Breaking the Type

Considerations Toward the Production of Innovative Architectural Designs by Evolutionary Design Models

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Abstract

Evolutionary architectural models often show only variation of a theme. They thus misrepresent the design process in architectural practice that eventually results in some innovative designs over the years. It seems that this misrepresentation arises from the analogy between biological and design models. The objective of this paper, then, is to shed light on the similarities and differences between the models, in particular on the notion of purpose and species, and on the use of precedents (as instructions) in both models. With the notion of purpose and species, we intend to question how architects "break" types and create innovative designs by recombining their parts. The ultimate objective of this article is to provide ideas for the improvement of evolutionary design models for architecture.

1. Introduction

Evolutionary Design Models have their origins in an analogy between biological evolution and design. We argue in this article that some differences between the two models were not well explained, causing misunderstandings in the representation of design practice. We argue that evolutionary architectural models often only show variation of a theme, thereby misrepresenting the design process in architectural practice that in the long run produces some innovative designs.

It is not necessary to mimic the mind (even if it were possible) or the behaviour of the architect to develop a tool, or even to make perfect analogies with other fields (an analogy cannot be used as justification of a claim), because a model does not need to be true or false, but fruitful and this depends of the objective of the model. In our case, the interest is not only in the production of variation of a typ, but also in the production of creative and innovative designs, which is the main concern of this paper. By innovation, we refer not only to the production of different forms, but also to technological advances in the field. We wish to contribute toward developments in this context.

Variation is a means toward and necessary condition for the development of new species in nature and for the development of innovative designs. However, we noted that there are important differences in the production of variation and selection in both fields. We wish to present two notions that are probably the key in expounding the differences. These are the notion of intention in design and the concept of species in nature.

We shall explain our arguments by means of examples. First, we shall concentrate on the use of precedents in design, focusing on the transference and adaptation of Le Corbusier's piloti and Santiago Calatrava's arch. Here we shall discuss the notion of intention and the concept of species. Second, we shall describe the creation of an innovative design from recent history: the creation of the Unité d'Habitation by Le Corbusier. With this example we will briefly show the origin of certain precedents, questioning the idea of species in design and trying to describe the possible mechanism in design.

To conclude, we shall pose a series of questions that may lead toward a better representation of the architectural process: a representation that supports the production of innovative designs or at least leads toward a re-evaluation of the actual research results in the field of evolutionary designs.

2. Designing with Precedents

Architects often explicitly make use of design precedents, such as Le Corbusier, James Stirling and Jo Coenen; and others less explicitly, such as J.J.P. Oud, Santiago Calatrava and Aldo van Eyk; both ways frequently lead to efficient, effective, and/or innovative results" (Moraes Zarzar 2003). We argue that in architectural practice, the use of design precedents as a source of knowledge is often considered to be a more efficient strategy in developing designs than initiating a project from tabula rasa." Evolution in nature takes place based on the transference of genes from one generation to another and eventually on erratic copies of genes that generate novelties and more variation. Looking this way they are very different models, however, it is implicit in both models that there is use of past information in the ontogeny of a new generation and in this way we can follow with our analogy. We also assume that by using this analogy, evolutionary design models depart from the use of a certain kind of design precedents.

Genes are instructions and copies of other genes. Organisms are the expression of those genes (phenotypes). By analogy, we could say that design precedents/projects/cases are the expression of design genes. A design gene then expresses a feature in a project/case: features are then the "material of the architect". Architects transfer features (and their hidden instructions), which may derive from other architectural projects or vernacular buildings as well as by analogical reasoning, even from bottles and bottle racks (Tzonis 1990).

In general, one can observe two kinds of transference. On the one hand, one may be interested only in the configuration of certain elements, such as Le Corbusier and the piloti of the savage hut. On the other hand, the designer may be concerned with the use of certain structures irrespective of the original use that the structure had, such as Calatrava's use of similar structures for different kinds of project; for example the "arch and hangers" of Lusitania Bridge (1988-91) in Mérida, Spain, and the "arch and hangers" of the roof of Tenerife Exhibition Hall (1992) in Tenerife, both to be described later in this paper. In this manner, Instructions from a feature are isolated from their original design and transferred.

The configurational and/or structural instructions of a certain feature of an artefact must obviously fit its corresponding part in the new design. In other words, it must fit with the other configurations of the new design as well as its own structure. Once separated from the original design, they may evolve by acquiring more meanings, such as in the case of Le Corbusier's piloti. They may also become a principle, as in fact the piloti did in becoming part of Corbusier's "five points for a modern architecture". At that point, it was no longer the savage hut that was essential to be recalled, but the principle.

3. Purpose and "Inheritance" in Designing

We are trying to mimic some aspects of the architect's behaviour to get insights into his/her creative mind when generating innovative designs based on design precedents. In turn, we want to improve the evolutionary design models that support the use and adaptation of design precedents.

Architectural design is an ill-defined kind of problem. However, this does not presuppose that designers have no purpose or that they may go freely in all directions. It seems unlikely that designers would go through their memories in a purposeless way collecting precedents and randomly changing them to see afterwards whether they fit or not. It would take millions of years to find a suitable solution. Designers have performances in mind that they want to match, although they could change their minds through the design process and aim for new or additional performances. When using precedents, they seem to examine them for configurations and structures that could help them to achieve a desired performance. It seems that the more experience an architect has, the more precedents he or she would find to match the same performances – at least if we excluded the power of biases that could block the actual search (Bay 2001).

We are thus led to an *artificial selection* rather than *natural selection.* In this sense, "evolution in design" is closer to breeding than to evolution in nature. Breeding refers to artificial selection, i.e. to purpose. Breeders have an intention and select by phenotype plants or animals, each having a particular desired performance to improve the quality of their grains or animals in the generations to come. More than one generation will be necessary, but eventually the breeder will have a generation that approximates or matches his/her goal.

In nature, but also in breeding, there is an important constraint: species. Once new species are formed, their descendants will evolve departing from the set of genes they have. The offspring of two different species are mostly unfertile. Based on case studies, we argue that this barrier is not so strict in design as it is in nature (Moraes Zarzar 2003). It seems that putting characteristics of other orders of objects together helps architects to generate innovative designs. Therefore, to approximate even more from design practice, one should provide architects with "genetic engineering knowledge"; i.e. architects should be able to isolate the genes that express the desired performance from any species, transfer them and adapt them to the new design. In this way, architects would have an "open" design gene pool rather than a perfect closed system.

This kind of transference seems to be a bottleneck in developing an evolutionary design tool since, besides the continuous recognition of new features over the years; it involves the use of analogy in the process of recognition.

Next we will present examples of two kinds of transference of features from precedents used by Le Corbusier and Santiago Calatrava.

4. Transmitting Characteristics in Design: species constrained?

If an intention exists, then we have stumbled over one of the principles of Darwinism. however, we may instead use breeding and artificial selection as analogues for architectural design based on precedents. Next, we shall show these ideas through two examples of the use of precedents from architecture. We question the validity of a closed system that randomly mutates its genes dealing with ill-defined problems in the very constrained field of architecture. We will describe Le Corbusier's transference of the piloti from the savage hut to his work and his subsequent re-use of it. Second, we will describe the possible transference of the arch and hangers of Lusitania Bridge to the Tenerife Exhibition Center. It goes without saying that they are described as a possible reconstruction of the facts based on the analysis of designs and on written material.

4.1. Le Corbusier: piloti and savage huts (Moraes Zarzar 2003)

The first time that Le Corbusier used the piloti was during the design of his Citrohan house of 1922. In his article "Hutten, Shiffe, und Flaschengestelle", Alexander Tzonis suggested that it was at this point that Le Corbusier would have asked himself: "Do I know any products which do not disrupt the natural continuity of the terrain (Tzonis 1992)?" Le Corbusier would search through his memory to find a precedent that would fulfil his intention of not disrupting the continuity of the terrain and came up with the "savage hut" which, being supported by stilts, did not disrupt it. A process of recognition of characteristics of the stilts (piloti) took place. Further analysis of the element would suggest that the piloti could suit other purposes as well, such as that the piloti allowed air to circulate without obstruction under the buildings, thereby protecting it from humidity; for this reason it was also environmentally good. This feature was then used in his Citrohan of 1922, stored in his memory and archives for later re-use in most projects.

As Tzonis asserted, Le Corbusier was selective in what he transferred. He was neither interested in the 'body' of the hut (room) nor in its 'top' (roof), only in its stilts. Looking deeper, we would claim that Le Corbusier was also not interested in all of the information of the piloti, but in its pattern of arrangement. When challenged to find some precedent that did not disrupt the natural continuity of the terrain, he considered the overall configuration of the piloti and some of its operations. However, at that stage, he was not interested in measure, material, technique or technology.

In the (as he himself termed it) "40 years of gestation" of the Unité d' Habitation, Le Corbusier's piloti first appeared in the Maison Citrohan, and through use and adaptation it changed from slender stilts to gargantuan columns, and from the individual domain to the collective domain.

Structurally, the piloti is in general a part of a building's structural framework formed by columns and beams or slabs. While each storey contains a set of columns mostly wrapped up by a "skin" (walls, glass etc.), the piloti is mostly exposed. Le Corbusier used it in reinforced concrete but also in steel, for example in the double Maison Citrohan of Stuttgart. It functions by distributing the structural forces from the "body" and "top" to the building's foundation.

The piloti is not just a set of columns; it is a set of columns at the ground floor, which in addition to supporting the artifact, should permit cross-ventilation to protect the building against humidity. Therefore, it should have few or no enclosure elements. Morphologically, it is composed of columns that do not touch each other, and it is at least one storey high to permit the circulation of people. The space generated by the columns may function as access to the building as well as a garden, garage, and/or recreation area. In the Unité d'Habitation, the piloti was supposed to be used on a large scale (several buildings in an environment), and was intended to permit the view of an open landscape from the ground floor level and be used collectively. In other words, the notion of piloti evolved from the private domain to the collective, first because of its potential to meet other needs on a larger scale, and second because it was compatible with other innovations.

Together with the rest of the structure, it was intended to free façades and plan layouts. This formed a chain of links which could be read as follows: to enhance the design of façades, neither the piloti nor the columns of the framework should be placed within but behind the façades' planes; to enhance a stable structure, the piloti needs to be linked to the total structural framework; and to enhance the design of free layout plans, the piloti and framework should allow partition walls to be freely placed in the layout, thereby freeing the layout of the units as well as, in the case of the apartments, permitting varying house sizes.

In summary, in the case of the piloti, Le Corbusier was not directly concerned with the rest of the structure of the savage hut; he was also not concerned with the use of timber and the technique used to put the parts together. He was concerned with the quality that this configuration would provide if he were to use it in his buildings. This configuration acquired more meanings over the years. It was used to free buildings from humidity, to free ground for private and later also collective activities, and to liberate the view of the horizon.

We could conclude that the recognition process of the piloti of the savage hut is intrinsic to Le Corbusier's creativity. He recognized in this configuration some qualities that could be interesting in his projects, a process that was carried out many years before the architect became involved with the creation of the Unité d'Habitation. In fact, many precedents used by Le Corbusier were collected on journeys in his early years. In the work of Corbusier it is clear that once a specific part of a precedent was recognized and separated from the whole, it could be part of his "d-gene pool" and eventually become enriched with new meanings as well as transformed.

4.2. Calatrava: Tenerife Exhibition Center and Lusitania Bridge (Moraes Zarzar 2003)

Through careful observation of Calatrava's Tenerife Exhibition Center and Lusitania Bridge, one may see the use of the arch and hangers of Lusitania Bridge adapted to hold the roof of the Tenerife Exhibition Center. Next, a structural description of Lusitania Bridge and the Tenerife Exhibition Center is given in a way that makes a comparison possible between the arches of these two projects.

Lusitania Bridge, 1988-1991, Mérida, Spain. The 34-meter deep arch is composed of two bases in reinforced concrete and, connecting these bases, three braced steel-arches (Figure 1). The steel arches are connected by linear rigid elements forming a truss, thus taking material out the center to give the whole a certain rigidity that prevents the arch from buckling as a consequence of, for example, wind load working on the structure (Figure 2). The cables are brought in pairs into an element pinned in the lowest of the three steel arches of the truss[1].

Like most Calatrava bridges, this bridge also presents a four-level structural hierarchy: dead and sometimes live loads carried by the roadways are transferred to the cables. These 23 pairs of steel cables transfer the loads to the arch, and thereafter the loads are transferred via the truss-like arch to its bases in reinforced concrete, and finally, to the abutments (Figure 3).

[1] The first and the last pair are fastened inside the reinforced concrete basis.

According to Frampton et al., the central load-bearing element of the bridge – the box girder or torque tube – is constructed from post-tensioned, pre-cast concrete elements (Frampton, Webster et al. 1996, p. 87). This is Calatrava's solution for dealing with the horizontal forces originating from the arch in the direction of the banks of the Guadiana River. In other words, the cables crossing the girder longitudinally generate a horizontal force opposed to that of the arch preventing the arch from collapsing.

Post-tensioned concrete wings supporting the road decks cantilever from the 4.45 meter-deep concrete box girder (Frampton, Webster et al. 1996, p. 87), i.e. there are cables crossing the box girder to connect each pair of opposed concrete wings.

The motorways on top of the wings are not directly in contact with the torsion box; they transfer the symmetric loads (Figure 4) to the structural wings. Horizontal components of the live and dead loads acting on both decks and transferred through each pair of wings counter-balance each other via cables because the forces are similar at both sides of the girder. Vertical components of these forces are transferred through the cables to the arch.

The asymmetric loads – loads that are only applied on one of the decks due to potential traffic on one side of the torsion box – are solved by adding another set of slanted beams that suspends the motorway transferring forces also to the top of the torsion box. These beams are placed between the torsion box and each roadway at regular intervals (Figure 5). The same elements also seem to prevent the whole from excessive vibrations generated by the friction of the wheels of the vehicles in the direction of their movement.

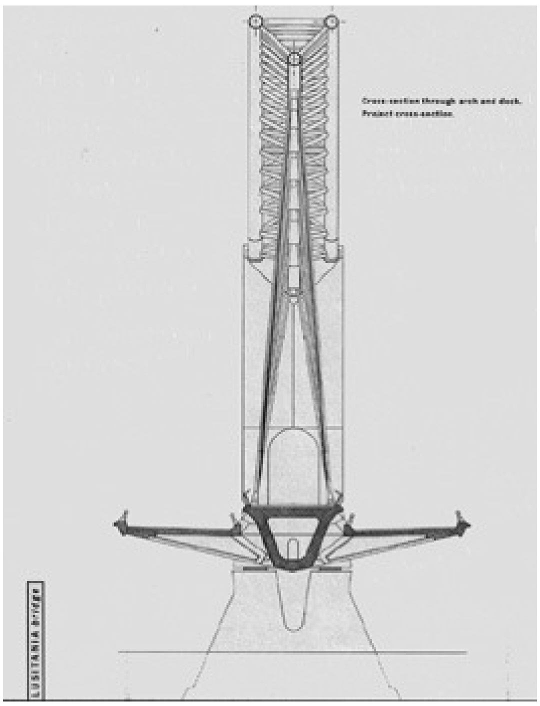

Figure 1: Section

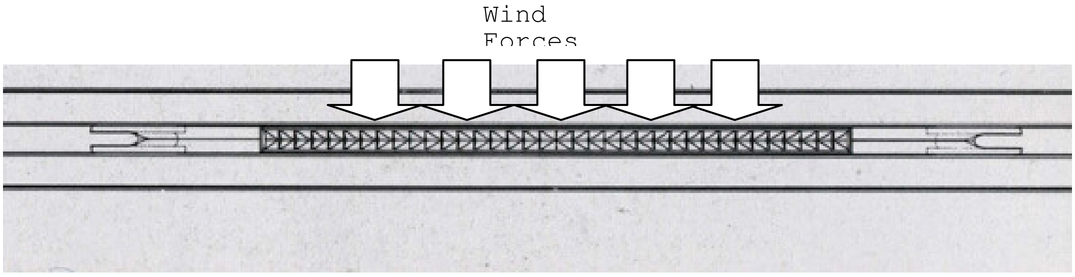

Figure 2: Truss Supporting Wind Forces

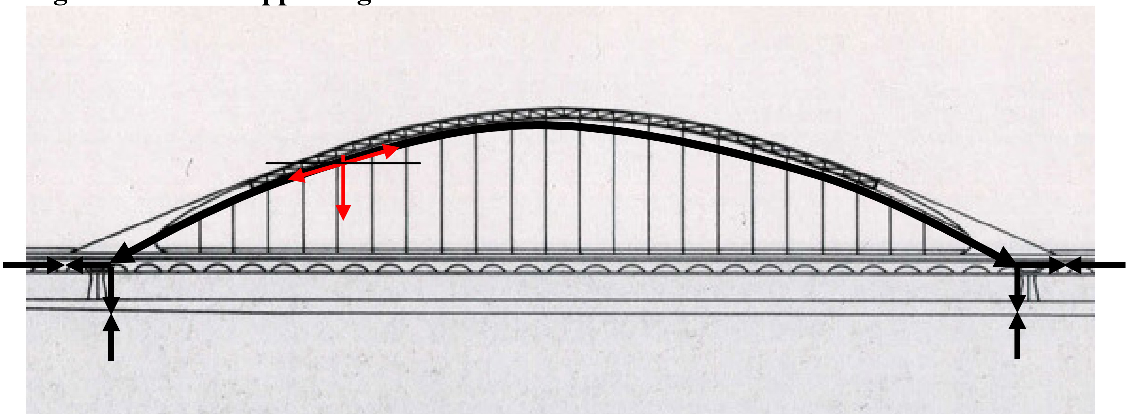

Figure 3: Diagram of Forces

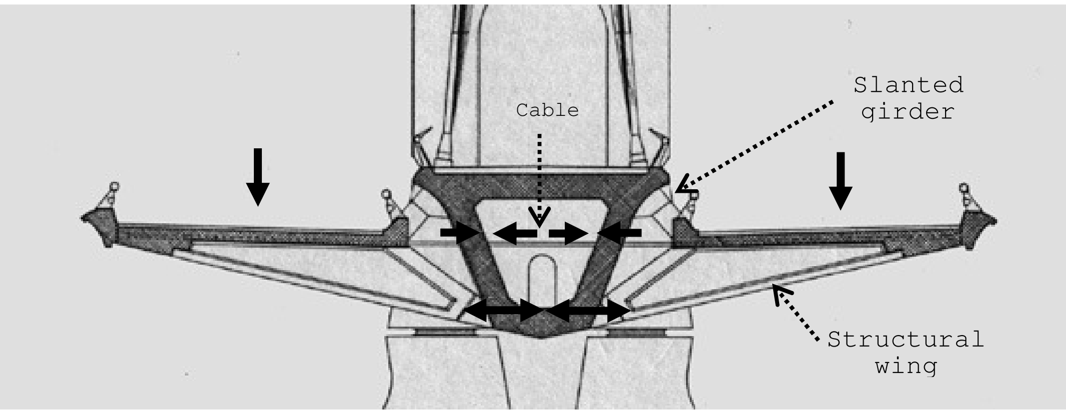

Figure 4: Symmetric Load Case

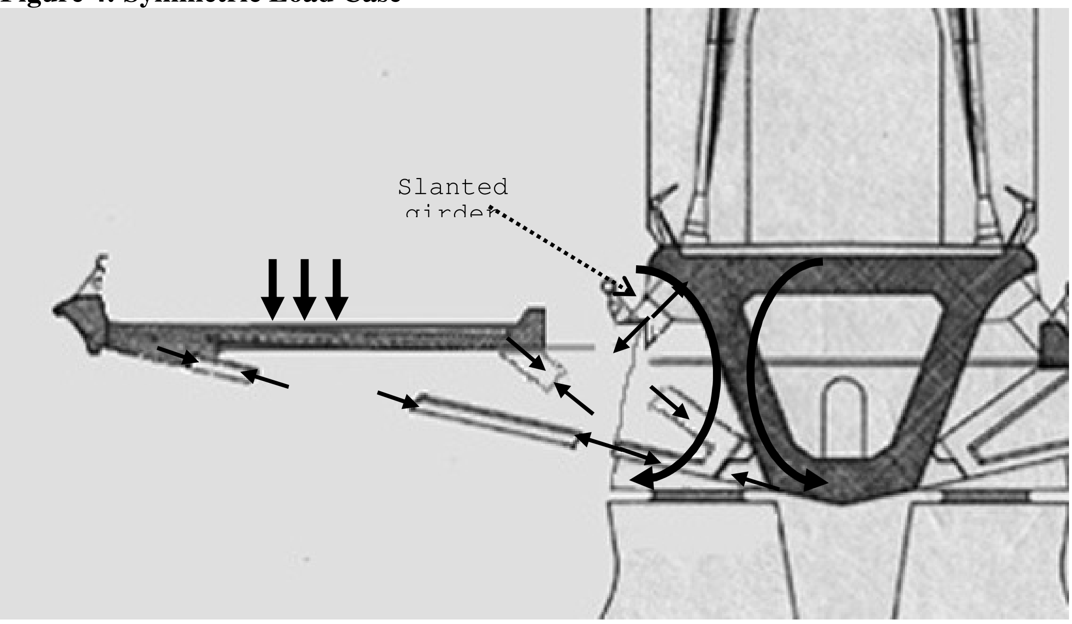

Figure 5: Asymmetric Load Case: torsion box comes to action

Tenerife Exhibition Center, Tenerife, 1992. The main function of the Tenerife Exhibition Center was to be to house fairs as well as carnival parties (Figure 6), and thus Santiago Calatrava's main task was to design a multipurpose space. For this purpose, Calatrava designed a hall that did not have any structural obstacles within it. A steel arch was used to span the 142-meter hall between two concrete, splayed buttresses at each end of the curved plaza slab. This 39-meter high arch suspends a shallower arch, whose apex is 30 meters high above the floor slab.

This arch is intended to hold the roof in its center together with the outside slanted columns. The transference of vertical loads, whether from the roof weight or from wind loads, is solved with the arch and slanted columns (Figure 7, Figure 8).

The shallower arch is linked to 18-meter long curved and triangulated latticework trusses that hold the roof weight. Through their form – slightly curved toward the middle – the trusses resist the moment created by loading this beam. These lattice trusses are held together in such a way as to resist the horizontal component of wind loads in two important ways: first, each two lattice trusses form a triangle that provides stiffening for the roof structure; and second, the binding of these beams creates shear forces between them which together produce a force equal and in an opposite direction to the horizontal component of wind loads (Figure 9).

Figure 6: Tenerife Exhibition Center, 1992

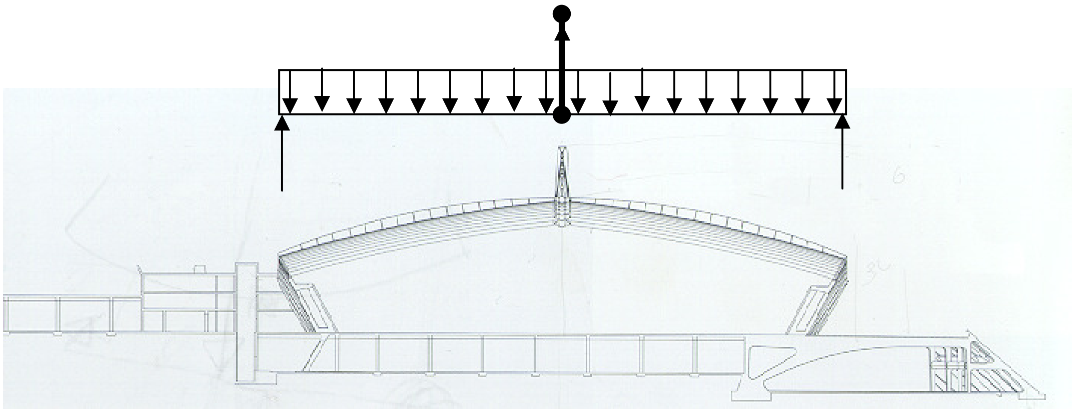

Figure 7: Cross Section, Symetric Loads (dead loads), Tenerife Exhibition Center, 1992

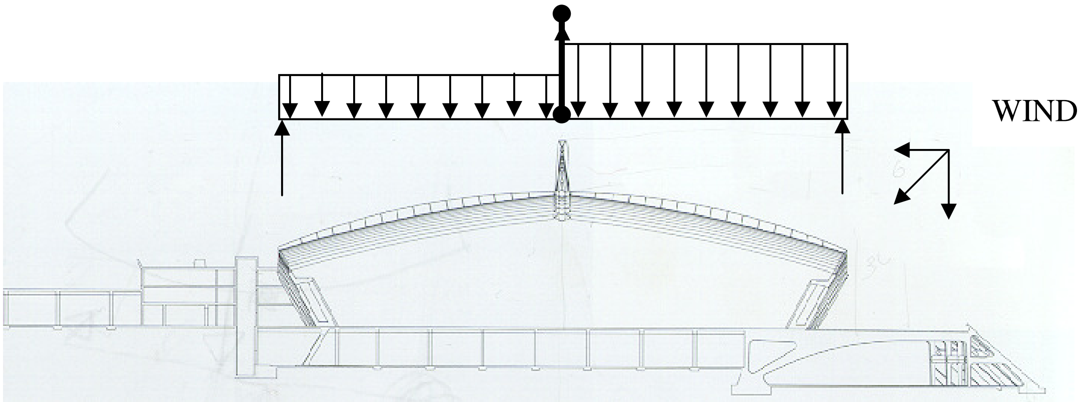

Figure 8: Cross Section, Asymetric loads (vertical component of wind loads), Tenerife Exhibition Center, 1992

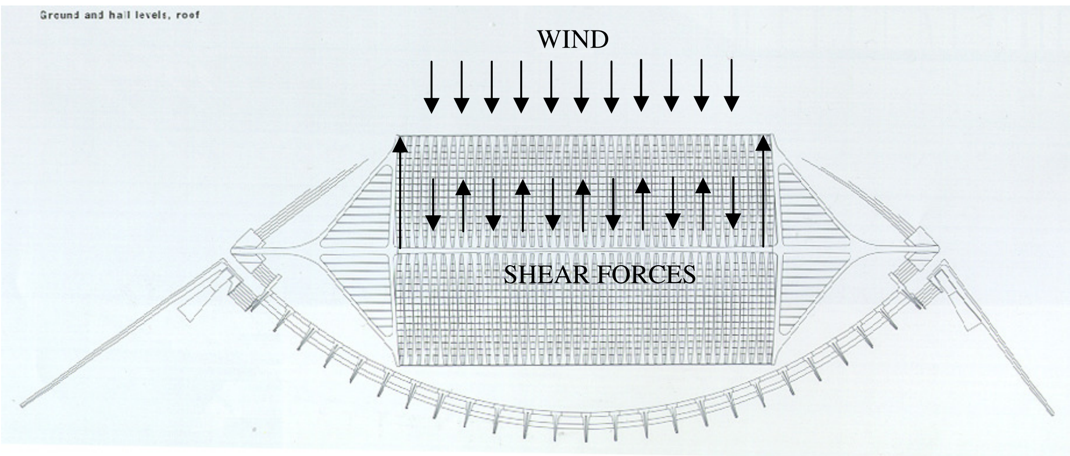

Figure 9: Roof Plan, Asymetric Loads (horizontal component of wind loads) Tenerife Exhibition Center, 1992

Comparison. Comparing the use of the arch in both the above projects, we may come to similarities that give support to our thesis of transference and differences that point to necessary or desired adaptations in the transference of the arch from the bridge to the Tenerife Exhibition Center.

Proceeding from the thought that bridges as well as roofs are beams, we provide several similarities and differences making it possible to exchange the explicitly similar data from one design to the other. However, in this case, it is the structure that is being transferred rather than just the configuration. These artifacts show topological dissimilarities. A bridge refers to the crossing of people, goods and vehicles from one point to another, surmounting an obstacle. These live loads are extremely changeable (e.g. the traffic of trucks and other vehicles exerting asymmetric loads on the carriageway) and are reflected in the structural solution. The roof of the Tenerife Exhibition Center is a means of protection against climate or environmental circumstances; there is no human traffic on the roof; and there is no vehicle traffic over the top of it. The structure of this roof is thus more straightforward than that of the bridge allowing the modifications that we observed on the morphology of the later arch.

This case provides an example of a second kind of transference of features from a precedent to another design. It is interesting to note that the arch structure seems to carry instructions of its configuration, in particular the geometric configuration, while it left the intentional function (topology) behind.

Obviously the configuration and structure (with its technique and materials) have a strong interdependency in the precedent. The transference of the first or the later alone can only succeed if the part transferred fits the corresponding part in the new design.

5. Breaking the Type: The Ontogeny of the Unité d'Habitation

The creation of the Unité d'Habitation by Le Corbusier was primarily the creation of a new housing type which reflected the architect's ideals for a new life-style: healthier and more enjoyable; an innovation in the production of housing for the worker class.

How was it achieved? It seems that it was created by "breaking" earlier types in the manner as illustrated above by Le Corbusier's use of the piloti and Calatrava's use of the arch.

Le Corbusier's inventions, such as Maison Dom-Ino and Maison Citrohan, combined numerous concepts within a fascinating network that involved different levels and domains. Concepts were carefully translated into architectural elements and vice-versa, often evolving a (re)combination with others, such as the elements that compose the "five points for modern architecture" or the elements of his "architectural promenade". Le Corbusier had a very peculiar way of looking at the object of design: on the one hand he proceeded from extremely general concepts trying to provide solutions for the primary needs of lodging, work, cultivation of body and mind, and traffic; on the other hand, he claimed to have proceeded from the concept of the kitchen as a modern hearth, from which the rest followed naturally.

Proceeding from the earlier examples of transferences of the precedent features, this section will present aspects of a possible "ontogeny" of the Unité d'Habitation of Marseilles.

The Grand Plan (Moraes Zarzar 2003). Le Corbusier claimed that the Unité d'Habitation was the result of "40 years gestation". We suggest that this "gestation" was not a question of development (ontogeny) but of lineage (phylogeny). The Unité was not the result of a consecutive combination of two design precedents or, in other words, a direct descent, from two parents to offspring, through the generations.[2] The creation of the Unité seems to be the

[2] This also seems to be the case with other designs carried out in architectural practice.

result of the use and modification of specific elements, often in small chains of linkages such as the aforementioned “five points for a modern architecture”, or Le Corbusier’s bottle, bin and bottle rack (linked features). At that moment he had a huge gene pool at his disposal, ready to be used.

In designing the Unité, Le Corbusier’s task was to provide a housing scheme for workers in the bad economic situation after the Second World War in France. His solution grouped 330 units to house a community of roughly 1600 inhabitants in an 18-storey building providing extensive services to the community. This was a unique opportunity to put all his ideas concerning multi-familiar housing schemes into practice. He had already developed the Maison Dom-Ino, the Maison Citrohan and the Immeubles Village as well as concepts at city planning level such as the concept of the vertical garden city. The Unité d’Habitation for the workers of Marseilles was the result of all these studies. In designing the Unité, he had certainly recalled many of those concepts; some of a general order (light, sun, greenery) but also others that could be more straightforwardly translated into architectural elements (the piloti, the roof garden, the free façades, and so forth).

In fact, many parts of this building block were already developed in detail through experiments in other designs. However, before he could use these precedent features, he needed to have an overall framework. Le Corbusier had to assemble the right features into a whole to match the new desired configuration. In his world full of metaphors, he then placed bottles (dwellings) into the bins (neutralizing walls) and the bins into the bottle rack (structural framework); a collective roof garden on top of the structure with activities for all inhabitants, and a piloti freeing the whole block from the humid ground, providing the whole community with parks, schools and other extensions of the home.

It was not only a question of assembling the existent elements, i.e. recalling them and putting them together. They needed to be adapted to the new constraints and available technology. By constraints, we mean the particularities of a commission such as the budget available, the particularities of the site such as its landscape and climate, and also the selected technology and materials. Due to these constraints and possibilities, “mutations” occurred.

Some features changed their physical expression, i.e. their pattern or structural configuration changed such as the change of the slender piloti of the houses of the 1920s to the gargantuan piloti of the Unité. Other features changed from domain level, meaning that the resultant element acquired uses different to the original one, such as the roof garden that was originally a family garden; after its recombination with the deck of the ocean liner (a precedent of a later date than the vernacular houses of Istanbul). It became the square, the club, the gymnasium of the building block community. Some of the linked “five points of a modern architecture” from 1927[3] were used in a “mutated” form. In other words, the initial linkage was broken; some features “mutated”, and were recombined and re-used in the Unité.

As an independent structure, the bottle rack allowed the creation of maisonettes of 23 different sizes and shapes to house[4]different types of families as well as the creation of a whole infrastructure of services for the block community. The roof garden, the bottle rack and piloti gave the primary or general structure of the Unité (Figure 10). This primary framework enabled Le Corbusier to use many of his precedents, some of them with further “mutations”.

[3] When Le Corbusier designed House 13 of Stuttgart

[4] The variation of the maisonettes was, however, based on the addition or subtraction of cells (rooms) of a prototype (Type E). The cells did not vary in size or layout.

Accordingly, in the Unité d'Habitation, not only the roof garden, but also the piloti and the free façade concepts changed their domain level: from the private (the dwelling) to the collective (the building). The free façade concept was initially tried out at the level of a Citrohan house as well as at the level of the apartment unit of his theoretical multi-familiar building, and then to a free façade at the level of the building block, where the façades of the units are standard and its freedom resides in the combination of the parts to make the whole.

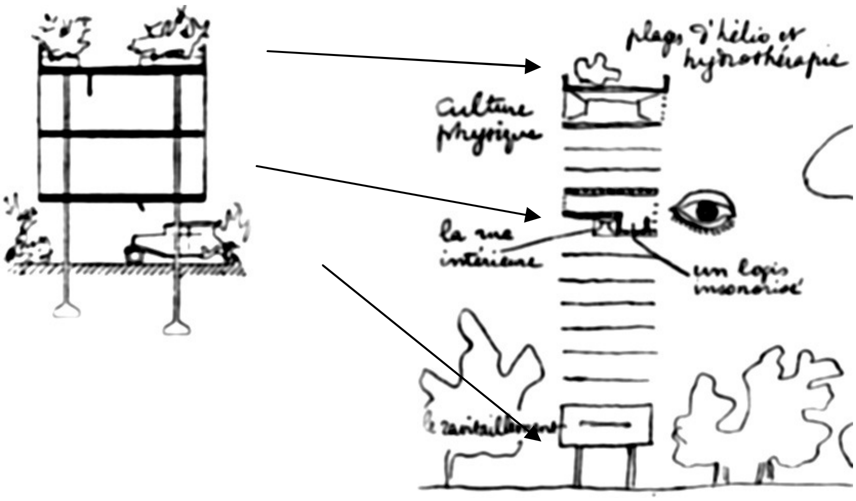

Figure: 10: The Mutated "Five Points of a Modern Architecture"

6. Conclusions

As mentioned in the introduction of this paper, it is not necessary to mimic the mind or the behaviour of the architect to develop a tool or even to make perfect analogies with other fields, because a model does not need to be true or false, but fruitful. However, proceeding from our interest in the production of innovative designs, it can be said that actual approaches are not tackling the problem accordingly. Models are not proving fruitful in the production of innovative architectural designs.

Indeed, variation is a means toward and necessary condition for the development of new species in nature and for the development of innovative designs. But variation occurs not only in form, but also in structure; and innovative designs, as far as the use of precedents is concerned, are a product of the accumulation of these small changes as well as of the recognition of different features and the introduction of them into the architect's vocabulary.

We can say that features are continuously identified within and outside the architectural field bringing small innovations to architects' own "d-gene pools" over the years. These small innovations are selected by architects when searching for precedents to help them to meet certain performances that fit the new design, instead of starting from tabula rasa. These features have their own evolutionary path through the use and adaptation that they go through to fit new situations. New types are often produced by recombination and adaptation of the features already found in the architect's "design gene pool", which is continuously renovated by the architect's creativity in the aforementioned process of recognition and transference of features from a precedent to a new situation, and which is searched purposively by artificial selection.

How, then, can evolutionary models for architecture cope with the need for “outside” information derived from new feature recognition? How can evolutionary models run by computers purposefully select the right precedent and adapt it so as to fulfil the multifaceted constrained world of architecture? Is it realistic to try to build a tool to substitute the architect? Is a support-tool not a more powerful tool toward the development of innovative designs in architectural practice?

By ending this article with these questions we hope to bring other frames of thought which may redirect future evolutionary design research in architecture.

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