition is still very much in place today, i.e. there are architects sustained by their directorships of academies, and architects who survive on the basis of hypothetical projections. In the worse cases, the visibility value in each may stand in old-fashioned perceptions of the authority of academic work and the artistic honesty of *independent creative research*.

One of the outcomes of globalization in respect to architectural practice has been the emergence of firms with a global portfolio. There are transnational corporations in their own right built up commercially, rarely winning awards and building up a lot; or the ones that have grown from practices that are design-oriented but business-centered. There are also design-oriented practices but whose senior partners have grown a great deal of visibility, a celebrity status even[439]. This *starchitecture* walks along commodification, of a global commercial culture that is enabled by changing consumer expectations, market opportunities or business plans. Traditional identity groups based on class, ethnicity, age or genre started blurring as people were growingly free to build their identities and lifestyles through their modes of consumption. Product design and niche marketing, as with branding, have become nuclear to the enchantment and re-enchantment of things. Guy Debord's *society of the spectacle* gave birth to a society of consumption[440].

The architectural manifestations of these developments include iconic sky-scraping banking towers and TV networks, chains of brand transnational hotels, franchise restaurants and shopping malls full global brand stores. Even city centers are commodified or transformed into a sort of museum by urban makeups and/or punctual state-of-the-art interventions by renowned architects. National and regional governments hire famous architecture personalities to refresh their city skylines and create memorable places. Examples of such buildings are the *Guggenheim Museum* (Frank Gehry, Bilbao), the *CCTV Headquarters* (OMA, Beijing) or the *Swiss Re* (Norman Foster, London). Their authors are part of the legion of *starchitects*. All of it could not exist without the media[441].

From the 1990's, the media buzz phenomena showed its great influence in the world of elite architectures, where media powered images started to predominate over real buildings. All of it is the expression of what was before announced by Marshall McLuhan in the 1960's: the predominance of visual media over the language and the contents. The era of digital image-media-production has cursed much of the architectural production to immediacy and often to a kind of futile search for instant memorability. Carefully selected photographs in slick magazines and professional journals become the ultimate glorification to their authors: a signal of self-cult and of commodification of architecture in a growingly global consumerist society; a quest for a sort of impressiveness that leads to the disappearance of perception and memory; a set where buildings, claiming for attention, struggle to be distinct from one another, where the cacophony of the whole results in a seemingness of the parts, all-new, all-different, looking kind of all-the-same. Sometimes the amazing photographs in slick magazines are just preview renderings or illustrations, authentic *virtual-architecture*. These are often at service of marketing strategies for all sorts of purposes, from seducing and convincing the architectural client with the aid of imagery, to large-scale publicity of speculative real-estate.

The global financial crisis and the major cuts associated in the construction industry that have occurred in the end of the first decade of the XXIth century forced many architects to deeply rethink their profession. It gave a stronger, conjunctural visibility to a state of epistemological transformation which has deep structural roots. Regardless the circumstances, in some cases, architects turn to a sort of boundary skills, for instance by selling their work also as virtual images creators, advertisers, graphic designers, and so on. In other cases, in larger structures, architects rethink their overall philosophy of architectural production. In such cases, the profession can be fostered into a sort of architectural consultancy scheme for areas such as fashion or advertising, as it is the case of OMA/AMO company[442]. In many circumstances, to be a business from which people can make a living from, architecture seems not to afford to be just architecture in its age-old *high* sense, or in the least be ready to ever change. Such is a deep conflict, which has been existing for long and probably will keep for long[443]. Tafuri has eloquently described the effect decades ago: "*Paradoxically, the new tasks given to architecture are something besides or beyond architecture. In recognizing this situation (…) I am expressing no regret, but neither am I making an apocalyptic prophecy. No regret, because when the role of a discipline ceases to exist, to try to stop the course of things is only regressive utopia, and of the worst kind. No prophecy, because the process is actually taking place daily before our eyes. And for those wishing striking proof, it is enough to observe the percentage of architectural graduates really exercising the profession. Also, there is the fact that this decline within the profession proper has not yet resulted in a corresponding institutionally defined role for the technicians charged with building activity. For this reason one is left to navigate in empty space, in which anything can happen but nothing is decisive*"[444].

The 2011 RIBA (*Royal Institute of British Architects*) call for the architects' role in 2025 was both a signal of a growing professional concern on the object of the very profession, and of a state of *crisis*. The question it poses says it all: *Will architects exist in 2025?*[445]. The very word *architecture* is often and increasingly borrowed, e.g., to computer programing language in expressions such as *programming architecture*, *system's architecture* or *software architecture*, giving emphasis on a blurred state of the word, and of the profession. All these can be seen as manifestations of crisis. By crisis, we do not necessarily mean a more or less conjunctural economic crisis of global effects, that may erode a construction sector and hence the architects' ability to produce their work into the built environment. It is also a crisis laying in the very ethos of the job. If even the *starchitects*, as in the AMO proposal, feel the need to turn themselves to other tasks, in the least, we can assume that we are moving towards a state of things where the architect's role is voided from a traditional or conventional sense.

6 CRISIS, CONFLICT AND EMPOWERMENT

No one could seriously expect architecture to solve societies' ills, as some modernist founding fathers apparently believed. However, even if it embodied such potential, it would have to reckon that the world is ever transforming. Nonetheless, architecture can contribute to make a difference. In the least, it can make a difference between something that exists and an aspiration, an intention into the future, a resolute target, set regardless contingencies, creating symbols and images, giving a more tangible body for such purposes. In this sense, architecture can work as a powerful political and/or ideological servant, vehicle towards certain purposes. Some political decisions set the course of entire nations, or even affect people across the world, but architecture per se is unlikely to reach such an influence. Anyhow, the ability for architecture to make a difference may often be less in what has a more direct visibility, and more in what remains invisible or untold, in the impressions it sets available to provoke in people's minds regardless any aprioristic intention.

Between the theoretical advances in the sciences or humanities, and architecture's developments, there is a vast unexplored territory. Broadly, that most probably has to do with a material and formal bond that architecture is required to fulfill, whereas in areas whose bond is predominantly set in a logical field, and/or a verbalized concretization, the development of ideas and concepts can expound without less of constrains of a practical order. In that perspective, architecture might not aim but to attain a lesser conceptual complexity, since its language starts from a more constrained milieu. That is, a milieu in which in the least some sort of perceptible form in space must be delivered, and that inevitably implies *mental* concessions for the sake of a sound *executive* deployment.

On the other hand, architecture can deliver things that other areas cannot, and that do not necessarily have to belong to a logical or verbal field, but simply to things which are latent within a sensible sphere, that is, whose language is *non-lingual*, thus with greater potential of engagement with the senses. Typically, this can be found in other artistic expressions, even in those art forms that we may not suspect of beforehand. For instance, in Robert Wilson's *theatrical plays*, an art which is canonically verbal, there is an assumed non-verbal dialogue between the different elements, between the actors, the set, the lights, the audience, and so forth, and finally in the space-time they all create[446]. Remarkable architectural specimens, aside their more or less describable features, can also transport us to *placeless* and *timeless* places, that is, create an effect that both exceeds and is deeply within us, speaking to us silently.

Aside the experience that architecture can provide us, there is also an illusional side, that is, the projection into a future, making us mesmerize in what the future may be, providing concrete images of how it may look. But as every illusion, that can also turn out deceptive. Regardless the criticism arising from prominent thinkers such as Guy Débord, the social movements of the 1960s were pretty much laid in the context of a techno-optimist worldview. Post-WWII economy was driven by consumption—the baby boom was a consumption boom, an unlimited belief in progress. Anticipating what would be the post-war trend, the 1939 *Flushing Meadows, New York World Fair*, was based on a vision of the future, with a view of forces, ideas and machines that prevail, plunging its visitors in a technological world of wonders, where they can be at the forefront, as empowered consumers[447]. The 1970s oil crisis would recall a deeper reality was at stake. From the unlimited belief in progress, uttermost expressed in architectural terms in the *ad novo* construction of Brazilia, to the Vietnam anti-war protests, it was just a small step.

The Keynesian economic theories served as a model in the developed countries to overcome the Great Depression, WWII, and subsequent postwar economic expansion (1945-73). The theories would lose influence with the oil crisis of the 1970s[448], but with the global financial crisis kicking in 2008, there was a resurgence of application of the Keynesian ideas by some countries. We do not have to go very far to find examples in which something that is planned as a bright future eventually reveals its faults. For instance, in Brazil, some of the stadiums built anew for the 2014 *World Cup* were set for sale in 2015[449], in the very least signaling the failure of a sort of delusional belief in techno-optimism. Between conservation or consumerism, durability or obsolescence, the 2015 *Volkswagen* scandal was just one more nail in the coffin, probably just the tip of the iceberg, in the least signaling how doubtful so-advertised eco-friendly intents may truly be.

In a famous paper, the *Dilemmas in a General Theory of Planning* (1973), Horst Rittel and Melvin Webber wrote that there could be no universal truths in design, there is no objective best solution, "*there are only good or bad solutions*"[450]. In a way, that opens way to an understanding that formulating the (design) problem is the problem. In this sense, form is (un-conscious) restrain and, thus, design should embrace wickedness and complexity. What remains, one may consider is applied technical knowledge, derivative knowledge stemmed from an initial formulation. Nonetheless, the technicality of the derived *remainder* is as important as the problem formulation to bring form into life, and can be extraordinarily complex to put in practice. One day Edgar Degas, the painter, complained to Stephane Mallarmé, the poet, that it had cost him a whole day to try to write a sonnet: "*And yet I'm not lacking in ideas, I've enough of those!*"; Mallarmé could not resist answering: "*But Degas you need words to make a sonnet, not ideas*". Anyhow, the technical expertise in many circumstances is simply not enough to address what can be urgent habitat issues, and in the harshest cases people have to manage a way to get a roof over their heads.

In contrast to an inescapable media culture of architecture, architects probably ought to spend more time reflecting on the socio-spatial effects of their work. Certainly, architecture on its own is not able to solve *society's ills*, but architects have an immense social responsibility, as their hands are traversed by an enormous communal investment towards the built environment. Architects are vehicles to formalize it, and by so they ought to deliver living environments which enact people to exert their own control (their freedom), and sustain voluntary or spontaneous social interaction. In the least people, should be free to pick if the dwelling is to allow a certain self-fulfillment and/or if *housing* is to be made and traded as any other consumer good, and so on. The *Pritzker* prize attributed in 2016 to Alejandro Aravena in the least denotes these concerns in the debate.

Nonetheless, to some architects, the contemporary *cathedrals*, such as the museums, have in many cases become the [formal] ideal of the house. By that, we mean that there is a kind of silent competition for public visibility to deliver the most extravagant, out-of-the-box concepts and forms. It is as if every piece of architecture was to acquire a grand artistic status or the notoriety of the remarkable and exceptional public buildings. Most likely, a built environment made exclusively of architectural exceptions would be as tedious as if uniquely made of monotonous repetition. The correspondence seems to be mutual, that is, a house too can be used as a prototype of an object of a larger scale, as has been exemplified with the model of a house blown-up to the scale of a music hall in Rem Koolhaas' *Casa da Música* (2005) in Porto. Overall, these references also signal an architectural culture where the *structures* float in shifting significances. Such is artistically and aesthetically fruitful, as it may be socially or sustainably neglecting. Truly addressing social or environmental matters is often faded, or left to a secondary plane. It becomes indirect consequence, not primary concern. With it, a *culture of congestion* truly becomes a culture of *form-casing-congestion*[451], where the only remaining ethics is aesthetics: individualistic society at its best.

Architecture is not like art, as in classical sculpture or painting, it creates spaces that are ought to be lived and experienced. It is not a museum art piece, although the museum itself is in display. As Herman Hertzberger ironically notes, "*the problem with buildings is that they are too vulnerable, too subject to deterioration, and too big to fit in a museum*"[452]. In this sense, architecture should be open-ended, capable of interpretation. That includes acknowledging the existence of diverse tones and shades in an architecture *vs* user/society *conflict*. When we say *conflict*, it is not only a conflict between the architects and the rest, that is, a conflict between those that need to be *educated* to understand what architecture is about, and those that supposedly know what it is all about—as we know, the noble intents to give and architectural *education* to the public have already astoundingly failed in Modernism. Instead, it is an unfolding epistemological conflict occurring in and out architecture.

It is important to remind that conflict is not necessarily a negative, antagonistic force. It can also be a creative force, enduring the ability to free think. A force involving direct communication, and that hence may be used as a generator to engage or maintain a participatory process, to escape an imposed alienation—participation as a means of exerting liberty, of individual control over how to live, how to deal with the body, to free think. A thus architecture of alterity seems to imply the blurring of the architect's role, and this can render a certain fear in the professionals on whether or not to include imponderabilities in the designs. Empowering the user is freeing, but also making it consciously responsible, accountable, and such does not mean voiding the architect's role, yet making the architect more aware of alternative modes of addressing the architectural design.

Moments of crisis, of conflict, are also moments of creative production. Fast-moving, unfolding conflict has an acritical, naïveté quality, which is mounted in crisis. On the other hand, long, pondered motion sets space for critique, and is of a very different type. Crisis intervenes in the avant-garde production of difference, the critique in recording, labelling, cataloging, and set comparably, acknowledging the change that occurs through difference. "*Coherence is the virtue of imbeciles*", said Oscar Wilde; "*todo cambia*" sang Mercedes Sosa; "*the constancy of change*", wrote Amos Rapoport. The space of contingencies is also the space of creative action, the freedom to act, of changing opinion, of changing circumstances (and change changes).

Then, there is also a double-sided gap of knowledge, and communication, which is conflictual, laying between the expert (architect or other) and an eventual user empowerment. On the ambiguous status of the professionals and the *outsider* relation, there is difficulty in identifying with the architectural occupant, and the occurring lack of communication leads to a form of imposition, which results in conflict. On the other hand, in an ultra-liberal marketing-flooded contemporary global society, the claims for social engagement must be carefully scrutinized, as sometimes it becomes extremely hard to distinguish if these are really for real, or just another way of getting on by a system engaged in profit: the business as usual.

Between the 1960s social movements and today, there is a major difference in the economic environment, to say the least. In a way, neoliberalism has become conspicuous, and *idealism* has given its place to his alter *entrepreneurism*, even if both can be considered as different names for an analogous purpose. The prolific development of *utopian* architectural proposals in that period is certainly related with a sort of intellectually naïve belief on non-limited prosperity and social well-being, provided in a time where economic growth seemed unlimited. James Howard Kunstler has delivered an expressive diagnose on the issue: "*The immersive ugglyness of our everyday environments is entropy made visible… One can call it many names, 'automobile slum', 'suburban sprawl', 'technosis externality ex-tra-fuck', or simply the greatest misallocation of resources in the history of the world… The end of the 'cheap' oil era is about to change everything, and there is not going to be a hydrogen economy… Therefore something will have to be done. We will have to downscale, rescale, downsize virtually everything we do, and we cannot start soon enough to do it… The age of the 3000 miles Cesar salad is coming to an end, and new urbanism must take it into account… Life in the mid XXI century will be about living locally, and necessarily be ready to help the neighbor next door… We are not consumers; we are first and foremost citizens*"[453].

We believe that the problems among our built landscapes are not in taking a certain building philosophy instead of another, say *density* vs *sprawl*. The greatest problem seems to be when we lose interest, when we stop seeing things worth caring about. The modes to engage in *care* do not come from architecture, but from a body of culture of *civic design* (some may simply call it education), informing not only geographically but also culturally who we are, where we come from, what is our (hi)story. The remedy for mutilated urbanism is not in a XIXth century nature, with its luxuriously designed gardens, or a XXth century modernist green field, hiding (or de-localizing) problems inside clean-designed social housing blocks or the like, and that eventually later will be demolished when it becomes clear that the problems are still there. Remembering Rittel & Webber's sentence, the remedy for wounded urbanism and buildings probably is good urbanism and good buildings, and not just caricatures of *nature*. There is not a single answer to it, perhaps a little bit more of ethics, or simply a little bit more of care, or a lot more of both.

In 2008, the housing crisis in the USA reached its peak. The crisis started from a bubble of housing speculation and evolved into the greatest economic crisis in the USA in a long time. It would spread to many other countries forcing millions into unemployment, many for poverty, or even for homelessness. Architecture does not have to be a privilege for the few who can afford it. Architecture should be able reach to all levels of society. As signaled in 2011 MoMA's exhibition, *Small Scale Big Change: New Architectures of Social Engagement*, projects such as Diébédo Francis Kéré's *Primary School* in Gando, Burkina Faso (1999-2001), Elemental's *Quinta Monroy Housing* in Iquique, Chile (2003–05), Hashim Sarkis A.L.U.D.'s *Housing for the Fishermen* in Tyre, Lebanon (1998–2008), Estudio Teddy Cruz's *Casa Familiar* in San Ysidro, California (ongoing since 2001), or Anna Heringer's *METI Handmade School*, in Rudrapur, Bangladesh (2004–06) are proof of a contemporary architectural concern in issues such as *social engagement* or *sustainability*.

These projects are hard, or even virtually impossible to methodologically grasp, and often seem to fall on imagery delivery more than anything. Nevertheless, they also depict a pragmatic attitude and knowledge of the local conditions, and their authors seem to be committed and sharing a vision: improving human habitat through good design and practical solutions. In the cases where necessary, these too use contemporary tools, such as remote, internet-based platforms for design and knowledge exchange between the intervenient. These envision that from a small scale, from the individual, great change is possible in a community: active otherness, not alien strangeness. Teddy Cruz, in the preparation of the exhibition, affirmed something like: "*ultimately, it does not matter whether contemporary architecture is wrapped by the latest morphogenetic skin, neoclassical prop, or LEED-certified photovoltaic panels if all approaches continue to camouflage the most pressing problems of urbanization today*". In any case, one must also not forget that social engagement or sustainability are also labels, and labels that are ought to be carefully scrutinized.

In a globalized world, where capital circulates instantly, new forms of establishing criticism and social engagement are also possible from local, but globally connected participation. Current technologies enable an empowering, organizational horizontalism, from where expertise can effectively share and exchange knowledge. Through connection, from a small, local scale, architecture may envision ubiquity rather than unity. The architect may even no longer be what we traditionally could assume it to be, but as long as society's ills are lessened and the built environment's is improved, at least some productive path has been proceeded. Robert Wilson once said, "*when you finally know the answer to the artist's question, the art disappears*". When you know the trick, magic is no longer.

7 CLOSURE

[1]

In a globalized world there are profound space-time changes in in relation to our modern(ist) inheritance. Nevertheless, the architecture that we make today still essentially traduces that inheritance.

[2]

Architecture participates in a wider human construction process, typically traducing its approach in the space-time conformation and construction of the built environment, translated into the architectural artifact. For that to occur it converges an intention or wish and conceptualization dimensions and a praxis and production of that intention in a certain context or reality.

[3]

Following a Cartesian logic, the essential building blocks of both these spheres can be categorized according to different perspectives, with different criteria and outcomes depending on the propositions—themselves subjectable to questioning or change. Even if partially or temporarily, one can ultimately aim at obtaining a methodological corpus that allows to ease the mechanization of certain processes, or at least to provide a heuristic that contributes to their concretion.

[4]

As component of an executive sphere, by definition, prefabrication fundamentally implies a fabrication of a part or the entirety of an artifact at another time and place other than its final location. Its feasibility will be all the greater, the greater precision to be embodied in the development of all the mechanics of the process that leads to the artifact. However, upstream there are a number of factors that constrain the process, of which only a small part can be influenced by the architecture.

[5]

Since architecture exists largely because of an intent of influence on the artifact, prefabrication would aprioristically be limitative of the full development of the architectural action. However, it is our belief that, in relation to other practices, the relationship can only win clarification, since the same difficulties are found in other levels of other executive spheres. On the other hand, implicitly or explicitly, it is evident a tendency of executive spheres in architectural production to make more and more use of prefabrication or prefabrication-related processes.

[6]

Most of the architectural discourse and practice are based on an implicit or explicit recognition of contextual realities, therefore of a 'local' character. However, even if it is only from a semiotic or etymological point of view, architecture is 'global(izing)' by nature. In this sense, there are 'local' or 'global' semiotics, that is, representations translating interdependent processes traceable to human origins, and thus to the linguistic evolution (logical, communicational) that socioculturally conforms all others—technique, aesthetics, and so forth.

Today's architecture is global, in the sense that, despite local idiosyncrasies—such as climatic, geographic or geological specificities, with potential impact on construction techniques; or the most accentuated social or cultural specificities of some architectural programs—the references are global, the images are global, the materials and techniques are available in a global factory inextricably subjugated to global capital mechanisms of various orders and depths. In addition, as a global reality and mediatic discipline, there is a broader semiotics, where it is included sociocultural processes of information transmission, which have a downstream impact on both mental and executive spheres.

[7]

The relationship of prefabrication with architecture is evident in the fabrication of constructive components with different shapes or dimensions and different degrees of complexity, and which would otherwise be more demanding or impracticable locally—the simple act of fabricating, a brick that is, already implies a space-time distance from the 'local'. But prefabrication is also the epithet of the acceptance of a global architecture, which can be regarded according to a logic of product, thus participating in the conflict of 'art' with 'reproducibility', or of the original with the replica, and so forth. Moreover, prefabrication can be read under the prism of the dialectics of the 'alterity' of architecture itself, that is, in the conflict generated between the necessity or aspiration of a certain 'control' over space-time and the indomitable course of that same space-time to the wills, changes, or whims of everything that happens after a certain point of order.

Prefabrication can be seen as vector, technological weapon, business as usual model, or exogenous solution of problems that are fundamentally 'local'. In that sense, it can be seen with skepticism. But prefabrication can also be seen as process, adaptable, integrable, dialogue vector, scale pointer of an economic response without qualitative concessions, allied with a sustainable approach to the built environment. In that sense, it can be seen with optimism. These two aspects have a conflicting side that finds an epistemological reflex in architecture itself, in conflict between the aspirations of the Art, the aspirations of Man, and the reality of Nature which essentially shapes them.

[8]

Latent changes in the architectural profession must meet industrial and commercial practices. Such is an issue long debated since industrialization's inceptions, and finds a wide field of discussion through the scope of prefabrication. The latter has long been the object of architectural interest, and yet the bulk of its developments has mostly occurred outside *an official architectural history. This fact is on its own indicative of biases in architectural circles. However, it is clear that architecture must search for alternative ways of endorsement.*

Architects who want to keep designing buildings have to unavoidably bond architecture with the business language, as well as an industrial language. As demographics evolve in a crowded world, maybe a certain romantic idea of a 'genius loci' becomes as important as the (apparent) industrial and business related trends of lean production and mass-customization. Besides, in many circumstances, producing new meanings through design seems less relevant than providing effective, technically fit answers to urgent demands. The house problem has shifted throughout the centuries, but persists as a problem. Perhaps the architectural profession can be faced more as a technical métier, maybe it can persist attached to a certain 'Beaux Arts' paradigm or other canonical nuances. The problems of the built environment are nonetheless out there.

[9]

It is the architecture's task to make non-discriminatory use of everything available to it, in order to provide an ethical and responsible answer in the integration of the built environment with the social fabric and the natural environment.

[10]

Prefabrication is not an end-in-itself.

[11]

Architecture is not an end-in-itself.

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Table of Acronyms

AHP	*Affordable Houses Project*
AIROH	*Aircraft Industries Research Organisation on Housing*
BIM	*Building Information Modelling*
BISF	*British Iron and Steel Federation*
BOM	*Bill of Materials*
CAD	*Computer-Aided Design*
CAM	*Computer-Aided Manufacturing*
CEO	*Chief Executive Officer*
CFS	*Cold-Formed Steel*
CIAM	*Congrès Internationaux d'Architecture Moderne*
CLASP	*Consortium of Local Authorities Special Programme*
CNC	*Computer Numerical Control*
DC	*District Capital*
DEWOG	*Deutsche Wohnungsfürsorgung Aktiengesellschaft für Beamte, Angestellete und Arbeiter* ["*Shareholder German Company for the Improvement of Housing for Civil Servants, Employees and Workers*"]
DSME	*Daewoo Shipbuilding & Marine Engineering*
DTI	*Department of Trade and Industry*
EPSRC	*Engineering and Physical Sciences Research Council*
EU	*European Union*
GDP	*Gross Domestic Product*
GDR	*German Democratic Republic, or East Germany*
GEHAG	*Gemeinnützige Heimstätten-, Spar- und Bau-Aktiengesellschaft* ["*Housing Cooperative for Savings and Construction*"]
HHI	*Hyundai Heavy Industries*
HUD	*Housing and Urban Development*
HVAC	*Heat Ventilation and Air Conditioning*
ICAT	*International Congress for Architecture and Town-Planning*
IFD	*Industrial, Flexible and Demountable*
IG	*Independent Group*
IMF	*International Monetary Fund*
ISISE	*Institute for Sustainability and Innovation in Structural Engineering*
ISNSC	*International Scientific Networks in Steel Construction*
ISO	*International Organization for Standardization*

IT's	*Information Technologies*
LCE	*life-cycle end*
LED	*Light-Emitting Diode*
LEED	*Leadership in Energy and Environmental Design*
LPS	*Large-Panel concrete Systems*
LT	*Lean Thinking*
MARS	*Modern Architectural Research Group*
MBOM	*Manufacturing Bill of Materials*
MC	*Mass-Customization*
MHI	*Mitsubishi Heavy Industries*
MIT	*Massachusetts Institute of Technology*
MP	*Mass-Production*
NASA	*National Aeronautics and Space Administration*
NYC	*New York City*
OECD	*Organisation for Economic Co-operation and Development*
OEM	*Original Equipment Manufacturer*
OPP	*Order Penetration Point*
OSB	*Oriented Stranded Board*
OSM	*Off-Site Manufacturing*
PE	*Polyethylene*
R&D	*Research & Development*
RIBA	*Royal Institute of British Architects*
SAR	*Foundation for Architects Research*
SFC	*Strategic Forum for Construction*
SFHC	*Steel Frame House Company*
TPS	*Toyota Production System / Temporary Housing Programme*
TV	*Television*
UC	*University of Coimbra*
UFO	*Unidentified Flying Object*
UK	*United Kingdom*
UN	*United Nations*
USA	*United States of America*
USSR	*Soviet Union*
VEHA	*Veteran Emergency Housing Act*
WBSC	*Walter Bates Steel Corporation (*
WWI	*World War I*
WWII	*World War II*

Table of Figures

Table of Tables

References

1 Cf. McLuhan (1962).

2 Translated as *this will kill that*. In *Notre Dame de Paris*, Victor Hugo shows a priest pointing first to a book, then to the Paris cathedral, and saying *ceci tuera cela*.

3 Article originally published under the title *Alles ist Architektur* ["*Everything is Architecture*"], in *Bau*, 112 (1968: 2). Revised in English in the catalogue Hollein. (cf. Ockman & Eigen, 1993: 460-462).

4 Grassi (2003: 31).

5 Architecture's forms are ought to arise from a thorough analytical process where things follow successive filters, depurating until they find their right place, that is, "*perfect, without leaving behind anything that will not remove itself*" (Grassi, 2003: 32). Grassi (2003: 28) writes "*This is the singular condition of the work in architecture: a work where constraints are actually elements of individualization of form, a work in which the overcoming of the practical difficulties and the definition of form are the same thing. This is also the beauty of this work: the safety of a work that is exclusively dedicated to its own object and that only in this object meets the conditions to move forward. A work in which form is always met at the end, after going through many trials: overcoming obstacles, surrounding them, following unexpected paths, adapting, gradually eliminating all that is superfluous, refining itself, we see the growth of its condition of need, acquiring thickness and experience; and no one, except the foolish or those acting in bad faith, can never say that such final form is thus determined by a specific formal will. Furthermore, the form is the only the result of this long process, its only witness; the liberated form, the form never sought. Not the stupid spontaneous form that does not exist, not least the natural formal that does not exist as we well know, but the built form, the temperate form, the form that is only intended under these conditions*" (free translation).

6 Grassi (cf. 2003) himself recognized it, as utterly shown through a quite expressive title of his famous book *Architecture, dead language*.

7 Cf. Meadows, Randers, and Meadows (2004).

8 Foucault, M. (1970) *The Order of Things: An Archaeology of the Human Sciences*. New York: Random House, p.332.

9 Interview to Maria Leonor Nunes in *Jornal de Letras*. No. 1128; December 25, 2013, to January 7, 2014. Portugal, p.11.

10 Calvino, I. (1974) *Invisible cities*. New York: Harcourt Brace Jovanovich, p. 82.

11 Empirically, space-time can be related to the notion of place, but also to motion or matter, or to the idea of extension or of geometry, as well as to notions of perception, experience, inner or mental construction, or of phenomena. It can also be related to culture, art, symbolization, and different perspectives or modes of representation, or even to human practices such as politics, geography, or colonization, and its different uses—aesthetic, architectural, military, economic, politic, and so on—corresponding to strategic and/or ideological relations.

12 Early on, in the classical period, the western thinking has given relevance to the concept of space. The atomists, such as Democritus (b.460BC-d.370BC), regarded space as an infinite void extension on which the basic indivisible bodies (the atoms, from which everything else was composed) were moving. Plato (b.427BC-d.327BC), in the *Timaeus*, would share a similar vision, but he would add an implicit correlation with matter (or the four elements as he stated). To Plato, space is the receptacle in which all becoming takes place. In the absence of things, space would exist anyhow, but as an empty, boundless receptacle. Each of the four elements, Earth, Air, Fire, and Water, would have a geometric correspondence, from which different transmutations and derivations can be made within the "*mother and receptacle of all created and visible and in any way sensible things, (…) an invisible and formless being which receives all things*" (Plato, 1998). Aristotle (b.384BC-d.322BC) took this idea further, regarding space as 'determined' by the motions of bodies, and thus, causally linking space, matter and time. The existence of a void would be impossible, since a void would not have properties of direction or change of motion, so there would be no such thing as *empty space*. Furthermore, no space, time or matter and their motions could be conceivable without a mind to account them. To Aristotle, space and time are interdependent and not definable by themselves but in relation to other parameters: time as change of motion, and space as change of place; time as the interval between two events, and space as distance between two points. He describes space as what it is defined as the limit of the surrounding body towards what is surrounded. The idea of change seems related to a mind to record that change: if the universe was immutable, there would be no time; if time is the measuring or counting of motion, it is only conceivable with the existence of a counting mind; if there were no mind to count, there could be no time (cf. IEP, 2005).

In the modern era, a revolution in the understanding of space took place with Nicolaus Copernicus' (b.1473-d.1543) heliocentric model, placing the Sun, instead of the Earth, in the center of the Universe. The debate would be pursued by notable figures such as Galileo Galilei (b.1564-d.1642), Johannes Kepler (b.1571-d.1630) or Isaac Newton (b.1642-d.1727). With René Descartes's (b.1596-d.1650) arguments, the whole essence of a body is understood as its geometrically definable extension—space, and hence the Universe, would be indefinitely extended. This idea was not entirely subscribed by Newton, who believed in space as an entity independent of ordinary material objects, and such also contrasted with the Aristotelian view of a spherical firmament of fixed stars. These and other ideas brought about in the Enlightenment age have laid out a new cosmology, posing central questions, and causing great convulsions, as Galileo famously experienced in first hand with his religious inquisitors. As Kant would put it, (rational) Man was now the center of all conceptual and empirical experience, overcoming not only the mystic-religious, yet fundamentally the rationalist-empiricist deadlock, typical of the XVII and XVIII centuries. With it, a new anthropocentric universalism was also being stated (cf. Markie, 2015).

13 Nonetheless, the Cartesian outset would begin to be philosophically questioned soon after Descartes. Leibniz would introduce the notion that space is of the order of the ideal essences and is made only by relations and co-presence of things. In the end of the XVII century, half a century after Descartes, Leibniz was already philosophically rejecting the Cartesian derived notion of space as a purely mathematical extension, as this notion would not allow "*the understanding of the interpenetrability and reciprocal 'action of the bodies', their movement, force and willingness to change*" (Delius, 2001: 47-52).

Kant would see it as an aprioristic form of sensibility, which cannot be deducted from experience or reduced to a concept—on the contrary, it was space that made experience possible. Kavanaugh (2007: 6) writes: "*Space and time, for Kant, are pure ontological categories that provide the Grund, "foundation", or the condition of the possibility of experience. Indeed, for Kant, space and time, as the only pure form of intuition, are of paramount importance in his architectonic. Kant emphatically states: "The only intuition that is given apriori is that of the pure form of appearances (phenomena) – space and time". (…) Space and time are not themselves phenomena, but the form of intuition; things that are given in space and time, on the other hand, are aposteriori in that they are represented in perception. Space and time are the only apriori intuitions. Simply stated, these intuitions, without which no object could be perceived in space and time, are merely the representations of phenomena to ourselves*". Such Kantian space also seems to correspond to a common perceptual notion, a space that is the philosophical transposition of the Euclidian geometric space—continuous, isotropic, homogeneous and tridimensional, and made by abstraction from a perceived space.

Phenomenologically, space-time can be understood as a property of exteriority in relation to *though*, or the *thought of self*, or simply the *self*, as existentialists would put it. A common idea is to define it as a boundless medium, which contains every finite extension, to the point of seemingly infinity, and where perception locates its objects and its movements, and in this sense, the different parts of space-time benefit of a mutual exteriority. In this perspective, it is by the relations, on how different elements of this mutual exteriority articulate, that space-time *becomes*. Linguistically, such can be illustrated by the dialectics of absolute and relative, mental and sensible, image and real, or even the mechanistic 0 and 1, and so forth. (cf. Saussure, 1959 ; cf. Silverman, 2012). Thus, acknowledging an *Entity* from a confrontation with an *Other*, towards and *existence—Dasein*—and through it enabling not only their come into being, but also the come into being of additional entities that were not implied in an initially perceived space.

In a different perspective, the evolution of geometries has implied that, in fact, space can in a way be *cultural*, since the non-Euclidian systems have configured spaces where the common perceptual notions are put in check. This is a concept which that has been remarkably depicted in Edwin Abbot's (b.1838–d.1926) prophetic novel *Flatland: A Romance of Many Dimensions* (1884), where the dimensional is put alongside the cultural, showing the extreme difficulty of corporeally imagining one's own existence in more or less dimensions.

14 Cf. Descartes (1637) appraisal of the *method* as *the only* path to unveil the *secrets of nature*.

15 In Newton's model, space and time were a background on which events would unfold, but which were not affected by them. This vision was still deeply rooted in the platonic conception of space, in which time was considered eternal, in the sense that it had always existed and would always exist. Time was viewed as an infinite line, independent of whatever is happening in the Universe (cf. Hawking, 2001: 29-65). For Newton, there was an absolute space, isotropic and immobile, extended into infinity in three dimensions, and an absolute, linear time. Relativity in space, time or motion was conceived only insofar it as a part of an absolute referential. Newton writes, "*relative, apparent, and common time, is some sensible and external measure of absolute time (duration), estimated by the motions of bodies, whether accurate or inequable, and is commonly employed in place of true time; as an hour, a day, a month, a year. (...) All motions can be accelerated and retarded. But the flow of absolute time cannot be changed. (…) Absolute space, in its own nature and without regard to anything external, always remains similar and immovable. Relative space is some movable dimension or measure of absolute space, which our senses determine by its position with respect to other bodies, and which is commonly taken for immovable [absolute] space*" (cf. Mach, 1919: 222-226).

16 Newton's theory proved spot-on for practical purposes. However, as Ernst Mach (b.1838-d.1916) would subsequently point out, it was short in advancing a causality between the apple that falls (i.e. gravity) and the movement it appears to make (i.e. space-time). It would not take long for criticism to Newton's ideas to appear. In his *Science of Mechanics*, first published in 1883, the Austrian physicist and philosopher Ernst Mach would firmly criticize Newton's ideas, rejecting the unilateral causality and the absolute concepts that had been cornerstones of science since the Enlightenment (cf. Mach, 1919: 222-255). Newton assumed that even relative measurements are possible to be referenced to an absolute system, and that had influenced Kant's philosophical conceptions. However, unlike Newton, to Mach all referential systems and all movements are relative. Relativity was certainly not a new idea, as the notion had been known and accepted for centuries, but not on those terms. Mach's ideas eventually attracted a younger generation of researchers of around 1900, among which Albert Einstein (b.1879–d.1955) was included.

From Einstein's, each system is autonomous and is ruled by its specific, local laws, but it also shares a mutual connection, where local laws are fundamentally variants of universal laws—duration and size relate to velocity; distance becomes equivalent to time; mass to energy; gravitation to acceleration, and so forth. With it, philosophically is no longer conceivable an isotropic void in the sense of the Newtonian space, nor a uniform system of coordinates in the sense of Descartes' extension. Yet, there is the conception of a complex, irregular space-time flow, varying with the concentration, distribution and relative movement of material bodies. Matter, or the equivalent energy, determines the structure of the space-time from place to place in a four-dimensional geometry of variable curvature (cf. Huggett & Hoefer, 2015).

The *relational* notion of space-time also definitely bonds gravity with a space-time continuum—gravitational fields cause warps in space-time, thus weaving gravity into the continuum. The effect would be validated during the 1919 solar eclipse, in which the curvature of light due to gravitational influence could for the first time be accurately measured, and found to be in agreement with Einstein's general relativity predictions. From the curved notions, space-time is bent, and thus, in a sense, both space and time have a form, even if we do not perceptually experience it, or have a hard time to imagine it.

17 The book is one of the major to understand modernism in architecture, a movement that arguably embodies what is the greatest change of paradigm in the profession occurring in the past centuries, insofar as it marks a shift towards architecture's definitive embrace of the ethos of an industrialized world. In the least, the proof of the book's impact can be measured by the numerous written sources on it. Moreover, its impact can for instance be noted by its subsequent protagonism in Manfredo Tafuri's formulation of *operative criticism*, which, as it is well-known, has been foremost a critique on a modernist ideological or even dogmatic approach to historical facts that conceals their inherent complexities and contradictions.

The modernism in architecture is certainly not just about the arguments expressed in Giedion's book. Notwithstanding, its expressive title makes a case that far extends the profession, winking to the technical trends of the epoch, and endorsed through a modern space and time perspective. As to the content, in the least it has the merit of relating modern architecture and urban planning with the historical and cultural context of its epoch, namely the compliant aspects of the industrial era, looking into similarities between architecture and areas as diverse as urban planning, arts or engineering—force-vectors in a thus implied space and time conformation of a modern machine-age.

Giedion (2004: 465) writes: "(it) *became mostly clear that the aesthetical qualities of space, for the eye, were not limited to its own infinity, as are an example the gardens of Versailles*". The naturalist idea of an absolutely definable, bounded space made no sense anymore, exploding in seemingly infinite possibilities of relations—Giedion (2004: 465) proceeds with: "*as to apprehend the true nature of space, the observer must project himself through it. The staircases of the superior floors of the Eiffel Tower are amidst the first architectural expressions of continuous interpenetration of internal and external space*". Alongside the relativity path, there was also an arising need to explore the forms that the industrial and technological development was bringing—Giedion's (cf. 2004) notes on *Iron Architecture* is a historic and critical architectural reference in this respect.

18 Tafuri (1976: xi).

19 Cf. Utzon and Weston (2009).

20 Cf. Valena, Avermaete, and Vrachliotis (2011).

21 For instance, the current mathematical principles used in the *string theory*, allows physics theorists to predict that our universe has eleven dimensions: three spatial (height, length, width), one temporal (time) and seven recurved dimensions (those attributed to properties such as mass, electrical charge, and so on), which would explain the characteristics of the fundamental forces in nature. A different theory, the *bosonic string theory*, predicts up to twenty-six dimensions. Other possibility, called the world of brana theory, is that we are stuck in a subspace with 3+1 dimensions, where the '3+1' is a reminder that time is a different kind of spatial dimension. In other words, we would be living in a universe inside another. In both cases, gravity plays a role in the occult dimensions producing the other non-gravitational forces such as electromagnetism (cf. Hawking, 2001).

22 Arnheim (cf. 2009: 9-32) refers that to the platonic idea of space as a void to be filled lacks the knowledge of modern physics as well as the modes in which its perception psychologically occurs.

23 On its classic visual dictionary, Ching (cf. 2007) illustrates with great depth some fundamental design considerations on how space can vary in form, organization, proportion, scale, etc., and how principles such as symmetry, hierarchy or rhythm may be applied, representing "*the basic elements, systems, and orders that constitute a physical work of architecture*". Its eloquent and seductive visual approach reminds us of the need to have some sort of representation, of coded system, that can readily be communicated and understood, and which is deeply attached to the referential sense of a coordinated tridimensional system. And its visual approach is also a reminder that no matter how coded this system may be, there is a haptic sense – which he purposefully sustains by presenting us hand-made, rigorous but sketch-like, drawings – that needs to be preserved to empower a greater empathy with a certain representation of reality or the proto-realities which are so remarkably present in architecture conception.

24 Brand (cf. 1995) writes on the importance of acknowledging that buildings have a life of their own, reflecting on how architects often neglect this foremost aspect of buildings. It is an implicit critic to modernist innovators like Buckminster Fuller, whose dome buildings were difficult to adapt or extend, or Frank O'Gehry for buildings extremely difficult to maintain, Le Corbusier for buildings with little consideration for the desires and needs of families, or Frank Lloyd Wright for not really caring if his buildings leaked or not. "*Finally completing a new building seems such a glorious culmination. But it is an illusion. A building is not something you finish; a building is something you start. (…) If we get more interested in buildings than with architecture it is likely we realize that in many cases architecture is allergic to time, because architects keep being asked to build lasting monuments, frozen in time. But buildings have no such presumption, buildings live in time, the same way we do. As in time we learn, and in time buildings learn*" (cf. Brand, 1995).

25 Cosmos, which is also an allegory to the ideal, desired, aspirational, mythical and never-ending source of knowledge, and hence as of abstract, mental-derived construct. Earth, which is also an allegory for gravity, to *keep the feet in the ground*, for the palpable, tangible, for what is connecting to everyday life, the mundane and ordinary. In an analysis to Vitruvius's *Ten Books on Architecture*, Dripps (1997: 14-16) writes: "*the skies now become the starry firmament, a symbolic construct that allows inquisitive humans to consider their own position within it. It is the knowledge gained from this act of orientation that provides stability for the foundation of human settlement. (…) In order for the idea of the starry firmament to remain vital it must be the subject to the fresh speculative gaze of each upright person. In this way its paradigmatic structure is repeatedly reinvented out of circumstances of each individual life. This process of reinvention also insures that the world will have particular meaning for each individual. (…) As the word 'firmament' convey, the vault or the arch of the heavens (…) possesses the orderly and systematic structure of the cosmos. Moreover, this structure has its counterpart in the orderly system that underlies the building of the first dwelling. The upright figure is an important part of this orderly system, in which all of these imputed structures originate*".

26 In a clear allusion to the dangers of considering definitive, aprioristic, notions of space, Lefebvre (2005: 209) writes: "*Function calls for something other, something more, something better than functionality alone*".

27 For this is still valid the image of the Vitruvian upright figure, as described in 1-3, Chapter I, of Book II: "*The men of old were born like wild beasts, in woods, caves, and groves, and lived on savage fare. (By finding and controlling fire), keeping it alive, (they) brought up other people to it, showing them by signs how much comfort they got from it. In that gathering of men, at a time when utterance of sound was purely individual, from daily habits they fixed upon articulate words just as these happened to come; then, from indicating by name things in common use, the result was that in this chance way they began to talk, and thus originated conversation with one another. (…) It was the discovery of fire that originally gave rise to the coming together of men, to the deliberative assembly, and to social intercourse. And so, as they kept coming together in greater numbers into one place, finding themselves naturally gifted beyond the other animals in not being obliged to walk with faces to the ground, but upright, and gazing upon the splendor of the*

starry firmament, and also in being able to do with ease whatever they chose with their hands and fingers, they began in that first assembly to construct shelters. (…) Next, by observing the shelters of others and adding new details to their own inceptions, they constructed better and better kinds of huts as time went on. (…) And since they were of an imitative and teachable nature, they would daily point out to each other the results of their building, boasting of the novelties in it; and thus, with their natural gifts sharpened by emulation, their standards improved daily" (Vitruvius, 1914: 38-39).

Standing by the fire, people were required to communicate in a way they did not need when they were by themselves. This metaphor of the gathering of people represents what ultimately led to the establishment of protocols to communicate – the birth of language and so forth. This initiating knowledge of fire as of the 'other' (which is similar but different from 'I') by language or other means of communication, as of the way of building, and mostly how these kinds of wisdom evolve and consolidate in time is fundamental to understand how the notion of dwelling evolved and, with it, how architecture came into being (cf. Dripps, 1997: 7).

28 In the broader concept of *home*, a myriad of popular sayings have it implied, e.g., *there is no place like home* or *home is where the heart is*, a common wisdom built of many layers. Whereas planet Earth can be regarded as humanity's *home*, the dwelling is the material expression of the personal, familiar *home*. It is again the Vitruvian sense of domestic life as a cell (or image-cell), of a larger social, cultural or political life of a community.

29 Cf. Kostof (1986).

30 Cf. Le Corbusier (1986).

31 Mumford (2000: 9-10) writes: "*CIAM's initial direction was shaped by the interaction of Le Corbusier and other mostly French-speaking proponents of a new architecture with the mostly German-speaking representatives of a leftist and technocratic approach to architecture and social organization. In the changed social and political conditions in Europe after the First World War, the limited prewar efforts to make a more socially responsive architecture took a new and decisive turn. Shortly after the La Sarraz 'preparatory congress': Giedion, the newly appointed CIAM secretary, wrote to the Dutch architect and town planner Cornelis van Eesteren (1897-1988) that the goals of CIAM were:*

a) To formulate the contemporary program of architecture.

b) To advocate the idea of modern architecture.

c) To forcefully introduce this idea into technical, economic and social circles.

d) To see to the resolution of architectural problems.

Insofar as a common agenda can be said to have existed, CIAM was intended both to define the basis of the new architecture and to vigorously promote it to official clients and the public at large".

32 Walter Gropius, in his intervention entitled *Sociological Premises for the Minimum Dwelling of Urban Industrial Populations*, in the 1929 congress, illustrates the reality within the metaphor: "*The invention of the machine leads to the socialization of labor. Goods are no longer produced for one's own needs but for the purpose of exchange within the society… With the progressive emergence of the individual the human birth rate decreases… The individual's mobility increases with the increasing transportation facilities, and the family is thereby diffused and diminished*" (Aymonino, 1976: 115-116).

33 The XVII[th] and XIX[th] century Imperialism had left an important legacy, by means of its portrayal of cultures or natural aspects of its remote places, as manifested by the works of Charles Darwin or Lewis Henry Morgan.

34 Mumford (2000: 9) writes: "*After La Sarraz, the tireless publicizing of modern architecture and the name of CIAM by Le Corbusier, Giedion, and other members gave the event a mythic quality, often remembered as the point where various avant-garde movements coalesced into what came to be known as the 'Modern Movement'. More recently, this interpretation has been challenged by historians who see the early history of CIAM as a series of disconnected episodes, with shifting participants whose positions were not always clearly defined, and whose goals were often in conflict. While this view provides a necessary counterbalance to the overstated claims of unity by CIAM's members, the formation of CIAM does appear to be a defining moment in the formation of a new approach to architecture*".

35 Cf. Le Corbusier (1973: 6-8).

36 Aymonino (1976: 127).

37 Cf. Aymonino (1976: 126-138, 233-243).

38 Cf. Le Corbusier (1973).

39 The conclusions of the charter are summed up in the following:

"*71 The majority of the cities studied (by the Fourth Congress) today present the very image of chaos: they do not at all fulfill their purpose, which is to satisfy the primordial biological and psychological needs of their populations. (…)*

72 This situation reveals the incessant accretion of private interests ever since the beginning of the machinist age. (…)

73 The ruthless violence of private interests provokes a disastrous upset in the balance between the thrust of economic forces on the one hand and the weakness of administrative control and the powerlessness of social solidarity on the other. (…)

74 Although the cities are in a state of continuous transformation, their development is conducted without precision or control, and in utter disregard of the principles of contemporary urbanism which have been laid down by qualified technical specialists. (…)

75 On both spiritual and material planes, the city must ensure individual liberty and the advantages of collective action. (…)

76 The dimensions of all elements within the urban system can only be governed by human proportions. (…)

77 The keys to urbanism are to be found in the four functions: inhabiting, working, recreation (in leisure time), and circulation. (…)

78 Plans will determine the structure of each of the sectors allocated to the four key functions and they will also determine their respective locations within the whole. (…)

79 The cycle of daily functions-inhabiting, working, recreation (recuperation)-will be regulated by urbanism with the strictest emphasis on time saving, the dwelling being regarded as the very center of urbanistic concern and the focal point for every measure of distance. (…)

80 The new mechanical speeds have thrown the urban milieu into confusion, introducing constant danger, causing traffic congestion and paralyzing communications, and jeopardizing hygiene. (…)

81 The principle of urban and suburban traffic must be revised. A classification of available speeds must be devised. Zoning reforms bringing the key functions of the city into harmony will create natural links between them, in support of which a rational network of major traffic arteries will be planned. (…)

82 Urbanism is a three-dimensional, not a two-dimensional, science. Introducing the element of height will solve the problems of modern traffic and leisure by utilizing the open spaces thus created. (…)

83 The city must be studied within the whole of its region of influence. A regional plan will replace the simple municipal plan. The limit of the agglomeration will be expressed in terms of the radius of its economic action. (…)

84 Once the city is defined as a functional unit, it should grow harmoniously in each of its parts, having at hand the spaces and intercommunications within which the stages of its development may be inscribed with equilibrium. (…)

85 It is a matter of the most urgent necessity that every city draw up its program and enact the laws that will enable it to be carried out. (…)

86 The program must be based on rigorous analyses carried out by specialists. It must provide for its stages in time and in space. It must bring together in fruitful harmony the natural resources of the site, the overall topography, the economic facts, the sociological demands, and the spiritual values. (…)

87 For the architect occupied with the tasks of urbanism, the measuring rod will be the human scale. (…)

88 The initial nucleus of urbanism is a cell for living – a dwelling – and its insertion into a group forming a habitation unit of efficient size. (…)

89 With this dwelling unit as the starting point, relationships within the urban space will be established between habitation, work places, and the *facilities set aside for leisure. (…)*

90 To accomplish this great task, it is essential to utilize the resources of modern techniques, which, through the collaboration of specialists, will support the art of building with all the dependability that science can provide, and enrich it with the inventions and resources of the age. (…)

91 The course of events will be profoundly influenced by political, social, and economic factors... (…)

92 and it is not as a last resort that architecture will intervene. (…)

93 There are two opposing realities: the scale of the projects to be undertaken urgently for the reorganization of the cities, and the infinitely fragmented state of land ownership. (…)

94 The perilous contradiction indicated above raises one of the most hazardous questions of our day: the urgency of regulating the disposal of all usable ground by legal means in order to balance the vital needs of the individual in complete harmony with collective needs. (…)

95 Private interest will be subordinated to the collective interest"

(Le Corbusier, 1973: 93-105).

40 "*65 Architectural assets must be protected, whether found in isolated buildings or in urban aggregations. (…)*

66 They will be protected if they are the expression of a former culture and if they respond to a universal interest… (…)

67 and if their preservation does not entail the sacrifice of keeping people in unhealthy conditions… (…)

68 and if it is possible to remedy their detrimental presence by means of radical measures, such as detouring vital elements of the traffic system or even displacing centers hitherto regarded as immutable"

(Le Corbusier, 1973: 86-88).

41 The complete list of *CIAM* meetings, their dates, locations and general themes is as follows:

CIAM 1 (1928 – La Sarraz, Switzerland), Foundation of CIAM;

CIAM 2 (1929 – Frankfurt am Main, Germany), or The Minimum Dwelling (also known as *Existenzminimum*);

CIAM 3 (1930 – Brussels, Belgium) on Rational Land Development;

CIAM 4 (1933 – Athens, Greece), on The Functional City;

CIAM 5 (1937 – Paris, France), on Dwelling and Recovery;

CIAM 6 (1947 – Bridgewater, England), on Reconstruction of Cities;

CIAM 7 (1949 – Bergamo, Italy), on Art and Architecture;

CIAM 8 (1951 – Hoddesdon, England), on the Heart of the City;

CIAM 9 (1953 – Aix-en-Provence, France), on Habitat;

CIAM 10 (1956 – Dubrovnik, Yugoslavia), on Habitat;

CIAM 11 (1959 – Otterlo, The Netherlands), with organized dissolution of *CIAM* by *Team 10*.

42 Cf. Giedion (2004).

As Heynen (1999: 40-41) writes: "*in* Space, Time and Architecture *Giedion (builds) up a case for the thesis that modern architecture, as a legitimate heir to the most relevant architectural trends of the past, is capable of contributing to bridging the gap between thought and feeling because it relies upon the concept of space-time, just as the sciences and the arts do. The whole aim of Space, Time and Architecture was thus to canonize modern architecture as a 'new tradition'.* Space, Time and Architecture *is not a pioneering text in the strict sense of the word: the book does not break new ground or announce a completely new paradigm. A number of elements of this paradigm had been around for some time already: the moral appeal (Morris, Loos); the concept of space-time and its application in architecture (van Doesburg, Lissitzky); the relating of new materials and construction technologies on the one hand with architectural design on the other (Le Corbusier); the fact that architecture and city planning influence each other and are mutually dependent (CIAM texts); the concern with the organic and the functional (Moholy-Nagy, the Bauhaus). It was Giedion, however, who forged these various elements of the modern movement into a closely-knit whole and who gave it a historical legitimization, tracing its roots back to the tradition of baroque architecture and to nineteenth century technological developments*".

43 Cf. Aymonino (1976).

44 With the WWI (1914-1918), the house deficit derived from industrialization would worsen in the city. The construction industry declined and eventually all activity stopped. After the war, conditions would deteriorate even further due to the precarious economic situation and the growth of inflation rate. As a way to mitigate the problem, one of the most consensual proposals was to implement housing controlled by the state.

The construction industry ought to be socialized, regulations reviewed, prices of construction materials regulated, credit and lease policies defined. Some of the key points, such as the policy of land use and redistribution of wealth, came into conflict with the class and power structures, which remained unchanged, raising substantive issues in German society and democracy. To what concerns ordinary practices, the actual management policy was taken over by supervisors at a municipal and regional level.

The first period, until 1920, was characterized by transitory and urgent provisions, such as restrictions on luxury buildings, regulation of prices of construction materials, attempt to achieve economies of scale through mass actions of long-term funding, or creation of public deposits of construction materials. In the second period, until 1923, the measures were mainly based on funding grants and the concession of mortgages at very low interest.

However, a rampant inflation would nullify the effectiveness of the estimated funding forms. The problem only begins to be solved with the currency stabilization and attraction of foreign investment. The opportunities offered by the reactivation of the construction and financing mechanisms contributed to consolidate the cooperative societies, which, during these years, would do most of the residential interventions through public housing subsidies.

Despite all the efforts, the housing deficit remained, determined by multiple phenomena of urban migration that ultimately lead to overcrowding and deterioration of the old heritage. Stability in these terms would be kept until 1931, the year that the global economic crisis bursted. From then on, there was a sharp drop in new construction due to a contraction in demand, as a there was a widening gap between rising rents and household incomes.

Cf.Klein (1980: 7-14).

45 Cf. Marques (2012: 67-90).

46 Cf. Aymonino (1976: 29-36).

47 Cf. Aymonino (1976: 50-55).

48 Aymonino (1976: 75).

49 Le Corbusier (1967: 143).

50 Evers and Thoenes (2003: 725).

51 Cf.Klein (1980).

52 Aymonino (1976: 120).

53 Gropius (1955: 99) writes: "*To allow for the increasing development of more pronounced individuality of life within the society and the individual's justified demand for occasional withdrawal from his surroundings, it is necessary, moreover, to establish the following ideal minimum requirement: every adult shall have his own room, small though it may be! The basic dwelling implied by these fundamental requirements would then represent the practical minimum which fulfills its purpose and intentions: the standard dwelling.*

The same biological considerations which determine the size of the minimum dwelling are also determinative in regard to its grouping and incorporation into the city plan. Maximum light, sun and air for all dwellings!".

54 Klein (1980: 33).

55 Le Corbusier (1973: 44) writes: "*2 Juxtaposed with economic, social, and political values are values of a physiological and psychological origin which are bound up in the human person and which*

introduce concerns of both an individual and a collective order into the discussion. Life flourishes only to the extent of accord between the two contradictory principles that govern the human personality: the individual and the collective"(Le Corbusier, 1973: 44)(Le Corbusier, 1973: 44).

56 Aymonino (1976: 93).

57 Cf. Klein (1980).

58 Cf. Teige (2002).

59 Teige (in Hays, 1998: 585-615) writes: "*The error of Le Corbusier's proposal is the error of monumentality (…). It reveals the danger (…) of the definition that a palace is a house, a 'machine for living in' which is endowed with a certain dignity and architectonic potential. Le Corbusier sins against harmony; having formulated such a clear and comprehensible notion as the 'machine for living in', he depreciates it by adding vague attributions of dignity, harmony and architectonic potential, through which he can then embrace all aestheticism and academicism (…).*

In its obvious historicism and academicism, the Mundaneum project shows the present non-viability of architecture thought of as art. It shows the failure of Le Corbusier's aesthetic and formalistic theories (…). In short, all those a priori aesthetic formulae which have formalistically been deduced from historical styles, in our times are unproven and unsupported. (…) In our century of machine civilization, which has no time for 'art' and monumental architecture, any intention to make art instead of houses, and monuments instead of schools, leads to hybrid shapes and impoverishes that work of natural and modern beauty which is characteristic of real, perfect things. (…) The Mundaneum is Reissbrett-ornamentik, a project born not from real and rational analyses of the program (…) but from a priori aesthetics and abstract geometric speculation, following a historic stereotype. It is not a solution for realization and construction, but a composition. Composition: with this word it is possible to summarize all the architectural faults of the Mundaneum (…). If we have occupied ourselves so carefully with the Mundaneum project, it is because we believe this work, whose author is a leading and foremost representative of modern architecture, should serve as a warning to its author and to modern architecture generally.

The Mundaneum illustrates the fiasco of theories and traditional prejudices, of all the dangers of the slogan 'house-palace', and thus of utilitarian architecture with an artistic 'addition' or 'dominant'. From here it is possible to go all the way to full academicism and classicism, or on the other hand, to return to the solid reality of the starting point demonstrated so precisely by the motto, the 'house as a machine for living in', and from there, once again to work towards a scientific, technical, industrial architecture. Between these two poles, there is space only for half-baked projects and compromised solutions"

60 Mumford's (cf. 2000) *The CIAM discourse on urbanism, 1928-1960* is a comprehensive reference in that respect.

61 Cf. Conrads (1970: 109-114).

62 Cf. Grassi (1983).

63 Le Corbusier writes an open letter sent to the *CIAM* 10 revealing all his sharpness, recognizing the inevitability of generational shifts: "*It is those who are forty years old, born around 1916 during wars and revolutions, and those unborn, now twenty-five years old, born around 1930 during the preparation for a new war and amidst a profound economic, social, and political crisis, who thus find themselves in the heart of the present period the only ones capable of feeling actual problems, personally, profoundly, the goals to follow, the means to reach them, the pathetic urgency of the present situation. They are in the know. Their predecessors no longer are, they are out, they are no longer subject to the direct impact of the situation*" (Frampton, 2007b: 271-272).

64 Kostof (1995: 747) described the change in terms of tribal ritual: "*Team 10 rejected the establishment guise of postwar Modernism, in which a handful of elders dominated the CIAM, setting the official agenda for design practice and theory… Team 10 staged a court rebellion stoked by intergenerational conflict*".

65 In Rotterdam, reconstruction priorities were not immediately given to housing. Instead, in the beginnings, they were focused in the reconstruction of the industrial facilities, as there was no point in providing housing if there was no conditions for working to sustain economy. In Rotterdam the docklands were first rebuilt, and large-scale housing projects only began in the fifties, all located south of the river, in Kleinpolder and Schiebroek (cf. Dijk, 1999: 100-121).

66 Due to the housing shortage, the postwar governments launched programs to build thousands of prefab houses in a short time. They were designed to last only 10 years, but some are still inhabited to this day (cf. Vale, 1995).

67 The Commission I of *CIAM* 6 writes: "*The aim of CIAM is to work for the creation of a physical environment that will satisfy man's emotional and material needs*" (Mumford, 2000: 172).

68 Mumford (2000: 196).

69 Old guard portrayed by figures such as Le Corbusier, van Eesteren, Sert, Ernesto Rogers, Alfred Roth, Kunio Mayekawa, Walter Gropius, Hannes Meyer, Siegfried Giedion, José Luis Sert or Fernand Léger.

70 Younger generation portrayed by figures such as Alison and Peter Smithson, Aldo Van Eyck, Jacob Bakema, Georges Candilis, Shadrach Woods, John Voelcker, Willliam or Jill Howell.

71 Frampton (2007b: 271).

72 In an interview, Candilis affirms: "*it seemed totally bogus (as was subsequently confirmed). By coloring up large surfaces of paper, anyone could declare himself an urban planner. We tried to explain that all of this had nothing to do with post-war development, that habitat could not be dealt with by coloring things in, that kitchen could not be drawn up according to the number of steps and to the gestures of a housewife; instead, social, cultural and ethnic particularities had to be taken into account. So the famous habitat charter never happened—which was a success in and of itself*" (Risselada & Van Den Heuvel, 2005: 321).

73 The *Statement on Habitat* explicitly rejected the *Chartre d'Athènes*: "*Urbanism considered and developed in the terms of the Chartre d'Athènes tends to produce 'towns' in which vital human associations are inadequately expressed. To comprehend these human associations we must consider every community as a particular total complex. In order to make this comprehension possible, we propose to study urbanism as communities of varying degrees of complexity*" (Mumford, 2000: 239-240).

74 "*We are of the opinion that we should construct a hierarchy of human association (house, street, district, city) which should replace the functional hierarchy of the Chartre d'Athènes. Although it is extremely difficult to define the higher levels of association, the street implies a physical contact community, the district an acquaintance community, and the city an intellectual contact community. In most cases the grouping of dwellings does not reflect any reality of social organization; rather they are the result of political, technical and mechanical expediency. The aim of urbanism is comprehensibility, i.e. clarity of organization; the community is by definition a comprehensible thing*" (Lüchinger, 1981: 31).

75 The Smithson's diagram was influenced by the early XX[th] century sociologically-based notions of the Scottish urbanist Patrick Geddes, expressed in his *Valley Section*. The *Valley Section* was initially presented by Patrick Geddes in 1905, in his book *Civics: as applied sociology*, and republished in different versions (cf. Ramos, 2013).

76 In Smithson's words, "*our hierarchy of associations is woven into a modified continuum representing the true complexity of human association…we are of the opinion that a hierarchy of human association should replace the functional hierarchy of the Chartre d'Athènes*" (Agrest, 1991: 47).

77 As later expressed by Van Eyck, they were looking to "*conglomeration of buildings in which community lived with all the functions mixed. We didn't simply believe in the four functions – that story was far too simple*" (Risselada & Van Den Heuvel, 2005: 330).

Alongside with a twin, subsequent, and more popularized *Doorn Manifesto,* the *State-*

ment on Habitat can be regarded as a core document of the referential *Team 10* group. The *Doorn Manifesto*, written in 1954, started as follows: "*It is useless to consider the house except as a part of a community owing to the interaction of these on each other. (One had to) study the dwelling and the groupings that are necessary to produce convenient communities. (But also emphasizing) that appropriateness of any solution may lie in the field of architectural invention rather than social anthropology*".

Commented comparison on both the *Statement of Habitat* and the *Doorn Manifesto* can be found in Ramos (2013).

78 To the records stands that a team of ten people would organize *CIAM 10* in 1956, "*hence Team 10*"—as affirmed by Georges Candilis, "*there were ten of us who worked on setting up the tenth CIAM conference – hence, Team 10*" (Risselada & Van Den Heuvel, 2005: 321). The *Team 10* was a loose group of individuals, with various compositions, spanning throughout the years. The group was hard to delimitate as such, as some elements attended all meetings, while others just a few or even only to one. With time, a core group became recognizable in elements such as Jaap Bakema, George Candilis, Giancarlo di Carlo, Aldo Van Eyck, the Smithon's and Shadrach Woods. "*According to the perspective taken, the historical source and the time under consideration, one may also include José Coderch, Ralph Erskine, Amancio Guedes, Rolf Gutmann, Geir Grung, Oskar Hansen, Charles Polonyi, Brian Richards, Jerzy Soltan, Oswald Mathias Ungers, John Voelcker and Stefan Wewerka; but even this list can in no way be considered complete, considering the broad context of Team 10*"(Risselada & Van Den Heuvel, 2005: 11). There was no such thing as membership; they liked to call themselves participants, which was in itself a statement implying detachment from the *CIAM* organization.

79 Risselada and Van Den Heuvel (2005: 321).

80 With a new avant-garde pointing to the inadequacies of functionalist theories, Le Corbusier's drawing on a copy of a letter illustrates *CIAM*'s dethronement, blessing the aspirations of the "*gens d'Otterlo*". "*Le Corbusier's drawing on a copy of a letter illustrates how CIAM found itself being dethroned at the end of the 50s by a new movement. He saw how a younger generation was facing up to the future with self-assurance and with a concept of its own, and how it was making use of the experiences of the previous 30 years, (to which he himself had contributed so much). In spite of this, and with some generosity, he was able to give his blessing to the aspirations of the 'gens d'Otterlo', as he described them in his letter*" (Lüchinger, 1981: 8-11).

81 Participants of the Team 10 informal organization would continue meeting until 1981, the year of Jaap Bakema's death, the *dynamo* who had always managed the secretariat of the group and one of the greatest responsible for keeping it in activity. In Aldo Van Eyck's words Bakema "*was Team 10 post box*" and "*had an unbounded energy (…) a dynamo, a huge dynamo*" (Risselada & Van Den Heuvel, 2005: 331).

82 Benevolo (2009: 15).

83 Aldo Van Eyck, one of the most prominent *Team 10* participants, notably expressed a livened ordinary through his built designs of children's playgrounds (cf. Strauven, 1998: 150-169). He was also known for his scientific and philosophical interests, with recognized affinities with the works of great physicists as Heisenberg or Einstein, the phenomenology of Merleau-Ponty, or the metaphysics of Bergson. He also empathized with Lévi-Strauss's structuralist work in anthropology, but generally had no particular affinity with the poststructuralist philosophers (cf. Strauven, 1998).

In 1953, he published an article in the *Forum* magazine, presenting a photographic report of his trip to different settlements in the Algerian Sahara. Seven years later, he would travel to Mali to study the *Dogon* settlements. The article was evidence of his interest in the bonds between social and built structures. He would later describe those vernacular settlements as prompts of an age-old tradition that do not differ much from the situation five thousand years ago. According to Van Eyck these vernacular settlements are "*the same laboriously fashioned bricks of sandy mud, then and now; the same sun weakly bonding and then harshly disintegrating them; the same spaces around a courtyard; the same enclosure; the same sudden transition from light into darkness; the same coolness after heat; the same starry nights; the same fears perhaps; the same sleep*" (Strauven, 1998: 149). He too considered the vernacular traditions intelligibly complementary to other traditions that western thinking had put between the classical and the modern.

84 In the first circle, three great traditions are blended: the classical, *immutability and rest*, with the Parthenon; the modern, *change and movement* with a Van Doesburg design; and the archaic, *the vernacular of the hearth*, with a plan of a vernacular village. These were not to be considered disjointedly, but integrated so to enrich architecture's formal and structural potential, in order to meet the complexity of contemporary demands. These three paradigmatic elements, united in a circle, stood for the realm of architecture, strengthened with the plea: "*when is architecture going to bring together opposite qualities and solutions?*". That is connected to a second circle, which stands for the human relationships, portrayed by a figure of dancing Kayapó Indians. The dancers form a spiral wall around an open center, expanding or shrinking, relaxing or tightening as it moves in the rhythm of the dance, breathing with life, and as life: "*for each man and all man*"; "*get closer to the center—the shifting center—and build*" (Strauven, 1998: 346-354).

85 Benevolo (2009: 7-8) confirms the idea of a modernity closure: "*Without question, the decisive innovations in our areas took place in the period between the two world wars; and this is a very clear historical fact that is even confirmed by recent experiments (postmodernist movements themselves, seeking to recover the ties with the past, only made possible thanks to the intellectual aloofness made after the first postwar). These years seem prodigious, however, they seem to be increasingly distant and Smithson evoke us precisely (in 1981) as 'the heroic period of modern architecture'. The present moment can in no way be defined as heroic and the problems we face have become radically different*".

86 Cf. Strauven (1998).

87 Le Corbusier (1986: 29) writes: "*Our eyes are made to see forms in light; light and shade reveal these forms; cubes, cones, spheres, cylinders or pyramids are the great primary forms which light reveals to advantage; the image of these is distinct and tangible within us without ambiguity. It is for this reason that these are beautiful forms, the most beautiful forms*".

88 Strauven (1998: 359).

89 Cf. Jencks (1987).

90 Venturi's (1966: 23) words are eloquent: "*Architects can no longer afford to be intimidated by the puritanically moral language of modern architecture. I like elements which are hybrid rather than 'pure', compromising rather than 'clean', distorted rather than 'straightforward', amibiguous rather than 'articulated', perverse as well as impersonal, boring as well as 'interesting', conventional rather than 'designed', accommodating rather than excluding, redundant rather than simple, vestigial as well as innovating, inconsistent and equivocal rather than direct and clear. I am for messy vitality over obvious unity. I include the non sequitur and proclaim the duality…. I am for richness of meaning rather than clarity of meaning; for the implicit function as well as the explicit function. I prefer 'both-and' to 'either-or', black and white, and sometimes gray, to black or white. A valid architecture evokes many levels of meaning and combinations of focus: its space and its elements become readable and workable in several ways at once. But an architecture of complexity and contradiction has a special obligation toward the whole: its truth must be in its totality or its implications of totality. It must embody the difficult unity of inclusion rather than the easy unity of exclusion. More is not less*".

91 Cf. Venturi, Scott Brown, and Izenour

(1972).

92 Cf. Tafuri (1976).

93 Evers and Thoenes (2003: 725).

94 Cf. Gropius (1919).

95 Cf. Hüttemann (2017).

96 For instance, Roland Barthes (cf. 1972: 213-220) defines it as a mode of studying the rules, norms, and organizing structures which make meaning possible, an activity, a (mental) means not and end.

97 Ferdinand de Sausurre's work would be rendered into a posthumous book, the *Cours de Linguistique Generale*, published in 1915 from students' notes of his classes. The book has since been an inspiration, establishing groundbreaking contributions.

98 It would not be until the interwar period that the approach would get the label 'structuralism' from the Russian formalists group (1910s-1930s)—with thinkers such as Viktor Shklovsky, Yuri Tynianov, Vladimir Propp, Boris Eichenbaum, Roman Jakobson, Boris Tomashevsky, Grigory Gukovsky. According to Eagleton (1996: 85), "*Saussure's linguistic views influenced the Russian Formalists, although Formalism is not itself exactly a structuralism. It views literary texts 'structurally', and suspends attention to the referent to examine the sign itself, but it is not particularly concerned (…) with the 'deep' laws and structures underlying literary texts. It was one of the Russian Formalists, however - the linguist Roman Jakobson - who was to provide the major link between Formalism and modern-day structuralism. Jakobson was leader of the Moscow Linguistic Circle, a Formalist group founded in 1915, and in 1920 migrated to Prague to become one of the major theoreticians of Czech structuralism. The Prague Linguistic Circle was founded in 1926, and survived until the outbreak of the Second World War. Jakobson later migrated once more, this time to the United States, where he encountered the French anthropologist Claude Lévi-Strauss during the Second World War, an intellectual relationship out of which much of modern structuralism was to develop*".

The Prague school (1920s-1930s) would eventually take structuralist notions outside linguistics, contributing to its expansion to a wider scope of symbolic systems. Eagleton (1996: 86-87) writes: "*The Prague school of linguistics - Jakobson, Jan Mukařovsky, Felix Vodicka and others - represent a kind of transition from Formalism to modern structuralism. They elaborated the ideas of the Formalists, but systematized them more firmly within the framework of Saussurean linguistics. (…) With the work of the Prague school, the term 'structuralism' comes more or less to merge with the word 'semiotics'*".

99 It would be mostly in the 1960s in France that the field of structuralism (or its critical other: poststructuralism) gained wider notoriety, with thinkers such as Jacques Lacan (b.1901-d.1981), Roland Barthes (b.1915-d.1980), Louis Althusser (b.1918-d.1990), Michel Foucault (b.1926-d.1984), or Jacques Derrida (b.1930-d.2004). It has since become an important method of analysis elsewhere. From its inceptions, notable contributions to the field can also be observed through the works of Charles S. Pierce (b.1839-d.1914), Noam Chomsky (b.1928), or Umberto Eco (b.1932), among others.

100 Cf. Barthes (1993).

101 The knowledge of a new language implies an appropriate learning of a vocabulary and syntax. For instance, each *discipline* (e.g. algebra, chemistry, or poetry) has its own symbolic systems, and practitioners of these know how to handle them. Language can also be regarded as a source of social and cultural values, since by learning new words, as it is more clearly noticeable in children, we implicitly acquire the social and cultural principles implied by those words. (cf. Belsey, 2002: 3-5).

102 For instance, houses can be connoted in language by their shape (e.g. *box-like*), by their style (e.g. *clean lines*), by their price (e.g. *expensive*), and so on. We might want to live in a so-described *art-déco* house, but probably we will not be very enthusiastic about living in a so-described *decrepit* house, even if both refer to the exact same house. In any case, a real-estate seller would not advertise an *art-déco* as *decrepit*, even if the adjective fits.

103 When we learn our native tongue, it is as if it is transparent, an invisible frame to the things in the world, even if some of those things may be imaginary, as for instance those of children's stories. The fact is that we do not realize it, because it comes naturally as a mediator with reality. Similarly, when we speak, the language is rendered invisible to us. (cf. Belsey, 2002: 6-7).

104 Cf. Saussure (1959: 79-100).

105 Barthes (1972: 219) writes: "*structuralism does not withdraw history from the world: it seeks to link to history not only certain contents (…) but also certain forms, not only the material but also the intelligible, not only the ideological but also the esthetic*".

106 In Lévi-Strauss' *Structural Anthropology* (1958), social life is portrayed as a system in which all aspects are linked with one another. In *Pensée Sauvage* (1962), he argues that primitive man thinks just as rationally as today's man. This mode of thinking is of a different degree of a Darwinist sort of view: it is transformative, instead of evolutionary (cf. Lüchinger, 1981: 15-16).

In his works, Lévi-Strauss focused that linguistics and anthropology had erred in aiming in on the terms (notions, structure) and not on the relations between these (the *value*), that although we consciously perceive things, unconsciously we perceive relations. By studying numerous tribes, he concluded that among early humans, communication was non-verbally conducted, and that was only in a later stage that language begun to take its use for verbal communicative function. Language had evolved for cognitive modeling purposes, rather than for the purposes of communication, and therefore it could be regarded more as a mental process than as an instrument for communication.

107 Saussure (1959: 122).

108 "*Everything that has been said up to this point boils down to this: in language there are only differences. Even more important: a difference generally implies positive terms between which difference is set up; but in language there are only differences without positive terms. Whether we take the signified or the signifier, language has neither ideas nor sounds that existed before the linguistic system, but only conceptual and phonic differences that have issued from the system. (…) But the statement [of negative difference] is true only if the signified and the signifier are considered separately; when we consider the sign in its totality, we have something that is positive in its own class (…), their combination is a positive fact*" (Saussure, 1959: 120).

109 "*Beside the phonology of species, there is then room for a completely different science that uses binary combinations and sequences of phonemes as a point of departure, and this is something else entirely*" (Saussure, 1959: 50); and "*The opposition of two terms is needed to express plurality: either* fōt: fōti *or* fōt: fēt; *both procedures are possible, but speakers passed from one to the other, so to speak, without having a hand in it. Neither was the whole replaced nor did one system engender another; one element in the first system was changed, and this change was enough to give rise to another system*" (Saussure, 1959: 85). Barthes adds his own thoughts on this issue: "*the binary classification of concepts seems frequent in structural thoughts as if the metalanguage of the linguist reproduced, like a mirror, the binary structure of the system it is describing*" (Barthes, 1993: 14).

110 Cf. Saussure (1959: 7-20).

111 Indeed, all things we come to know, previously unknown to the entire humanity or to each of us individually, a name is given to. Heidegger notes it when writing: "*Language, by naming beings for the first time, first brings beings to word and to appearance. This naming nominates beings to their being and from out of that being*" (Heidegger, 2002: 46).

112 Cf. Sturrock (1979: 8).

113 Cf. Barthes (1993).

114 Cf. Saussure (1959: 65-70).

"*The linguistic sign unites, not a thing and a name, but a* signified *(concept) and a* signifier *(sound-image). (…) The linguistic sign, as defined, has two primordial characteristics*" (Saussure, 1959: 66-67).

115 This conception also suggests that meaning does not depend on a reference to the world or to ideas. Such can be illustrated by the issues of translation, which, as non-native speakers know, can sometimes cause embarrassment, as unaware of certain connotations carried by certain words they can cause offence on the native speaker by inappropriate use. For instance, the word *horse* is possibly quite straightforwardly translatable among different natural languages. However, other words may not be so much. For instance, different words with equivalent meaning (e.g. Portuguese *gato* vs English *cat*), same words with equivalent meaning, (e.g. Portuguese *nostalgia* vs English *nostalgia*), or no straightforward translation (e.g. Portuguese *saudade*).

116 Expressing a trichotomic reasoning, rather than dichotomic, Pierce adds a new element to Sausurre's methodological distinction. He expressed a preference throughout his work of grouping things in threes, of triadic relations: trichotomies. Although the reasons for such preference are not entirely clear, it was seemingly based in what he called *phaneroscopy*, that is the observation of phenomenal appearances, of which he regularly commented in the *phaneron* the phenomena just fall into threes, irreducibly expressing triadic relations. "*He regularly commented that the phenomena in the phaneron just do fall into three groups and that they just do display irreducibly triadic relations. He seemed to regard this matter as simply open for verification by direct inspection*". There are phenomena that seem to naturally fall in such a tripartite division, however Pierce's recurrence is such for anything imaginable is likely to be driven by something other than the mere acknowledgement of examples. "*Perhaps it was the influence of Kant, whose twelve categories divide into four groups of three each. Perhaps it was the triadic structure of the stages of thought as described by Hegel. Perhaps it was even the triune commitments of orthodox Christianity (which Pierce seemed in some extent to subscribe). Certainly involved was Peirce's commitment to the ineliminability of mind in nature, for Peirce closely associated the activities of mind with the triadic relation that he called the 'sign' relation (…). It is difficult to imagine even the most fervently devout of the passionate admirers of Peirce, of which there are many, saying that his account (or, more accurately, his various accounts) of the three universal categories is (or are) absolutely clear and compelling*" (cf. Burch, 2013).

Besides the concepts of *signified* (in Pierce's also *thing* or *object*) and *signifier* (in Pierce's also *sign* or *representamen*, that is, the representation medium), the concept of *interpretant* is acknowledged. In language there is the sound, what it represents, and its representation in a mental status derived from cognition. When a *significate effect* is produced, that is, when the representation occurs, it can become a new signified, producing a regression, now needing a further signifier and an *interpretant*. In other words, there is a representing relation, where whenever there is an occurrence, there is one *thing* (the *signified*, or *object*) being represented by (or: in) another thing (the *signifier*, or *representamen*), and being represented to (or: in) a third thing (the *interpretant*). In subsequent levels, the *interpretant* may become *thing*, or *representamen*, of a yet another *interpretant*. Hence, these may possibly produce an infinite unfolding sequence, where signs may (de)generate from the original, producing new meanings. "*One of Peirce's central tasks was that of analyzing all possible kinds of signs. For this purpose he introduced various distinction among signs, and discussed various ways of classifying them. One (early) set of distinctions among signs was introduced by Peirce (was) on whether the particular instance of the sign relation is 'degenerate' or 'non-degenerate'. The notion of 'degeneracy' here is the standard mathematical notion, and as applied to sign theory non-degeneracy means simply that the triadic relation cannot be analyzed as a logical conjunction of any combination of dyadic relations and monadic relations. More exactly, a particular instance of the obtaining of the sign relation is degenerate if and only if the fact that a sign* s *means an object* o *to an interpretant* i *can be analyzed into a conjunction of facts of the form P(*s*) & Q(*o*) & R(*i*) & T(*s,o*) & U(*o,i*) & W(i,s) (where not all the conjuncts have to be present). Either an obtaining of the sign relation is non-degenerate, in which case it falls into one class; or it is degenerate in various possible ways (depending on which of the conjuncts are omitted and which retained), in which cases it falls into various other classes*" (cf. Burch, 2013). As in Sausurre, here again, the distinction is purely methodological.

117 Cf. Belsey (2002: 11).

118 One of the most well-known features of his work is the devising of universal laws through the study of myths of different cultures around the world. As he asserted, from the multiple products derived from culture and cultural practices, myths can certainly be regarded as the most random and fantastic. However, paradoxically, if abstractly regarding their essential narrative elements, they seem to possess many similarities. Their totality is made up of basic, constant, universal structures, through which they can be explained.

The most general version of a myth is composed of elements that oppose or contradict each other; and of elements that relate them together, resolving or mediating their oppositions. The myth is seen as a language system, which may be broken into smaller individual units, which in turn can be read in relation to each other rather than as reflecting a particular version. In the myth, there is hence an underlying *set of relations*, or a type of *grammar*, which is common in their narrative structures. Lévi-Strauss claims that if even the fantastical and unpredictable products of mythical thought obey universal laws, then all human thought must obey universal laws. It is most likely impossible to verify such idea without any remaining reasonable doubt. Anyhow, in smaller sets of inquiry, analogous processes can be verified, or in the least be given a more tangible sense. For instance, in the example of chess, it can be observed that there is a limited set of elements and rules, which nonetheless provide ever-different, endless outcomes. Likewise, such universality, rather than being regarded as limiting or reducing scope, can instead be regarded as a solid argument for nurturing richness and diversity.

119 Cf. Damásio (1996).

In last instance, the arguments may result in a sort of discussion of neurological processes, in understanding the body's ways to produce memories, language, movement, or to regulate its own temperature or other functions, and so forth. In another perspective, the arguments may eventually redound to a point where there are no longer imaginable words good enough to describe such processes, as in the interplay of signifier and signified we would ultimately enter in a cyclically redundant process from where nothing could be extracted.

120 Cf. Barthes (1993).

121 Cf. Sturrock (1979: 6-8).

122 As Fromm (1966) writes: "*Freud and Marx have in common that both (…) are concerned not as much with superficial phenomena as rather with driving forces, which act in certain directions and with varying intensity, and evoke phenomena that are changing and temporary. Psychoanalysis is the only scientific form of psychology, as Marxism is the only scientific form of sociology. Only these two systems allow us to understand the hidden driving forces behind the phenomena and to predict what happens to an individual in a certain society when, under certain conditions, the acting forces evoke phenomena that seem to be exactly the opposite of what they actually are. (…) This does not mean that Marx or Freud were absolute determinists (…) Freud's and Marx's theories have a common element in the assumption that man is driven by forces. Realization and awareness of these will lead to liberation, even though only within the boundaries set by*

society and human nature".

123 Cf. Wittgenstein (1995).

124 Cf. Sturrock (1979: 3-5).

125 Cf. Sturrock (1979: 5-6).

126 Sartre (1994: 567-568) writes: "*Freedom in fact, (…) is strictly identified with nihilation. The only being which can be called free is the being which nihilates its being. (…) Freedom is precisely the being which makes itself a lack of being. But since desire, (…) is identical with lack of being, freedom can arise only as being which makes itself a desire of being; that is, as the project-for-itself of being in-itself-for-itself. Here we have arrived at an abstract structure which can by no means be considered, as the nature or essence of freedom. Freedom is existence, and in it existence precedes essence. The upsurge of freedom is immediate and concrete and is not to be distinguished from its choice; that is, from the person himself. But the structure under consideration can be called the truth of freedom; that is, it is the human meaning of freedom*".

127 Heidegger (2002: 45-46) writes: "*According to the usual account, language is a kind of communication. It serves as a means of discussion and agreement, in general for achieving understanding. But language is neither merely nor primarily the aural and written expression of what needs to be communicated. The conveying of overt and covert meanings is not what language, in the first instance, does. Rather, it brings beings as beings, for the first time, into the open. Where language is not present, as in the being of stones, plants, or animals, there is also no openness of beings, and consequently no openness either of that which is not a being [*des Nichtseienden*] or of emptiness*".

128 Belsey (2002: 52) writes: "*Identity implies sameness: that's what the word means. Subjects can differ from themselves*".

129 Belsey (2002: 57-58) writes: "*We are born organisms (of course), and we become subjects. How? By internalizing our culture, which is inscribed in the signifying practices that surround us from the moment we come into the world. We turn into subjects in the process of learning language, which means that we become capable of signifying*".

130 Cf. Barthes (1972: 213-220).

131 Cf. Gil (2010).

132 Cf. Wittgenstein (1995).

133 Barthes (1972: 215).

134 Barthes (1972: 216) writes: "*It is not the nature of the copied object which defines an art (though this is a tenacious prejudice in all realism), it is the fact that man adds to it in reconstructing it. (…) We recompose the object in order to make certain functions appear, and it is, so to speak, the way that makes the work; this is why we must speak of the structuralist activity rather than the structuralist work*".

135 Peirce (1931-58: (2)308).

136 Lacan (1966: 9).

137 Cf. Baudrillard (1994).

138 Cf. Barthes (1972: 218).

139 Ultimately, as Barthes (1977: 42-43) notes in his essay on *Rhetoric of the Image*, the denotation is purely utopian: "*the denoted image can appear as a kind of Edenic state of the image; cleared utopianically of its connotations, the image would become radically objective, or, in the last analysis, innocent. This utopian character of denotation is considerably reinforced by the paradox (…) that the photograph (in its literal state), by virtue of its absolutely analogical nature, seems to constitute a message without a code. Here, however, structural analysis must differentiate, for of all the kinds of image only the photograph is able to transmit the (literal) information without forming it by means of discontinuous signs and rules of transformation. The photograph, message without a code, must thus be opposed to the drawing which, even when denoted, is a coded message*".

140 Călinescu (1987: 92) writes: "*(…) Modernity as a 'tradition against itself'. When modernity comes to oppose concepts without which it would have been inconceivable (…) it is simply pursuing its deepest vocation, its constitutive sense of creation through rupture and crisis*".

141 Călinescu (1987: 68-69) writes: "*(…) the suffix ism – indicative, among other things, of irrational adherence to the principles of a cult – was added to the term modern not by the moderns themselves but by their adversaries. The defenders of classical tradition were thus able to suggest that the attitude of the moderns was biased, that their claim of being superior to the ancients contained an element of dubious and finally disqualifying partisanship. An expression of intellectual contempt, 'modernism' was little more than a terminological weapon in the hands of the antimoderns*".

142 Heisenberg (2000: 25).

143 Barthes (1972: 219-220).

144 Cf. Craige (1982: 15-26).

145 Lévi-Strauss (1979: 19-20).

146 For instance, Doxiadis (cf. 1968) developed the cross-disciplinary *Ekistics*. The term, coined by himself, refers to a cross-cultural study of human settlements, overlapping fields such as human geography, environmental psychology, and sciences of the built environment. The human settlements are organized through five ekistics elements: nature, anthropos, society, shells, and networks.

147 For instance, in theoretical development, manifestations can be found in works such as Kevin Lynch's *The Image of the City* (cf. Lynch, 1960), or Gordon Cullen's *Townscape* (cf. Cullen, 1988), first published in 1961.

148 Rapoport (1969: 5-6) defines the vernacular building as being characterized by: "*lack of theoretical or aesthetic pretensions; working with the site and micro-climate; respect for other people and their houses and hence for the total environment, man-made as well as natural; and working within an idiom with variations within a given order. (…) Although a vernacular always has limitations in the range of expression possible, at the same time it can fit many different situations, and create a place at each. It is, of course, precisely this limitation of expression which makes any communication possible. To communicate, one must be prepared to learn as well as use language – which implies the acceptance of authority, trust, and a shared vocabulary. Another characteristic of vernacular is its additive quality, its unspecialized, open-ended nature, so different from the closed, final form typical of most high-style design. (…) Vernacular is also characterized by the greater importance and significance of relationships between elements, and the manner in which these relationships are achieved, rather than by the nature of the elements themselves. (…) Since knowledge of the model is shared by all, there is no need for drawings or designers. A house is meant to be like all the well-built houses in a given area. The construction is simple, clear, and easy to grasp, and since everyone knows the rules, the craftsmen is called in only because he has a more detailed knowledge of these rules. (…) As long as the tradition is alive, this shared and accepted image operates; when tradition goes, the picture changes. Without tradition, there can no longer be reliance on the accepted norms, and there is a beginning of institutionalization*" (Rapoport, 1969: 5-6).

149 To a degree, this kind of description reflects what perhaps is one of the greatest myths of anthropological *functionalism*, expressed by Bronislaw Malinowski, where different cultures in different people are deterministically related through the habitat, via natural conditions and the like—steep mountains, plains, rain, snow, heat, cold, flood, dry, and so on. To some extent, the notion also reflects structuralism's Universalist intentions, as expressed by Lévi-Strauss, but also inevitably an evolutionary perspective.

Lévi-Strauss (1979: 15-16) writes: "*the feeling in Malinowski was that the thought of the people he was studying was, and generally speaking the thought of all the populations without writing which are the subject matter of anthropology was entirely, or is, determined by the basic needs of life. If you know that a people, whoever they are, is determined by the bare necessities of living – finding subsistence, satisfying sexual drives, and so on – then you can explain their social institutions, their beliefs, their mythology, and the like This very widespread conception in anthropology generally goes under the* *name of functionalism. The other fashion is not so much that theirs is an inferior kind of thought, but a fundamentally different kind of thought. This approach is exemplified by the work of Levy-Bruhl, who considered that the basic difference between 'primitive' thought - I always put the word 'primitive' within quotes - and modern thought is that the first is entirely determined by emotion and mystic representations. Whereas Malinowski's is a utilitarian conception, the other is an emotional or affective conception; and what I have tried to emphasize is that actually the thought of people without writing is, or can be in many instances, on the one hand, disinterested - and this is a difference in relation to Malinowski - and, on the other hand, intellectual - a difference in relation to Levy-Bruhl*".

150 Rapoport (1969: 108-109) refers that "*it has been suggested that primitive and preindustrial vernacular builders always use materials most conveniently available, and that, since materials determine form, the nature of local materials determines form. These oversimple beliefs are not necessarily true; it has already been shown that the same materials may produce very different forms (…) There are many instances where choice of materials is determined by the tendency to use permanent solid materials, such as stone, for cult buildings and tombs, while houses are built of more perishable materials. (…) It remains true that what is not available cannot be used, which is another example of negative impact – of things becoming impossible rather than inevitable. Because of the low criticality a choice exists, and use of materials is decided by fashion, tradition, religious proscription, or prestige value.*

151 Evolutionary cultural processes have been subject of intensive research, namely from anthropological perspectives. The 2002 book by Stephen Shannon, *Genes, memes, and human history: Darwinian archaeology and cultural evolution*, is a good example of such research trend (cf. Shennan, 2002).

152 Stewart Brand notes that ordinary buildings traditionally built have a deep cultural embedment, raised from evolutionary principles. To build these people use quite straightforward rules of thumb. For instance, 'this is how you build a roof so it doesn't leek' or 'this is how you build a fireplace so it doesn't smoke'. These are clear, logical rules, that everyone within a certain cultural context will under-stand, rules that are embedded in a culture and do not change or are only slowly changed. The clear principles guiding them makes it possible for rules to be slowly and gradually tested, and by that slowly and gradually embedding new principles into it. By this process, when a rule gets improved slightly, it gets embedded in the culture (cf. Brand, 1995).

153 Cf. Gonçalves (2012).

154 Cf. Le Corbusier (2007).

155 Cf. Rudofsky (1987).

156 Cf. Thompson (1945).

157 Cf. Sindicato Nacional dos Arquitectos (1961).

158 Frank Lloyd Wright writes: "*The three major inventions at work building Broadacres, wheter the powers that over-built the old cities like it or not, are: (1) The motor car: general mobilization of the human being; (2) Radio, telephone and telegraph: electrical intercommunication becoming complete; and (3) Standardized machine shop production: machine invention plus scientific discovery*" (Sergeant, 1976: 130).

159 Cf. Sergeant (1976: 121-136).

160 Cf. Aymonino (1976: 245-249).

161 Frank Lloyd Wright writes: "*What would be really sensible in this matter of the modest dwelling for our time and place? This house for a young journalist, his wife, and small daughter is now under roof. Cost: Fifty-five hundred dollars including architect's fee of four hundred and fifty. Contract let to Bert Grove. To give the small Jacobs family the benefit of the advantages of the era we live, many simplifications must take place. Mr. and Mrs. Jacobs must themselves see life in somewhat simplified terms. What are the essentials in their case, a typical case? It is not necessary only to get rid of unnecessary complications in construction, necessary to use work in the mill to good advantage (off-site prefabrication), necessary to eliminate, so far as possible, field labor, which is always expensive: it is necessary to consolidate and simplify the three appurtenance systems – heating lighting and sanitation… At least this must be our economy if we are to achieve the sense of spaciousness and vista we desire in order to liberate the people living in the house*" (Sergeant, 1976: 16).

162 The Usonian houses would develop through diverse concepts, addressed to different audiences (and pockets). The *do-it yourself*, as expressed in the *Berger House* (1950), was designed to be built by its owners in stages. The *usonian automatic*, as exemplified in the *Adelman House* (1953), eliminated unions, masonry and plasters in favor of a dry construction. The *prefabricated houses*, such as the *Raymond Carlson House* (1951), where despite the intentions to economize, and as shipping and assembling doubled the costs, it became unaffordable. Or the *self-build methods*, where a set of recommendations such as for designing houses to *look bigger* or *work better* inside and outside were widely publicized in popular magazines (cf. Sergeant, 1976).

Albert Frey would also make a very particular account on his perspective of the bonds of nature, industry and man, sensitively expressed in his book *In Search of a Living Architecture* (1939) and thoughtfully designed in his *House Frey I* (1941-53), where furthermore a sense of open-endedness is too present (cf. Frey, 1999).

163 Cf. Reed (1998).

164 According to Alvar Aalto, "*still the main task of architecture is to humanize the Machine Age. In doing this, however, it must always work with form*" (Schildt, 1998: 179).

165 Alvar Aalto affirms: "*Nature, biology, has rich and luxurious forms; with the same construction, the same tissues, and the same principlesof cellular organization, it can create billions of combinations, each of which represents a definitive, highly-developed form. Man's life belongs to the same category*" (Schildt, 1998: 93).

166 With notions such as these, it is opened up a perspective on which the architectural experience is sensorially engaged with the entire body. It is not to be merely formalistically retrieved, as if bold photos could ever reflect the spatial experience. While pictures may pick particular details or individual architectural gestures, spaces are ought to be imperceptibly engaging, as, unlike their publicizing photos, they have no ideal viewpoint: spaces need not to be asked for permission.

167 Cf. Weston (2002).

168 *"(We) saw in (Nigel Henderson's) photographs a perceptive recognition of the actuality around his (neighborhood): children's pavement playgraphics; repetition of 'kind' in doors used as site hoardings; the items in the detritus on bombed sites, such as the old boot, heaps of nails, fragments of sack or mesh and so on. Setting ourselves the task of rethinking architecture in the early 1950's we meant by the 'as found' not only adjacent buildings but all those marks that constitute remembrances in a place and that are to be read through finding out how the existing built fabric had come to be as it was... Thus the 'as found' was a new seeing of the ordinary, an openness as to how prosaic 'things' could re-energize our inventive activity*"(Heuvel et al., 2004: 18).

169 The Smithson's would later affirm: "*we were concerned with the seeing of materials for what they were: the woodiness of wood; the sandiness of sand*" (Heuvel et al., 2004: 18).

170 Cf. Lynch (1960).

171 Cf. Cullen (1988).

172 In *House form and culture* cf. Rapoport (1969).

173 In *Housing by people: towards autonomy in building environments* (cf. J.F.C. Turner, 1976).

174 With the development of the *Segal System*, and his book *Home and Environment* (cf. Segal, 1953).

175 In *Supports. An Alternative to Mass Housing* (cf. Habraken, 1972). With the posterior *The Structure of the Ordinary: Form and Control in the Built Environment*, (cf. Habraken &

Teicher, 1998) a synthesis of the principles is made, distinguishing *form, the physical order*, from *place, the territorial order* and *understanding, the cultural order*, observing those through concepts such as *levels*, *hierarchies*, *structures*, *patterns*, *systems* and *types*.

176 With his *How Buildings Learn, What Happens after they are Built* (cf. Brand, 1995).

177 Cf. Antonio Lopes Correia, Simões da Silva, and Murtinho (2016).

178 Cf. Tafuri (1976).

179 Cf. Rossi (1969).

180 Cf. Grassi (1983).

181 Cf. Paola (2013).

182 "*So here I stand before you preaching organic architecture: declaring organic architecture to be the modern ideal and the teaching so much needed if we are to see the whole of life, and to now serve the whole of life, holding no 'traditions' essential to the great TRADITION. Nor cherishing any preconceived form fixing upon us either past, present or future, but – instead – exalting the simple laws of common sense – or of super-sense if you prefer – determining form by way of the nature of materials, the nature of purpose so well understood… Form follows function? Yes, but more important now, Form and Function are One*"— Frank Lloyd Wright, An Organic Architecture, 1939 (cf. Wright & Pfeiffer, 1992).

183 Cf. Lobos and Donath (2010).

184 Cf. Whyte (1985).

Étienne-Louis Boullée's both astounding, and somewhat credible, utopian imagery had been leaving a referential imprint in the architect's imaginary since the XVIII[th] century, with designs such as the *Cénotaphe de Turenne* (1786) or the *Cénotaphe a Newton* (1795). In the XX[th] century, the utopian theme had left its mark in the 1920s with the *Crystal Chain Letters* [*Die glaserne Kette*] of Bruno and Max Taut, Walter Gropius, Hans and Wassili Luckhardt, and Hans Scharoun, with their visions of an ideal communal society in a series of astounding descriptions and drawings of a fantasy world. Among these, probably the most famous is Bruno Taut's mystical *Alpine Architecture*.

185 Cf. Le Corbusier (1980).

186 The Smithson's entry for the *Golden Lane* competition (1952), alongside *Robin Hood Gardens* (1972), can be considered as a re-interpretation of Le Corbusier's Unité d'Habitation (1947). Instead of corridors in the middle, there are corridors on the sides, and the contact with the ground floor is different, nonetheless, the sociability principles are all there, through large circulation spaces and the intention to bring nature to the block.

187 Heuvel et al. (2004: 18).

188 Cf. Reyner Banham (1955).

189 Reyner Banham (1955) makes reference to an Alison Smithson's article where, about a small apartment renovation in the Soho, she refers: "*It is our intention in this building to have the structure exposed entirely, without interior finishes wherever practicable. The contractor should aim at a high standard of basic construction, as in a small warehouse*".

190 Cf. Reyner Banham (1955).

191 Cf. Calabuig, Gomez, and Ramos (2013).

192 Cf. Herman Hertzberger (2000: 218-219).

193 Alison Smithson (cf. 1974) writes: "*Still existing in the simple Arab town, an interchangeability, in which the neutral cube contains a calm cell that can change; from home to workshop; green-grocery to paraffin store; an alley of houses in whose midst is a baker, made into a Souk by simple expedient of adding pieces of fabric over the public way… as needs grow*".

194 Cf. Calabuig et al. (2013).

195 Cf. Smithson (1974).

196 Cf. Feliciano (2009).

197 With members such as Kiyouori Kikitake, Kisho Kurokawa, Fumiko Maki, Kenzo Tange, or Arata Isosaki.

198 The latter is one of the few remaining built *metabolist* specimens to these days. The construction, which took only one month to complete, consisted of 144 pre-cast concrete capsules of 2.3×3.8×2.1m attached to one of the two shaft cores. The capsules were to be individually removed or replaced as needed, as if a space-station. Nevertheless, the constructive interface between the capsules and the shafts, led such to be economically prohibitive practice (cf. Bergdoll, 2008: 144-147).

199 Cf. Andreotti and Costa (1996).

200 Sadler (2005: 137).

201 Herman Hertzberger (2005: 92).

202 For that matter, we can refer Reinhard Köning's arguments: "*The structuralist activity consists primarily of the combination of particular elements within a particular framework or set of rules. The rules are understood as a kind of deep or primary structure that serves to organize different elements within a whole, (where) the whole is more important than the sum of its parts. (…) It is important not only what parts belong to the whole, but also how these parts relate to each other. However, a valid criticism of this approach to what is supposedly a structuralist design method that it runs the risk of trivializing structuralism in architecture. The assertion that certain elements have to be combined according to certain rules is so vague as a description of the approach to the design that it can ultimately be applied to almost any architectural or design activity*" (Valena et al., 2011: 275).

203 In his *Critique of Pure Reason*, Kant analyzes the limits of human reason. He concludes that the three things that involve our moral concerns, *God*, *immortality*, and *freedom*, can only be thought and not known effectively. Thus, our reason cannot objectively know the objects that correspond to the concepts of thought: *God*, *immortality* and *freedom*. In this way, Kant sees the need to go beyond the reflexive and intellectual use we make of reason for a reason that also has a practical use. This is what Kant called *practical reason*. Thus, if we do not get to know these concepts intellectually, and for not to accept them dogmatically, it is necessary to fundament them through *practical reason*. It is inherent in *practical reason* to admit the reality of *freedom*, of *immortality* and of *God*. Kant wrote: "*I have therefore found it necessary to deny knowledge in order to make room for faith*". But in this phrase 'faith' presupposes a fundament by *practical reason*, not by revelation and belief.

204 Cf. Schwartz (2004).

205 Cf. Brand (1995).

206 Herman Hertzberger (2005: 22) writes: "The character of each area will depend toa large extent on who determines the furnishing and arrangement of space, who is in charge, who takes care of it and who is or feels responsible for it".

207 Herman Hertzberger (2005: 92).

208 André Malraux (1901-1976), created the concept of *Musée Imaginaire*, (from the homonymous essay published in 1947), considering that the reproduction of works of art through photographic print would be an excellent way of boosting contact the general public with the art world, promoting an individual or collective imaginary. When the museum gained popularity, its function was to bring together works of art deemed of quality and to use them to better teach a story of culture and history. With photography, it became practical to make reproductions of art works and put them into books. Anyone who could look at a book had access to a virtual museum, democratizing learning. The concept would be used among the Forum group, regarded as an unconscious field of knowledge within which the architect finds forms (cf. Lüchinger, 1981: 19).

209 Cf. Brand (1995).

210 John John F. C. Turner (1976: 18) writes: "*How many admirers of Brazilia, for example, stay longer than necessary to see the principal buildings and, perhaps, one of the superblocks? And how many designers of such places, prefer to spend their holidays in places like Mykonos?*".

211 In such context stand theoretical works such as Edward Hall's *The Hidden Dimension* (1966), Amos Rapoport's *House Form and Culture* (1969), or Constantinos Doxiadis' *Ekistics* (1968). Edward T. Hall argues that "*one of man's most critical needs (…) is for principles for designing spaces that will maintain a healthy density, a healthy interaction rate, a proper amount of involvement, and a continuing sense of ethnic identification. The creation of such principles will require the combined efforts of many diverse specialists all working closely together on a massive scale*" (Hall, 1990: 168). Rapoport writes: "*The more extreme the constraints, the less the choice, but some choice is always available. Constraints make it necessary to provide spaces desired for various human activities by the most direct means. Limited materials and techniques, used to their ultimate, must be used to define place*".

212 Herman Hertzberger (2005: 47) writes: "*The whole suppressive system of the established order is geared to avoiding conflicts; to protecting the individual members of the community from incursions by other members of the same community, without the direct involvement of the individuals concerned. This explains why there is such a deep fear of disorder, chaos and the unexpected, and why impersonal, 'objective' regulations are always preferred to personal involvement. It seems as if everything must be regulated and quantifiable, so as to permit total control; to create the conditions in which the suppressive system of order can make us all into lesses instead of co-owners, into subordinates instead of participants. Thus the system itself creates the alienation and, by claiming to represent the people, obstructs the development of conditions that could lead to a more hospitable environment*".

213 Matthew Breatore (2013: 18-19) writes: "*Of the many complications between the two parties [Mies and Farnsworth], perhaps the principle problem was a lack of mutually agreed upon terms. That the house was designed as a weekend retreat for a single person rather than a full-time residence further unburdened Mies – or so he believed – of the requirement to account for domesticity and its inherent effects on a living space, aspects of modern life for which he had little patience. Consequently, he and Farnsworth disagreed on what constituted the essential with regard to possessions to be kept at the house. One such dispute was over the necessity of a clothes closet. Farnsworth insisted that, as a resident of the. household, she needed a place to hang her dresses. In Mies's opinion the doctor required no more than a single dress to keep at the weekend house. This incident demonstrates the extent to which the architect desired to minimize not only the house's presence in nature, but also traces of the occupant within the house. Mies would in fact go to great extents, perhaps absurd, to curtail indications of residency. Though the house was designed as a weekend retreat for a single person, the architect incorporated a second bathroom. During those occasions in which the doctor, or Mies himself, had company, the additional bathroom was to eradicate traces of occupancy, concealing the domestic in favor of formal purity. Mies's assistant Myron Goldsmith explained simply that designing and building an additional bathroom was more elegant than for a guest to come in and see Farnsworth's nightgown hanging. The architect did acknowledge some of Farnsworth's needs and ultimately conceded to design a freestanding wardrobe, but not without protest*".

214 Cf. Ábalos (2003).

215 Cf. Breatore (2013).

216 Schneider and Till (2007) have classified these two notions as *hard* and *soft*. In *hard*, elements that more specifically determine the way design may be used, with a certain tendency to both visually and technically, foreground their flexibility. Whereas in *soft* referring to tactics which allow a certain indeterminacy, generally working on the background. These may work at different levels, depending on a *user* or *designer* perspective, and even may occur simultaneously.

217 Cf. Leupen (2006).

218 Cf. Leupen (2006).

219 The related *Einstellung* effect, describes a state of mechanization of complexity in problem solving, where the prior knowledge of a certain solution leads to mechanize analogous problems in similar complex fashion (even if not adjusted), instead of using the simpler routes that are engaged in non-previously informed cases (cf. Luchins, 1942).

220 The original expression, *das Ganze ist mehr als die Summe seiner Teile*, is often translated as "*the whole is greater than the sum of its parts*". However, according to Koffka, it should be translated instead as "*the whole is other than the sum of its parts*", since notions such as 'greater' or 'bigger' would imply an unwanted additive valuation (cf. Hothersall, 2004).

221 Lévi-Strauss (1979: 9).

222 Both terms, which find a correspondence in the theoretical developments of *Structuralism* or of *Systems Theory*, have aroused in the natural sciences, although in a later stage the notion of structure would assume a great notoriety from the social implications of the studies of language. The notion of structure can early be found related with the idea of form reflecting the internal disposition of bodies. In the Enlightenment, it would enter the vocabulary of biology and the study of minerals, and later to linguistics and thereon to humanities, anyhow related to an essential condition of things or of *Form*. Structure derives from the Latin *structura* (from the verb *struere*, i.e. 'to build'), originally used to mean both (1) the architectural schema of a building, (2) the ordering of organs in the human body, and (3) in rhetoric, the ordered connection between the thoughts and the words in a speech. The meanings have broadly persisted until the present times (cf. Cornelis, 1967). As to the notion of system, it can early be found in the realms of diverse areas such as philosophy, theology or law. From its most primitive usages, the concept has been related with the question of the organization and codification of knowledge. Modernly, that became clearer in philosophical thinking since Leibniz's (b.1646–d.1716) *System Nouveau*, first published in 1695 (cf. Bertalanffy, 1969: 10-17). With the Enlightenment, it becomes indelibly related with an idea of method, epitomizing a materialistic and mechanistic perspective typically associated with scientific thinking.
However, it should also not be forgotten its understanding through the Kantian notion of *architectonic*—and thus of *systematicity*. Indeed, more than speaking of a *system*, instead it often makes more sense to speak in the Kantian architectonic sense of *systematicity*. In his *The Critique of Pure Reason*, first published in 1781, Kant described it as "*the unity of the end, to which all the parts of the system relate, and through which all have a relation to each other, communicates unity to the whole system, so that the absence of any part can be immediately detected from our knowledge of the rest; and it determines a priori the limits of the system, thus excluding all contingent or arbitrary additions*"(cf. Kant, 2013). In a Kantian sense, reason cannot be fulfilled simply with a mechanical conception. However, Kant too acknowledges two key distinct faces of reason, the theoretical and the practical reason. If the metaphysical ground of the unity of nature is an indispensable notion for both the theoretical and practical functions of reason, on the other hand such can only be satisfied in the latter. Thus, in this perspective, the *objective* reality of the theoretical reason can only find its suitable proof in the practical (cf. Ostaric, 2009). Observing the issue from the opposite direction—i.e. following the *system* over the *systematicity* way—for instance we have that numerous environments pose questions such as: what is a system?, how is it manifested?, on what boundaries?, exhibiting certain distinctions that are susceptible of leading to certain areas of though. Thus posed from a practical side, the problem is extremely vast, and it would not likely conduct to an examination of all the variants of the

term. From the biological systems, to the systems of coordinates, to systems of values, and so on, we would have to go through every area of knowledge, and that is simply unfeasible.

223 Cf. Staib (2008).

224 Cf. Knaack, Chung-Klatte, and Hasselbach (2012).

225 The notion departs from *Systems Theory* body of work, which was primarily developed by the biologist Ludwig von Bertalanffy, constituting a broadly-purposed effort to bind a conceptual with an operational sense of systems. It fundamentally refers to the interdisciplinary study of the abstract organization of phenomena, regardless their type, substance, spatial or temporal scales of existence, investigating the common principles to complex units, as well as the models that can be used to describe them. Its intents are not to establish a unique *general theory of everything*, replacing the role of other theories in specific subjects. Its aims are, however, located somewhere in between the specificity of the content and the generality of its frame, searching an optimum degree of generality, close enough not to lose the object, distant enough to be able to regard the object in a larger context.

In Systems' praxis, evolutionary systems design is one of the most recent advances, and one example of the conceptual tools which would fit as an outcome would be the diagrammatic-like cognitive maps. More direct applications can be found among e.g., Biology, Engineering, Sociology, Psychology, Communication, Cybernetics or Information Theories. In more recent approaches, dynamical systems theory, family systems theory, dissipative structures and holistic paradigms are the areas that have been subject to more intensified exploration among researchers (cf. Laszlo & Krippner, 1997).

In the history of *Systems Theory*, as a more or less defined branch of research, many relevant thinkers can be named, ranging from diverse fields such as Philosophy, Physics, Computer Sciences, or Economics, however, a Biologist, Ludwig von Bertalanffy, stands out for its precursor role. With an implicit aspiration of answering to the increasing fragmentation and redundancy of scientific and technological research and decision-making, von Bertalanffy developed what he called the *Allgemeine Systemlehre* (General Systems Theory), a founding and referential work for the Systems Theory movement.

In the 1930's Bertalanffy had "*formulated the organismic system theory. His starting point was to deduce the phenomena of life from a spontaneous grouping of system forces – comparable, for instance, to the system developmental biology nowadays. (…) In the 1940's he conducted his theory of open systems from a thermodynamical point. (…) As a metatheory derived from both theories, Bertalanffy introduced the GST as a new paradigm which should control the model construction in all the sciences (…). As opposed to the mathematical system theory, it describes its models in a qualitative and non-formalized language. Thus, its task was a very broad one, namely, to deduce the universal principles which are valid for systems in general. In a first step he reformulated the classical concept of the system and determined it as a category by which we know the relations between objects and phenomena. The new system concept now represents a set of interrelated components, a complex entity in space-time which shows structural similarities (isomorphisms). It constitutes itself in such a way that the systemic particles maintain their structure by an assemblage process and tend to restore themselves after disturbances – analogous to the features of a living organism. Since those isomorphisms exist between living organisms, cybernetic machines, and social systems, one can simulate interdisciplinary models and transfer the data of a scientific realm to another one. (…)*" (cf. Brauckmann, 1999).

226 Cf. Laszlo and Krippner (1997: 7).

227 Ackoff (1981: 15-16) apud Laszlo and Krippner (1997).

228 Cf. UT (2013).

229 For instance, in "*The fundamental systems-interactive paradigm of organizational analysis features the continual stages of input, throughput (processing), and output, which demonstrate the concept of openness/closedness. A closed system does not interact with its environment. It does not take in information and therefore is likely to atrophy, that is to vanish. An open system receives information, which it uses to interact dynamically with its environment. Several system characteristics are: wholeness and interdependence (the whole is more than the sum of all parts), correlations, perceiving causes, chain of influence, hierarchy, suprasystems and subsystems, self-regulation and control, goal-oriented, interchange with the environment, inputs/outputs, the need for balance/homeostasis, change and adaptability (morphogenesis) and equifinality: there are various ways to achieve goals. Different types of networks are: line, commune, hierarchy and dictator networks*" (UT, 2013).

230 As entropy implies, systems will dissipate energy unless they are maintained by an external entity, that is, unless if energy is provided from outside the system. Internal relations within a system towards which energy is not externally inputted, will tend to degrade until reaching a state of thermodynamic equilibrium, where it stagnates. For instance, observing the classic *open/closed* distinction, we have that, as opposed to an open system, a closed system is fundamentally a system that does not interact with the environment. In a closed system, its 'walls' do not allow energy or matter transfers, and hence is more likely to weaken or even disappear than an open system, unless an outside entity 'holds' it, exogenously inputting energy into it. On the other hand, the more open it is, the more likely it is for the system to thrive in the long run, as it is exchanging energy by dynamically interacting with its surroundings.

231 If not more, ultimately a thermodynamic system would be subjected to gravity, with eventual interactions that are (still) unknown to physicists

232 For instance, an analogy could be made when a company has severe financial problems and as consequence is bought by another, injecting the first with fresh currency. Another known example occurs in current software development technologies, where two trends can be observed, with the said *open* or *closed* philosophies, each potentiating their digital ecosystem through different sorts of constraints (and freedoms).

233 Systems' concepts such as *openness* vs *closeness*, along with other systems' characteristics that can be inferred, such as *hierarchy*, *interchange* or *adaptability*, are architectural conceptions that have seen a great boost of theoretical development from the 1960s onwards, following a methodological trend in the discipline. Some of its children developments in architectural theory and practice can still be observed, such as in the *Open-Building* movement (cf. Kendall & Teicher, 2000), where both stability and change are addressed as realities in the building environment, regarding them not as static pieces stagnant in time, but as flowing living organisms which are hard-wired to cope with change. Nonetheless, to these days it remains dubious how to proceed with some of such approaches, given that they must be framed within contexts where there is necessarily a social and cultural control exerted through building regulations and the like.

234 Cf. Marchal (1975).

235 Marchal (1975: 464).

236 In *The Human Condition*, Hanna Arendt (2013: 154) writes: "*The ideal of usefulness itself, like the ideals of other societies, can no longer be conceived as something needed in order to have something else… Obviously there is no answer to the question which Lessing once put to the utilitarian philosophers of his time: 'And what is the use of use?' The perplexity of utilitarianism is that it gets caught in the unending chain of means and ends without ever arriving at some principle which could justify the category of means and end, that is, of utility itself…*

Utility established as meaning generates meaninglessness… In the world of homo faber*, where everything must be of some use, that is, must lend itself as an instrument to achieve something else, meaning itself can appear only as an end, as an 'end in itself' which actually is either a tautology applying to all ends or a contradiction in terms*".

237 For instance, when designing a house, enerally, unless of an exceptional importance, the architect most likely will not be prioritizing the thinking of say, the chemical properties of a certain material in use, over say, the spatial or structural considerations. Likewise, to assure that a certain paint will endure a certain amount of time, the architect will just have to trust in the product specifications, as he will not likely be testing it himself.

238 Cf. Rapoport (2005).

239 According to Agudin (1995: 373), "*the notion of a primitive form, considered as the model or principle from which architecture derives, is one of the fundamental ideas associated with the notion of Type. Every theorist, who has been concerned with the issue of the origins of architectural form, has assigned to the primitive form a different meaning, in accordance with the conceptual framework within which he operated. Vitruvius, for example, was working within the frame of the Greek doctrine of imitation. According to this, the original form or model from which architecture would have derived was provided by nature. Laugier's frame of reference was the emerging epistemology of the seventeenth and eighteenth centuries, which put the emphasis on the relation between perception and acquisition of knowledge. Accordingly, his primitive hut was more a concept in the mind than a physical structure created by nature.*"

240 In *The Prodigious Builders*, first published in 1977, Bernard Rudofsky (1977: 13) writes: "*Vernacular architecture owes its spectacular longevity to a constant redistribution of hard-won knowledge, channeled into quasi-instinctive reactions to the outer world. So-called primitive peoples have none of the devil-may-care attitude when confronted with the reality of their environment. Above all, they have no desire to dominate it. Admittedly, the vernacular's unforgivable weakness is constancy. Unlike the apparel arts or pedigreed architecture, it follows no fads and fashions but evolves only imperceptibly in time. As a rule, it is tailored to human dimensions and human needs, without frills, without the hysterics of the designer. (…) In some places the exclusive reliance on local building materials alone guarantees the persistence of time-honored construction methods. Conversely, when alien materials and alien methods are introduced, local traditions wither away, customs are displaced by trends, and the vernacular perishes*".

241 For a broad, class-based social perspective on high culture and 'taste', cf. Pierre Bourdieu's *Distinction: A Social of the Judgement of Taste* (1979). For a perspective on the blurring of distinctions between a *high* culture of the elite and a *low* culture of the masses, the Frankfurt School enquiry is referential. As it has been scholarly observed, the distinction between *high* and *culture* has disappeared, following an interest in popular culture, which includes such diverse media as magazines, comic books, television, or the internet. Accompanying it, has occurred a reevaluation of the conservative view regarding mass culture as degraded, and elite culture as uplifting. Following it, rather than an aesthetical or intellectual difference, the distinction between *high* and *low* have been gradually regarded as political distinction. For a perspective of *high* culture in the formulation of national identity, cf. Ernest Gellner's *Nations and Nationalism* (1983).

242 Cf. Tafuri (1976: 24-39).

243 There are Egyptian references to the human anatomy as early as 1600 BC. The Greeks made considerable advances in nomenclature and methods. Leonardo da Vinci himself was trained in human anatomy, beginning in 1489 a series of drawings depicting the ideal human form (cf. Persaud, Loukas, & Tubbs, 2014).

244 The requirement for a *type specimen* is just one of the many rules of scientific nomenclature and alpha taxonomy for describing a new species. In older usage (pre-1900 in botany), a *type* was understood more as a *taxon* rather than a *specimen* (cf. A. S. Hitchcock, 1921).

245 Quatremère de Quincy writes (in Hays, 1998: 618-619): "*the word type presents less the image of a thing to copy or imitate completely than the idea of an element which ought itself to serve as rule for the model… The model, as understood in the practical execution of an art, is an object that should be repeated as it is; the type, on the contrary, is an object after which each [artist] can conceive works of art that have no resemblance. All is precise and given in the model; all is more or less vague in the type. At the same time, we see that the imitation of types is nothing that feeling and intellect cannot recognize, and nothing that cannot be opposed by prejudice and ignorance. This is what has occurred, for example, in architecture. In every country, the art of regular building is born of a pre-existing source. Everything must have an antecedent. Nothing, in any genre, comes from nothing, and this must apply to all inventions of man. Also we see that all things, in spite of subsequent changes, have conserved, always visibly, always in a way that is evident to feeling and reason, this elementary principle, which is like a sort of nucleus about which are collected, and to which are coordinated in time, the developments and variations of forms to which the object is susceptible. Thus, we have achieved a thousand things in a genre, and one of the principal occupations of science and philosophy, in order to understand the reasons for them, is to discover their origin and primitive cause. This is what must be called 'type' in architecture, as in every other field of inventions and human institutions*".

246 The currently pervasive characterizing notions of *genotype* and *phenotype*, would only be introduced by Wilhelm Johannsen, in 1908. The *genotype* is the descriptor of the genome, which is the set of physical DNA molecules inherited from the organism's parents, whereas the *phenotype* is the descriptor of the *phenome*, i.e., the manifest physical properties of the organism, its physiology, morphology and behavior (cf. Lewontin, 2011).

247 Cf. Habraken and Teicher (1998: 248-250).

248 Durand had worked for the architect Étienne-Louis Boullée and the civil engineer Jean-Rodolphe Perronet. In 1795, he would become a Professor of Architecture at the *École Polytechnique*, exerting a wide influence. The poetic symbolism of Boulée's approach contrasts with Durand's rationality. The technological demands of an enlightened post-Revolutionary France where imbued in the *Polytechique* philosophy. Architectural students were given a solid mathematical and scientific ground.

249 These include Egyptian, Greek or Roman temples, orders details or decorative objects, but also mosques, Gothic churches, domes, thermal buildings, amphitheaters, Roman, Greek or Palladian houses and palaces, gardens, and so forth.

250 Cf. Rapoport (2005).

251 Cf. Agudin (1995).

252 "*We can distinguish that both the idea of 'type' and the idea of 'module' are two different but interconnected ways of perceiving reality. It does not matter if these are real or mere abstractions as long as they allow us to obtain a useful model*" (Duarte, 1995).

253 In nature, if we would ask what two distinct animals have in common, we could answer *animal cells*. If we included a tree, we could say *cells*. If we included a mineral: *atoms*. If we would stop here, atoms would be our *type*, our most general category, but also our smallest *module*. If we would continue, we would eventually reach the most basic element to all things in the Universe, which being the smallest *module* would also be the most general *type*, and vice-versa (cf. Duarte, 1995).

254 Cf. B. Mitchell (1965).

255 Cf. Duarte (1995).

256 This notion is quite well illustrated in the shape grammar's rationale, which was "*one of the earliest algorithmic systems for creating and understanding designs directly through computations with shapes*" (Knight, 1989). In it, is conveyed the idea of forms to be produced by basic objects via particular sets of operators and rules, of relations which are established to develop (cf. Stiny, 2006). By deriving shape-grammar rules, multiple shapes can be obtained with a recognizable pattern, which has its origins in the grammar's rules. As increasingly different types are combined, or more initial objects or rules are added to the algorithm, also potentially the end result will be more complex. Additionally, in order to *control* of the outputs will require handling more variables by not letting them to *chance*.

257 Agudin (1995: 373).

258 In some of the most depurated expressions of a conceptual approach the *De Stijl* movement, would be one of the major contributors to explore a direct bond between the abstract (conceptual) in art with architecture, where too the type acts, if not least as an implied operator. As van Doesburg writes, "*Elimination of all* concepts of form *in the sense of a* fixed type *is essential to the healthy development of architecture and art as a whole (…) The new architecture is elemental (…), functional, (…), formless and yet exactly defined; that is to say, it is not subject to any fixed aesthetic formal type. (…) The new architectural methods know no closed type, no basic type,* (but instead) *the new architecture is open* (made of) *space and time*" [van Doesburg, Theo (1924), *Towards a plastic architecture*, (in Conrads, 1970: 78-80)].

259 With the rise of the cognitive sciences, fields suc-h as the psychology of form, have put forth their influence, as with the case of Arnheim's *structural skeleton* conception, derived from his research based on Gestalt's psychology: "*In speaking of 'shape' we refer to two quite different properties of visual objects: (1) the actual boundaries produced by the artist (the lines, masses, volumes), and (2) the structural skeleton created in perception by these material shapes, but rarely coinciding with them. (...) The same structural skeleton can be embodied by a great variety of shapes (...). (Moreover), if a given visual pattern can yield two different structural skeletons, it may be perceived as two totally different objects (...), (as is the case) of the famous duck-rabbit*" (Arnheim, 1974: 92-95).

260 Cf. (Stiny, 2006).

261 Cf. Duarte (2000).

262 Cf. Alexander (1979); Alexander, Ishikawa, and Silverstein (1977).

263 Agudin (1995: 371).

264 Cf. Frampton (1995).

265 As Laugier notes, to man some fallen branches in the forest are the right material for his purpose; he chooses four of the strongest, raises them upright and arranges them in a square; across their top he lays four other branches; on these he hoists from two sides yet another row of branches which, inclining towards each other, meet at their highest point. He then covers this kind of roof with leaves so closely packed that neither sun nor rain can penetrate. Thus, man is housed (cf. Laugier, 1755).

266 Cf. Lavin (1992).

267 Frampton (1995: 4).

268 Cf. Frampton (1995).

269 Pevsner (1969: 30).

270 Viollet-le-Duc's approach was initially synthesized in his *Dictionnaire Raisonée de l'Architecture Française du XIe au XVIe Siècle* ["*A Reasoned Dictionary of French Architecture from the Eleventh to the Sixteenth Century*"], first published between 1854 and 1868, bonding the need for a rational, non-arbitrary spirit, with the Gothic architecture. In the posterior *Entretiens sur l'Architecture* ["*Conversations on Architecture*"], first published between 1863 and 1872, he analyzed the great architecture of the past, evidencing that each epoch derived its greatness from an underlying rationality. In it, he has also concordantly systematized not only his approach to architecture, but also to architectural education, in a manner that totally diverged with the *Beaux-Arts* school, which he had avoided and even despised in his youth.

271 In that regard, quoting Viollet-le-Duc, Summerson (1998: 156) writes: "*if we get into the habit of proceeding by the light of reason, if we erect a principle, the labour of composition is made possible, if not easy, for it follows an ordered, methodical march towards results which, if not masterpieces, are at least good respectable works--and capable of possessing style*".

272 Pevsner (1969: 26-27).

273 Leupen (2006: 29).

274 Cf. Habraken (1972, 1976, 1988a).

275 Cf. Duffy (1993).

276 Cf. Brand (1995).

277 Cf. Leupen (2006).

278 Cf. O'Neill (1986).

279 Cf. Habraken (1988b).

280 Cf. Habraken (1988b).

281 Cf. Duffy (1993).

282 Cf. Brand (1995).

283 Cf. Leupen (2006). Fundamentally, Leupen maintained Duffy's *scenery* terminology, excluded Brand's *stuff* because of its non-architectural character, and added *access* (general access to enclosed spaces and/or individual homes, such as stairs, corridors, lifts or galleries), detaching it from *services*. For instance, the latter makes more sense under a spatial-constructive flexibility analysis framework, but not so much in a lifecycle analysis as it often can be part of the *structure* or of the these authors call *scenery*.

284 Leupen (2006: 223) writes: "*the effectiveness of the frame concept and the disconnection between frame and changeable layers, are first and foremost design issues. Choosing the right construction and materials for the excision is the architect's job (…). To leave it entirely to the building industry brings with it the risk that the technical solution for the excision would overshadow the architectural impact of the frame*".

285 Cf. Parkes (2011). For instance, in Japan, the expected and accepted lifespan of a house is smaller than in Europe, which results from an ancient tradition of timber construction, but also from a philosophical ethos, that of facing basic reality from the idea of *mujo* (impermanence).

286 The notions of architecture as its *production* and as its *experience* often come up intertwined. Broadly, we can say that architectural *production* concerns on the bring into being of an inhabitable *artifact*, in a process that is intrinsically of a social nature. Inhabitable because serving for human dwelling, thus implying a boundary condition (e.g. interior-exterior, open-closed, light-shadow, heavy-weightless, and so forth) whose distinction can have different degrees of clarity. *Artifact*, because it results of a human-made construction. In its *production*, typically there is a movement from a *mental* set (design) to an *executive* set (construction). These concur in providing content, manifested in form, to the *experiential* stage. In turn, this will inform subsequent interpretations (e.g. a new design), and so forth. It is from the bonds of such a back and forth motion, that architecture evolves and can aspire to deliver a meaningful sense.

Dwelling is here understood in its broadest sense of humanly built place, as expressed by Heidegger (1951): "[…] *today's houses may even be well planned, easy to keep, attractively cheap, open to air, light, and sun, but-do the houses in themselves hold any guarantee that dwelling occurs in them? Yet those buildings that are not dwelling places remain in turn determined by dwelling insofar as they serve man's dwelling. Thus dwelling would in any case be the end that presides over all building. Dwelling and building are related as end and means. However, as long as this is all we* *have in mind, we take dwelling and building as two separate activities, an idea that has something correct in it. Yet at the same time by the means-end schema we block our view of the essential relations. For building is not merely a means and a way toward dwelling—to build is in itself already to dwell*".

287 Cf. Fitchen (1981).
As Fitchen (1981: 1) writes: "*the primary structural problem in building is that of spaning space. Basically, there are not very many systems of doing this: the post and lintel, the arch with its vault and dome derivatives, the truss, the metal skeleton, the suspension cable, and, largely in the twentieth century, the thin shell, typically of double curvature. In the medieval period, in western Europe, it was the vault that was almost exclusively the system for spanning space in masonry. But the medieval vault system underwent remarkable diversity of shape, and developed the most effective, the most daring and expressive forms by the time the Gothic era was in full flower*".

288 According to Christian Schädlich (in Staib, Dörrhöfer, & Rosenthal, 2008: 19), "*the iron industry performed the function of a pecemaker for the general industrialization of the building industry. It developed those elements of industrial technologies relevant to building: from the dismantling of the product into large elements, their prefabrication in the factory and mechanized assembly, to the standardization of dimensions and forms for the purpose of serial production, and on to new organizational structures of the construction business*".

289 Cf. Passanti (1997).

290 Aymonino (1976: 126).

291 Le Corbusier (1986: 6-7).

292 *Dom-Ino* was to be fabricated out of standardized elements to be attached to one another. It reflected Le Corbusier's famous motto that "*house is a machine for living*" since it related both industrial cutting-edge (concrete use was yet not very common at the epoch), a social answer to dwell the masses and the ability to do so using industrialized and standardized components. *Dom-Ino* is first, and foremost, a theoretical exercise inspired in industrial mass-production concepts. However, by using concrete technology, the system is conceived to a high degree of in-situ production and therefore, to some extent, contradictory to its own industrialization proposal. Nevertheless, despite some observable misunderstandings about what is industrial-production and mass-production, it stands a major influential design proposal. Cf. 'Fondacion' (2012); Le Corbusier (1960, 1986).

293 Cf. 'Building' (2014).

294 The *Gaiola Pombalina* is a groundbreaking complex system, acting in multiple design scales, which was developed as part of the concerted efforts of reconstruction applied in Lisbon, in the aftermath of an earthquake in 1755. The name stands for cage (*gaiola*) and as reference to the political leader responsible for its undertaking, the equivalent to today's prime-minister, known as Marquis of Pombal.

295 Cf. NESDE (2005). The example of the Portuguese *Gaiola Pombalina* is remarkable in this respect. The construction system, which became an architectural and engineering landmark at the time, used wood elements whose juxtaposition resembled a cage ('gaiola' in Portuguese), and was influenced by naval construction and used standardized principles. Nonetheless, the system is not merely a constructive system, it is part of a typical enlightenment-style proposal acting on a considerably large urban ground, affecting it at all levels: functionally, programmatically, urban, and so on. To prevent future disasters, the *gaiola pombalina* was thought of to have anti-seismic properties. Constructively, it is a tridimensional wooden structure embedded in masonry walls. The earthquake had demonstrated that the masonry walls of current use at the time were simply not capable enough to absorb and dissipate the energy produced by such a powerful force. Inspiration came from naval construction, namely on the great structural performance of ships relatively to the dynamic actions transferred by the seas. The military engineers involved in the reconstruction made an analogy of such behavior with the buildings' behavior during an earthquake. There was no doubt that the great behavior of the boats was related to a tridimensional structure made up of deformable elements, which simultaneously resisted to tensile and compressive strengths and to the way the connections between the different elements was made, enabling an articulated whole of different elements.

296 Cf. Bigott (2005); Ibach (2003).

297 Cf. Bigott (2005); Giedion (1941).

298 "*What a linguist should never do is just define a very expressive language which allows self-reference, or reference to truth or reference to knowledge and belief, and then proceed as if nothing could ever go wrong*" (Van Eijck, 1995).

299 Cf. 'Building' (2014).

300 Cf. Kieran and Timberlake (2004); Woudhuysen and Abley (2004).

301 Cf. Edge (2002).

302 The values are retrieved from the German context, a highly industrially developed country with great tradition of industrialization in construction, from which the figures can plausibly be regarded as a benchmark.

303 Larousse dictionary defines prefabrication as a "construction system to carry out works using standardized components, or components, manufactured in advance and that are assembled according to a predetermined plan". In Oxford dictionary, is described as "manufacture sections of (a building or piece of furniture) to enable quick assembly on site". As to Webster dictionary, it is defined as "to fabricate the parts of at a factory so that construction consists mainly of assembling and uniting standardized parts". Encyclopædia Britannica defines it as "the assembly of buildings or their components at a location other than the building site".

304 Many have sought to define prefabrication, or to use other words to describe the basic principles behind the approach. In a 1951, a study by Burnham Kelly (Kelly, 1951), through the *Albert Farwell Bemis Foundation*– one of the most relevant institutions producing research on housing in the prefabrication-wise important post-WWII period in the USA – it is acknowledged the difficult consensus on a definition for the term *prefabrication*.

Definitions of fellow contemporary authors are cited in this study, ranging from a specific to a generic extreme definition, starting by the one considered has being the most consensual: (1) A prefabricated home is one fabricated prior to erection, in contrast to the conventionally built home which is constructed piece by piece on the site (1947 apud Kelly, 1951); (2) Prefabrication is a question of degree, if the field operation is essentially assembly, rather than manufacture, you have prefabrication. The amount of scrap and waste may be taken as a rough index of the degree of prefabrication (Fisher, 1948 apud Kelly, 1951); (3) Prefabrication is a movement to simplify construction by increasing the proportion of work completed before erection (1945 apud Kelly, 1951); or (4) Prefabrication is a state of mind (McLaughlin, 1945 apud Kelly, 1951). While the latter statement may be seen as extremely generalist, making virtually any definition possible within it, it may also be understood as a conceptual frame, set for enabling different levels of what might be established for the term according to the scope in which is used in each case.

Three main ideas arise from the definition survey portrayed in Kelly's work: (1) as the dictionary definitions also implied, it seems to convey a spatial and temporal lapse between a sort of previous controlled construction environment and a final in-situ, not so controlled, construction environment; (2) a sort of layering, or hierarchy of processes, through the acknowledgement of the notion of *degree*; (3) finally it is described as a way towards simplification of construction processes.

In a contemporary work by Senaratne, Ekanayake, and Siriwardena (2010), an overview on more recent definitions is described: (1) Prefabrication is the transferring stage of construction from field to offsite (Tatum, Vanegas, & Williams, 1986); (2) Prefabrication is making of construction components at place different from the point of final assembly with a likely better control of the inherent complexity within the construction process (Bjornfot & Sarden, 2008, apud Senaratne et al., 2010); (3) Prefabrication is a manufacturing and pre-assembly process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation (Chiang et al., apud Senaratne et al., 2010). From these, Senaratne et al. (2010) reach their own definition: "*Prefabrication is a manufacturing and pre-assembly process, whereby, construction components are made at a location different from the place of final assembly, under specialized facilities with different materials, may lead to better control of the inherent complexity within the construction process*".

As with Kelly's, the idea of a temporal lapse between two different construction environments is also present, as it is the idea of layering (in Senaratne et al. referred as *components* within different spatial and temporal frames) or even the idea of *simplification* (in Senaratne et al. referred as *control*, if one understands it as a means for the end of simplifying).

The sixty years separating Kelly's from Senaratne's surveys on the word, apparently do not reveal major differences, albeit the major differences on how processes that surround it are referred. These are, to say the least, demonstrative of an updated technological state of the art, which as in any case safeguarded the word in its popular, common use. These are just two examples of approaches towards a definition, yet their comprehensiveness seems through enough for admitting a good level of plausibility in the conclusions.

305 Etymological root is *fabricate*: from Latin *fabricatus*, pp. of *fabricare* (i.e. *make, construct, fashion, build, construct, forge, shape*) from *fabrica*.

306 Properties such as acoustical, chemical, electrical, environmental, mechanical, optical, thermal and so on (e.g. shape, density, tensile strength, conductivity), by means of techniques of molding, cutting, heating, mixing, separating, and so on.

307 Etymological root is *assemble*: from French "*assembler*" (i.e., *come together, join, unite; gather*), from Latin "*assimulare*" (i.e., *to make like, liken, compare; copy, imitate; feign, pretend*), later "*to gather together*" from *ad-* (i.e. *to*) + *simulare* (i.e. *to make like*).

308 Joining together by means of bolting, welding, gluing, nailing, stapling and so on.

309 From the Latin "*prae*" (i.e. *before*).

310 Etymological root is *prefabricate*: recorded from 1932, from *pre-* + *fabricate*; shortened form *prefab* is attested from 1937; meaning *prefabricated housing* is recorded from 1942.

311 Other words may mislead or confuse with *fabrication*. Such is the case of *manufacturing* [root is *manufacture*, i.e., *something made by hand*, from Latin "*manu*", ablative of "*manus*" (i.e. *hand*) + "*facture*" (i.e. *a working*)], which suggests factory production and includes both fabrication and assembling. Such is also the case of *making* [root is "*make*": *to arrive at*, or *manner in which something is put together* - from Old English "*macian*" (i.e., *to form*, *construct*, *do*; *prepare*, *arrange*, *cause*; *behave*, *fare*, *transform*), from West Germanic "*makon*" (i.e., *to fashion*, *fit*) and from Proto-Indo European "*mag-*", (i.e., *to knead, mix*; *to fashion, fit* or *macerate*)], which also covers them, although not restricted to a factory outcome. Another possibility would be *production* [root is *produce*: *bring into being*; *to develop*, *extend*, from Latin "*producer*" (i.e. *lead or bring forth, draw out*), from "*pro-*" (i.e. *forth*) + "*ducere*" (i.e. *to bring*, *lead*)], but this is even more general, likely to come to be related with any sort of industry, or any sort of *product*. The latter is hence impractical for our purpose, which is foremost related with an architectural, or constructive sense, and not necessarily with a commercial one. There is also *constructing* (root is construct: from the Latin "*construere*": *heap up, pile up together, accumulate; build, make, erect*), which can be related to a sense of *fabricate* and *assemble*. On the other hand, *constructing* may seem of practical use, since it disambiguates the relation with the construction industry that we find in *production*, but in another hand might not be very helpful since it does not particularly express a sense of factory outcome. Also *edifying* and *building* convey a deep architectural sense (cf. Frampton, 2002: 25-42). *Edifying* [root is *edify*: from the Latin "*aedificare*", from *aedes* (i.e. a *building*, or, even more originally, a *hearth*) and *fiacre* (i.e. *to make*) or *building* [root is *build*: from late Old English "*byldan*" (i.e., *construct a house*) verb form of "*bold*" (i.e., *house*), from Proto-Germanic "*buthlam*" (i.e., *building a house*), from Proto-Indo European "*bhu*" (i.e. *to dwell*), and from root "*bheue-*" (i.e., *to be*, *to exist*, or *to grow*)], in the same logic as *constructing* (and as with *fabricate* vs *assembly* ambiguously related with *constructing*), could also be a possibility, but its use is not found in literature, hence of no practical use.

Distinction between *prefabrication* and *preassembling*, as with *fabrication* and *assembling*, may potentially be ambiguous, as is evidenced in some attempted definitions[311]. In this particular sense, the more general *premaking* could be an option to set things clear, yet this is of no common use, hence also impractical. *Premanufacturing* is also quite suggestive, yet the construction industry is site specific, requiring, even in the most optimized cases, in-situ as well as ex-situ work. This means there are construction events happening outside the factory, therefore its scope is short because it suggests a restriction to factory environment. The term *off site fabrication* coined by Gibb (1998), and widely used in the UK, also fells short for the same reasons.

Despite the possible ambiguity between *edifying* or *building* and *construction*, the word *preconstruction* could be relevantly considered, as it seems to have all it takes to convey a proper terminology, and as additionally remits to the specific industry we are here concerned with. Indeed, the word *preconstruction* is even used in some cases, as some literature occurrences demonstrate. Yet, its reference is not formally noted, as it does not appear in dictionaries, and its use is secondary when compared with *prefabrication*, which additionally has a wider usage in multiple natural languages - it is observable that *prefabrication* has commonly used forms in the main spoken languages in the world, as in also the main western languages, and so revealing extended unanimity: *prefabrication* (English), *prefabricación* (Spanish), *pré-fabricação* (Portuguese), *préfabrication* (French), *vorfertigung* (German), *prefabbricazione* (Italian).

312 Cf. Ballard and Arbulu (2004).

313 In Gibb's (cf. 1998) words, *prefabrication* is a "*useful but imprecise word to signify a trend in building technology. (…) If prefabrication was related to every factory manufactured product, the term could be stretched so wide as to lose all meaning*".

314 Cf. Gibb (1998).

315 On a historical perspective, the term *prefabrication* is quite recent. In the western world, the term formally arouse from the spoils of WWI to generalize a type that had progressively been breed since the burst of the Industrial Revolution, with the construction of colonial English settlements, in USA, Australia and elsewhere, since the early XVIIth century. In countries such as Japan, its development is inextricably linked with evolution of age-old practices of wood construction. Indeed, the notion of prefabrication had already become *traditional* in countries such as the USA or Japan by the time it

got to reference dictionaries in the 1930's in the western world.

316 Cf. Oliver (2007: 9-18).

317 Cf. Kelly (1951).

318 Cf. Kieran and Timberlake (2004); R. E. Smith (2010); van den Thillart (2004).

319 Cf. Bergdoll, Christensen, and Broadhurst (2008); Staib et al. (2008).

320 Cf. Woudhuysen and Abley (2004).

321 Cf. 'Forbes' (2015).

322 The tier terminology is especially common in the automotive industry. A tier-1 can supply one or several OEMs simultaneously. For instance, *Exedy* is a tier-1 clutches supplier to 11 Japanese car manufacturers along with *Ford* and *GM*. Following the same logic, tier-2 companies are the key suppliers to tier-1 suppliers, without supplying a product directly to OEMs. There is an interchanging logic in the terminology, in which a single company may be a tier-1 supplier to an OEM company and a tier-2 supplier to another company, or may be a tier-1 supplier for one product and a tier-2 supplier for a different product line. That depends on several factors, such as the businesses strategies and agreements, or the internal norms and requirements that the higher-tiers or the OEMs themselves have. Sometimes companies find it convenient to distinguish even further tier levels, with tier-3 companies supplying tier-2 firms, and tier-4 companies as providers of basic raw materials, such as steel and glass, to higher-tier suppliers. Finally, it is worth stressing that tiers are not official terms, they are more terms of a descriptive nature, and although more frequent, they are not exclusively used by the automotive industry. Moreover, the concept of tier does not reflect how big or important a company is, it mostly indicates who the end user of that company's product is. In any case, the terminology simplifies the tracking of the complex reality of the production relations.

323 Kieran and Timberlake (2004: 20).

324 That for instance the case of the *Volkswagen Group Platform*, in which there is a transversal codification of components, enabling, for instance, an *Audi* to share modules, or a group of modules (i.e. a *platform*), with a *Volkswagen*, a *Seat* or a *Skoda*. An *Audi A7*, a *VW Tiguan*, and a *Porsche Cayenne* on the same platform can hit 3 different price points sharing the same chassis/foundation, thus saving time and money in the development process. There are even cases in which components are shared in joint-venture with other OEM companies, as is the case of *Volkswagen*'s joint-venture platform *LT/T1N series*, used in the light commercial vehicles of the *Volkswagen LT range* (owned by the *Volkswagen Group*) and the *Mercedes-Benz Sprinter* (owned by the *Daimler Group*), which have synergies under the same platform.

GM, *Toyota*, *VW*, *Mercedes*, *Chrysler* and others have modular platforms upon which they can design different niche models to appeal to different market segments.

325 In 2015, in a $5 billion operation, with each unit costing around $50 million, *Embraer*'s newest aircraft, the *KC-390* airlifter has been set to compete with the old *C-130* from *Lockheed Martin*. Its components are built in several countries. The operation is centralized in *Embraer*'s *Eugenio de Melo* engineering facility in São José dos Campos, Brazil. Czech manufacturer *Aero Vodochody* delivers the rear fuselage; Argentina's *Fabrica Argentina de Aviones*, builds the cargo ramp door, tail cone and spoilers; *Portugal Engineering Manufacturing* (OGMA), provides fuselage panels, fairings and doors; St. Louis-based *LMI Aerospace*, supplies the leading-edge slats; Spain's *Aernnova*, is responsible for the composite flaps, ailerons and rudder. All the different facilities work in *vertical integration*.

326 Referring to 2014 (cf. 'Forbes', 2015).

327 Cf. 'Airbus' (2015).

328 For that matter, *Airbus* developed their own specialized five-airplane fleet of giant air carriers, the *Belugas*, dimensioned to carry any of the major airplane construction components, from vertical tail planes, to fuselage or full wings.

329 Two of these locate in Europe, the original in Toulouse, France (building A320s), and the biggest in Hamburg, Germany (A318s, A319s, A320s and A321s). The more recently open is located in Tiajin, China (A319s and A320s), and there is one opening in 2016 in the USA (in Mobile, Alabama, to build A319s, A320s and A321s), the homeland of its main competitors.

330 For instance, *MAN*'s maritime two-stroke engine *ME* or *MC* series, able to deliver a top power of over 82 000 Kw (or ~110 000 hp), equips large vessels.

331 The *Triple E* design is made by *Maersk* staff, in the company's headquarters in Copenhagen, Denmark, under the supervision of head naval architect Troels Posborg. Construction takes place across three different shipyards, in China and South Korea, and with the final assembly in HHI-DSME's Goeje Island shipyard, in South Korea. The *Triple E*'s two propellers, of 90 tons each, are cast in Germany, by *MMG*, a specialized foundry which builds more than 200 ship propellers every year, and the two engines, powering up to 40 000 hp each, are made in Denmark, by *MAN*. Its construction resembles a gigantic 3D puzzle, of 31 prefabricated mega-sections, enabling the reduction of time at the dock. The first of the twenty *Triple E* contracted to be built by HHI-DSME was scheduled for an astonishing tight schedule of 38 weeks, quite remarkable for a 58 000 tons of steel put to float. The production is not entirely automated. Starting with an army of cutting and welding robots, but also using a lot of human labor, parts grow bigger and bigger until finally a mega-block arises. However, most remaining labour in the final assembly and fitting is made by human hands, including welding together of major sections, the placement of hundreds of kilometers of wires and pipes, or the painting work. About 250 people work on each ship in the final stages of construction, at the dry dock. Despite the high degree of manual labor, after being transported in site, or overseas by specialized transporters, each mega-section is dropped by monster cranes into the dry dock, and is neatly aligned within a precise four millimeters of the adjacent block, so to be welded together by dozens of individual welders.

332 Such commitment to quality begins with R&D, for which they have their own *HHI Maritime Research Institute* and *HHI Industrial Research Institute*, or collaborating with the *Techno Design Institute* and *Electromechanical Research Institute*, working in a range of projects to improve ship performance and quality. The company has made considerable efforts for a broad integration of IT's systems. Through a 3D *Aveva*® CAD system, an *Enterprise Resources Planning* system to support effective resources management, and a *Product Lifecycle Management* system, they claimed they had been able to increase efficiency in ship design and construction. They have their own data center, and a shipyard wide wireless internet network, which widely contributes for real time communications between the construction and the design and management offices. In 2000, they had opted for the *Siemens Teamcenter*® software to improve the integration of their management and R&D information. Only considering these and other concerted IT's integration efforts, they claim they had since been able to achieve a total of US$ 9.8 million in savings, with increased productivity and quality.

333 Cf. Kieran and Timberlake (2004).

334 Frampton (2007a: 124).

335 Cf. Edge (2002).

336 (cf. Kostof, 1986; Robinson, Jamieson,

Worthington, & Cole, 2011).

337 Cf. Crowley (1998).

338 The value of a building element and the costs of transporting determines the economical transport radius. To optimize deployment, the order of loading the elements onto the vehicles should be dictated by the assembly sequence on the building site. Optimal assembly processes can be achieved if building elements can be unloaded directly from the transport vehicles by hoisting cranes and immediately placed and fixed in position on the site. Due to the exorbitant cost of transport helicopters, delivery by air is usually practical only for extremely inaccessible sites. Transport by road is standard procedure for continental travels and particularly distances up to 1000km, avoiding repeated and costly load transfers (cf. Staib, 2008).

339 Larger elements eventually require the use of transport frames, transport spreader beams or rope systems for securing hoisting equipment. For example, heavyweight precast reinforced concrete elements can be manufactured complete with lifting lugs or anchors for transportation and assembly, placed in the formwork during the manufacturing process.

340 The notion of batch-size refers to how many products can be made with a given technology. It is typically used to establish optimal relations between production volume and investment. For instance, a single pencil can be sharpen with a knife, but if, instead, a thousand pencils were to be sharpen, it would pay to buy an electric sharpener. If it were a million, probably it would be better to equip with an automatic feeding, gripping, and sharpening system, and to cope with pencils of different length and diameter, it would be better to have an automated system with sensors to measure pencil dimensions, sharpening pressure, and so on, in order to adapt to different pencils' characteristics. Thus, the choice of process depends on the number and/or kind of pencils that need to be sharpen, i.e. on the batch size, and the best option is that one that costs least per pencil sharpened.

341 Cf. (Maslow, 1954).

Simons, Irwin, and Drinnin (1987) write: "*Abraham Maslow developed a theory of personality that has influenced a number of different fields, due in part to its high level of practicality, accurately describing many realities of personal experiences. Maslow is a humanistic psychologist, and thus did not believe that human beings are pushed and pulled by mechanical forces, either of stimuli and reinforcements (behaviorism) or of unconscious instinctual impulses (psychoanalysis). Humanists focus upon potentials. They believe that humans strive for an upper level of capabilities. Humans seek the frontiers of creativity, the highest reaches of consciousness and wisdom. This has been labeled "fully functioning person", "healthy personality", or as Maslow calls this level, "self-actualizing person". In Maslow's hierarchic theory of needs, all basic needs are instinctoid, equivalent of instincts in animals. Humans start with a very weak disposition that is then fashioned fully as the person grows. If the environment is right, people will grow straight and beautiful, actualizing the potentials they have inherited. If the environment is not "right" (and mostly it is not) they will not grow tall and straight and beautiful. Beyond these needs, higher levels of needs exist. These include needs for understanding, esthetic appreciation and purely spiritual needs. In the levels of the five basic needs, the person does not feel the second need until the demands of the first have been satisfied, nor the third until the second has been satisfied, and so on. Maslow's basic needs are as follows.*

Physiological Needs - These are biological needs. They consist of needs for oxygen, food, water, and a relatively constant body temperature. They are the strongest needs because if a person were deprived of all needs, the physiological ones would come first in the person's search for satisfaction.

Safety Needs - When all physiological needs are satisfied and are no longer controlling thoughts and behaviors, the needs for security can become active. Adults have little awareness of their security needs except in times of emergency or periods of disorganization in the social structure (such as widespread rioting). Children often display the signs of insecurity and the need to be safe.

Needs of Love, Affection and Belongingness - When the needs for safety and for physiological wellbeing are satisfied, the next class of needs for love, affection and belongingness can emerge. Maslow states that people seek to overcome feelings of loneliness and alienation. This involves both giving and receiving love, affection and the sense of belonging.

Needs for Esteem - When the first three classes of needs are satisfied, the needs for esteem can become dominant. These involve needs for both self-esteem and for the esteem a person gets from others. Humans have a need for a stable, firmly based, high level of self-respect, and respect from others. When these needs are satisfied, the person feels self-confident and valuable as a person in the world. When these needs are frustrated, the person feels inferior, weak, helpless and worthless.

Needs for Self-Actualization - When all of the foregoing needs are satisfied, then and only then are the needs for self-actualization activated. Maslow describes self-actualization as a person's need to be and do that which the person was "born to do". "A musician must make music, an artist must paint, and a poet must write". These needs make themselves felt in signs of restlessness. The person feels on edge, tense, lacking something, in short, restless. If a person is hungry, unsafe, not loved or accepted, or lacking self-esteem, it is very easy to know what the person is restless about. It is not always clear what a person wants when there is a need for self-actualization".

342 Whereas the product-push brings the content to the user, making the customer aware of the product to the point of the purchase, the product-pull involves strategies to motivate customers to actively seek the product. The *Dictionary of International Trade* (Hinkelman & Putzi, 2005: 144) defines the pull strategy as "*a production and distribution strategy based on specific customer demand. In a pure pull strategy only goods and services actually ordered by customers are produced and shipped; there is no inventory of completed products. The term is used in many fields to describe decision making by demand of the marketplace rather than by a central authority*". Conversely, the push strategy is defined as "*based upon forecasts rather than on specific customer demand. The term is used in many fields to describe centralized decision-making authority without the immediate input of data from the marketplace*". Finally, a push/pull strategy is defined as "*based upon the combination of forecasts and specific customer demand. For example, a manufacturer might purchase component parts based upon sales forecasts, but manufacture finished products only upon actual customers orders*".

343 The term was coined by B. J. Pine II (1993), who refers that MC solves the dilemma of offering individualized products at the price of standardized ones by eliminating inefficiencies and waste by ordering the productive process (cf. Antonio Lopes Correia, Murtinho, & Simões da Silva, 2011).

344 Cf. Olhager (2003).

345 The *make-to-stock* is a typical MP strategy, hence where products ordered by customers are to be produced quickly with no customization. The order is made between the final assembly and shipment. Typical examples include beverages (e.g. beer, wine, soft drinks), food products (e.g. canned food such as tomato or tuna, packed food such as sugar or flour), and health and beauty products. The typical speculative real estate also broadly fits this category.

346 The *assemble-to-order* is a strategy where products are to be produced quickly while allowing a small degree of customization. Products are partially *made-to-stock*, i.e. stock is buffered, but final assembly only takes places after orders are received. Typical examples include partial postponement of paint color mixing, where the white base is made-to-stock, and the adjustments can quickly be made on customer order. Dell computers makes use of large stocks, however final assembly is postponed until orders are received. The historical concrete panel systems in the former USSR or in Germany broadly fit this category. *Assemble-to-order* and *made-to stock* distinction can thus be tenuous, nevertheless it is from its threshold that the orientation of the *push-pull* boundary is set. In last resort, the *push-pull* boundary will be

defined by the difference of buffer stock.

347 The *make-to-order* is typically associated with custom-built products, such as tailored clothing or jewelry. *Make-to-order* strategy may typically be pursued by producers of high cost products requiring excessive inventory carrying cost of finished product. Aircraft producers illustrate it, since relatively minor changes can be required by specific customers; nonetheless, production of parts is postponed until after orders are received.

348 *Engineer-to-order* is pretty much self-explanatory, with totally custom-designed products fitting the category.

349 Cf. Womack and Jones (2003).

350 The path towards LT was begun in *Toyota* in the aftermath of WWII, when, in the 1960s, a company executive, Taiichi Ohno (b.1912-d.1990), sought to optimize production processes within the company, developing the famous *Toyota Production System* (TPS). Back then, America was impressively producing vehicles and aircrafts, which in essence used the *Fordist* and *Taylorist* methods, making use of principles of economies of scale, integrating the inceptions of automation in their assembly lines, and so forth. Ohno fundamentally attempted to adapt these principles to the Japanese culture, where from he could regard the *Fordist* way with new eyes. The resulting TPS system was since highly acclaimed, receiving awards around the globe for its focus on people, through the use of economies of scope. The innovative methodology of production organization would become a reference, with several other industries since beginning to use it as a production model towards their own practices.

351 Ohno first identified seven *muda* types, however more can probably be found as it is pointed out by Womack and Jones (2003): mistakes which require rectification; production of items no one wants, with inventories and remaindered goods piling up; process steps which are not actually needed; movement of employees and transport of goods from one place to another without any purpose; groups of people in a downstream activity standing around waiting because an upstream activity has not delivered on time; goods and services which do not meet client's needs. (cf. Womack & Jones, 2003).

352 An internal study revealed that about 80 percent of the variety being offered by the implemented MC process was only corresponding to 20 percent of sales.

353 Other kinds of risks have been thoroughly scrutinized. What can go wrong, what is the likelihood that it will go wrong and what are the consequences are fundamental questions in traditional risk assessment (RA), which has become a discipline in its own right, dealing with highly complex subjects amid uncertainty and vagueness. The concept has too been applied to construction, where selecting an appropriate technique for evaluating the uncertainty associated with a specific project is critical (cf. Chen, 2008). Risk factors are beyond the control of the construction organizations, yet the underlying idea sustaining RA models is that they can be managed, and are relatively predictable and measurable by adequate statistics. Construction risk assessment (CRA) typically deals with management aspects that consider the entire AEC industry related aspects and not just a portion of it. These are naturally more concerned with potential hazardous circumstances that may have financial impacts in the overall process, than directly with architectural design issues. Of the few of these that may be analyzed in an overall CRA, architectural design related issues are typically left in secondary stances, as overall construction risks depend a lot more on decisions taken upstream.
Different CRA categories are used for different purposes, and different methodologies can be used. Among these, it can be found not only the indicators, but also weighted analysis, or proposals for mitigation measures. Some authors classify it into external risks (referent to a different country from where it is originated) and internal risks (referent to the country where it is originated), others have more detailed categories, e.g. political, financial, market, intellectual property, social, safety, and so on, of which it can be categorized within different scopes (client, contractor, etc.). The typology of risks seems to depend most if a project is local or international. Internal risks are common to both, while external are normally more sensible to aspects such as unawareness of social conditions, economic and political scenarios, regulatory framework, and so on[353]. Data collection for these is not an easy task, as multiple sources have to be considered in the target region, although some authors have a particular concern in providing general methodologies for this particular problem (cf. Hastak, et al.,2000), and the same may, apply to areas other than RA or CRA.

354 Cf. Antonio Lopes Correia, Murtinho, and Simões da Silva (2017).

355 Cf. Swamidass (2000).

356 Cf. Pahl, Wallace, Blessing, and Pahl (2007), K. Ulrich (1994), K. T. Ulrich and Eppinger (2012).

357 Cf. Alexander (1964).

358 Cf. Balakrishnan (1991).

359 Cf. K. T. Ulrich and Eppinger (2012).

360Cf. K. Ulrich (1995)

361 Cf. Greven and Baldauf (2007), Cf. International Standards Organization (1983).

362 Cf. Greven and Baldauf (2007).

363 Cf. K. T. Ulrich and Eppinger (2012).

364 Cf. K. Ulrich (1995).

365 Cf. Alexander (1964).

366 Cf. Simon (1996).

367 Cf. Sosa, Eppinger, and Rowles (2007).

368 In graph terminology, the *node* is a representation of a thing or component, and so forth. An *edge* is a connection between a pair of nodes, thus presuming that a relation between both nodes is established. The *degree* of a node is the number of edges incident with it—a *degree* 0 means it is an isolate node, a *degree* 1 means it is an end-node. Note that the sum of all the node-degrees is an even number, since we must count twice the number of edges. This essentially results from Euler's 1736 handshaking lemma, implying that if *n* people shake hands, the handshakes must be *2n*, thus even (cf. R. J. Wilson, 1996). A *path* is a sequence of connected nodes, and the *path length* is the corresponding number of edges on it. A *geodesic* (or *distance*) is the shortest path between two nodes in a network of nodes, measured by the corresponding path length. A graph is *connected* when every pair of nodes is connected. A *bridge* is when if removing a node, we disconnect the original graph. The *center* of a connected graph is the node, or set of nodes, with the smallest maximum distance to all other nodes in the graph (i.e. of minimum eccentricity). A *star* graph is when there is one node connecting with several nodes, which connect only with the first and no other. When the edges of a graph are noted with arrows, we can call it a *digraph* (or directed graph). In these conditions, between each pair of nodes there can be three types of directed connections: *adirectional* (simple connection), *unidirectional* and *bidirectional*. A *multi-edge* is when there is more than one edge connecting a pair of nodes. Each edge of a multi-edge connection can be noted with any of the directed connection types (cf. Ruohonen, 2013).

369 Cf. Agrawal (2009).

370 Cf. Sanchez and Mahoney (1996).

371 In brief, symmetry is when some aspect of an object stays the same despite the

changes. In other words, it is a type of invariance, i.e. the property that something does not change under a set of transformations. For instance, a sphere has rotational symmetry, insofar as when rotated about its center it maintains its appearance. A Rorschkelach inkblot has reflectional symmetry, since its mirror image matches the original. In 3D, a screw axis—or rotary translation—has an helical symmetry, thus combining rotation and translation symmetries, which can be observed in common objects such as drill bits, augers or springs. Also in 3D, a rotary reflection, combines a rotation about an axis with a reflection in a plane perpendicular to that axis, as is the case of the antiprisms. In geometry, symmetry occurs when there is a 'transformation' or 'operation'—technically, an isometry or affine map—mapping an object onto itself, meaning there is an invariance under the proceeded transformation. The Euclidean group of isometries figure among the most commonly aknowledged and straighforwardly recognizable of these operations, consisting of reflections, rotations, translations, or combinations of these. Scaling, which is another commonly aknowledged geometric operation, can too be considered an isometry, meaning that if an object is expanded or reduced in size, the new object retains the same properties as the original. Notwithstanding, this does not apply to most physical systems, where a change of scale typically implies structural or morphological changes.

372 Cf. Schilling and Hill (1998).

373 Cf. Schilling and Hill (1998).

374 Cf. Agrawal (2009).

375 Cf. Salingaros and Tejada (2001).

376 Cf. Vitor Murtinho et al. (2010); V. Murtinho et al. (2010a); Murtinho et al. (2009).

377 Cf. Santos et al. (2010).

378 Among the different national proposals, it would later become clear that the better outcomes came from those works involving greater architectural weight. As generally acknowledged by the different representatives attending the general meetings, it turned out that the challenges posed by architecturally driven concepts produced more attractive proposals. To a certain extent this means that this sort of proposals end up becoming a key driver for the different engineering expertise's, challenging them and thereby making them evolve throughout. On a different perspective, this also signals a social acceptability predisposition to accept innovation, if such innovation is properly contextualized, and thus understood by the different parts that may be directly or indirectly involved. Indeed, from a societal point of view, the approach towards innovation in housing construction tends to be conservative, since it is an activity that requires heavy investment, as it is clearly noticeable in the weight that housing expense typically plays in family bills, draining the greatest bulk of the income.

379 Worldwide there are different formulas, using different criteria, to calculate property price or affordability indexes. There are diverse targets and diverse insights, for instance, the concept may be used for purchase or rent purposes, addressed by the real-estate, the construction, or financial sector, and can be a useful macro-economic or political instrument. For instance, in the USA, the National Association of Realtors (NAR), publishes a housing affordability index. Their methodology, including computation and criteria, basically measures whether or not a typical family could qualify for a mortgage loan on a typical home: "*To interpret the indices, a value of 100 means that a family with the median income has exactly enough income to qualify for a mortgage on a median-priced home. An index above 100 signifies that family earning the median income has more than enough income to qualify for a mortgage loan on a median-priced home, assuming a 20 percent down payment. (…) The calculation assumes a down payment of 20 percent of the home price and it assumes a qualifying ratio of 25 percent. That means the monthly P&I payment cannot exceed 25 percent of the median family monthly income*" (cf. NAR, 2014). Also in the US, the *National Association of Home Builders* (NAHB) publishes Ranks and quarterly Press Releases on housing affordability (cf. NAHB, 2014). In Australia, the *Housing Industry Association* (HIA) also publishes regular reports on house prices and housing affordability. Working at worldwide scale, the *NUMBEO* user contributed database on cities and countries worldwide, provides information on world living conditions including cost of living, housing indicators (including affordability index), health care, traffic, crime and pollution. They provide a comprehensive of their methodology and correspondent codification (cf. NUMBEO, 2014). At a European level, recent documentation on the theme has been published in 2012 by the *CECODHAS Housing Europe's Observatory*. Their definition too acknowledges the relativity and context-sensitivity of the housing affordability concept, which measured against economic variables such as GDP, purchasing power, and so on. However, it also refers that a common way to address it is to consider the percentage of income that a household is spending on housing costs. A few options are described: "*Despite consensus across Europe on housing affordability being increasingly stretched, the idea of what is affordable is subject to national interpretations. The most common notion of affordable housing implies that households that spend more than 30% of their gross income to obtain adequate and appropriate housing have an affordability problem. Nevertheless, this definition is far from being universally accepted, and poses questions on which costs should be included (such as for instance whether to consider utilities bills). According to Eurostat's definition, a household is considered 'overburdened' when the total housing costs ('net' of housing allowances) represent more than 40 % of disposable income ('net' of housing allowances), where housing costs include mortgage or housing loans interest payments for owners and rent payments for tenants. Utilities (water, electricity, gas and heating) and any costs related to regular maintenance and structural insurance are likewise included*" (Pittini, 2012: 2).

380 Indeed, real-estate terms sum it up eloquently when often affirming that 'location is everything'. In fact, although not departing from the construction cost, but from the selling price point of view, many current real-estate procurement methods use the m^2 price approach as a comparison means between different products to their prospective buyers.

381 Nonetheless, given the nature of the architectural task, any solution will ultimately have some degree of dependence from a certain subjective interpretation.

382 Cf. Murtinho et al. (2009).

383 There are different ways to understand this setting, considering either the common circulation areas or the circulation within each space. In a certain room, the distribution of furniture, doors and windows dimensions and location, and so forth, influences how circulation can be made within that room, and how much area is in the least necessary for it. A proper handling of the circulation zones within a so considered enclosed space may bring substantial area savings. By increasing the degree of embedded design within a space may bring area savings. However, as shown by Leupen (cf. 2006), such has a reverse effect in polyvalence, undermining important spatial flexibility aspects. For instance, a shelf that folds down to a bed, while expanding the possibilities of use of space, lowers the potential for change, and so forth. Space may 'augment' through multifunctional furniture and the like, but then it is also difficult to change the spatial layout throughout the building's life. While 'freeing' space in this fashion, we are also 'imprisoning' it.

There are plenty of validated functional studies that have long set clear definitions in this particular, to the point of influencing the different legal frameworks in different national or regional contexts, and which in any case the design necessarily had to comply. In the case of the Portuguese legal framework, RGEU (acronym for 'General Regulation for Buildings and Urbanizations') is, among others, a key legal documents in this respect. For instance, it sets minimum areas for the different house areas according to their typologies, establishing limits on room proportions in relation to a direct source of light and ventilation, and so forth. An overview of the Portuguese legal framework was one of the delivered elements in the first stage of the AHP.

384 Cf. full project in the provided digital documentation.

385 Cf. full project in the provided digital documentation.

386 For instance, when compared with the Portuguese minimum requirements for typological labelling (i.e. T0 meaning zero bedroom, T1 meaning one bedroom, and so on), these are astoundingly bigger, since the minimums for inhabitable areas are set in: T0≥22m² (gross ≥35m²), T1≥30.5m² (gross ≥52m²), T2≥43.5m² (gross ≥72m²), T3≥54.5m² (gross ≥91m²), T4≥61m² (gross ≥105m²), T5≥74m² (gross ≥122m²), T6≥82.5m² (gross ≥134m²). These figures are generally smaller than what can be currently found in the real-estate market for houses in apartment buildings. Exceptions stand in the smaller typologies T0 and T1, where these figures seem to approximate. On the other hand, if comparing with real-estate market for residential houses, the disproportion is a lot bigger, with figures such as T1~100m2, T2~130m2, T3~175m2, T4~230m2, T5~265m2, or T6~370m2. Additionally, in this niche we are talking of great variations that can go all the way from over 30m² until little over 300m² in the T3, or from over 80m² until little over 400m² in the T4.

387 Cf. Lobos and Donath (2010).

388 Cf. Stiny (2006).

389 Cf. V. Murtinho et al. (2010b);V. Murtinho et al. (2010a).

390 Cf. António Lopes Correia, Silva, and Murtinho (2012); Antonio Lopes Correia, Simões da Silva, and Murtinho (2013).

391 From the examples that, in one way or another, have been inscribed in an 'official architectural history', some strongly assume a conceptual intention, which will, or will not be used in later developments (e.g. *Maison Dom-Ino*, 1914 and later *Maison Citrohan*, 1920, by Le Corbusier).

Other examples, while conceptual, convey a deep architectural sensibility and design focus (e.g. *Espansiva*, Jørn Utzon, 1969). Some are fundamentally derived from constructive concerns (e.g. *Manning Portable Cottage*, H. Manning, 1837).

Some others are made to sell via catalogues, fulfilling wishes borrowed from flashy colored pages (e.g. *Alladin Ready-Cut Houses*, 1906), and have no architectural aspirations whatsoever.

There are even those that do not expect becoming much more than prototypes, to be questioned, desired and dreamt about (e.g. *Keck Crystal House*, George Fred Keck, 1933-34).

A few others, are fundamentally conceived as a design system, a grammar to convey a style of making (e.g. Usonian Houses, Frank Lloyd Wright, 1936-onwards).

Some take it to the level of corporate brand (e.g. *BoKlok*, from joint-venture of *IKEA* and *Skanska* companies, 1996-present).

Soon it becomes clear that the diversity of examples and their different connecting dots makes any attempt of classification virtually impossible.

392 Nonetheless, there are prefab examples in which technological aspects stand-out. Such is the case of the *Ballon Frame* (1833-present), developed from a mixture of needs and improvements, such as small, lightweight, wood parts (easier to handle in transport and assembling), and added to other technological breakthroughs such as the industrialization of nail production. It even become an iconic construction system throughout the USA (and beyond), enabling an immense variety of styles and architectural layouts, still lasting presently.

393 High-density materials, such as brick or concrete, have a higher thermal mass, which gives it more inertia to temperature changes, absorbing and storing heat and releasing it slower than lower thermal mass materials such as wood or insulation foam.

394 Excepting more extreme climates, as a rule of thumb, aiming at higher thermal mass is most effective when ranges exceed 10ºC, whereas in a 7º-10ºC it depends on the climate (in tropical climates can cause discomfort unless carefully designed, with insulation and shades), and 6ºC is insufficient Cf. Reardon, McGee, and Milne (2013).

395 For instance, optimal zones in masonry materials are located in the first 100mm, whereas in wood they are in the first 25mm. Nonetheless, there are already available market solutions, namely the new phase change materials, aiming to increase the thermal mass of lightweight constructions without significantly increasing weight, which can be incorporated in buildings, although with inherent costs.

396 Cf. Baudrillard (1994).

397 As many other terms, globalization does not have a consensual definition. Definitions on globalization vary from the knowledge field, group or scholar who provides it, as is easily verifiable in a quick browse on some of the abundant literature available. For instance, in a Google Scholar search conducted on March 2012 there was a return of over 1.5 million entries for the word in scholarly books and articles. A quick browse on the search results also reveals the wide variety of subjects portrayed within the thematic. Herod (2009: 231-233) points out that outlining a term such as globalization may seem an intellectual luxury, but it can also be quite relevant, as "*ideas, rhetorics, and material practices all have real consequences for real people*".

398 Eco (1991: 132).

399 Lévi-Strauss writes: "*Throughout my life, this search was probably a predominant interest of mine. When I was a child, for a while my main interest was geology. The problem in geology is also to try to understand what is invariant in the tremendous diversity of landscapes, that is, to be able to reduce a landscape to a finite number of geological layers and of geological operations. Later as an adolescent, I spent a great part of my leisure time drawing costumes and sets for opera. The problem there is exactly the same - to try to express in one language, that is, the language of graphic arts and painting, something which also exists in music and in the libretto; that is, to try to reach the invariant property of a very complex set of codes (the musical code, the literary code, the artistic code). The problem is to find what is common to all of them. It's a problem, one might say, of translation, of translating what is expressed in one language - or one code, if you prefer, but language is sufficient - into expression in a different language*" (Lévi-Strauss, 1979: 8-9).

400 Eco (1991: 331) writes: "*the codes… would then be nothing more than iconological, stylistic or rhetorical lexicons. They offer no generative possibilities, but finished schemata, not open forms about which one could talk, but hardened forms, general relations of an unexpected type. Architecture is thus rhetoric (…)*".

401 Such triadic understanding is was put in these terms by Adolf Loos' *Architecture* essay (cf. Opel & Opel, 2002). The triadic notion also denotes Hegelian foundations, of which Charles S. Pierce triadic sign, with *object*, *sign* and *interpretant*, is a key semiotic reference.

402 Tafuri (1976: 181).

403 Cf. Norberg-Schulz (1980).

404 Harvey (2005: 240) writes: "*As space appears to shrink to a* global village *of telecommuni-*

cations and a spaceship earth *of economic and ecological interdependencies and as time horizons shorten to the point where the present is all there is, so we have to learn how to cope with an overwhelming sense of* compression *of our spatial and temporal worlds. The experience of time-space compression is challenging, exciting, stressfull, and sometimes deeply troubling, capable of sparking, therefore, a diversity of social, cultural, and political responses*" (Harvey, 2005: 240).

405 Scheuerman (2010) writes: "*The human experience of space is intimately connected to the temporal structure of those activities by means of which we experience space. Changes in the temporality of human activity inevitably generate altered experiences of space or territory. Theorists of globalization disagree about the precise sources of recent shifts in the spatial and temporal contours of human life. Nonetheless, they generally agree that alterations in humanity's experiences of space and time are working to undermine the importance of local and even national boundaries in many arenas of human endeavor*".

A classic example of the changes in humanity's experiences of space-time through global effects is the shifting of the boundary conditions which have been archetypally defining the idea of country or nation inherited since the French Revolution: in one hand, the nation-state is overwhelmed by transnational forces, on the other it is inescapably depending on its very social scrutiny.

According to Rodrik (2012), the global financial crisis unleashed in the late 2000's seems to have shattered the myth that national policymakers are largely powerless in the face of global markets: "*For now, people still must turn for solutions to their national governments, which remain the best hope for collective action. The nation-state may be a relic bequeathed to us by the French Revolution, but it is [yet] all that we have*". In any case, if this return to the state, as the last credible warranty, may be true in (at least) economic-wise and although in counter-cycle with a certain common belief of how things evolve (that is on the path of blending and while economically growing), it is socially certainly very far away from what is given to observe in (at least) powerful social movements that were only made possible some by *globalization* by-products, such as the ones that enabled the so-called Arab Spring unleashed in early 2011. That is to say the state, again (and accidentally) relevant, is now more than ever entangled between powerful global economic forces and powerful social forces globally driven.

406 Virilio (2000: 101).

407 Frampton (2007a: 85).

408 A relatively recent trend of artistic projects has given visibility to their forms, showcased in cinema, exhibitions or TV commercials, inspiring a certain 'coolness' to its shapes. There is even a trend of travelling experience niche market, where the tourist can spend the night in the slum's hotel, or join a slum-like resort: 'third-world' romanticism with luxury service.

409 Cf. Le Corbusier (2007).

410 (Lévi-Strauss, 1979: 20) writes: "*Differences are extremely fecund. It is only through difference that progress has been made. What threatens us right now is probably what we may call over-communication – that is, the tendency to know exactly in one point of the world what is going on in all other parts of the world. In order for a culture to be really itself and to produce something, the culture and its members must be convinced of their originality and even, to some extent, of their superiority over the others; it is only under conditions of under-communication that it can produce anything. We are now threatened with the prospect of our being only consumers, able to consume anything from any point in the world and from any culture, but of losing all originality.*

We can easily now conceive of a time when there will be only one culture and one civilization on the entire surface of the earth. I don't believe this will happen, because there are contradictory tendencies always at work - on the one hand towards homogenization and on the other towards new distinctions. The more a civilization becomes homogenized, the more internal lines of separation become apparent; and what is gained on one level is immediately lost on another".

411 GLA (2013).

412 NYC (2013).

413 INSEE (2010).

414 The heterotopia concept is also not consensual, yet is certainly a conceptual instrument that helps explaining spatial derivatives of globalization processes. First coined by Foucault (1967), the notion is set between what may be called the real space and the utopian, or unreal space, carrying a sense of abnormality within a seemingly normality, a sense of otherness in a familiar environment, and so on, including heterogeneity within homogeneity and vice-versa.

415 Cf. Augé (1995).

416 Other kinds of non-places can be found among those spaces where some important forms of private interaction are manifested, as those purposefully designed to house certain socially-stigmatized behaviors—e.g. prostitutes, homeless, or addicted—providing them with a bit more of dignity than they would get in the streets.

417 Eldemery (2009: 344) writes: "*place exists not only physically but also in peoples' minds as memories. The identity of a specific place becomes interesting when it brings about a certain experience, evoking associations or memories*".

418 Issues affecting local forces are case of tension between anti-global and pro-global forces, have been widely scrutinized, as is the case of the architectural regionalism debate.

Regionalism was never a singular theory or practice but is most often a means by which tensions, such as those between globalization and localism, modernity and tradition, are addressed. Its origins are remote in time, becoming particularly clear with the Roman practices of territorial management – the regionalism of Vitruvius. It may be allied with other disciplines concerned with spatial phenomena such as cultural geography or historical studies, but differs from these in dimension and application. "*Watersheds, topographical difference, areas of distinctive land use, climatological difference, and consistencies of architectural, cultural, linguistic, and political organization are criteria available to the regionalist for consideration in the design of environments for those places. Further, thinking in terms of regions affords architects the opportunity to derive unique and relevant environments from a specific and local context with a wider perspective*" (Canizaro, 2007: 18-19). Architectural regionalism differs from other disciplines with that concern (e.g. cultural studies, sociology, anthropology) fundamentally in its relation to practice. Unlike processes of analysis and description used by these, which tends to be more neutral, practice tends to be polemical and its theorization, prescriptive. (cf. Canizaro, 2007).

419 Montaner (2002).

420 Cf. Norberg-Schulz (1980); Canizaro (2007).

421 Cf. Benjamin (2008).

422 Cf.Klingmann (2007).

423 OMA, Koolhaas, and Mau (1995: 364-365)

424 Dias (2003: 6) writes: "*by definition, architecture has always been* transnational*, international, cosmopolitan*". And indeed, "*the Romanesque, the Gothic, the Renascence, the Baroque, the Neo-Classical, the International Style are all* modes*, more or less known by everyone, more or less mastered by all, for in any place, and acknowledging them stylistically and constructively, build several types of programs*".

425 Opel and Opel (2002: 76-77).

426 Cf. Kostof (1986).

427 The diversity of attempted frames of reference is abundant. For instance, Frankl (cf. 1968) distinguishes between the *spatial form* of the buildings and the *corporeal* (physical building elements, mass, surface), *visual* (light, shadow, color), and *purposive* (social

function) qualities that result from the physical realization of spatial form; Le Corbusier (cf. 1986) famously makes an appraisal on *space*, *light*, *air* and *order*, from where the image of buildings suspended by *pilotis* in the middle of an idyllic green city immediately arises: *everything in its right place* (as the Radiohead song of the *Kid A* album (2000) transmits, *Everything in its right place* as the obsessiveness of human logic, the *madness* of taking it to extremes). Vitruvius (1914: 17; i.e. Book I, Chapter 3, #2) had expressed a triad of *firmitatis* (durability), *utilitatis* (convenience) and *venustatis* (beauty).

428 Frampton (2007a: 86) writes: "*As a result of these successive global disturbances it became increasingly clear that modernization, most frequently personified in architecture by the white, abstract rationality of the* International Style*, would not come into being overnight as a brave new world, but would instead be subject to an infinite series of reversals and deviations, not to mention the sporadic violent conflicts at both local and global scale that will be fought in its name*".

429 Cf. Jencks (2002).

430 Cf. 'Palladio's Literary Predecessors' (2010), Kostof (1986), Wittkower (1995).

431 Cf. Wittkower (1995: 26-37).

432 Cf. 'Palladio and Britain' (2011), 'Palladio's Literary Predecessors' (2010), Wittkower (1995).

433 Other include e.g.: Francesco di Giorgio's (1439-1502) *Trattati di Architettura* (1476-1492); Fra Luca Pacioli's (1445-1517) *De divina Proportione* (1509), Diego de Sagredo's (1490-1528) *Medidas del Romano* (1526), Torello Sarayna's *De origine et amplitudine civitatis Veronae* (1540), Antonio Labacco's (1495-1570) *Libro di Antonio Labacco appartenente a l'Architettura nel qual si figurano alcune notabili antiquità di Roma* (1552), Pitro Cataneo's (1510-1574) *I quattro primi libri di Architettura di Pietro Cataneo Senese* (1554, 1567), Alvise Cornaro's (1484-1556) *Trattato dell'Architettura* (1557-1566; published posthumously), Vignola's (1507-1573) *Regola delli cinque ordini dell'Architettura* (1562), Fra Anton Francesco Doni's (1513-1574) *Le ville* (1566), Philibert De l'Orme's (1514-1570) *Le premier tome de l'Architecture de Philibert de l'Orme* (1567), Silvio Belli's *Della proportione, et proportionalità* (1573), Wendel Dietterlin's (1550-1599) *Architectura* (1593) (cf. 'Palladio's', 2010).

434 Cf. Kostof (1986).

435 Cf. 'Palladian' (2010).

436 (Davies, 2005: 118).

Davies adds: "*From John Shute's First and Chief Croundes of Architecture of 1563 to the lavish publications of the eighteenth century, such as Colen Campbell's Vitruvius Britanicus (1715-25) and James Gibb's A Book of Architecture (1728). The builders of the elegant streets and squares of Georgian London took their correctly proportioned façades and Doric door-cases straight from smaller, cheaper pattern books such as William Halfpenny's The Art of Sound Building (1725) and Batty Langley's The Builder's Jewel (1741). In the early nineteenth century dozens of architects produced pattern books to meet the demand from a growing middle class for suburban villas and country cottages. One of the pioneers of the so-called 'villa book' was Sir John Soane (…) His Sketches in Architecture of 1793 is purely speculative, containing designs for modest, affordable dwellings pictured in imaginary rural settings*" (Davies, 2005: 117-118).

437 Cf. Colomina (1998).

438 Cf. Ábalos (2003).

439 Cf. Gutman (1988).

440 Cf. Ahlava (2002).

441 Nevertheless, the notion of *starchitecture* seems to be in process of review, as ambiguously and paradoxically affirmed by the starchitect Rem Koolhaas while curator of the 14th Venice Bienalle in 2014, with *Fundamentals* as general theme, stating that what mattered was architecture, not its authorship—indeed, when backs are covered, it is easy to say anything.

442 Making use of their expertise they claim to sell their services for multiple consultancy purposes such as corporate identity or visual communication, operating in areas such as media, politics, sociology, renewable energy, technology, fashion, curating, publishing or graphic design.

443 Cf. Kostof (1986).

444 Tafuri (1976: ix-x).

445 (Cf. Robinson, Jamieson, Worthington, & Cole, 2011).

446 To describe the idea, Wilson once told the story of a friend female soul singer who called him just right after 9/11, saying she could not perform in her show as scheduled, because she felt so affected that she sensed that if she had to sing that night she would just burst into tears. Wilson told her that if she felt that way, the best was just to sing anyway, no matter what. She sang indeed, but soon after starting, she could not do it anymore, and she just kept silent. She stood there for minutes and eventually tears came into her eyes, but she kept silent. While she was standing silent in stage, nothing more than her solid presence - no sound, no movement, no expression, just her and the deepness of her feelings - one by one, all the audience started to cry.

447 Within it, the *Futurama*, the General Motors pavilion, immersed its visitors in a diorama of miniature towns, individually designed homes, highways, vehicles, waterways and trees of diverse species, a colored 3D illustration of a fast-moving neoliberal philosophy.

448 Cf. Fletcher (1987).

449 The company *Grupo OAS*, owner of some of the stadiums, has struggled for months with the impact of a corruption scandal at major oil company *Petrobras*, which undercut the builder's access to financing. Facing cash flow problems, *Grupo OAS* begun to search for buyers for the totality of *Arena das Dunas* (in Natal, Rio Grande do Norte), and for 50% of the *Arena Fonte Nova* (in Salvador da Baía). This is just one of the many unfortunate stories involving each of the twelve stadiums in the post-World Cup. The ground in Cuiaba was closed because of structural problems, and other venues have seen bigger crowds for religious events or music concerts than for football (cf. Downie, 2015).

450 Rittel and Webber (1973).

451 Cf. Koolhaas (1994).

452 Herman Hertzberger (2000: 199).

453 Cf. Kunstler (2004).