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The Study of Emergence, Analogy and Mutation in the Architectural Design of Le Corbusier

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Abstract

The study of Architectural design and Creativity has for long been a touchy subject. The examined literature has revealed a multitude of concepts related to this dimension, characterized by their linearity and over-simplification. This research draws an Analogy with GERO-SHI model, which represents a complex adaptive system (CAS) model that introduces a commodity between diversity in biological world and diversity in design. A simplified mathematical model has been designed and then applied on eight Architectural works of Le Corbusier according to a geometric order with a first approximation. This study could figure out that the creative process of Le Corbusier seems to obey to the CAS laws according to a decrease pattern, in which emergence, analogy and mutation represent generative concepts. Emergence appears in the earliest Architectural works of Le Corbusier with emergent forms representing generally the ≤Pilotis≤ as the smallest design components. The major part of forms seems to be generated by Analogy or by mutation. Analogy represents the main concept in Le Corbusier's Architectural design process, with an Analogy ratio beginning often by a value equal to three. The concept of mutation represents an unexplored dimension that seems to deeply structure Le Corbusier's creative process and may reflect many other channels of creativity.

Keywords: Architectural Design, Creativity, Le Corbusier, CAS, Emergence, Analogy, Mutation, Chaos, Complexity

1. INTRODUCTION

Since the 1950's, there is an increasing interest in understanding how designers think and generate creativity. Part of this interest comes from the need to provide a basis for design models and computational support tools for designers. Generally, the exploration of the Creative dimension in Architectural Design has been tackled according to four main approaches (Figure 1):

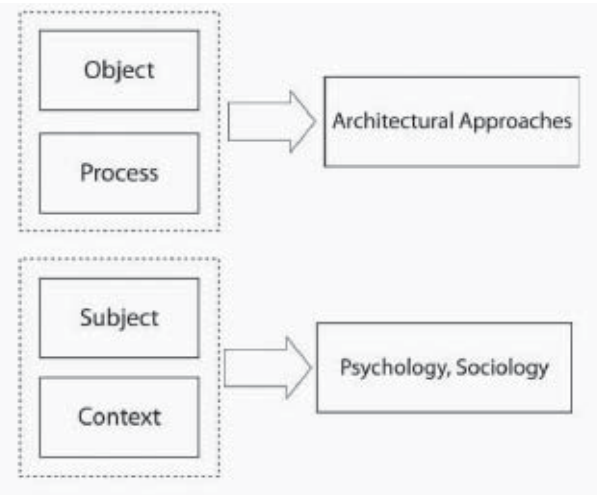

Figure 1. The different approaches related to the study of Architectural Creativity

1. Object-oriented approaches, which are centered round the study of the design works in order to demystify the nature of the processes that produced them.

2. Process-oriented approaches (Protocol Analysis), ((Akin (1993), Chan (1990), Eastman (1970), Purcell et al. (1994), Gero & Tang (2000), Goldschmidt (1991), Suwa&Tversky (1997)). In this type of approaches, the Creativity of Architects is investigated by studying them in action as a more direct way of analyzing the nature of the processes they use.

3. Subject-oriented approaches (Allport (1954), Mackinnon (1962), Smith (1964), Hudson (1966)),

which generally represent psychological approaches based on the study of the personalities of Architects in order to see what kinds of people they are.

4. Context-oriented approaches ((Kuhn (1962), Feyerabend, MacAllister (1999)), which use methodologies of Sociology and history of science and study the conditions and the implications of Creativity within its contexts.

There are a lot of critics attributed to Creativity studies. The context-oriented approaches seem to be centered only on the contextual consequences and conditions of Creativity and the Subject-oriented approaches studied the Architect as a person rather than as a creator. Process-oriented approaches were criticized because of the fact that our presence may disturb the Architect in action and also because of the human memory characteristics that may influence the results (Gero, 2000). Finally, the main critics of object-oriented approaches were related to the fact that many designs that look similar may have been designed in quite different ways. Broadbent (1988) noticed also that researchers may be misled when they try to deduce the process from the product.

2. CONCEPTUAL FRAMEWORK

This study has revealed that the greater part of theoretical interpretations concerning Architectural Creativity seems to be general and informs us a little about its intrinsic nature. Many models (Füeg (1982), Broadbent (1988), Antoniades (1990)) have tended to describe the process of Architectural Creativity by presenting general interpretations emphasized on its extrinsic channels and aspects. Füeg's pedagogic-professional model defines Architectural Creativity as a behavioral, logical and idea-graduated process through an active-minded way of thinking that depends upon the Architect's checking, knowledge, experience and imagination. Broadbent's model, based upon a historic-Archaeological study, proposes 04 design channels, that is to say: Pragmatic, Typological, Syntactic and Analogical, through which many creative Architectural works have been achieved. According to this model, Analogy seems to be the most creative way. Antoniades's aesthetic-emotional model describes Creativity as a state of total emergence of the cognitive mechanisms through which the designer should go during the design process. His model explored some tangible as well as intangible channels through which many Creative works have been achieved, like: metaphor, transformation, mimesis, etc.

In the 1990's, three important models (Chan (1995), Gero (1996), Gero & Shi (1999)) tried an intrinsic exploration of the creative dimension in Architecture. The approach of Chan (1995) focuses on the study of individual style as an intrinsic aspect of Architectural Creativity. According to Chan, individual style is any distinctive mode of designing that is repeatedly manipulated in the design process and which consequently generates common features across design works. A style manifests by the appearance of constant cognitive phenomena that produce constant forms as a result of the constant application of certain factors, including design constraints, search methods, goals and the sequential order of applying them, Focused on Artificial Intelligence approaches, Gero (1996) suggests that Creativity is not simply concerned with the introduction of something new into a design, but this introduction should lead to an unexpected result in which models are perturbed by the introduction of new variables. Gero-Shi model (1999) introduces a commodity between diversity in biology and diversity in design by developing an analogy based on the processes and principles behind the production of diversity in the biological world. Diversity of design variation is highly valued by modern designers and markets and contributes to the Creativity of designs (Cross, 1994). In the sense of producing variation, design development becomes a process to explore the potential diversity under a defined theme. A design is considered as being composed of a number of components. If all these components are connected one by one according to mathematical expressions, the relationships between components in geometry, logic and attributes are expressed through iteration equations that describe the structure development process of a complex system.

The relationships between the design components as well as the unexpected combinations and arising patterns are subject to 3 main concepts, mainly related to chaos theory. That is to say: Emergence,

Analogy and Mutation. According to Gero, Emergence in design is the process of making explicit, the implicit schemas and properties in a representation. It is related to a conscious or a subconscious process of merging, combining and modifying forms or pictures in the mind that leads to discoveries in Design (Gestalt & cognitive psychology). It is considered to play an important role in the introduction of new schemas (Holland, 1975) and consequently new variables (Figure 2).

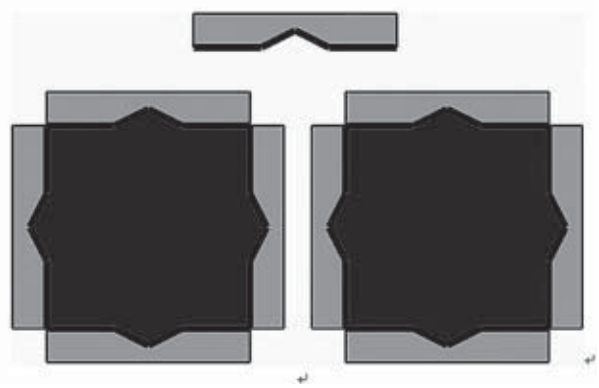

Figure 2. Copies of a single form, strongly exhibit new emergent shapes

Analogy is defined as a partial similarity between two things or representations. According to Gero's model it is the product of processes in which specific coherent aspects of the conceptual structure of one problem are matched with and transferred to another problem. Finally, Mutation is defined as the gruff and hereditary modification appearing in creatures, which represents the origin of a new variety. In Gero's model, it is the alteration of a variable in a design prototype by an external process.

3. THE RESEARCH FOCUS

Many methodological constraints related to research feasibility, lead the research to be focused on an object-oriented approach that seemed to be the most feasible strategy. Subject as well as context-oriented approaches require dealing with different epistemological and methodological research concepts and tools related to psychology and sociology that may help us very little in our search for the understanding of the Architectural creativity intrinsic nature. To have recourse to psychological tests do not seem evident. Many examples show how creative Architects refused to participate to such studies (Barron, 1969). For this study, process-oriented as well as object-oriented approaches seemed to be feasible. Nevertheless, some technical obstacles prevented us to focus our study upon the process, because of the difficulty of the selection procedures and the means unavailability (video recording, rooms, etc.). This study is then focused on the object, because of many reasons, among them is the fact that for many researchers, the Architects Creativity has to be extracted from their own writings and seen through the study of publications on their projects and their efforts to develop them (Antoniades (1990), Pauly (1983)).

4. THE RESEARCH PROBLEM

This study is focused on the exploration of the Black box as a container of the Architectural Creative processes. A study of some models, issued from different scientific fields related to the exploration of Creativity, has revealed some aspects that could not reflect its complex nature. These aspects are related to the following points:

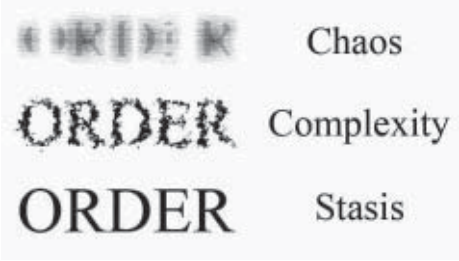

Figure 2. Copies of a single form, strongly exhibit new emergent shapes

- Models linearity (Helmholtz, Wallas (1921)).
- The proposed models do not reveal the real behaviour of the interdependent mechanisms that interact in every phase of the complex creative dimension. The suggested hypotheses, that is to say: the mental set (Kertchfield), the unconscious mental effort and the potential of resolution (Guilford)) are subjects to many ideological

divergences and inform us very little about the intrinsic creative nature (Broadbent, 1988).

- In the Architectural context, the generalizing character of certain Architectural Creativity models (Füeg (1982), Broadbent (1988), Antoniades (1990)) sketches design methodologies rather than diagnosing the intrinsic creative mechanisms.

Researches about Architectural Creativity are faced with the nature of processes that may take place in the creative Architect's mind and make him choose, from a plethora of possible combinations, the one that beautifully solves the design problem. Holland (1998) suggests that in Creativity, the process of selection in our mind could be similar to the ones that take place in evolutionary biology, but in a much faster scale. According to this hypothesis, exploring creative mental processes could not be well achieved through an analytic and linear approach. In front of a very complex dimension, concepts from chaos theory may contribute to clarify some aspects of this complex dimension (figure 3).

4.1. Le Corbusier as a case study

The delicateness that characterizes the choice of a creative Architect as a case study among many others, led us to make a choice based upon feasibility criterions. Time limits and literature availability oriented this research to be based on Le Corbusier's Architectural works. Other reasons strengthen this choice:

- Le Corbusier's Architectural works reveal his great talent and creative abilities.
- The richness and diversity of his design themes and Architectural forms (Ronchamp, Atelier ozen fant, villa Savoye, etc.).
- His writings that reveal some of his creative secrets (Antoniades (1990), Pauly (1983)).
- The availability of his Drawings and theoretic data.

Literature examination has revealed that the theory of complex adaptive systems (CAS) is among the models that well reflect the interaction mechanisms within chaotic systems. This study sketches a simplified mathematical model based upon GERO-SHI approach, which introduces an analogy between diversity in the biological world and diversity in design in order to explore Le Corbusier's intrinsic geometric logic that permitted the generation of his Architectural works, according to a first approximation.

5. THE METHOD

According to Stanislaus Von Moos, the work of Le Corbusier should be studied through forms rather than themes. The Creativity related to Architectural design as an art of sculpting the three-dimensional space, can be considered as the search for the model that allows the generation of forms, which obey to the proportional and topologic norms of harmony. Exploring Architectural Creativity through the design works requires the elaboration of a mathematical model that covers all its aspects and attributes, like shape, volume, texture, materials, etc., which necessitates a complex model with "n" dimensions. The recursive nature of chaos theory algorithms, which are used to create computational artworks, represents the same basis of human creation process. The general expression of chaotic recursive algorithms is in the form (lansdown, 1995):

Action (T) = Action (T-1) _ Modifier
(T= Time)

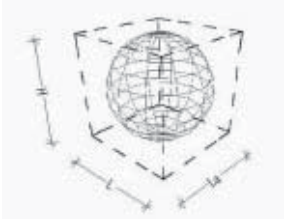

Figure 4. The concept of approximation

The approach of this research is based upon the exploration of Le Corbusier's Creativity according to a first approximation. The concept of approximation means that the design is considered as a coherent set of volumetric components (whatever can be the shape) considered as cubic components in a first approximation (figure 4).

A simplified mathematical model has been designed in order to take into consideration the size attributes of the design components.

$$O_i = L^{path} \times O_{(i-1)}$$

Oi: Design component "i" represented by a matrix (xi,yi,zi). (xi,yi,zi) represent the size attributes of the component.

Lpath: Design pathway represented by a square matrix composed by the proportions between the size attributes of the biggest design component and the smallest one (extreme components).

O(i-1) : Previous design component (i-1), represented by a matrix (x(i-1),y(i-1),z(i-1)).

A decrease and an Increase patterns, as two possible evolution and variation patterns of the design components, have been proposed and applied on eight Architectural works of Le Corbusier (figure 5).

The application of this mathematical model in the study of Le Corbusier's designs has been carried out according to two phases. First, the Graphical data have been collected from the multimedia document: "Le Corbusier, Architecte-Artiste"[1] (Foundation Le Corbusier). Then, a MATLAB (Ver.5.1.0.421) program has been designed and then applied on eight Architectural works of Le Corbusier, according to a chronological and a typological selection, in order to simulate design variation and to study the role of emergence, analogy and mutation in the Architectural Design of Le Corbusier. These Architectural works include: Maison DOM-INO (1914), Maison CITROHAN (1922), Atelier OZENFANT (1922), Villa La Roche (1923) and Villa Savoye (1929) for the Individual houses category. Unité d'habitation of Marseille (1946) for the Apartments category and finally the Chapelle Notre Dame du haut Ronchamp (1951) (figure 6), as well as the Couvent Sainte Marie de la Tourètte (1957) for the Religious buildings category.

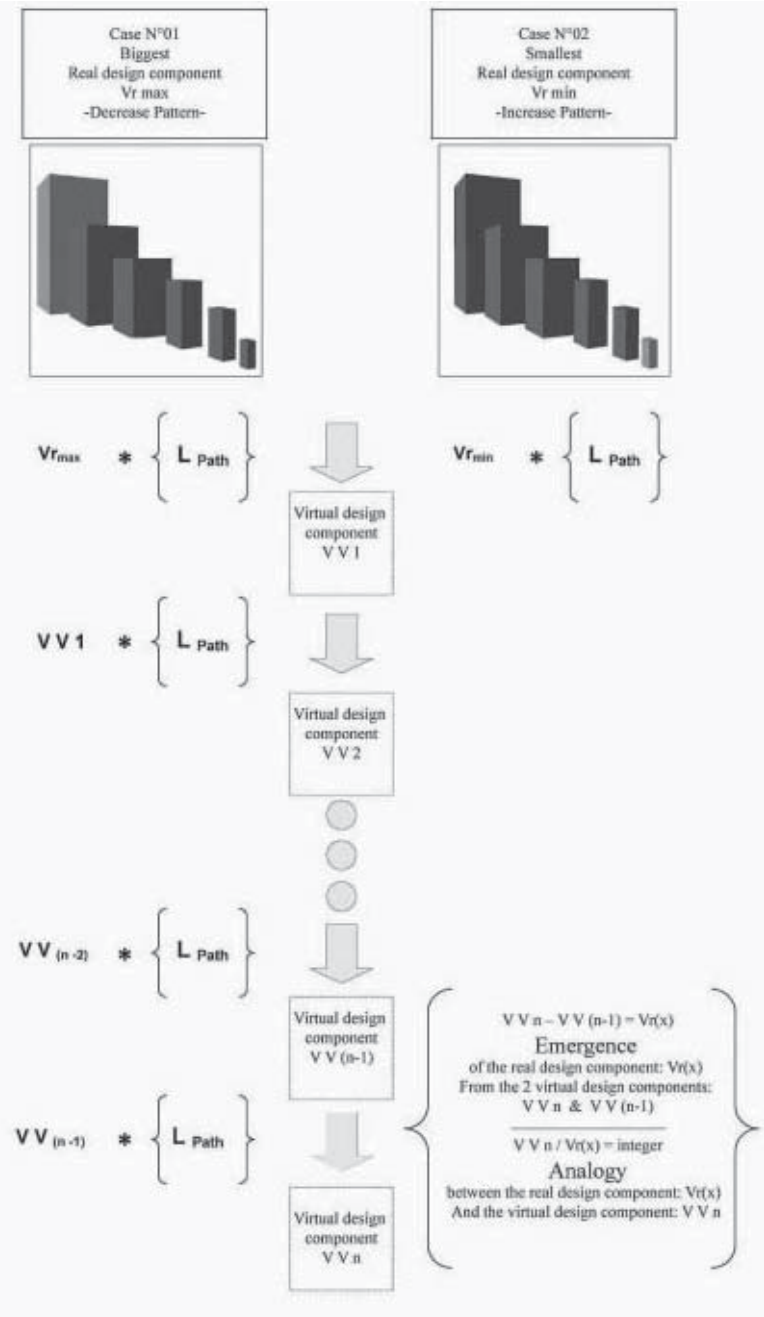

Figure 5. The decrease and the increase patterns

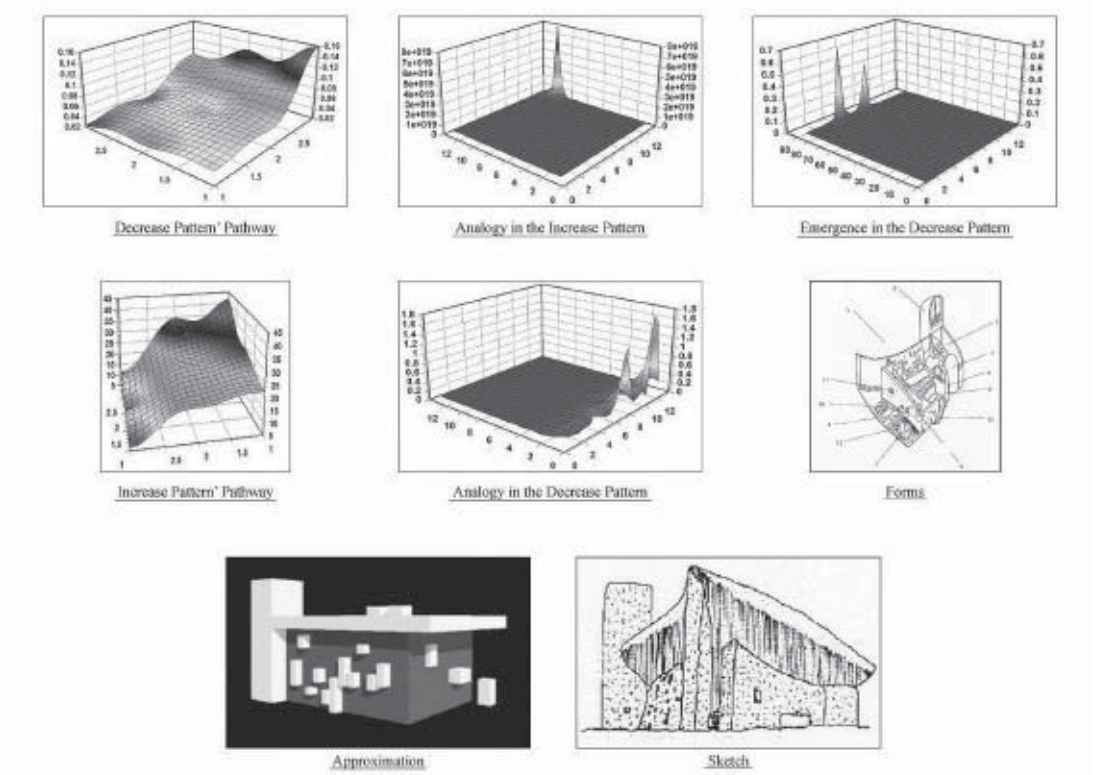

Figure 6. The application of the mathematical model on the study of the Chapelle Notre Dame du haut Ronchamp (1951)

6. RESULTS AND DISCUSSION

This research work is focused on the simulation of some processes that may take place in the creative mind of the Architect (black box), and make him able to choose from a plethora of possible combinations, the one that beautifully gives a response. Throughout the analysis of the results, the following points could be figured out:

The creative process of Le Corbusier seems to obey to the complex adaptive systems laws. Emergence, Analogy and mutation represent concepts that may structure Le Corbusier's creative way of designing. Le Corbusier's design process seems to follow the decrease pattern (figure 7). Le Corbusier's purism might make him begin with a main form (biggest design component) that is often a cube or a parallelepiped, and then try to generate a series of smaller forms to make an Architectural composition. Emergence appears in the earlier design works of Le Corbusier. Emergent forms represent generally the ≤Pilotis≤ as the smallest design components (Table 1); nevertheless, no emergent forms have been found in the Unité d'habitation of Marseille (the 1st application of the MODULOR) and the Couvent Sainte Marie-de-la Tourètte.

The major part of forms seems to be generated by Analogy or by mutation. Analogy represents the main concept in the Architectural design process of Le Corbusier (Table 2). The Analogy ratio begins often by a value equal to three in all Le Corbusier's design works (figure 7). Le Corbusier's researches concerning the Modulor and proportions may have as background the concept of Analogy. Therefore, Atelier Ozenfant represents some exceptions related to the increase of the Analogy ratio from the value of 3. This was not the case in the other design works characterized by the decrease of this ratio.

The concept of mutation represents an unexplored dimension that seems to deeply structure Le Corbusier's design process and reflects many other creative channels, that is to say: metaphor, transformation, etc. Mutation is generally related to forms smaller than the main form (biggest design component) (Table 3). Therefore, Atelier Ozenfant represents again an exception because mutation is relat-

Table 1. Emergent forms according to the Decrease pattern

Type	Design Work	Year	Decrease Pattern			Increase Pattern		
			Emergence	Analogy	Mutation	Emergence	Analogy	Mutation
Houses	Dom-Ino	1914	33,33%	33,33%	66,66%	0%	33,33%	66,66%
	Citrohan	1922	12,50%	87,50%	12,50%	0%	12,50%	87,50%
	Ozenfant	1922	20%	20%	80%	0%	20%	80%
	La Roche	1925	9,09%	91,66%	8,33%	0%	9,09%	90,90%
	Savoye	1929	27,27%	100%	0%	0%	9,09%	90,90%
Apartments	Marseille	1946-52	0%	66,66%	33,34%	0%	8,33%	91,66%
Religious buildings	Ronchamp	1951-55	14,28%	92,85%	7,14%	0%	7,14%	92,85%
	Tourètte	1957	0%	40%	60%	0%	4%	96%

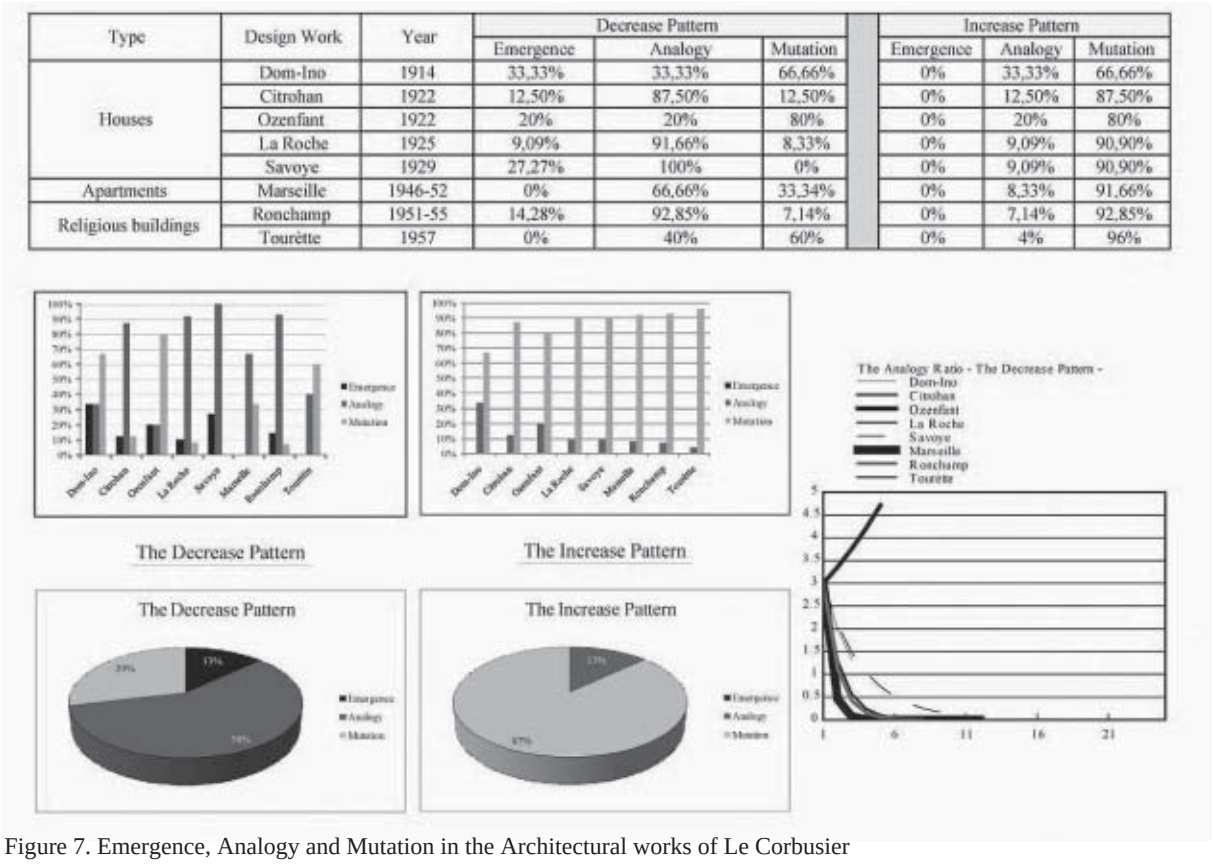

Figure 7. Emergence, Analogy and Mutation in the Architectural works of Le Corbusier

ed to its main design component. In the case of villa Savoye, no mutated forms have been found.

Exploring Architectural Creativity represents an interesting experience related to the sphere of creation, therefore it might be problematic. Mutation, as a concept and as dimension, seems to have implicit many ingredients and key-concepts related to the creative dimension in Architecture and could be an interesting subject for future researches concerning Architectural design and Creativity.

Table 2. Forms generated by Analogy (Decrease Pattern)

Design Work	Year	Forms generated by Analogy (Decrease Pattern)
Dom-Ino	1914	Pilotis.
Citrohan	1922	Pilotis, inhabited volume, entrance volume + 2nd floor volume + 1st floor terrace volume, stairs, 2nd floor slab + overhanging slab.
Ozenfant	1922	Triangular roof volumes.
La Roche	1925	All forms, except the kitchen' volume in the ground floor.
Savoye	1929	All forms.
Marseille	1946-52	The principal Volume, pilotis, fire stairs, gymnasium, ventilation chimney, elevators' case, roof terrace theater wall, canopy.
Ronchamp	1951-55	All forms, except the big tower.
Tourètte	1957	The U-like volume, organ, Chimney, galleries, parlor, pyramid, oratory, terrace access, pilotis, Kitchens volume.

Table 3. Forms generated by Mutation (Decrease Pattern)

Design Work	Year	Forms generated by Mutation (Decrease Pattern)
Dom-Ino	1914	Slab, staircase.
Citrohan	1922	Slab (terrace).
Ozenfant	1922	All forms, except the triangular roof volumes.
La Roche	1925	Kitchen' ground floor volume.
Savoye	1929	No mutated forms
Marseille	1946-52	Cell (Apartment), nursery school, entrance hall.
Ronchamp	1951-55	Big tower.
Tourètte	1957	Chapel, steeple, footbridge, sacristy, triangular wall, pilotis (round posts), balcony, spiral stairs, atrium, entrance, crypt.

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