Metaphoric and Analogical Reasoning of Structures in Contemporary Architecture of Iran

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ABSTRACT

Structural and design concepts are two important parameters of building design process. Structural ideas transform solutions to general structural problems and range from guiding structural forces to defining visual factors. One way to make observable and tangible structural and design concepts more practical and recognizable for architects, is using popular analogies and metaphors. As such, metaphor and analogy constitute two vital cognitive tools associated with the development of concepts for architects at various stages of the design process. The main goal of this study is identifying metaphors and analogies that have paved the way for expressing structures in architects' conceptual thinking. Within the realm of architectural practice, this study is among the few instances that tend to compare analogy with metaphor simultaneously. Considering both metaphor and analogy in one research would help researchers to examine the ones that practicing architects prefer more, and the ones they use in various stages of their design process. Also, the study only focuses on the Iranian contemporary architecture, and more specifically, on the Iranian architects with over 10 years of professional practice. The research methodology involved contacting and conducting interviews with architects about their design processes and design products. With a structural focus in mind, the data obtained from these interviews were then analyzed, coded, and categorized (by using inductive reasoning). The review and analysis of the selected projects by each architect resulted in subsequent coding (through abductive reasoning). Conducting the interviews and data analysis based on the architects' projects resulted in comparing the tentative codes and categories, and conceptualizing and modeling a framework.

Keywords: design process, metaphor, analogy, structure, Iranian architecture

ÖZ

Yapısal ve tasarım kavramları, bina tasarım sürecinin iki önemli parametresidir. Yapısal fikirler, çözümleri genel yapısal sorunlara dönüştürür ve yönlendirici yapısal güçlerden görsel faktörleri tanımlamaya kadar uzanır. Gözlenebilir ve somut yapısal ve tasarım kavramlarını mimarlar için daha pratik ve tanınabilir hale getirmenin bir yoludur, popüler analojileri ve metaforları kullanmaktadır. Bu nedenle, metafor ve analoji, tasarım sürecinin çeşitli aşamalarında mimarlar için konseptlerin geliştirilmesi ile ilgili iki hayati bilişsel araç oluşturur. Bu çalışmanın temel amacı, mimarların kavramsal düşüncesinde yapıları ifade etmenin yolunu açan metafor ve analojileri tespit etmektir. Mimari uygulama alanında, bu çalışma aynı anda benzetmeyle benzetme yapma eğiliminde olan birkaç örnek arasındadır. Bir araştırmada hem metafor hem de analojiyi göz önünde bulundurmak, araştırmacılara pratik yapan mimarların daha çok tercih ettiklerini ve tasarım sürecinin çeşitli aşamalarında kullandıklarını incelemelerini sağlar. Ayrıca, çalışma yalnızca İran'ın çağdaş mimarisine ve daha özel olarak da, 10 yıldan fazla mesleki uygulamaya sahip İran mimarlarına odaklanmaktadır. Araştırma metodolojisi, mimarlarla tasarım süreçleri ve tasarım ürünleri hakkında röportajlar yapmak ve bu çalışmaları yürütmek olmuştur. Yapısal bir odaklanma ile bu görüşmelerden elde edilen veriler daha sonra analiz edildi, kodlandı ve kategorize edildi (endüktif akıl yürütme kullanılarak). Seçilen projelerin her mimar tarafından incelenmesi ve analizi müteakip kodlama ile sonuçlandı (kaçınılmaz muhakeme ile). Mimarların projelerine dayanarak görüşme ve veri analizi yapmak, deneysel kodları ve kategorileri karşılaştırmak ve bir çerçeveyi kavramsallaştırmak ve modellemekle sonuçlandı.

Anahtar Kelimeler: tasarım süreci, metafor, analoji, yapı, İran mimarisi

I would like to dedicate this study to my wife and daughters as an indication of their significance in this study as well as in my life.

Special Thanks to my parents and my sister, Dr. Azadeh Hadian for their endless love, support, and encouragement.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Background

Design is the activity which brings into the world an original crude idea. The idea will then become materialized in the real world. Architecture relies heavily on the practicality and creativity of ideas worth exploring. According to Brawne (2003), design theory offers a descriptive explanation of the way the design process operates. Description needs to be general enough to accept a considerable number of examples, and ought to conform rationally to the ways in which we actually design or, at least, we think we design, and as such, it could be influenced by our views.

On the other hand, Forty (2000) believes that architecture is a system including the building, the image of the building, and the related opinions. It is therefore, an expression of an idea. Architecture is a kind of visual art which shows a particular concept in different styles and ways, and in that sense, is a linguistic sign. The way architecture communicates with audience is a type of language consisting of signs or symbols. In this way, architectural design is a physical art, and an act of resolving the conflict between man and the built environment. Man and the surrounding environment should integrate well and effectively.

In that regard, Lawson (2005) emphasizes that the design process must have three stages. In the generator stage the designer decides what might be an important aspect of a problem. In the conjecture stage the designer develops a raw design on this basis. In the analysis stage, the designer examines what else he or she can discover

about the problem. The generator stage includes imagination of form, which could be sensitive and key for the other two stages. Creativity and reasoning are important partners of imagination, and have key roles in design too. Designers do not solve considered problems, but define them. They assess the problem and analyze it, while engineers try to solve them. The architectural design process significantly affects the structural and conceptual aspects of buildings. Conceptual ideas provide power for the building appearance and design in all parts including internal and external spaces and surfaces. Structural ideas transform solutions to general structural problems and include a range from guiding structural forces to defining beauty values.

As a way of exploring the good arrangement of metaphors and obscurity in design, semiotics in architecture presents one such discussion about these design- and built environment-related discourses. In this sense, and to try to better realize building communication (Mallgrave & Goodman, 2011), the meaning does not tend to change and grow over time based on a specific context. As Patin reported in 1993, Eisenman categorized semiotics into three models. Semantics refers to the relationship between form and icon. Pragmatics model is about the relationship between form and function. The syntactics model discusses the relationship between physical form and conceptual space. Semiotics is thus, a type of visual literacy. Dondis (1974) believes that visual literacy is the ability to produce and perceive images, for the people. The visual experience of humans, firstly, has to do with their learning, perceiving, and relationships to the surrounding environment. Hence, the influences and roles of semiotics in architecture, could not be neglected and should be considered seriously and practically.

Design and structural concepts should be more observable and tangible for architects. One way to do this is by using analogies and metaphors as two popular

tools of recognition. These tools could aid designers to show structural and design ideas physically, and for better perception. Metaphors and analogies are certainly important factors in the understanding and conceptualizing the design process. Analogies and metaphors typically affect our discussion process in dealing with our day-to-day life ideas, and aid designers to determine the problems of design too (Hey, Linsey, Agogino and Wood, 2008). Metaphors and analogies can incorporate and conceptualize users' needs too. Hence, they can help the designer to foretaste their reactions to a given product. In this sense, by identifying the design's thematic relations, they make a particular outcome more purposeful to the user. Metaphor applies to surface or relational features of the design while analogy employs the functional or structural features by identifying the connection between two things.

It is also noteworthy that analogy and metaphor provide an induction of likeness, and can recognize the communication between the target and source according to common features. Therefore, metaphoric and analogical reasoning could operationalize at various stages of the design process. Framing a design situation in a new way in problem-solving tasks helps architects to understand the design itself and its most important constituent elements. However, prior studies show that metaphoric and analogical reasoning complement each another in different stages throughout the design process, and help the architect to reach and expect the design outcome.

As Hey (2008) emphasizes, metaphors can be used at the beginning stages of the design process (descriptive metaphor), where the current reality can match as close as possible to make sense with the problem at hand. Later in design process, however, metaphors could become tools for concept generation (prescriptive metaphor), and inspiring architects with their creative ideas. In contrast, rather than helping architects to understand the design problem, analogies can help in ideation or

concept generation by uncovering solutions for particular design problems. Although these trend have not yet fully panned out, they justify why this research makes sense. That said, both metaphors and analogies demonstrate inseparable reasoning tools that need to go together throughout the design process. Hence, this study aims to shed light on the ways in which architectural and structural concepts have been used metaphorically and analogically.

1.2 Problem statement

Design plays as one of the most important and discussed issues in the field of architecture and engineering. Architecture is the physical manifestation of workable ideas. Imagination plays crucial roles in this conceptual transformation and presentation. Lawson (2005) believes that imagination, creativity and reasoning are designers' important thinking tools. Based on their skills and educational trainings, designers face problems and try to analyze and evaluate them during the design process. Concomitant with today's complexity of architectural design process, new problems have emerged in adapting technological advancements. New technical improvements in the structural engineering sciences have also amplified the gaps between architectural and structural thinking.

There are some discussions that innovations in the area of architectural design may not have much helped to reduce these gaps. The advent of modernity in engineering and building industries have intensified or exacerbated the situation by further specializing architecture and engineering and their sub-fields. Hence, in the current era, familiarity of architects with structural concepts, in some issues, has remained quite limited. Lin & Zhen (2016) explain that the duality of art and architecture from structural concepts has made dual responsibilities in building design. Based on new advanced techniques, architects may consider technical issues less important now.

This new way of thinking has created some problems according to the artistic dimension of the architectural trainings and the structural training of the engineers' trainings. This is wrong. A good engineer needs as much imagination as good designers require enough technical knowledge.

A rational consideration of structural concepts could make the needed basis for the following initial and detailed designs. Architects should cooperate with structural engineers in the early stages of the architectural design process. The other side of the design process or conceptualizing the design thinking becomes effective when the structural concept equally provides better designs with higher qualities. These thinking concepts help the problem solving issues too. Therefore, good design, is usually a single response to the chain of issues including architectural and structural concerns. As such, as two effective cognitive tools in design process, both metaphorical and analogical reasoning, can help architects. This research focuses on the views and discussions of famous practicing Iranian architects in this regard. It is fundamental to explore the extent to which Iranian professional architects use architectural and structural concepts in various stages of their design process, and hence, to see how this familiarity with these concepts might have them toward problem-defining or solving. To conceptualize and interpret effective design processes, and to provide some useful recommendations, the architectural and structural attributes of the selected projects by Iranian architects have been reviewed and analyzed.

1.3 Aims and objectives

Based on the extent of architects' familiarity with the design and structural concepts, analogies and metaphors represent the two important cognitive tools they apply and configure in order to hone their perceptions of architectural and structural

issues. While recent years have witnessed an increase in the number of studies that consider the use of metaphor and analogy, a very few have comprised views and opinions of architects regarding the utility of structural concepts in architectural practice. This gap in research pushed this research to aim for certain goals. The first goal is to see the possible utility of metaphors or analogies in the case of Iranian architects' design thinking. The second goal also aims to see the role of structural engineering and concepts in architecture according to metaphorical or analogical thinking. The third goal is to configure the relationships and integration between architectural and structural thinking among architects and their related facilitators.

1.4 Significance of study

Results of this research can help those interested in more in-depth research about the relationship between structural concepts and architecture, and also conceptual facilitators. Also, the results of this research could stimulate designers to develop an overall and functional perception of the unified structural reaction and related design process facilitators. Furthermore, with important implications in contemporary architecture, using metaphor and analogy can inspire architects to generate forms that have firmness and aesthetic qualities at the same time. As expertise develops abilities in analysis, synthesis, and conceptual thinking, the use of metaphor and analogy can contribute to better structural thinking for architects and encourage them to learn from all related phenomena. The results of this study can also help architects to identify the design problems by making inferences of similarities between two things. By using the metaphors and analogies that are going to be extracted from this study, less experienced architects can have a better understanding of concepts in architectural and structural thinking, so hopefully they become better problem-definer in the future.

1.5 Scope of Study

In this study the researcher only investigates the use of metaphor and analogy as two cognitive tools because the types of reasoning metaphors and analogies provide are powerful in understanding architectural and structural situations, and enhancing design problems experienced in architectural practice (Hey, Linsey, Agogino and Wood, 2008; Mansilla, 2003; Casakin, 2003, 2004, 2007, 2010 and many more). These two problem solving detectors this study addresses are both used to pit the known against the unknown. By doing so, the designer can reach infrequent relations with remote domains, reflected in design problems. Moreover, as it was mentioned earlier, in the architectural domain, this dissertation presents a case among the very few studies that tend to compare analogy with metaphor in one single study. Therefore, considering both metaphor and analogy in one research will help see which one of the related professional architects prefer to use more and which one of them they use in various stages in their design process.

1.6 Study Limitations

This study focuses primarily on the Iranian professional architects residing in Iran. Therefore, some limitations to findings' generalizability indeed exist. According to Hey and Agogino (2007) there are many metaphors, for instance, that are universal but there are also others specific to a designers' personal approach to design. The reviewed literature has suggested some mental representations in problem solving process. However, this study only uses two cognitive tools: metaphor and analogy, in order to see how professional architects reason within the domain of their design process. Any findings or generalizations made, therefore, will naturally be limited to this particular variety.

1.7 Methodology

Analogy and metaphor play two effective and essential cognitive tools in the architectural and structural design processes. Drawing from Iranian architects and their selected projects, this research aims to better understand what and how metaphors and analogies integrate into the architectural and structural domains. The content analysis method is also used to analyze the literature review. Content analysis typically refines, simplifies, and to some extent quantifies the narratives (or text) suitable for qualitative methods. The collected data once read, coded, and analyzed, identifies the skeleton and the framework of the themes (Ro & Bermudez, 2015) (Ryan & Bernard, 2000). Thus, qualitative content analysis of the related literature includes studies of wide range of related subjects be it online, offline, and/or from library databases (from 2012 to 2018), which subjects comprise concepts, conceptual thinking, types of metaphors, analogies and their theories, architectural design, structural design, architecture and structure relationships, and structural detailing. The publication of studied books and articles include series from 1945 to 2017 through ingenta connect, CiteSeer, research gate, ERIC, ScienceDirect, google scholar, Springer, ASCE, ASEE. The newest published data had precedent to be studied, especially those by famous publishers. Older sources had reviews from historical backgrounds and developmental paths of considered issues.

The cited subjects and terms searched as titles and keywords helped find relevant, potential and useful texts selected for reading and analysis, and framing the objectives of the study. The most important collected data focused on metaphor, analogy, structural aspects and relations between architecture and structure. Irrelevant and useless texts and data of books and articles were excluded from the study. Totally, 156 references were searched and studied, 28 of which focused,

considered, and reviewed more closely and precisely. Seven of these references were books and other 18 were articles. Following analysis, two separated tables showcased the metaphor and analogy dataset, with subjects including authors, objectives, participants, instruments and findings.

Also, another table showcased the reviewed structural data, based on the study subject, author, year, focused subjects, and points. Since none of the studies reviewed for the literature included the concepts of structural and design thinking from metaphors and analogies, the information (as case studies) for this study represents the information Iranian architects with long track record of practice shared including their known and acknowledged projects. These projects also contain more conceptual forms and use of structure from metaphorical and analogical viewpoints.

This research also benefited from purposive sampling because contributors were selected attentively according to their required specifics that they had and were particularly suitable for this research (Creswell, 2005). To do this, a method called snowball sampling helped collect the data (Cooper and Schindler, 2003). Accepting this method, the researcher found potential study participants through referral networks in which participants explored other potential participants who shared similar characteristics. In other words, in the interview with one potential participant, a researcher had asked them to introduce two or three other potential participants who he or she thought had the characteristics suitable for this research at hand. Finally, eleven architects were selected for interviews, and conducting them took about one year. Before each interview, the interviewer first proposed definitions of metaphor and analogy to the interviewees (architects). However, some architects did not still answer the questions relative to metaphor and analogy clearly during the interviews.

The researcher, then, had to interpret and evaluate these answers based on metaphorical and analogical definitions and characteristics. In order to investigate traces of analogies and metaphors in architects' designs, semi-structured qualitative interviews seemed appropriate and relevant. The researcher aimed to ask the interviewees questions based on Mansilla's (2003) qualitative part of his questionnaire. These questions helped the researcher to further explore the reasons why the architects used metaphors and analogies in conceptual and structural thinking in design thinking. It is worth mentioning that the questions used to express conceptual and structural thinking in their design process asked of the professional architects were discussed in detail with the researcher's committee members in order to obtain the richest data possible. Based on the objectives of this study, interviews with the Iranian architects consisted of the following questions:

Objective 1:

- Do you usually use metaphors or analogies in your conceptual design thinking?
- If yes, in what ways (i.e., sketches, photos, or words)? Provide examples from your own designs.
- Describe your selected buildings either by sketch or writing.
- What was your conceptual idea of this building in design process?
- What kind of metaphor or analogy do you usually use? Would you please give an example.
- In case you do not use metaphor or analogy in your designs, what other cognitive tools do you use to visualize your design ideas?
- Have you ever used any metaphors or analogies in describing your designs to others? If yes, provide examples.
- Where in design process do you usually use metaphor or analogy?

Objective 2:

- What was the most important metaphor or analogy expression of structure while you were designing this building?
- Which one (analogy or metaphor) was used to express structure in your selected building?
- How structure is used in generating the architectural idea?

Objective 3:

- In what ways in your opinion, metaphor and analogies have facilitated your design process?
- Would you like to share other comments regarding your design experience?

As two prominent types of interpretive analysis, inductive and abductive reasoning (Hatch, 2002) helped investigate the Iranian architects' design modus operandi (their opinions and their selected projects' description) based on the conducted interviews with them. Through interpretive analysis, researchers can see the emergent patterns, configuring the themes, exploring relationships and finally making interpretations based on the literature review. Inductive reasoning helped collect data and analyze the conducted interviews. Inductive analysis mainly uses detailed readings of raw data to get concepts and themes via interpretations of the raw data by a researcher. Data analysis comprises evaluating the objectives (to configure investigated domains) and findings as directly made through the analysis of raw data, not primitive or premature expectations or conjectures. Findings, by the same token, reflect the experiences and assumptions of the evaluators (Thomas, 2006).

Using inductive analysis condenses varied raw data into a preferred summary format, making clear links between objectives of research and findings of summary, and developing models on fundamental elements of experiences and processes which

emerge from raw data. Inductive studies typically consist of three to eight main categories that make up the findings (Thomas, 2003). The inductive analysis strategy includes the following steps: initial reading of text data, recognizing specific parts of the narrative related to the objectives, tagging parts of the text to create categories, decreasing overlap and abundance from categories, and making a model combining most important categories. Findings in inductive approach emanate from frequent and important themes throughout the research (Liu, 2016). Since the researcher aimed to check the relationship between the experiences of contributors and the applying analogies and metaphors in conceptual design thinking, coding helped decrease the data into categories. Table 6 includes the specific narratives gleaned from the interviews. Table 7 includes most important codes based on the transcribed data. Table 8 compares emergent codes and refined them according to objectives. Thus, codes like flexibility, creativity, visual effects, structural efficiencies, stability, strength and structure as form are introduced.

Furthermore, abductive reasoning applies to analyzing the architects' selected projects. Abductive analysis emphasizes mainly the domain of the theoretical background a researcher brings to the fore. The literature review (theoretical backgrounds, metaphorical and analogical definitions), and the primary description of selected projects and project facts discussed by architects during the interviews, paved the way for the analysis. An abductive conclusion includes making an educated guess based on the interaction between existing theories and data. This approach emphasizes the development of unique and new experimental findings (Timmermans & Tavory, 2012). In this way, the considered objectives (regarding conceptual design and structural design), and the literature review, resulted in a set of conclusions for each selected project. Modern researchers mostly consider abduction

as a process of finding a best explanation for a set of observations (Wang & Sun, 2012). Reasoning is abductive in its nature which introduce possible guesses rather than introducing fixed conclusions (Meadows, Langley, & Emery, 2014).

The structural focus of this study, introduced and described the structural analysis (information and conclusions) for each project. Further assessment helped integrate structural design and architectural design in each project. Ultimately, conclusions and project analysis and review result in exploring the main themes and categories by summarizing the collected data. Therefore, each project has a specific table of structural analysis including structural arrangements and expressions. Table 38 introduces summarized structural information and resulted codes. Focusing on each project, table 39 illustrates conceptual and structural types for each project per the metaphorical expression of structure. The last table in this analysis concludes structural efficiency and creativity as two important codes. Finally, findings of abductive analysis (projects) will be compared and matched to findings of inductive analysis (interviews' data) in order to reach to the final categories, keys and possible models.

1.8 Summary

This chapter has presented the background and nature of this study. It has also provided information about architectural and structural thinking and the need for using metaphors and analogies as two cognitive tools that make them more tangible for architects. This chapter also justified the researcher's intention or motivation behind this study. The study significance, scope, and the limitations were presented next. This chapter ended with the adopted methodology in which the researcher tried to fully explain the population, design, and the questionnaire content. There is therefore, a need for reviewing the literature in order to go over definitions of

metaphor and analogy and the empirical studies on metaphor and analogy. The next chapter will review different issues about concept, conceptual thinking, cognitive tools, metaphor and analogy. This is essential to have overview of these key points before studying related cases.

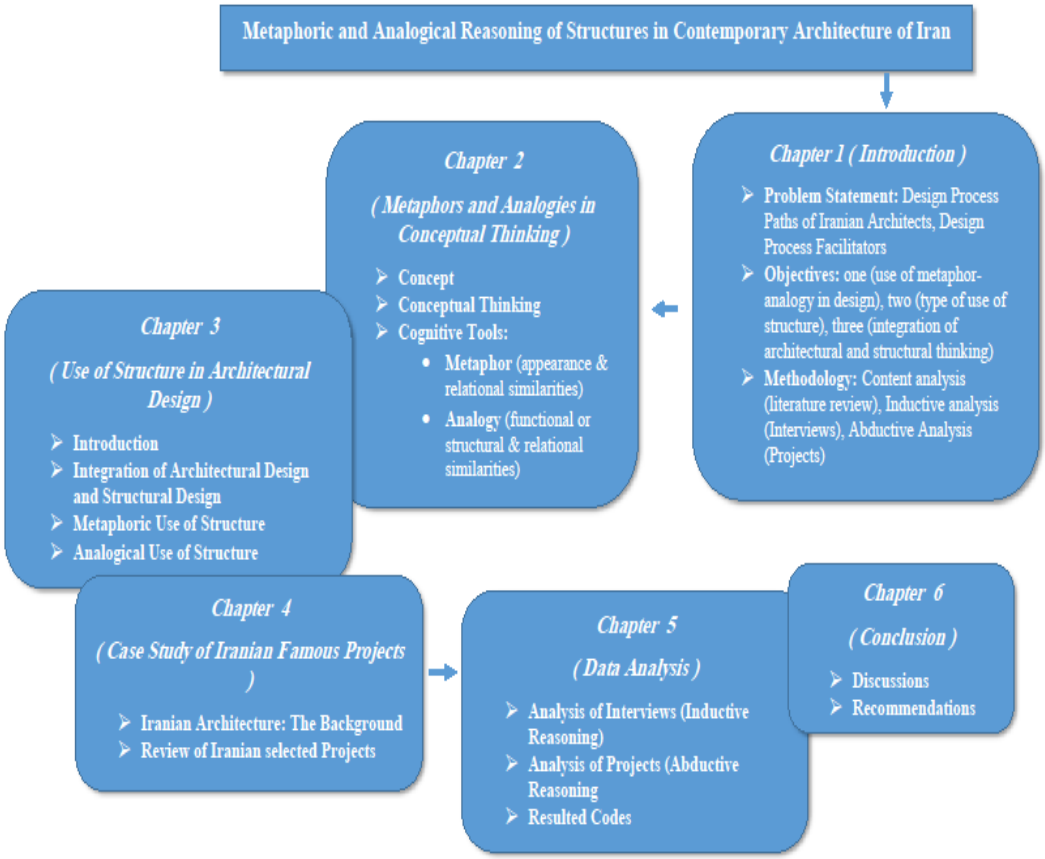


Figure 1: Overall diagram of the research including points of chapters

Chapter 2

Metaphors and Analogies in Conceptual Thinking

2.1 Overview

The introduction discussed some important and related issues including problem statement, objectives, significance of study, and methodology. This chapter first deals with the concept and conceptual thinking and the ways in which they help architects to see things differently. Using two cognitive tools in conceptual design, metaphor and analogy are then defined and reviewed based on some related theories and some other related studies.

2.2 Concept and Conceptual Thinking

Concept is an idea that helps one to identify the links between thoughts and observations. In architectural practice, architects respond with an emphasis on perceptual terms and representative meanings and concepts, in order to develop innovative design solutions. To design a building, architects begin with a meaningful concept, which plays a central role for the rest of the project. However, Steier and Pierroux (2011) assert that these initial ideas very much depend on architect's expertise and his/her observed patterns that can be recalled later to form the basis for those concepts. Conceptual terms describe the elements of a design and its envisioned experience.

Gero (1998) emphasizes the designers' skills and their related experiments and experiences in order to use them in other designs. Although sometimes the concept serves like an afterthought (post-rationalizing), most monumental works have been

created from powerful themes. For example, the concept, “my design is like a tree” coined by Toyo Ito led to the creation of famous Sendai Mediatheque Library in Japan. The concept was quite visible in his plans, sections, elevations, details, etc. seen in Figures 2 and 3. Toyo Ito won Pritzker prize, the highest honor in architecture, in 2013 because of the balance made between physical and virtual worlds.

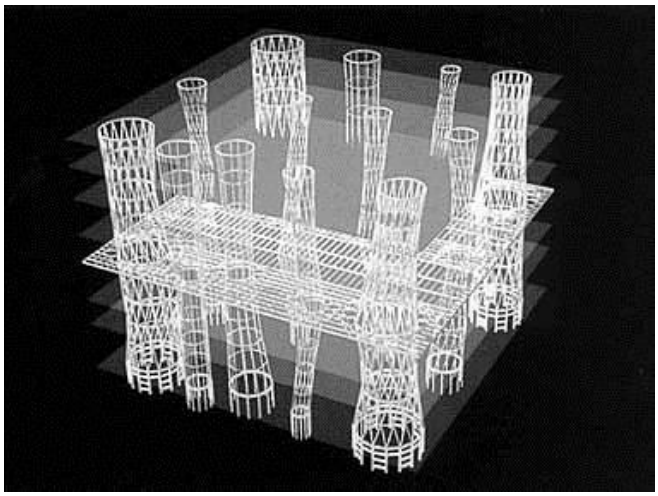


Figure 2: Tree-like channels of Sendai Mediatheque library (archdaily1, 2016)

Figure 3: Night façade of Sendai Mediatheque library (archdaily1, 2016)

Frank LIoyd Wright coined the organic architecture as another famous concept that fosters harmony between dwellings and the natural world. Inspired by nature, this concept refers to the human inhabitants as organisms, which unfolds from the seeds within. The “Falling Water” project in Pennsylvania represents the most famous building Wright designed based on this concept (Figure 4).

Figure 4: “falling water” house (fallingwater, 2016)

Designed based on the concept of porosity borrowed from biology, medicine and organic chemistry, and ten stories high and 382 feet long, the third example presented here is a famous Simmons Hall dormitory at MIT, Massachusetts. As it can be seen in Figure 5, the state of being porous indicates a large number of small openings and passages with various sizes and forms that allow matter to pass through.

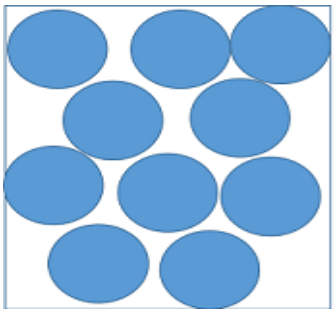


Figure 5: Concept of "porosity" (study, 2017)

In order to produce positive effects to an urban scale, architect Steven Holl used the driving concept of a sponge which manifested throughout the building by better air and light circulation, better accessibility and visibility at an urban scale, and better communication between interior and exterior spaces (Kotsopoulos 1996). The following pictures represent the interior and the exterior design of this student residence.

Figure 6: Perspective and interior of Simmons Hall dormitory (casaligroup, 2016)

As such, concepts give architects fresh outlooks that can help them see things differently, or more clearly, or as Kotsopoulos (1996) puts it the border line between creative design versus re-design. Holl (2002, p. 73) too depends "entirely on concept diagrams," which to him serve as his "secret weapon." He further adds that "They

allow [him] to move afresh from one project to the next, from one site to the next" (ibid.)

Figure 7 represents the famous architect Calatrava's Tenerife Auditorium known also for its conceptual approach. Located near the port, the crashing wave rising from the base represents its main concept (Calatrava, 2019). This concert hall has different concrete shell roofs, in curved forms, about 60 meters above the ground, and in the middle of the surrounding plaza. Jodidio (1998) describes it as one of the most visual buildings, designed by Calatrava. Based purely on appearance, the building certainly has symbolic value. The form of the main hall evokes human eye, as architects believe.

Figure 7: The general view of the Auditorium, by Calatrava, Tenerife, Spain (calatrava1, 2019)

Indeed, since the design process in architectural practice represents an intuitive as well as a complex process, concepts can help architects to not only mediate his/her thinking but also create aesthetic objects in their conceptualization stage (Piotrowski, 2001). While working on a project, the multidimensional nature of the design process requires the architect to think about bringing forward multiple architectural proposals, digesting the complexity of issues, and sharing them with clients and

constructors to name a few stakeholders. In all this, conceptual negotiation involves the exchange between different modes of thought and points of view, between verbal and visual interpretations, or between universal scientific laws and the kind of understanding that a particular design process reveals.

In a note on "competencies meteorologists", Environment Canada defines conceptual thinking as "the ability to understand a situation or problem by identifying patterns or connections, and addressing key underlying issues. Conceptual thinking includes the integration of issues and factors into a conceptual framework. As such, it involves using past professional or technical training and experience, creativity, inductive reasoning, and intuitive processes that lead to potential solutions or viable alternatives that may not be obviously related or easily identified" (eco.ca, 2017). From an architectural view point, however, conceptual thinking constitutes a valuable analytic or problem solving tool which enables architects to identify patterns or links between seemingly unrelated issues. Conceptual thinking is the same as what Edward de Bono coined as "lateral thinking" or "out of box thinking" because it requires openness to new ways of seeing the world and a willingness to explore (Borno, 2006). Once the work of analysis is completed through this indirect and creative approach, conceptual thinkers can clarify complex situations and think of creative solutions to new problems.

During the conceptual design process, two cognitive tools namely, metaphor and analogy, play key roles in enabling architects to understand the design process itself (Hey and Agogino, 2007). The following section provides detailed analysis of these cognitive tools according to definitions, related theories, architectural design, types and related studies.

2.3 Metaphor and Analogy: Definitions for Design

2.3.1 Metaphor Definition

Metaphors served as a form of complementary language expression in the past. This method of thinking evolved in ways representing metaphors not only as themes referring to something, but also as describing aspects of something else. This can be seen as how Master Tropes described metaphor in 1945: To consider A from the point of view of B is, of course, to use B as a perspective upon A. The innovative path regarding metaphor began in late 1970s when cross-domain mapping emerged as a common across all ranges. Recent views of metaphor provide understanding abstract concepts by revising or repurposing them into familiar and concrete objects. The cross-domain mapping by metaphor can be seen in Wulff, Evenson and Rheinfrank's (1999) model in Figure 8.

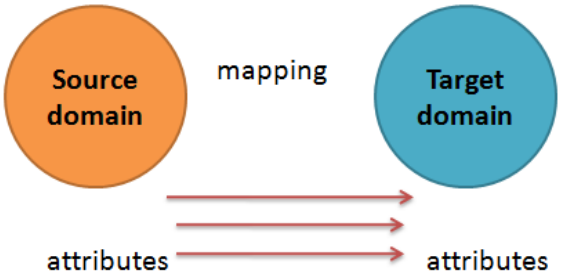


Figure 8: A model of cross-domain mapping

We should, nevertheless, keep in mind that the metaphor is not only about seeing the unknown in the known. It is not even about the list of commonalities between the two. According to Coyne, Snodgrass and Martin (1994), What features does society have in common with the sea? Indeed, as Lakoff and Johnson (1980) argue, the power of metaphor lies in its structuring of our cognitive system. This argument sounds somewhat similar to James Carse's assertion that:

> It is not the role of metaphor to draw our sight to what is there, but to draw our vision toward what is not there and, indeed, cannot be anywhere. Metaphor is horizontal, reminding us that it is one's vision that is limited, and what one is viewing. (Saffer, 2005, p. 8)

Metaphor in this study is considered as a cognitive tool used during the different stages of the design process by the architect in order to make the unfamiliar, abstract or fundamentally unstructured subject matter, familiar, more concrete or a more highly structured subject matter (Fez-Barringten, 2012). Metaphors encompass two peripheral elements which are both unlike, and belong to different contexts, are apparently unrelated, but share readily unapparent commonalities. Such a thing can be seen in the following examples: Mother Nature, celestial harmony, great chain of being, and the book of nature.

Metaphor in this study represents anything that encompasses surface or appearance and/or relational similarity (Hey, Linsey, Agogino & wood, 2008). This can be seen in the surface similarity of "jail" and "zebra" (Hey, 2008), or in the surface similarity of a sawfish and an underwater robot used to harvest lumbar (Figure 9). As it can be seen in the following picture, the above mentioned domains are visually similar but share little functional similarity.

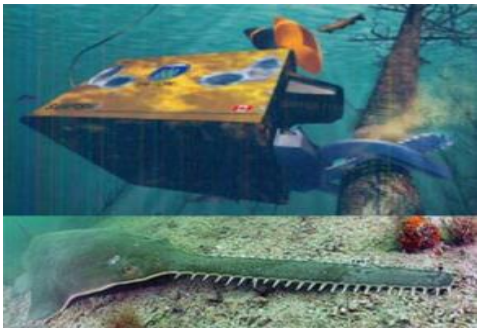


Figure 9: The surface similarity between a sawfish and an underwater robot (Linsey, 2007, p. 10)

If analogy applied to this case, the best example for functional similarity between the source domain and the target domain would have been the saw fish and the chain saw (Linsey, 2007). Figure 10 shows this similarity.

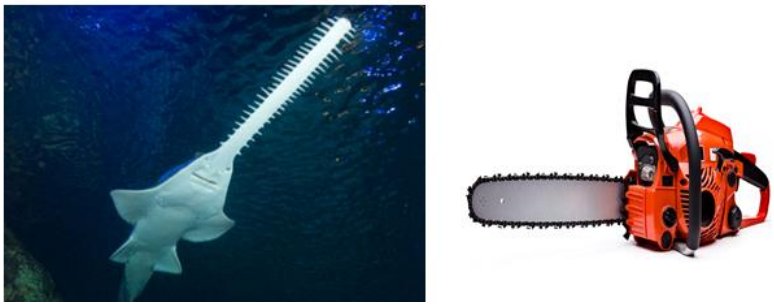


Figure 10: The functional similarity between a saw fish and a chain saw (elasmodiver, 2016) (arborist101, 2016)

Although the inspirational source in any metaphoric reasoning can be a) linguistic, b) visual, or c) auditory construct, this study solely relies on linguistic and visual stimuli metaphors because using auditory sources happen to rare apply in architecture. Literary or linguistic metaphors "…associate meanings and emotions which otherwise would not have been related. Words (essences) which have a preferential or primary use in one context are explicitly employed in another" (Fez-Barringten, 2012, p.5). However, the origin of verbal and visual metaphors resemble Rothenberg's (2008) "visual metaphor," coined in ancient times by Aldrich (1968). In this type of metaphor, a person, place, thing, or idea can be represented by the means of a visual image that suggests a particular association or point of similarity. This can be seen in the imperial war museum, designed by Daniel Libeskind in Manchester, UK (Figure 11).

Figure 11: Aerial view of the Imperial war museum, which has three parts joined together (arch2o, 2017)

Jørn Utzon's Sydney Opera House (Figure 12) represents one of the most famous examples in field of metaphors, which evokes cliffs of Sydney and on the other hand, also the sails on Sydney's harbor (sydneyoperahouse, 2019). Utzon wanted to design shell forms (reinforced-concrete) similar to large sails which have contrast with its adjacent blue water. However, due to the structural difficulties, a series of concrete ribs were used in construction. Therefore, iconic forms are considered for this opera house (archdaily 7, 2019). An architect has designed a building that not only contains function of performing arts but also includes architectural and sculptural roles in other views (worldarchitecture1, 2019). Architecturally and structurally speaking, the building, as Sharp (2002) confirms, broke the normal related rules, according to its unique conceptual form and type of construction.

Figure 12: Side view of the Sydney Opera House, by Utzon (abc 1, 2019)

Since this study does not aim to explore the type of metaphor (linguistic or visual) as might apply to the Iranian architects, any type of metaphor used or mentioned by them in the analysis has been collectively considered as *metaphor*.

2.3.2 Defininig Analogy

Analogy characterizes a recognition process of conducting assigned aspects between two things in the analogue (inspiration source) and the target (Verbrugge and McCarrell, 1977). In analogical reasoning 'A is to B as C is to D' (Do and Gross, 1995) which reveals or introduces an unknown idea by the help of a known idea similar or parallel to it in some special aspects (The New Oxford Dictionary of English, 2003). Some aspects, as previously noted, from the source domain communicates the aspects from the target domain at a deeper level (structural or functional analogies). Analogy can be better understood when compared with metaphor in the following section.

Analogy is derived from the Greek word *ana* and *logon* means according to ratio and is another cognitive tool used in this analysis, and is defined by comparing two things based on their structure rather than their appearance. This employs the structural aspects by determining the relationship between two things similar to the

relationship between two other things (relational similarity). This can be best understood by the example provided by Hey (2008) as the similarities between “the job” and “the jail”. As it can be seen here, the relationship between the two is not the appearance similarity but the relational and structural similarity which represents analogy (Emirates Aviation College) (Figure 15).

Bringing out the meaning of a concept or idea in a way that can be easily understood is the key purpose of an analogy. Therefore, analogies play key roles in problem solving, decision making, memory, creativity, emotion, perception and communication. An analogy can be classified as within-domain (close field) and between-domain (far field) depending on the relationship between a represented visual display and the target problem to be solved (Casakin, 2003; Vosniadou, 1989). The former applies when the source and the target domain belong to the same realm or domain. One of the oldest analogies used in design is reel lawn mower inspired by nap trimming machines for carpets.

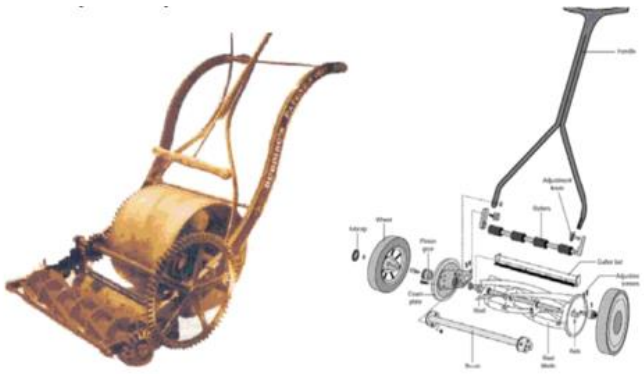


Figure 13: of the carpet nap trimming machine and early lawn mower (Linsey, 2007, p Displays. 8)

Between-domain analogy, on the other hand, refers to cases where the transformation of knowledge happens between two entirely different and remote conceptual domains. This type of analogy, is a core element in explaining novel

design concepts mainly because a similar explanatory structure between the source domain and the target domain, or the target problem is totally new and distant. The best example illustrated here comes from Casakin's (2008) study regarding the impact of analogical reasoning on the design process. In this study, one student was given a task of designing a prison with the large number of cells, but the challenge was that the prison should have been designed in such a way that having too many cells in the prison, need not result in large distances from the guards to prisoners. Using think aloud protocol for this study, the students explained everything out loud so that the researcher could trace back his thought chains. By focusing mainly on between-domain displays such as a snail, and a shell (the company logo), architectural students came up with designs that had one major feature common between the two (e.g. the shell and the prison). Both had a geometrically marked center point.

Figure 14: Displays for the prison problem and the shell company logo and the snail (yopriceville, 2016) (logodesignlove, 2016) (prairieghosts, 2016)

Figure 15: Emirates Aviation College, (bsbgltd 1, 2017)

2.3.3 Commonalities and Differences

Analogy like metaphor compares a situation in the source domain (familiar situation) with the situation in the target domain (unknown situation) needing elucidation and clarity. In another example, *design is search*, the source domain is the better-known domain of "search." When we use this source domain, we evoke the idea of "finding something" which makes us enrich our understanding about design.

However, it is important to stress the definition of each because in many studies reviewed in the literature analogy is sometimes defined, equated to and used interchangeably for metaphor. According to Do and Gross (1995, p. 3) "much of what is often seen as visual analogy in architecture may better be understood as

metaphor and shape borrowing" and vice versa. An example of overlapping definition is Qian and Gero's (1996) definition for analogy, defined as "using features from appropriate source for a design problem at hand". Another fuzzy definition for metaphor is, "the transfer of the name of one object to another through a relation of analogy".

Arguing that while in analogical reasoning structural features are engaged in design, it is the surface features that are engaged in metaphorical reasoning, Goldschmidt (1992, 1994) offers a more distinct definition of metaphor and analogy. When it comes to surface features, somehow this might sound confusing when one comes across with the way Casakin (2003) classifies analogy as surface and structural analogy. While the former involves superficial concepts of object properties, the latter relates to higher order relations of deep properties. Perhaps, the problem can be solved when we seek the answer in Gentner, Bowdle, Wolff, and Baronet's (2001) book chapter, Metaphor is Like Analogy, in which they claim that metaphors could be considered analogies when comparisons are based on "primarily relational information". In other words, some comparisons can be both analogy and metaphor.

Most metaphors studied in the literature are indeed analogies, where according to Gentner et al., (2001) "they convey chiefly relational commonalities; for example, *Encyclopedias are gold mines*," (ibid., p. 200). It seems that the best distinct definition provided so far for analogy and metaphor is in the comparative study Hey, Linsey, Agogino and Wood (2008) did between analogies and metaphors in creative design. They argue metaphor is a type of simile that "span[s] the spectrum of relational similarity at one end, and appearance similarity at the other", while in analogy the relational and structural similarity between the source and the target

domain is primarily mapped so it helps to explain the new problem in terms of familiar problem. For instance, in “his eyes were burning coals” metaphor, just an alignment of properties has been established rather than higher order relations between the base and target (Casakin, 2006b). The modification of metaphor and analogy can be seen in Figure 16.

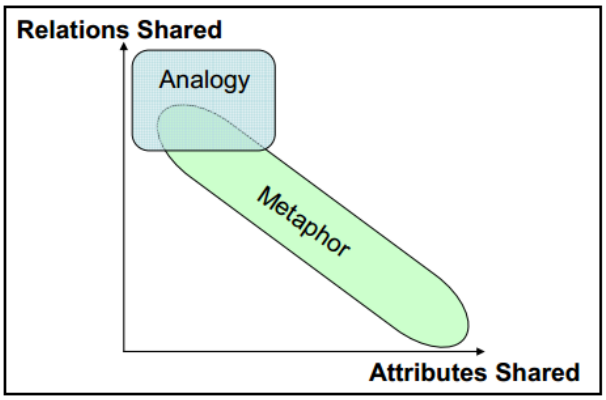


Figure 16: Relationship between analogy and metaphor (Linsey, 2007, p. 3)
Another difference between metaphor and analogy is in the context that relates to both.

Metaphor, according to Gentner (1982), serves explanatory-predictive as well as expressive-affective purposes, whereas analogy applies to explanatory-predictive contexts. Ortony (2001) suggested further contrasts between analogy and metaphor, and about the reversibility of analogies in the sense that they can convey a system of relations from source to target, and from target to source without changing meaning, while metaphor, in essence, can change the meaning drastically. Gentner and others (2001) have illustrated this in the metaphor “the acrobat is hippopotamus” (a clumsy acrobat) as compared to “the hippopotamus is acrobat” (graceful hippopotamus) which the meaning is drastically changed when the source and target domains are

reversed. The summary of the differences between analogy and metaphor can be seen in the Table 1 below:

Table 1: The differences bretween metaphor and analogy

Metaphor	**Analogy**
Convey chiefly relational commonalities	Convey relational and structural commonalities
Used in explanatory-predictive & expressive-affective purposes context	Used in explanatory-predictive contexts
Not reversible	Reversible

2.3.4 Initial Stage of Design Process

According to Gentner (2001), the initial design process characterized the first step in which the designer extracts a variety of unfamiliar and unknown concepts from remote domains in order to establish higher orders mapping between the concept and the problem at hand. This study too uses a stage in identifying and retrieving a phase in which the architect/designer identifies the potential source of analogy or metaphor where he or she has previously learned, and can represent the target situation and solve a new problem.

2.3.5 Concept Generation Stage of Design Process

This stage is known as the solution phase aided by memory recovering hints. Casakin (2004) believes that the designer could begin making communications between the source and target (mapping) thereby causing the transition of suitable metaphorical or analogical principles successfully. In this study, concept generation

phase refers to the stage in which inference based on the mapping between the target problem and the source is found (solution).

2.4 Cognitive Metaphor Theory

As Lakoff and Johnson discussed in 1980, cognitive metaphor theory (known as conceptual mapping theory), pertains to studying, processing and working of conceptual metaphors, at the thinking level. According to this theory, metaphors connect the source of inspiration including literal existences, metaphoric features and relations with the target. A main root of this theory emphasizes that metaphors are not just language decorations but are matters of essential cognitive processes that create meaning and thinking (Lackoff & Johnson, 1980). Metaphors are also "not merely embellishment in language, rhetoric, or poetry, but rather, the capacity to use metaphors in expressing concepts is a fundamental aspect of human cognition" (Hashemian, 2007, p. 43). It is also visible in Shakespeare's metaphor (*All the world is a stage)* which according to conceptual metaphor theory, it is a comparison between the world and a stage to transfer the message of *Life is Theatre*. Figure 17 shows the figurative model.

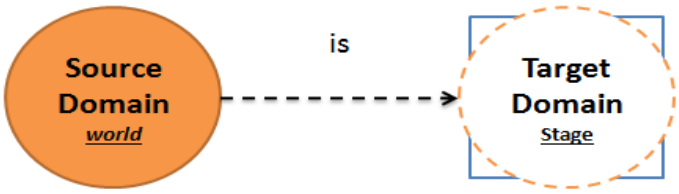


Figure 17: Shakespeare's Cross-domain mapping based on conceptual metaphor theory (Neo, 2010)

2.5 Structure-mapping Theory

It is a theory of the cognitive structures and mechanisms on the backside of analogical thinking rather than talking about how and why we apply metaphorical

language. According to Genter and Markman (1997) and Gentner (1988), analogy mapping is a making process of a structural similarity between two considered conditions and then getting results. Generally speaking, structure-mapping theory presumes "the existence of structured representations made up of objects and their properties, relations between objects, and higher order relations between relations" (Gentner et al., 2001, p.200). Analogical thinking with high level of relationships about nature has been shown in Figure 18, illustrates how the dividing and scattering of the fluid over its surface in bipolar fuel cell plate emerges from the dividing pattern of fluid between the dorsal and ventral surfaces of the leaf.

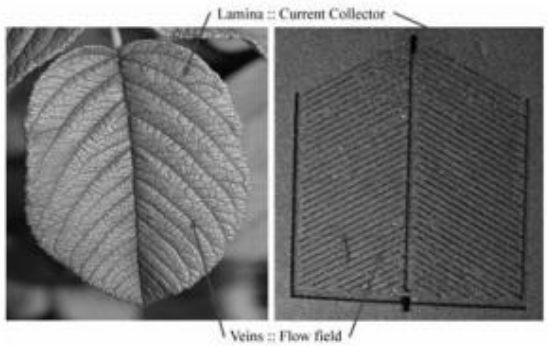


Figure 18: Structural relationships between a leaf and a bipolar plate (Hey et al. 2008, p. 284).

2.6 Metaphors in Architectural Design

The inspirational source for metaphoric reasoning can be a) linguistic, b) visual, or c) auditory constructs in which the source refers to the target. Numerous examples illustrating the relevance of metaphor as a potent tool derived of nature can be found in conceptual design thinking. For example, according to Colquhoun (2002), proposed by the modern movement, the dictum 'form follows function'- meaning that the external appearance of a building is the consequence of the building's interior use-affected all of architects recognized with the Modern Movement. The

prairie houses by Frank Lloyd Wright in practice, uses metaphors, formed by combination of simple volumes with functional needs (Brik, 1998; Levine, 1996). Another famous architect, Mies van der Rohe, used the metaphor 'less is more' referring to the engineering idea of reducing architectural design to its minimal and basic essence. He uses metaphors as a means of using spaces by cutting down the number of unnecessary materials and decoration, as well as designing simple details. Another outstanding example of the use of metaphor in architectural design belongs to Calatrava's Lyon Airport Railway inspired from the metaphor 'free flight of an enormous bird' (Figure 19).

Figure 19: Façade of the Lyon airport railway station (structurae, 2016)

Another influential architect, Antoni Gaudi, had used metaphoric concepts, in his iconic work, Casa Mila (Figure 20). Using cliff walls like traditional African cave-like buildings in that project, he mimicked the natural, maritime, and mountainous characters of Catalonia, Spain (britannica, 2019). The porous wavy facade, evokes beach sandy forms, also reminding the bee hive when the observer views the façade. Zerbst (1988) explains that, as the last secular building which Gaudi designed, there is a contrast based on artificial versus natural design which at the same time,

symbolized the essence of all his previous famous designs. The roof is similar to the bench from his Guell Park and also his impressive design of unique chimney forms.

Figure 20: Main façade of Casa Mila, Spain, by Gaudi (britannica, 2019)

In another case, Cathedral of Brasilia (figure 21), Oscar Niemeyer uses different metaphoric concepts for the building. The overall form of the building evokes a crown of thorns (related to Christ), and also multiple columns show the hands toward the sky (atlasobscura, 2019) (archdaily 3, 2019). According to Jodidio, Niemeyer has tried to use simplified and minimal forms of modernism by combining them with the new attractive types of forms. These forms include wavy, complex and encouraging shapes and geometries. During that time, these designs were new attempts to introduce some new concepts in different building types. He introduced the curvy forms in the realm of concrete which has rough character naturally (Jodidio, Niemeyer, 2016).

Figure 21: Aerial view of the Cathedral of Brasilia, designed by Niemeyer (archdaily 3, 2019)

2.7 Analogies in Architectural Design

The inspirational source for analogical reasoning, as Cubukcu and Dundar (2008) describe, can be a) verbal i.e., word or sentence clues; b) visual i.e., picture clues; and c) both combining pictorial and word clues. Although children tend to think in pictures while adults in words (Fodor, 1975), for designers, including architects, the influence of pictorial clues (visual thinking) rather than verbal clues plays a greater role in motivating omnific solving ways considered problem.

From an architectural domain's perspective, many design studies have used close and foreign domains for architects in order to spark creativity and inspiration for their own designs. The term "analogous architecture" was coined by an Italian architect called Aldo Rossi, who received his inspirations from many natural and unnatural references. He saide that, analogies are the essence of architectural

meaning. Inspired by Walter Benjamin's quotation, "I am unquestionably deformed by relationships with everything that surrounds me" (Rossi, 1976, p.75), he believed "this deformation affects the materials themselves and destroys their static image, stressing instead their elementally and superimposed quality." As referred to our surroundings, natural references happen to be great stimuli for architects. To name a few we can point to references such as shells, insects, plant patterns. In order to boost creativity, Le Corbusier (1985, p.83) believed "a plant, a leaf, the spirit of a tree, the harmony of sea shell, formations of clouds, [and] the complex play of waves spreading out on a beach" can be great stimuli. Apart from natural references, human organs, human artifacts, musical scores, letters, engineering works, famous buildings of the past and paintings characterize other visual references used by architects for spatial and physical forms of buildings (Do and Gross 1995).

To point to empirical examples mentioned in the reviewed literature, we can refer to Le Corbusier (1958) who claimed that he was inspired by a horseshoe crab shell when he designed the roof of Le Ronchamp Chapel. Likewise, visual references of palm trees were used for the columns of BCE place Gallery (Blaser, 1989). Rather than focusing on forms, some architects like Wright (1943) focused on a building concept when he designed Unitarian meeting house at Madison derived from the image of the hands clasped in prayer (Figure 22). Another such example borrows from the violin in its case which led to the creation of Kahn's Fort Wayne Performing Art Theatre.

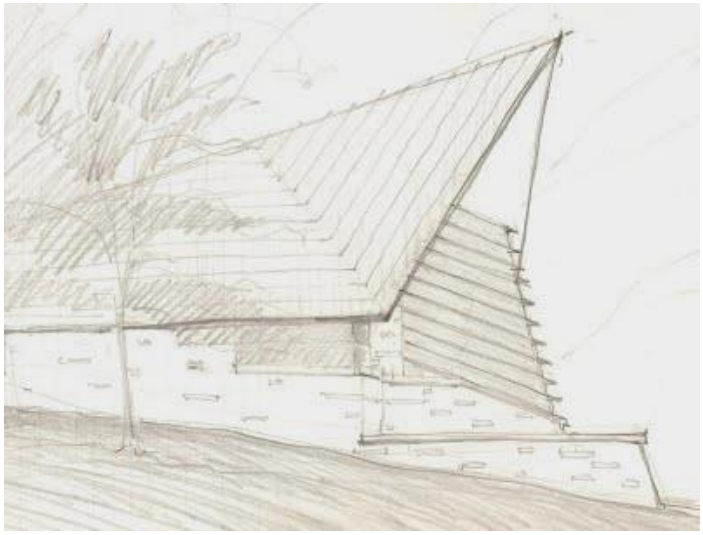


Figure 22: Unitarian meeting house sketch (newamericanvillage, 2016)

Using the concept of flight and curves to create spaces that flowed into one another, architect Saarinen designed the TWA terminal in New York (Figure 23). The concrete roof of the building symbolizes a bird in flight. The interior is formed as a continuous movement of the exterior. All parts, spaces and elements of the building were designed in a way to follow a main concept as uniform natural movement took from flight (archdaily 2, 2017). For sure, this building is one of the most exhibitive airline terminals in the world, because of its unique building form--especially in its own time. There are only a few linear lines in design of this building. Sylvia Wright (1992) says that the exterior curvy form of the whole building, unconsciously, expresses a flying bird. Internally, the main lobby lines, all walls, its shaped staircases, designed seating areas, and most of other elements combine pleasant sculptural shapes chosen to present the sensation of the travel.

Figure 23: TWA terminal, like a flying bird (designboom 1, 2016)

2.8 Types of Metaphors

Antoniades (1992, p. 30) has classified metaphors as intangible, tangible and combined. The intangible metaphor is characterized by abstract ideas, qualities and concepts. Tangible metaphor, particularly applies to the architectural realm, and relates to visual aspects and material representation (Casakin, 2006b). Using the tangible metaphor in architectural design by literally representing the visual characteristics of the battleship, Hans Scharoun used ‘museum as battleship’ metaphor to design a German shipping museum. Supposedly if Hans Scharoun had used intangible metaphors in the same design, he would have used abstract concepts such as ‘fearlessness’, ‘perfection’, ‘tension’ and ‘off-balance’ (Antoniades, 1992, p. 36). However, relying only on either tangible or intangible metaphors is not ideal because combining concepts with visual representations (a combination of intangible and tangible metaphors) allows for new and different meaning. In the same example adding ‘museum as battleship’ tangible metaphor to ‘museum is battleship’ intangible metaphor, generates a series of cross-domain associations: ‘profile is

fearless', 'structure is perfection', 'window is tension' and 'symbol is off balance' (Antoniades, 1992, p. 30).

2.9 Types of Analogies

An analogy can be classified between two different domains: within-domain and between-domain depending on the relationship between a represented visual display and the target problem to be solved (Casakin, 2003; Vosniadou, 1989). The former is established when the source and the target problem belong to the same realm or similar domain. The design-by-analogy study done by Davies, Goel & Nersessian (2009) captures this type in which novice designers were presented with within-domain visual display (Figure 24), and asked to design a weed trimmer with a pole that can pass through the sign posts without stopping. A sample of a student's sketch after he/she was presented with within-domain visual display can be seen in Figure 25.

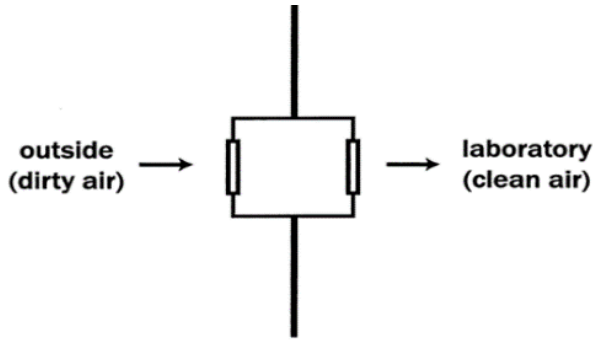


Figure 24: Within-domain visual display, a laboratory clean room, presented to student designers (Davies et al., 2009, p. 32)

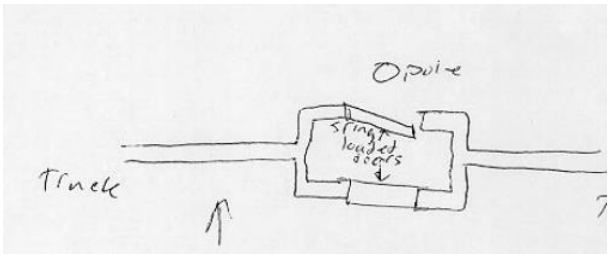


Figure 25: Participant's data, scanned from what was drawn and written on the experimental sheet (Davies et al., 2009, p.36)

Between-domain visual display however, applies when the domain between the visual inference and the problem at hand is distant, and the two come from two different areas of interest (Casakin, 2005). Figure 26 shows an example of an art work presented to architectural students in order to see the impact of analogical reasoning in design education as well as an example of a work produced by a student as a result of between-domain visual display to show the concept of "emphasis".

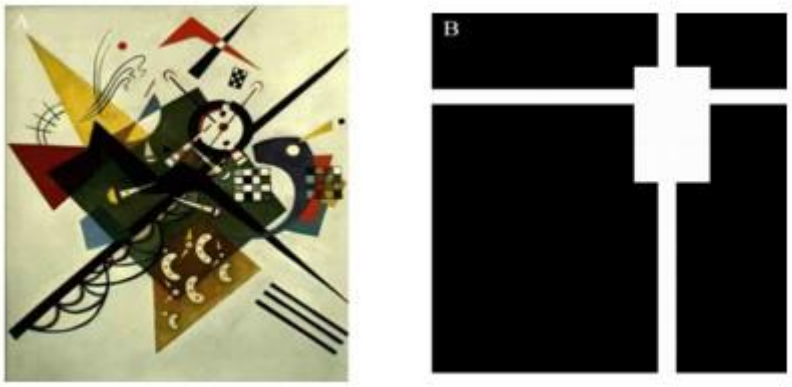


Figure 26: An example of art work painted by Wassily Kandinsky conveys the expression of emphasis (on the left) and a work produced by a student (on the right) (Cubukcu and Dündar, 2008, p. 72).

2.10 Metaphors and Analogies in Design Problem Solving

Omnific qualifications constitute the main element in design problem-solving. Goel (1995) discusses the main reason that design is normally a complex activity, where problems cannot be solved by sheer calculations. In addition to the requirement for qualitative knowledge and experience, the finding of unknown and informal design solutions need creative skills (Cross, 1997; Hsiao & Chou, 2004; Gero, 2000). When engaging with design problems, metaphors and analogies as problem-solving aids help the conception of an unknown condition in terms of a known situation (Ortony, 1991). Metaphors and analogies, therefore, make it possible to reference what is clearly understood in order to elucidate the unknown.

Basically, metaphor and analogy constitute an uncommon juxtaposition of the familiar with the unusual. Lakoff (1993) believes they induce the discovery of innovative and creativity associations that broaden the human capacity for interpretation. For that reason, metaphors and analogies are valuable aids in problem-solving tasks.

Peter Rowe (1987, p. 31) terms visual analogies as "solution images" because he echoes this sentiment: "…initial design ideas appropriated from outside the immediate context of a specific problem are often highly influential in making of design proposals." According to Boden (1999), recognizing analogies in terms of unusual juxtaposition of ideas can finally lead to exploration, evaluation and problem solving. Refereeing to the general theory of human creativity, blending ideas through metaphors and analogies is what Koestler (1964) coined as bisociation. Gentner and others (2001) contribute that the relationship between metaphor and problem-solving design comprises three basic steps. The first step includes getting a variety of unknown concepts from distant domains, where possible relevance with the problem at hand are not always obvious. The second consists of making a mapping of deep or high level relevances between the metaphorical concept and the problem. The last step engages with transferring and using structural communications related with the metaphorical source to the problem at hand, which at the end generally leads to a novel solution.

Casakin (2004) argues that in the analogical reasoning, the process includes two stages: (a) identification and retrieval, and (b) mapping and transference. Identification refers to recognizing the potential source of analogy which one has knew previously and can show the target condition and solve a new problem. Provided with memory detection hints then, the designer can start communicating

between the source and the target domain (mapping) which may successfully reach to transition of suitable analogical elements. Goldschmidt (1997, p. 68) divides the process into three steps starting from detection and show of an image, going to "diagrammatic representation that is sufficiently abstract to accommodate any number of images," and finally, getting a known shape from the context of the task to the same diagram. The power of the diagram in Goldschmidt's second stage is vital in order to show secessions. She explains her point by using the Le Ronchamp Chapel as an example, whose design was inspired by a horseshoe crab shell. She argues that "the abstraction that Le Corbusier saw in his mind's eye … are none other than diagrams of both crab shell and the roof" Goldschmidt (1994, p. 510). In this step, it is totally up to the architect on how he or she changes the visual reference by fragmenting, stretching or even squeezing the reference in order to sew it to the needs of the design (Do and Gross, 1995). Human reasoning by either metaphor or analogy in the field of psychology is illustrated like the following (Figure 27).

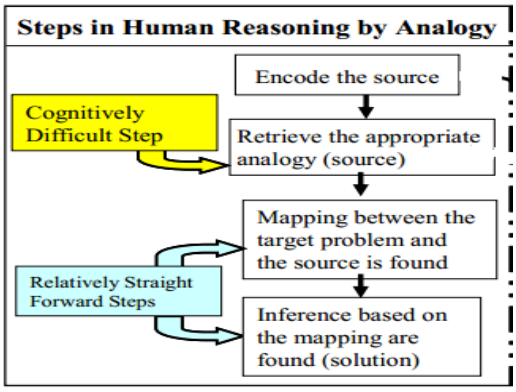


Figure 27: Process steps in human reasoning by metaphor and analogy (Hey *et al.* 2008, p. 285)

Something that has an impeccable effect on the design problem solving process is the type of the problem that problem-solver is dealt with. A problem at hand can be classified as ill-structured (also known as ill-defined) or well-structured (also known

as well-defined) (Simon, 1984; Casakin, 2002). Ill-defined problems refer to designs and scientific discovery problems in which the problem solver is faced with more than one possible solution; hence, he or she uses "… all kinds of configurations [that] may provide bases for a representation that would be considered a satisfying solution to the problem" Goldshmidt (2001, p. 208). While in well-defined problems, a problem solver deals with clear initial requirements, for the ill-defined problem solver, requirements are not specified. In the former, the goals are clear while in the latter they are ambiguous; hence in ill-defined problems, a problem-solver may come across as a large number of obscure solutions as well as novel ones which cannot be found by known algorithm. This however, is not that difficult in well-defined problem conditions because a problem-solver can seek help from a set of known operators and algorithms.

According to Goldschmidt (2001), analogical reasoning can be either rule-based or similarity-based. The latter is a kind of reasoning that pertains to largely visual, figurative qualities. Even though both play important roles in problem-solving in design thinking, for ill-structured problems, imagistic similarity-based reasoning is more useful. That is, because the problem-solver cannot really retrieve or use instruments that are specified for reaching a solution from the get-go. According to Kaufmann (1980), similarity-based reasoning gives a designer the freedom of imagery from rules which lead to creativity and problem solving.

Although it has widely been argued that analogies and metaphors are beneficial engines in problem-solving design, their influence on creative solution is not always positive (Casakin and Goldschmidt, 1999; 2000; Eckert, Stacey and Christopher, 2005; Malaga, 2000; Cameron, 2002 to name a few). As Smolkov (2006) argues, when a failed detection happens, or when the mapping is based on unfit design

solution, influences are not only negative, but also prevent problem-solver's creativity to come up with a potential creative solution.

The negative impact of analogy over creativity is called the fixation effect of analogy (Eckert, Stacey and Christopher, 2005). Similarly, metaphors can sometimes be useless and confusing if they are not understood in design. Baumer, Sinclair, and Tomlinson (2009) discuss that sometimes design students themselves select the wrong source for the target problem at hand. Sometimes even if they have access to the right sources, they are not cognitively expanded enough to correctly map the right aspects of the source to the target. Like analogies, metaphors can limit creativity and lead to faulty thinking and less-quality design product (Saffer, 2005).

A good metaphor, according to Tourangeau and Sternberg (1982) is a kind that a) involves two distant domains; hence, has high between-domain distance; b) shows low within-space distance between the source and target items in their distant respective spaces. For example, the metaphor *Brezhnev is a hawk*, according to Gentner et al., (2001, p.204), is considered a good metaphor because Brezhnev and hawk occupy the same relative position in their domain spaces, from domain of birds to domain of politicians.

2.11 Studies on Metaphor

This section presents two types of studies. First, the one in which metaphors have been investigated in order to shed light on various concepts used in design domain. The second type represents metaphors that have been used as tools to enhance critical thinking by reasoning with metaphor.

In order to study the ways in which architects communicate ideas and concepts about their projects using metaphors, Mansilla (2003) focused only on two basic categories of a *building* and a *city* and distributed a self-devised questionnaire to 62

architects in order to find out various ideas and images architects have about the *building* and the *city*. The findings show that metaphors play important roles for architects, and that they consciously and even sometimes unconsciously use metaphors at work. Furthermore, the detailed analysis of the results show that metaphors can be grouped into three categories: 1) living organisms, 2) objects and 3) miscellaneous. Interestingly, many architects use "building is life" and "city is life" showing that they are both living entities since they are both part of people's life. The next discovery was about the situation and the person(s) who architects use metaphor with and the result shows that first of all they use metaphors mainly in public talk and second, they use it with other architects to communicate and adapt technical concepts more manageable.

With the aim of sharing in design teaching and culture, Hey and Agogino (2007) investigated the common metaphors used to structure our understanding of important design concepts and design itself from selected chapters of nine widely used English language design textbooks. To achieve this, two researchers conducted a qualitative content analysis on "ideas", "problems", and "solutions" metaphors in the target domain. After collecting the metaphoric statements, they categorized metaphor instances relative to each metaphor. For example, for the "ideas" metaphor all qualifying statements were listed like this: ideas can be 'refined', 'polished', 'amassed', 'shared', 'bounced around' to name a few. Then each metaphor was mapped to its source domain and finally the implications of the use of metaphors in design were analyzed. The result of the study is summarized in below:

1) "Problem" metaphors can characterize puzzles (they can be solved and resolved), locations (they can be explored and approached), gaps (there are gaps in the problem space), objects (they can be divided and decomposed), formulas (they can be

formulated) and obstacles (they can be barriers); 2) "Solution" metaphors can symbolize living entities (they can appear and have origins), children (they can be borne), locations (they can be arrived at), objects (they can be sought and discovered), products (they can be produced) and resources (they can be suggested by analogy); 3) "Ideas" as metaphors can represent living entities (they can emerge or come), children (they can be embryonic), explosives (they can be triggered off), liquid (they can flood and flow), locations (they can lead to a solution), objects (they can be created), products (they can be modified) and resources (they can be exploited).

Their findings also show that out of 396 metaphors identified some capture largely universal, and some those specific to an author's personal approach to design. In other words, different scholars approached the design process differently. For instance, textbooks which adopted more systematic approaches to design emphasized "Design is Search" and "Design is Decomposition." Furthermore, our understanding of design reflects the metaphors we use. For example, by stressing the "Design is Search" concept, the textbook authors considered "problems", "solutions" and "ideas" more as location metaphors in the "Design is Decomposition" concept, and in the "Design is Exploration," paradigm and design methods convey maps, guides, and signposts.

One year later, Hey, Linsey, Agogino and wood (2008) conducted a cross-cultural comparison between design metaphors in 10 design textbooks from US (6 textbooks), Germany (1), UK (2) and Mexico (1). In it, they determined whether American design students are taught similar perspectives on design as other countries. Like in Hey and Agogino's (2007) study, the authors first extracted the metaphor instances, then categorized them, and finally identified the coherent

metaphors. Adopting content analysis, more than 430 metaphors were extracted for "ideas", "solutions" and "problems" from all design textbooks. Then two researchers identified the overlapping metaphors between American and the non-American textbooks. The findings showed an 86.5 % overlap between the textbooks from Germany, Mexico and the UK, and the the US. The authors believe, however, that this strong overlap may hinder critical thinking in design domains, especially in higher education.

To determine the role of metaphor and analogy in creative design, in the second half of this research, 12 mechanical engineering teams designed a device to shell peanuts. Discourse analysis was adopted to code teams' written communication (words only, sketches only, or a combination of both) for metaphors and analogies used. Although in this study, analogy coding worked on explicit references to other designs such as "analogy to potato peeler", nothing captured the criteria met for coding metaphors. First of all, the study findings show that the teams used both metaphors and analogies to solve the problem. While 65% of the design teams used metaphors, the rest used analogies in their design process. When the design process shared between the problem definition, and concept generation phases, the findings revealed that metaphors primarily reflected the early problem framing stages of the design process. As such, they enhanced the understanding of a design situation whereas analogy mainly helped map the causal structure between a source idea in one domain, and the target design problem solved in the concept generation phase of the design. This finding is in line with Casakin's (2006a) that for understanding the problem, metaphors are employed, while analogies have utility in generating solutions.

With the goal of gaining insights into architectural students' metaphorical reasoning in design problem solving, Casakin (2006a) investigated fifty-five first year architectural students, who participated in the design task to design a 200-metro long pathway located in an urban area. In order to do that they had to choose a crowded area with low-rise dwellings. Sixteen four-hour organized sessions dealt with the pathway design. Since as junior students, the subjects lacked any prior design experiences, they were guided in using metaphors in design. While designing, students provided example(s) of metaphors in their design problem-solving process, and at the end of the task, the students provided feedback in a survey with four main questions: 1) What did you learn from the use of metaphor? 2) How did the use of metaphor help you to design? 3) What were the difficulties in using a metaphor as a design aid? And, 4) How will you use metaphors in the future? In front of each question, the students a few alternatives to choose from, and Chi-Square test was applied to statistically analyze the data. For the first part of the study, students used variety of metaphors from "a pathway as a fountain to light", to "a pathway as a roundabout experience", to "a pathway as a cup of sugar into a glass of water" and to "a pathway as a hurricane" that enabled them to come up with innovative design solutions. For the second part, statistical differences for the first question were found for this answer: "to understand a design situation anew", for the second question, this answer: "to clarify the design problem", and for the third question, this answer: "to transfer abstract features from the metaphor to the design problem", and finally for the last question, this answer: "as an original way to deal with design problems".

In the same year, Casakin (2006b) conducted a similar study to investigate the use of metaphor in different stages of the design process. However, they mainly focused on the effect of metaphor on the following themes: a) concept definition and framing

of a design situation, b) specification of goals and constraints, c) mapping and transference, and d) application of the design concept to the design problem, and development of the design solution.

Fifty-eight junior architectural students participated in this study, and were asked to design a 200-meter pathway in an urban context (like in Casakin's, 2006a). Based on the aims of the study mentioned above, the students were given a short five-likert questionnaire (1 for not complex at all to 5 for very complex) to answer the following 5 questions: 1) How complex was choosing metaphors to define the design concept, and framing the design situation anew?; 2) How complex was using metaphors to specify design goals and constraints?; 3) How complex was using metaphors to establish a system of relationships between the design concept and the design problem?; and, How complex was the use of metaphors in order to apply a concept to the design problem, and develop an unconventional design solution? The results show that students used metaphors in various stages. However, its use in initial stages of the design problem solving was less complex. In other words, while dealing with defining the design concept and framing the design situation, students could use metaphors while during mapping and transferring concepts, and generating goals and constraints stages, students encountered difficulty to use metaphor, or enhancing their design quality.

In another research, Casakin (2007), assessed the use of metaphors by sixty-five junior architectural students in design problem solving, with a particular focus on design creativity. In order to improve the environmental quality, in that study, the students designed a mixed-use compound consisting of 15 dwellings plus a series of small public buildings while writing their design goals, requirements and programmatic needs. Within 18 sessions, the students were first briefed about the

concept of “urban life”, followed by visiting the actual site (the old bus station) where they were supposed to fit their designs to, third they familiarized themselves with metaphors used in exploring the design problem, and as for the final ten sessions, the students started developing their design concepts and generating solutions. By the end of the design session, architectural students assessed a 5-likert questionnaire which referred to design creativity evaluation, and the metaphor use in their design process. The first finding reveals that when it comes to evaluating design creativity, ‘innovation and constraints consideration’ emerged as the first factor followed by ‘utility and adaptability’. Out of 14 variables to measure metaphor use in design, architectural students considered metaphors as tools for generating innovative design solutions. This however, is not in line with the findings of other empirical studies (see for example Casakin, 2006a, 2006b, and Hey et al., 2008), where they reported that the aid provided by metaphors developed unconventional solutions, more fruitful in the initial stages of the design process (known as conceptual design). According to Casakin (2007) and Lawson (2004), this might be attributed to lack of experience and developed cognitive schemas on behalf of novices.

Casakin (2012) extended the previous research on metaphor by analyzing the relationship between metaphorical reasoning and architectural design with a population of 65 architectural students. Before defining a problem (ten innovative habitats), they explored science, engineering and art domains in order to generate metaphors and retrieve concepts. After completing the design task, they gave feedbacks in two questionnaires. Casakin’s (2007) had previously used the first questionnaire in a study with 14 questions. The second questionnaire reflected Casakin’s (2008) study with 11 questions dealing with the attitudes experienced

during the design problem solving process. Although the samples of the questionnaires were neither included here nor in Casakin' (2007) and (2008) studies, the following illustrate samples of three questions regarding both questionnaires:

Metaphor use questionnaire: 1) Metaphors organize design thinking; 2) metaphors help ask critical questions to frame design situations; 3) metaphors help analyze the problem from different viewpoints. For this type of statements, the subjects assessed their ideas based on a four Likert-scale ranging from 1 representing 'strongly disagree' to 4 representing 'fully agree'.

Design questionnaire: 1) during the design process I enjoyed taking risks and facing challenges; 2) during the design process, I tried to transcend the known and familiar; 3) the goals and intentions helped me define the design problem. These statements were assessed using four Likert-scale like the one explained above.

Analyzing the "metaphor use questionnaire" shows that design students found using metaphors more important to produce innovative outcomes as well as analyzing and reflecting on design problems. Furthermore, the findings reveal that there is a significant correlation between metaphor and design in general. Most importantly, by analyzing and reflecting on design problems, metaphors can influence restructuring and reforming design problems. Looking at the design situation from a different perspective and focusing on novel relations, according to Casakin (2008), has a positive correlation with creativity in design because it makes for applying novel thinking which at the end positively affect the quality of final result.

From several types of mental representations, Dixon and Johnson (2011) studied propositions, metaphors and analogies to see the extent to which novices and experts use them in the problem and solution situations as well as the extent of attributes of

these mental representations used by students and the professionals in design problem solving. 3 junior students, 3 senior students and 4 practicing engineers from United States participated in that study. Like many other studies, the above-mentioned participants faced an ill-defined design problem to solve and think out loud, where they adopted and taped including their notes and sketches for further data analysis.

The think aloud utterances were then transcribed, coded, and the problem space was separated from the solution space. The former identified primarily activities done by the participants including information gathering, problem definition, identifying the constraints, specifying evaluation criteria, and initially, searching for alternative solutions. The latter however, included activities that involved decision-making between two alternatives, developing a specific solution, and determining relevant specifics.

The following summarize the findings of the study: (1) due to the lack of experience and the nature of the problem at hand, engineering students spent a longer period of time on the problem space compared to professionals; (2) 59% of engineering students' mental representations focused on the solution space while 76% for professional engineers; (3) professionals rarely used analogies or propositions at initial stages of their problem solving process; (4) metaphors were rarely used compared to other mental representations (5% students and 6% professionals); (5) probably influenced by key terms in the design question, the types of metaphors and analogies used by engineering students were closer while professionals were capable of using both close and distant domains; and (6) students used heuristics while professionals equally used both heuristics and formulas.

For the purpose of better comparison between all the above mentioned studied on metaphors, table 2 summarizes the major points:

Table 2: Summary of specifications of reviewed metaphor studies

	Author/year	Objectives	Participants	Design/ instrument	Findings
1	Mansilla (2003)	to study the ways in which Spanish architects communicate concepts of "city" and "building" using metaphors	62 architects	Quantitative and qualitative a self-devised questionnaire	1. the metaphors used can be grouped into three categories namely: a) living organisms, b) objects and c) miscellaneous 2. architects use metaphors mainly in public talk and second, they use it with other architects to communicate and adapt technical concepts more manageable
2	Hey & Agogino (2007)	(1) What are the common metaphors we use to structure our understanding of important design concepts and design itself? (2) How does our understanding of these concepts influence our approach to creative design?	1. Extracting metaphors from design texts [9 widely used English language engineering design textbooks] 2. categorizing metaphor instances 3. identifying underlying metaphors	Qualitative content analysis was done on the target domain of "Ideas", "Problems", "Solutions", "concepts" and "design" metaphors.	Totally 396 metaphors were identified in these textbooks. The results also show that some metaphors are largely universal and some are specific to an author's personal approach to design. Different overall perspectives on design leads to different metaphors for the core design concepts e.g. a view of "Design is Search" is likely to employ the metaphor problems are ***Locations***, whereas a view of "Design is Decomposition" is likely to employ the metaphor problems are ***objects***.
3	Hey, Linsey, Agogino & wood (2008)	(1) To determine whether US design students are taught similar perspectives on design as other countries, (2) to determine the role of metaphor and analogy in creative design	(1) broke down the analysis in to 6 US design textbooks, 1 from Germany, and 2 from the UK and a Spanish design textbook in use in Mexico (2) 12 teams were assigned to design a device to shell peanuts.	Content analysis/ (a) Extracting instances of metaphors from design Texts. (b) Categorizing the metaphor instances. (c) compared the overlap of qualifiers for the design concepts 'ideas,' 'problems' and 'solutions,' between the US Textbooks and non-US textbooks. (2) Discourse analysis / analyzing written communication/ the text was coded for metaphors and analogies used.	Study (1): over 430 individual metaphor instances were extracted from the textbooks. Textbooks from Germany, Mexico and the UK share 86.5 % overlap of qualifiers for "ideas", "problems" and "solutions" with those present in the US textbooks. Study (2): significantly, the results suggest that metaphor use is primarily employed in the early problem framing stages of design to enhance understanding of a design situation. Conversely, analogy is mostly used in the concept generation phase of design to map the causal structure between a source idea in one domain to the target design problem being solved.
4	Casakin (2006a)	to gain insight about architectural students' metaphorical reasoning in design problem solving	fifty-five first year architectural students	Task: To design a 200-metro long pathway located in an urban area Survey questionnaire with the following questions: 1) What did you learn from the use of metaphor? 2) How did the use of metaphor help you to design? 3) What were the difficulties in using a metaphor as a design aid? And 4) How will you use metaphors in the future?	1. students used various metaphors 2. Statistical differences for the first question: "to understand a design situation anew",. For the second question: "to clarify the design problem", for the third question: "to transfer abstract features from the metaphor to the design problem". Last question: "as an original way to deal with design problems".
5	Casakin (2006b)	To investigate mainly: a) concept definition and framing of a design situation, b) specification of goals and constraints, c) mapping and transference, and d) application of the design concept to the design problem, and development of the design solution	fifty-eight junior architectural students	Task: To design a 200-metro long pathway located in an urban area Instrument: short five-Likert questionnaire	1. The results show that students could use metaphors at various stages; however, its use at initial stages of design problem solving was less complex. 2. while dealing with defining the design concept and framing the design situation, students could use a great deal from metaphor while in mapping and transferring of the concept, and generating of goals and constraints stages students encountered difficulty to use metaphor to enhance their design quality.

6	Casakin (2007)	The study aims to assess metaphor use by students in design problem solving, with a particular focus on design creativity	65 first-year architectural Ss from Israel were chosen to design a mixed-use compound consisting of 15 dwellings and a series of small-size public buildings for the Old Bus Station. 18 sessions/ 2 meetings per week/ 4 and half hours per session	(a) Ss produced a brief about design goals, design requirements, and programmatic needs. (b) quantitative (self-devised survey questionnaire) 11 Qs: attitudes about design creativity 14 Qs: attitudes about the role of metaphors in design	(1) These findings suggest that when students are requested to evaluate design creativity, their attention is mainly directed toward the innovation of a design. Another important issue is that for a design to be creative, it must first satisfy initial design constraints. (2) First factor: 'Synthesis of design solutions,' the second factor: 'Analysis of design problems,' and the third and weakest factor: 'Conceptual thinking.' the use of metaphors was seen by ss mainly as a tool supporting the production of innovative design solutions. Only thereafter, ss valued the analytical and conceptual role of metaphors in design. First year design students who lack expertise and have not developed cognitive schemas might have found it easier to think in terms of concrete and practical situations while dealing with the design situation.
7	Casakin (2012)	To analyze the relationship between reasoning by metaphor and architectural design	65 architectural design students	Task: design ten innovative habitats Instrument: (1) Metaphor use questionnaire (2) Design questionnaire	1. design students found using metaphors more important to produce innovative outcomes as well as to analyze and reflect on design problems. 2. metaphors can have an influence on restructuring and reformation of design problems
8	Dixon & Johnson (2011)	1. How does the frequency of propositions, metaphors and analogies used by engineering students and professional engineers differ in the problem and solution space? 2. How do the attributes of the propositions, metaphors and analogies used by engineering students and professional engineers differ whet they are solving a design problem?	Engineering students (3 juniors and 3 seniors) and practicing engineers (4 engineers who have worked for 7 to 40 years) from Midwestern United States. Each participant was given the same engineering design problem for which to find a conceptual solution.	Comparative case study/ a purposeful, maximum variation sampling/ qualitative approach using "think aloud" verbal protocol analysis. Al the notes and sketches were collected too. After finishing the task, an interview was conducted to clarify sections of the protocol.	(1) 59% of engineering students' mental representations were generated in the solution space as compared to professional engineers only using 2% of mental representation in the problem space (76% used in the solution space). (2) the total number of metaphors used was small in comparison to other mental representations (5% students and 6% professionals). (5) the use of analogy and propositions is more prevalent, particularly within the solution space. (3) the types of metaphors used were not from distant domains and seemed to be influenced by key terms in the design question. (4) students used heuristics while professionals used both heuristics and formulas more equally.

2.12 Studies on Analogy

During the past decade, some theoretical works and few empirical studies have addressed analogy. In those empirical studies, either novice students or experts assessed their designs by using analogy. The following summarize these studies. Casakin and Goldschmidt (1999) first studied whether novices use analogical reasoning, and second, the extent in which visual analogy helped novice and expert designers to improve design problem-solving. 61 architectural designers participated into three different groups of experienced designers (7 years of experience), advanced architectural students (seniors), and finally, beginning architectural students (juniors) in order to represent three levels of professional expertise with high, moderate and low design experience. Although this was an experimental design, this study was conducted under two experimental conditions, namely test condition and control condition. But nothing has been mentioned about the number of participants in each group.

It is not really clear whether all 61 participants sat for two conditions which is highly unlikely, or the group engaged between two and half of the participants were part of the test condition, and the other half part of the control condition. It is however, clear that individuals were evaluated during the design process, designing the prison, the viewing-terrace and the dwellings. For those subjects as part of the test condition, visual displays were presented (with-in-domain and between-domain visual displays) and they were specifically told to use analogy in problem solving. For the control condition, nevertheless, subjects addressed the same visual displays, where the other group dealt with but were not told or encouraged to use analogical reasoning to solve design problem. Think aloud protocol was adopted, sessions videotaped (qualitative part), and design performance was assessed according to the

quality of design ideas and design solutions by three experienced judges (quantitative part). However, another shortcoming in this study was that the authors did not exactly mention how inter-rater reliability between judges was achieved. That is the degree of agreement among raters or judges in this study.

The qualitative result from think aloud protocols by novices show that there is a significant correlation between use, misuse and lack of use of analogy in design. The novice problem solvers who successfully completed the design-problem (e.g. the viewing terrace) used analogy first, and used deep analogies subsequently. In other words, among many visual displays at hand, a given problem solver chooses the right sources (some within-domain and few between-domain visual displays), and from those sources transferred deep similarities of relations between the source and the target domains. However, another novice problem solver who used analogy out of all visual displays available, could not pick the ones, he shared principles with the problem, was not able to successfully complete the task due to inability to take advantage of analogical reasoning.

Furthermore, the quantitative results of the study show that using visual analogy improved the quality of design across the board, but was particularly significant in the case of novice designers despite their lack of strong knowledge structure. Similar findings were reported for experts. Among the two professional architects who were provided with visual displays and were told to use analogical reasoning, the professional architect successfully fulfilled the task that made higher-order relations between a source and the target problem (deep analogies). The quantitative results also show that the design performance of professional architects in experimental group (explicit requirement to use analogy) was greater than the control group. Although under “Subject” sub-heading, Casakin and Goldschmidt (1999) mentioned

having three groups with three different experience levels; however, while reporting their findings, nothing has been mentioned about advanced architectural students (the second group) with moderate experience level.

Casakin (2003) focused specifically on the differences between the performance of novices and experts in terms of using analogy in architectural design. In his study, he he divided twenty-six participants into eleven professional architects with minimum seven years of experience, and fifteen novices from undergraduate architectural students. The subjects were presented with visual displays and were asked to use analogical reasoning in three design problems, as in the Casakin and Goldschmidt's (1999), prison the viewing-terrace and the dwellings. In the prison problem, subjects had to design a single-story prison including 80 cells with one side of each cell facing the exterior. The viewing-terrace problem challenged the subjects with a two part 30 square meter viewing terrace with one part with maximum contact with the ground while the other part with the minimum contact.

Finally, in the third problem, the subjects designed 20 small compact dwelling units with minimal exposure to the exterior. Think aloud protocol was adopted for twenty-minute session to solve the design problem and the session was videotaped. Subjects' performance was assessed by three judges based on the following criteria: a) identifying the visual displays (2 points for identifying between-domain visual displays and 1 point for within-domain ones), b) retrieving the visual displays (1 point for retrieved between-domain display and 0 point for retrieved within-domain display), c) using analogical principles (in the scale from 1-5, 3-5 was assigned for those who used deep analogies and successfully solved the design problem and 1-2 for those who did not), d) adding constrains (1 point for additional constraints and 0 point for no additional constraints), and e) producing alternative design solutions (1

point for alternative design solutions and 0 point for only one solution). The findings show that unlike what it was hypothesized that novices are not able to make high-order relations between the source and target domain, undergraduate architectural students were able to use deep analogs and retrieve deep principles just like professionals. It was also found that among all between-domain and within-domain visual displays, experts used more between-domain visual displays while novices used both domains equally. Another significant finding was that when it came to finding additional constraints to the design problems, it was only experts who were able to add extra constraints. Novices; surprisingly however, were able to produce a large number of alternative solutions by the use of visual displays and analogical reasoning.

Another study conducted by Cubukcu and Dundar (2008) studied the extent in which creativity can be taught by using visual analogy. In this study 52 first year students studying city and regional planning were asked to design eight compositions (ill-defined problems) to convey the expression of eight design concepts including: a) harmony, b) contrast, c) emphasis, d) cluster, e) unity, f) variety, g) radial balance, h) asymmetrical balance. The participants conducted this study in four days, and in each day they came up with two design concepts using only three basic forms: square, triangle and circle. For half of these concepts (harmony-contrast and unity and variety), students were not presented with any visual references, whereas for the other half they displayed and showed some visual images from between-domain and within-domain analogy. While students were presented with visual references, they were explicitly told to use analogical reasoning to fulfill their tasks. Students' creativity was measured subjectively on a scale of 1-7 by four experts. Findings showed affirmative effects of visual analogy on creativity because students achieved

higher creativity score when visual clues were present than when they were absent. The authors believe that this kind of findings have a great role in design education.

Casakin and Goldschmidt (2000) studied the relationship between the role of guidance and explicit instructions and analogical reasoning by professional and design student architects. The total number of the participants was 29 divided into two groups of 17 professionals and 22 students (undergraduates in their third, fourth and fifth year of their study). They were asked to solve design problems under two conditions of test and control. In the test condition, participants were provided with visual displays and procedural instructions and told to use analogical reasoning; however, they were not provided with specific analogical relationships between the sources and the target problem. In the control condition, the participants had to solve the same design problems and were provided with the same visual references; nevertheless, they were not given explicit instructions about analogy use and they were not told explicitly to use analogical reasoning. The findings revealed that explicit guidance to use analogy plays an important role in the manipulation of visual sources and the quality of design solution. The authors have also emphasized on the number of visual displays used as stimuli and suggested to use a collection of large number of visual references specially the ones with a figurative emphasis rather than schematic visual displays from abstract sources. The findings also show that with or without explicit instructions to use analogy, both experts and students had a cognitive ability to make use of visual references in order to enhance their design problem solving; however, with explicit instructions, they were more conscious to use spontaneous analogical reasoning. Accordingly, pedagogical training to use analogy was stressed using a large collection of visual images.

10 years later, Casakin studied visual analogy in two design conditions with 17 architects, 22 advanced students and 24 novices comprise of 63 architectural designers to solve three ill-defined problems and 54 designers including 17 architects, 17 advanced and 20 novice students to solve two well-defined problems. Each group was again divided into two groups. Half of those who were supposed to solve ill-defined and well-defined problems were exposed with visual displays and were told and reminded that some of the displays may serve as potential analogues for their problem at hand and the other halves were presented with the same visual displays but were not encouraged to use analogy. Architectural students and the experts who were requested to solve well-defined problems were given a staircase and a parking garage as their tasks while ill-defined problem solvers were given a prison, a viewing terrace and dwellings as their tasks to solve (like in Casakin and Goldschmidt, 1999). At the end three professional judges scored the solutions on the scale of 1-5. The findings show that in the first condition that novices and experts were presented with visual displays and were told specifically to use them to solve their well-defined problems, there is not a significant difference between the quality of design between students and experts. Nevertheless, this difference was remarkable when students were not guided by their instructors to use analogical reasoning. Not surprisingly though at this point, professional architects could use their prior knowledge to retrieve the relations between the source domain and the target one even without being told to do so. Similar to well-defined problem condition, no differences in performance were found between professionals and advanced architectural students when they were presented with visual displays and were given instructions to use analogy; however, novices did not produce satisfactory solutions as well as advanced students. Likewise, with no explicit instructions to use analogy,

experts and advanced students could apply analogical reasoning whereas novice architectural students struggled to establish structural relations between visual displays and the ill-defined problem at hand.

The above mentioned result; however, was not partially in line with the findings of the study Casakin presented five years earlier. In 2005 Casakin studied the relationship between visual displays and well-defined and ill-defined problems with absolutely no instructions to use analogy on behalf of instructors as well as the relationship between the present and absent of visual displays and the quality of design. In that study Casakin (2005) used both within-domain and between-domain visual displays for 53 architectural designers with three level of expertise (architects, advanced and novice students) to solve ill-defined problems (the same as Casakin's, 2010) and 63 architectural designers comprised the same level of expertise to solve well-defined problems (the same as Casakin's, 2010). Visual displays were present for half of ill-defined problem solvers and were absent for the other half. The same procedure was followed for well-defined problem solvers. The disagreement between the two findings in two different years was on the effective use of visual displays on novices' design performance even without being given instructions to use analogy in ill-defined condition. Since it is not really clear what and how many visual displays subjects of both studies were presented with, perhaps the number of the displays as well as the richness of the collection of visual displays could play an important role in novices' ability to make abstractions from visual sources and to retrieve and apply analogical reasoning in ill-defined problems. In the case of well-defined problems, the results show that even though professional architects could establish high-level relations between the sources and the well-defined problems, novices remained

unable to do so even when specific analogical relation needed to be established between the source and the well-defined problem at hand.

The design literature is rich in examples of metaphors and analogies use in design. However, with the exception of a few studies (e.g., Casakin and Goldschmidt, 1999; Casakin and Goldschmidt, 2000; Casakin 2006; Coyne, 1997), metaphorical and analogical reasoning were not empirically investigated in design in architectural domain. It is claimed that more research is needed to study the contribution of these cognitive strategies to problem solving of conceptual design. The main points of the above mentioned studies have been highlighted in Table 3.

Table 3: Summary of specifications of reviewed analogy studies

	Author/year	objectives	Participants	Design/ instrument	Findings
1	Casakin and Goldschmidt (1999)	1) To verify to what extent the use of visual analogy helps novice and expert designers to improve design problem-solving.	61 architectural designers divided into three different groups: 1) 17 experienced designers (7 years of experience); 2) 23 advanced architecture students (seniors); 3) 21 beginning architecture students (juniors) TWO CONDITIONS: a) test condition (solving design problems with visual displays provided and with explicit requirement to use analogy; b) Control condition (solving design problems with visual displays provided without explicit requirement to use analogy). Three different design problems: 1) the prison, 2) the viewing-terrace, 3) the dwellings	Quantitative and qualitative analyses of architectural design problem-solving episodes Think aloud protocol was adopted and sessions were videotaped. Design performance was assessed according to the quality of design ideas and design solutions by 3 judges. An ordinal scale from 1 to 5 points was established to assess the quality of the design ideas and design solutions (1-2: the design idea and solution was not satisfactory; 3-5 the design idea and solution were satisfactory)	1. The results indicate that the use of visual analogy improves the quality of design across the board, but is particularly significant in the case of novice designers. 2. The quantitative results also show that the design performance of professional architects in experimental group (explicit requirement to use analogy) was greater than those in the control group. 3. the quantitative results of the study show that the use of visual analogy improved the quality of design across the board, but was particularly significant in the case of novice designers despite their lack of strong knowledge structure.
2	Casakin (2003)	To study the differences between the performance of novices and experts in terms of using analogy in architectural design	twenty six participants (11 professionals+ 15 novices)	Task: prison, the viewing-terrace and the dwellings Instrument: Think aloud protocol and subjects' performance was assessed by three judges	1. undergraduate architectural students were able to use deep analogs and retrieve deep principles just like professionals. 2. among all between-domain and within-domain visual displays, experts used more between-domain visual displays while novices used both domains equally. 3. only experts were able to add extra constraints. 4. novices were able to produce a large number of alternative solutions by the use of visual displays and analogical reasoning.
3	Cubukcu & Dundar (2008)	Can creativity be taught using visual analogy?	52 first year students (from Turkey) studying in city and regional planning department Participants were asked to design 8 compositions (ill-defined problems) to convey the expression of 8 design concepts including: a) harmony, b) contrast, c) emphasis, d) cluster, e) unity, f) variety, g) radial balance, h) asymmetrical balance. Participants had to only use 3 basic geometric forms: square, triangle, and circle. The study: for half of the concepts (harmony-contrast, and unity-variety) the	The creativity was measured subjectively by 4 experts.	Findings show affirmative effects of visual analogy on creativity. Students achieved higher creativity score when visual clues were present than when they were absent.

			instructor did not show any visual displays and showed some visual images for the other half (emphasis- cluster, and radial balance- asymmetrical balance) For each concept, half of the visual displays were chosen from between-domain analogies and the other half from within-domain analogy.		
4	Casakin and Goldschmidt (2000)	To study the relationship between the role of guidance and explicit instructions and analogical reasoning by professional and design student architects.	29 participants divided into two groups of 17 professionals and 22 students	test condition: participants were provided with visual displays and procedural instructions and told to use analogical reasoning; however, they were not provided with specific analogical relationships between the sources and the target problem. control condition: the participants had to solve the same design problems and were provided with the same visual references; nevertheless, they were not given explicit instructions about analogy use and they were not told explicitly to use analogical reasoning.	1. The findings revealed that explicit guidance to use analogy plays an important role in the manipulation of visual sources and the quality of design solution. 2. with or without explicit instructions to use analogy, both experts and students had a cognitive ability to make use of visual references in order to enhance their design problem solving; however, with explicit instructions, they were more conscious to use spontaneous analogical reasoning. 3. pedagogical training to use analogy was stressed using a large collection of visual images.
5	Casakin (2010)	(1) To understand how designers with different level of expertise apply analogical thinking when solving design problems (ill-defined and well-defined) (2) To study differences between novice and expert designers in the use of visual displays.	ill-defined: 17 architects, 22 advanced students, 24 novice students = 63 well-defined: 17 architects, 17 advanced, 20 novices= 54	Half of those who were supposed to solve ill-defined and well-defined problems were exposed with visual displays and were told and reminded that some of the displays may serve as potential analogues for their problem at hand and the other halves were presented with the same visual displays but were not encouraged to use analogy.	1. The findings show that in the first condition that novices and experts were presented with visual displays and were told specifically to use them to solve their well-defined problems, there is not a significant difference between the quality of design between students and experts. 2. with no explicit instructions to use analogy, experts and advanced students could apply analogical reasoning whereas novice architectural students struggled to establish structural relations between visual displays and the ill-defined problem at hand.
6	Casakin (2005)	To study the relationship between visual displays and well-defined and ill-defined problems with absolutely no instructions to use analogy on behalf of instructors as well as the relationship between the present and absent of visual displays and the quality of design.	a) 53 architectural designers to solve ill-defined problems b) 63 architectural designers to solve well-defined problems	Visual displays were present for half of ill-defined problem solvers and were absent for the other half. The same procedure was followed for well-defined problem solvers.	1. In the case of well-defined problems, the results show that even though professional architects could establish high-level relations between the sources and the well-defined problems, novices remained unable to do so even when specific analogical relation needed to be established between the source and the well-defined problem at hand. 2. effective use of visual displays on novices' design performance even without being given instructions to use analogy in ill-defined condition.

2.13 Summary

As Table 2 shows, the studies on metaphor are generally categorized into two main domains. The first one consists of three major studies on the use of metaphor in communication and textbooks. What the first set of studies has in common is that metaphors are cognitive tools that help designers, architects, architectural students and instructors and design textbook writers to make sense out of intangible and abstract ideas and to communicate their ideas via more manageable and tangible concepts. In other words, metaphors in design domain play key roles in easing the communication among or within particular socio-professional groups such as architects, and they are used to structure design students' understandings of important design concepts in design textbooks. Consequently, we can conclude from the findings of these studies that architects and textbook writers purposefully or otherwise introduce metaphors to create more perceptible designs.

The second set of studies on metaphor consists of studies that empirically investigated the ways in which metaphors enhance human reasoning in design problem solving. What all these studies have in common is a set of problems that was given to architectural students to solve and while doing so the researchers investigated the role of metaphor in the design process and the quality of design solution. What all these studies come up with was that students could use various metaphors. Nevertheless, the study findings contradicted one another regarding the stages in which students use metaphors during the design process. Some studies (like Casakin, 2006a, 2006b, and Hey et al., 2008) reported that metaphors are used mainly at initial stages of design problem solving stage to clarify and understand the design problem while other studies (like Cakaskin, 2007) reported that metaphors are used at final stages of design process to generate innovative design solutions. This

paradoxical finding perhaps can be considered as one of the gaps in the literature that can be filled by the current study if the appropriate questions are asked from Iranian professional architects regarding the time when they think they use more metaphor in their design process. There were six studies identified in the reviewed literature regarding visual analogy (Table 3). Like metaphor studies, all these visual analogy studies tended to see if use, misuse or lack of use of visual analogy had a role in the quality of design solutions. Many of these studies were experimental in nature; the population was divided into two control and test condition groups consist of a mixture of novices and professional architects in order to represent various levels of professional expertise.

What made these studies different from metaphor studies was firstly the type of visual references that were presented to the participants and secondly the explicit or implicit instruction given to participants to take advantage of visual analogy to successfully fulfill the task given. The visual references were divided into two main categories of between-domain and within-domain analogies that based on the findings of studies played a great role in the design quality of the participants. Like the research on metaphor, the findings of all studies shared the finding that novices who use visual analogy (both within and between domains) enhanced the design quality. Nevertheless, all these studies emphasized the explicit guidance in using analogy because without it novice architectural students, although applied analogical reasoning at some point, reportedly struggled to establish deep analogs and retrieve deep principles. Surprisingly, only one study (Casakin, 2005) reported that novices could successfully apply high-order analogical reasoning even without being given explicit instruction to use analogy on behalf of their instructors.

Chapter 3

Use of Structure in Architectural Design

3.1 Introduction

Chapter 2 gave an overview of the concepts of metaphor and analogy, conceptual thinking, and the ways in which they help architects to see things differently. Using these two cognitive tools in conceptual design were then defined and reviewed based on some related theories within the broader context of other studies. This chapter focuses on the concept of structure and its related nuances such as structural terms, materials, elements, types, requirements and design. These nuances come into play and in broader terms, form the relationship between structure and architecture as the focus of this chapter.

Scholars have explored the role of structure in architecture for long. Macdonald (1994) argues that the famous architectural critic and writer Vitruvius, during the Roman empire, identified 'firmness', 'commodity' and 'delight'[1] as the three basic elements of architecture. Theorists have also introduced different methods for analyzing buildings, realizing their negotiated or designed qualities, and meanings. However, the Vitruvian method still stands valid for testing and critiquing buildings' various visual and actual qualities. Perhaps as the clearest of the three Vitruvian principles, 'commodity' refers to the building's functionality regarding its necessary ingredients for creating useful spaces for various purposes. 'Delight' on the other hand, refers to aesthetic considerations of people who come into contact with it.

[1] Firmitas, utilitas, and venustas

Symbolic meanings of its formal or volumetric specificity, the aesthetic characteristics of those forms, textures and colors, the elegance of solving programmatic issues pertaining to its design aspects, encompass the components of perceived 'delight'. 'Firmness' however, addresses the building's ability to keep its physical unity. Structure materializes how the building and its constituent parts firmly hold together. Without structure, there is no building, and obviously, no commodity. By the same token without appropriate structural integrity, there would be no delight either.

To perceive the architectural qualities, a critic or observer, must have some information about the structural characteristics relative to a given building. Therefore, as a structural object, we need sensorial abilities to observe the building, and if equipped with these qualities and knowledge, we can configure the structural and non-structural elements of a building. Some aspects of this issue address mechanical issues relative to statics, equilibrium and the properties of materials. Some other aspects focus on buildings' and their construction techniques.

The form of a structural skeleton directly impacts supporting the building. So architectural design affects structural design. However, this relationship has different forms and guises. As Macdonald (1994) describes, at one far side, an architect could not think through structural issues while designing a building, which hides related structural elements in the final design outcome. The Statue of Liberty, located at the entrance to New York harbor exemplifies this type of structural design, which involves a set of internal circulation, stairs, and elevators. As an example of early 20^{th} expressionist movement, and some recent deconstruction types of buildings, he Einstein Tower designed by Mendelson exemplifies another such structural and architectural design. While these buildings have structures, their technical and

structural necessities have not seriously affected their architectures. In other words, their respective structural elements have not exerted additional impositions, or negatively influenced their architectural beauty.

The flip side is designing buildings with giving more weight to structural considerations. The Munich Olympic Stadium, designed by the architects Behnisch and Partners, is a case in point. We can deduce different approaches to this type of relationship between structure and architecture. Introduced in the 1980s, Hi-tech architecture, characterize how structural elements trump architectural design, and have important roles to play in visual expressions of buildings both internally and externally. Gropius, Mies van der Rohe, Le Corbusier and others, in their early modern buildings, had used shapes which were widely influenced by different kinds of geometry, appropriate for steel and reinforced concrete structural skeletons.

Farrelly (2007) defines construction as relevant to architecture making, by way of its physical and material properties. On a bigger scale, a building consists of a structural system, i.e., roofs, walls and floors. But at the same time, it also requires a sets of details which explain different methods of combination and unification of structural elements. For example, a designed building should work effectively with systems like ventilation, heating or lighting, which prepare diverse and comfortable internal environments. Buildings as such, work like machines which include a series of interrelated elements and systems that make them overall to be effective and habitable.

Structures linked the building support systems with either solid construction structures (walls support the building), or framework construction structures (frame is independent of the building's walls and floors). Solid construction creates heavy, solid forms, and define buildings' interior spaces. Solid construction involves

masonry structural systems with patterns of stone or brick, or even concrete (either prefabricated out of site making) or in site making. Applying framework construction introduces potentialities for flexibility with internal construction and design, and positions of related openings. The structural frame could work with different materials such as timber, steel or concrete quickly, fairly adjustable to future requirements and conditions.

3.2 Integration of Architectural Design and Structural Design

Coordinating the general arrangement and the form with the building support play critical roles within the architectural structure domain. As such, the primary design stage of an architectural structure strongly correlates with the building's entire design process (Macdonald, 1997). The general building form's configuration can make selecting its respective structural arrangements much easier. Hence, architectural design operations could include structural design operations, and their respective decisions.

The structure is not a useless architectural component. It affects the spaces around it, and because of its important roles visually and technically, requires thorough architectural analysis. "Architects should allow their design ideas to drive the structural design" (Charleson, 2005, p. 208). Starting from its form and layout, and then structural detailing, the architectural design stage should encompass the structure in its entirety. Realizing a design concept and fortifying it, the architectural success of structure needs assessment and evaluation. This way of looking at structure not only does not limit design creativity, but indeed creates potentials and opportunities. This view releases structure from the barriers of formal practice and its two related aspects, namely, constructability and economy, and enables it to play more functional and aesthetic roles in architecture. Structural coordination with

architectural plans and sections give an additional sense of constructional reality to building representation. As one related type, exposed structure changes surfaces, spaces and viewers' experiences of architecture (Figure 28).

Figure 28: Industrial Park Office Building, Völkermarkt, Carinthia, Austria, Günther Domenig, 1996. The framed block supporting the cantilever and the lift and stair tower behind. (Charleson, 2005, p. 205)

Cooperation between architects and those with technical structural savvy is imperative. This relationship plays out in different ways, which ultimately, affect the connection between structure and architecture. Macdonald (1994) distinguishes between structure and architecture categorized as *structure as ornament.* This distinction includes using structural elements by predominantly visual principles. Three types of *structure as ornament* are as such conceivable. First, the structure may apply symbolically. In this proposition, the elements related to structural efficiency, (with topics such as aerospace industry and science fiction), serve as visual signs in transferring messages. In the second type, exposed structures may play key roles to visually exhibit somewhat unreal conditions. That is, the considered

shapes of exposed structures may be justified technically. However, they could only solve unnecessary technical problems created by designers. The third type includes expressing structures in creating legible buildings with technological trends. But visual characteristics follow more than merely coordinating of configuring a structural logic. We can always find examples of buildings which only have structures but nothing more. These buildings reflect technical issues and feasible structural elements without neglecting the needs of structure inevitably. Macdonald (1994) considers "structure without ornament" asserts as another type of relationship between structure and architecture. The phrase "structure as form generator" explains the relationship between structure and architecture too. That is, structural requirements strongly affect architectural shapes and forms. This kind of a relationship includes determining the structural elements that adapt to architectural forms.

Unlike industrial or agricultural products, architecture is a specific product showing spatial arrangement and the surrounding environment (Lin & Zhen, 2016). Each architecture uniquely portrays its special nature and interaction with its surroundings. No two natural objects in the world look exactly the same, as is also true for architectural products. As a result of architect's and structural engineer's collaboration, structures ought to consist of creative components. The ability of an architect's architectural design and a structural engineer's structural design must integrate and complement each other. Architects and structural engineers negotiate and coordinate the main ideas in the schematic design by pinpointing the entire structural integrity and wholeness, rather than attention to details of local elements. Only a deep conception of connections between different spatial and architectural shapes can increase the understanding of and attention to detailed elements.

The complete spatial and architectural form comes up first, followed by a thorough structural analysis of the whole structure, and the subsequent configuration of substructural systems and key elements. Major mechanics of design appropriate for structures including all essentials of architectural design come next. The design process including decisions on architectural design and mechanical and technical concepts occur quickly and in a timely fashion. A rational consideration of structural ideas can make the basis for undertaking detailed design. Architects ought to cooperate with structural engineers from the early stages of the design process.

The relationships between structural and non-structural elements of a building vary widely. As structural elements, walls, floors and roofs (space-enclosing elements), may resist and bear load in some buildings. In other buildings, however, like the ones with large glazing walls, we can have completely separate and independent structures from the space-enclosing elements.

The structure in all buildings connects the main body of the building or its skeleton to all non-structural elements. Regarding the visual consideration of structure, we can have wide variations. Macdonald (1997) explains that the building structure could have great preference in forming an effective selection of architectural character and design. Using structural elements with less apparent influences, on the other hand, can decrease the visual character of the structure. Hence, between these extremes, different conditions exist. In all debates, the building structure, with the help of its specific volume, influences its visual character, even when it is not directly visible. It is not important how the structure impacts visually, but thinking about technical issues must not be forgotten.

Incorporating imaginative, creative and economic functional structures into the buildings' design process, has always played a key role in architectural history, as

Smith (2016) argues. The architectural structure is nothing simple or neglectable, and is not something only for supporting loads and forces. Its role is certainly more than these things, and could have other roles in the design process too. The structure has important relationships with the planning and design of space, and can be used even to define spaces in any kind of building.

Professionally, engineers design structures, and architects design building forms. According to Dutton (2000), this meaningful and skillful definition is repeated on site, where structural elements (concrete, steel, etc.), and cladding elements (glass, aluminum cladding, etc.) work in their respective fields. This industry works around these differences among occupations and elements to the extent that everyone included with a considered project, reminds the standard procedure. The structure is used for a single idea of backing the building, while cladding is a cover around the structure to keep the building away from natural events. While construction, development, and business industries are becoming more specific, using weatherproof covers are becoming rather rare.

Integrating the design requires removing barriers among different professional, industrial, and construction fields. If we want to succeed, architects should understand the potentials and limitations of each of these respective domains along the design process. A high likelihood for integration in these debates, may require looking into alternatives such as structural skins. According to new technical and technological advancements, new lighter walls/skins/enclosures for buildings could act and function as their structures too. In these buildings, surfaces can be both structural and waterproof, thereby integrating the structure and the skin. The three-dimensional surface structures with special forms can result in optimal transferring of

loads in surfaces. Therefore, the architectural visual character of these buildings are expressions of structural and its formal needs.

Construction plays key roles in architectural projects. Therefore, structural engineers ought to work side by side with architects throughout the building design process. To reach and accomplish unified design outcomes, architects should share their main architectural design objectives with structural engineers. Having structural engineers work with architectural knowledge requires certain skills by itself, specially to reach a point of cooperative or collaborative design. This is clear for structural engineers who during their structural design calculations, might influence or impose their works on architects and the architectural design process. Structural engineers who have information about architecture, have big roles to play, and propose ideas for building design and project objectives. An engineer with not much clue about architectural design, renders somewhat useless in his or her role to help with the process. That is why these potential collaborations come in different types or guises.

Overall, three main categories for projects are conceivable: engineering design, architectural design, and design/build. An engineer leads the engineering design process. An architect guides the architectural design, and the structural engineering team has more role in the design/build stage. Structural engineers play parts in building design, for the predicted future, and will cooperate under the guidance of or alongside architects. The client or property owner chooses the architects for their related services and for specific reasons. Uihlein (2014) believes that architecture and its elements are widely unaddressed in educational fields. So they are not part of the professional knowledge of the structural engineer. Structural engineering is more a technical- oriented profession with professional safety and public ramifications.

There is no doubt about the importance of materials behavior and their efficiency in the professional world. Engineers take part in associative design by realizing the architectural idea of a project, and influencing the design process. In cooperation, the structural design helps better create the entire project. A structural engineer's assistance is broader than structural safety and consists also of originating and assessing solutions to reach the multiple preferences of cost, efficiency, architectural goal, compatibility, and functions. Structural engineers cooperate by listening, investigating, and proposing ideas in parallel with the architectural team and their goals.

Structural forms and functionalities pertain to architectural and landscaping spaces. These spaces are art types which effectively connect with people. Architectural and landscape forms depend on aesthetics and human space control. Differently put, they are magnetic elements which reveal designers' emotions and geometry. These forms align with basic regulations of aesthetics and technical aspects, but are not similar to traditional related principles. Sun (2014 believes that based on scale, architectural aesthetics in different designs have also different forms. The structure starts with mechanics and the architectural design starts with aesthetics. Therefore, for a long time, building techniques have been the largest limitations of architectural design. Architects have tried to hide structure to follow their desired pure design thinking.

Structural and civil engineering design create the largest objects the mankind can build. These artefacts or objects include dams, bridges, skyscrapers, and other physical things for which engineers are responsible. In spite of their relevance, not solely because of their sheer size, but also because they belong to many people everyday, engineers are not usually trained in conceptual design, or formal analysis

in ways similar to other professionals like architects, sculptors, painters or designers, usually are (Songel, 2010). These trainings which are mostly visual oriented, are not connected to engineers' education, and instead, they predominantly emphasize efficiency, safety, economy, and similar themes, which are interrelated with topics like math and physics.

3.3 Metaphoric Use of Structure

Structural concepts relate to architectural concepts visually or relationally according to the main source of inspiration in the design process. The architectural success of a structural reflects in realization and materializing the design concepts. Understanding the structure creates opportunities not limitations. Architectural form is based on managing its aesthetic issues. It is obvious that designers' emotion plays important roles in building's functions, meaning and architectural philosophy. This is kind of visual expression could be subject to serious studies and discussions. Aesthetic elements can be considered on purely visual terms. Considering visual elements is a common technique architects universally use, although, some consider technical elements and designs even more. This apparent tool is not much relevant to the building's main structure. Hence, superficial design reduces or undermines the design quality (Songel, 2010) (Sun, 2014).

We can first look at a structure technically. In this way, the structural system could be considered and analyzed. *Non-form-active* structures (post and beam) with just vertical and horizontal elements, and also *semi-form-active* structures with more efficiency than post-beam systems (with elements which include combination of bending and axial forces), can be a category which we may consider in this section (Macdonald, 1994). We may also categorize *structure as ornament* which relates to visual characteristics. This relation between structure and architecture could be

symbolically or exposed with less technical logic (Macdonald, 1994) (Charleson, 2005).

The second goal of this research is trying to see the relationships between the cognitive tools of the design process, and structural thinking. It is important to see how we can think about and define a structure based on cognitive tools. The term used in this research is called the use of structure. A metaphoric use of structure applies to any type of structure with surface or appearance similarity, and relational similarity to the structure of source of inspiration. For example, see the Longaberger Building in Ohio (Hey, Linsey, Agogino & wood, 2008). Non-form-active structures (with least structural efficiency, least structural form flexibility), and semi-form-active structures (with semi structural efficiency, semi structural form flexibility) could be considered among the metaphorical uses of structure. Also, structure as ornament with mostly visual effects than technical, can also be considered in this category of structural description (Figure 29).

Figure 29: No relation of structure and building, Longaberger Building, (bsbgltd 1, 2017)

3.4 Analogical Use of Structure

Structural concepts deal with architectural concepts physically or functionally according to the main source of inspiration in design process. The structure in architecture is something more important and effective than supporting loads imposed by external and internal forces. It has a close relationship with the organization of space. It may even emphasize the definition of space. This is great potential for designers to gather as a team, and consider structure more realistically and functionally. Structure realizes and defines space or place. To provide workable design potentials for any kind of project, experts ought to promote the relationship between structure and architecture more effectively. In that case, the project becomes more acceptable, attractive, permanent and effective for users and visitors (Smith, 2016).

In interactive designs, structural engineers apply architectural design goals in their work, in which case teamwork plays an essential part. Coordination between architects and engineers can greatly help and benefit the design process. However, it proves challenging in most cases. But engineers by the help of their current technical knowledge could design functional structures (Uihlein, 2014). The *full-form-active* structures could come into play in this type of structural impression. These types of structures include high structural efficiency and complex forms, with specific geometries and shapes (Macdonald, 1994).

Structure as form constitutes yet another such categorization, which gives precedence to technical logic rather than ornaments or aesthetics. This relationship is deeper, with both architects and engineers serving each other. Therefore, to create a design foundation, structural concepts must come into play from the beginning of the design process. This type of relationship may connect internal and external structures

together (Charleson, 2005) (Macdonald, 1994) (Lin & Zhen, 2016). From another perspective, any type of structure, with relational similarity and functional or structural similarity to the inspirational source (for example, Dockland, Hamburg), can be a form of analogical use of structure (Hey, 2008). Therefore, full-form-active structures (with high structural efficiency, high structural form flexibility) could work as analogical expressions of structure. Also, structure as form type, with mostly technical effects than visual, can be considered a type of structural expression (Figure 30).

Figure 30: Night view of Dockland building (haditeherani, 2017)

3.5 Summary

Important relationships between architecture and structure focus on different views. Based on an overview of the literature, we could label the use and functionality of the structure as either metaphoric and analogical. Table 4 illustrates and summarizes these related studies. Structure is not a neutral architectural element. In a metaphoric view, visual architectural thinking with people is fairly common in the design process. This view includes non-form-active structure and semi-form-active structure. The type of structure in this way, could be called structure as ornament. From an analogical view, structure could portray and realize the defined

space or place. This view includes full-form-active structure, and structure-architecture are well integrated.

Table 4: The Summary of specifications of reviewed structure studies

Study Subject	Author	Year	Focused Subjects	Points
Basic Structures for Engineers and Architects	Philip Garrison	2005	- Structural Definitions - Structural Terms - Structural Elements	- The structure study includes the forces and stresses analysis happening among a structure. - A force is an effect on an object (like building part) that could make a movement. - The cables face tension and should be designed to support considerable tensile forces.
Structural Design for Architecture	Angus Macdonald	1997	- Structural Materials - Structural Type - Structural Requirements - Structural Design - Structural Arrangements - Structure & Architecture	- Steel is the most powerful mostly used structural material. - Complete glazing of building exterior is, generally related to open plan that frame structure could be suitable for it. - The structure design that supports a building, is a recognizable and separate part of the general design process. - The architectural design action is structural design action too.
Structure and Architecture	Angus Macdonald	1994	- Structural Terms - Structural Materials - Structural Type - Structural Requirements - Structural Design - Structural Arrangements - Structure & Architecture	- Structures are tools for transferring forces from the points where they are started in buildings to foundations where they are finally supported. - The very low tensile strength of masonry structure, causes limitations to use it as elements. - Architectural structures should could achieve balance in case of all directions of load. - The form of a structural skeleton is needfully very closely connected to building which it supports. - Full form-active structures include geometries which are more complex than post-beam or semi-form-active structures and they make buildings which include specific shapes. - There have always been buildings which included only structure. These buildings had technical feasible approaches as limitations.
Structure as Form	Andrew Charleson	2005	- Structural Definitions - Structural Design - Structure & Architecture	- Some architects consider a more active state towards exposing structure. They know its potential to fortify exterior architecture. - A raw and unkind structure is different from the one that attracts and expresses a sense of protection. - Structure is not a useless architectural element. It affects the space around it, and its strong impression attracts architectural analysis or readings.
Comparative Design of Structures	Shaopei Lin, Hung Zhen	2016	- Structural Engineering - Structural Materials - Structural	- Structural engineering is the composition of technology (mechanics) and art (aesthetics). - When choice of structural kind, tools, and material is under focus, first thing is to consider the character of sustainable issues based on the economic efficiency and logic of life circle process of structure.

			Requirements - Structure & Architecture	- During process of schematic design, general stability and its relation to geometric conditions should be checked. - Structures are should to be a creative result complemented by designers and structural engineers together.
Building Structure Design as an Integral Part of Architecture	Ali Unay, Cengiz Ozmen	2006	- Structural Design	- People must realize that structural design is a complete part of the technical and artistic point of architectural design and first task of the architect. - In case of skilled design, structural design is one of the major elements of a space quality of buildings, functional issues and beauty aspects.
The Fundamentals of Architecture	Lorraine Farrelly	2007	- Structural Materials - Structure & Architecture	- Some type of masonry structure is modular, so it requires to behave in a specific way. - Reinforced concrete could be spanned wide distances and is applied in engineering projects like road, building and bridge construction.
Structural Design of Buildings	Paul Smith	2016	- Structural Materials - Structure & Architecture	- The functionality of concrete is the simplicity of the way to work with it or to compact it. - The structure in architecture is beyond a resisting the loads entered by external forces.
Analysis of Steel Structure Aesthetic Performance	Wei Sun	2014	- Structure & Architecture	- The landscape and architecture form is depended on the management of the human and beauty according to space.
Integrating Structure and Architecture: Guidance for the Structural Engineer	M, Uihlein	2014	- Structure & Architecture	- To have integrated design, a main element is that engineers apply architectural design goals in their process.
Form and Structure in Engineering and Visual Arts	J, Songel	2010	- Structure & Architecture	- Responsible persons for the biggest object design (as ability of man), are structural and civil engineers.

Chapter three covered the literature review and studied themes of structural related aspects such as integration between structure and architecture. The following chapter, focuses on the background of Iranian architecture and also the review of the Iranian selected projects.

Chapter 4

PRECEDENTS IN IRANIAN ARCHITECTURE

4.1 Iranian Architecture: The Background

Figure 31: Ruins of ancient Palace of Persepolis, Shiraz, Iran, Achaemenian PeriodThe Iranian architecture dates back to at least 5000 BCE.

The two broad categories of pre-Islamic and post-Islamic styles or “sabk” broadly classifies the Iranian architecture. Before the arrival of Islam, Iran’s architectural styles drew on three to four thousand years of architectural development ranging various civilizations in the Iranian plateau. Some of the greatest architectural monuments, temples, cities and palaces were inspired from periods of Elamites, Achaemenids, Parthians and Sassanids. One of the most majestic well-known monuments from this era is Persepolis, the ceremonial capital of the Achaemenid Empire, which Achaemenids built on a grand scale and was later burned by

Alexander the Great. But its remains, including bas-reliefs, columns and sculptures, still provide a picture of its classical architecture and beliefs about the ancient Persians (Figure 31).

Drawing ideas from its pre-Islamic predecessors, post-Islamic architecture includes a wide range of secular and religious styles with geometrical and repetitive forms decorated with calligraphy, carved stucco, floral motifs, and tiles. The principal Islamic structures encompass mosques, bridges, tombs, palace, bazaars and forts. A great example of harmony, depths of symbolic meaning and unity of Islamic architecture can be found in the Nasir al-Mulk Mosque (Pink Mosque) in Shiraz built during the Qajar era. This monument displays colored glass in its facade, and other traditional elements such as five concaves (panj kāseh-i) (Figures 32).

Arthur U. Pope (1971, p.1), a pioneering American expert on Persian-Islamic buildings echoes this sentiment: “The meaningful impact of Persian architecture is versatile. Not overwhelming but dignified, magnificent and impressive.

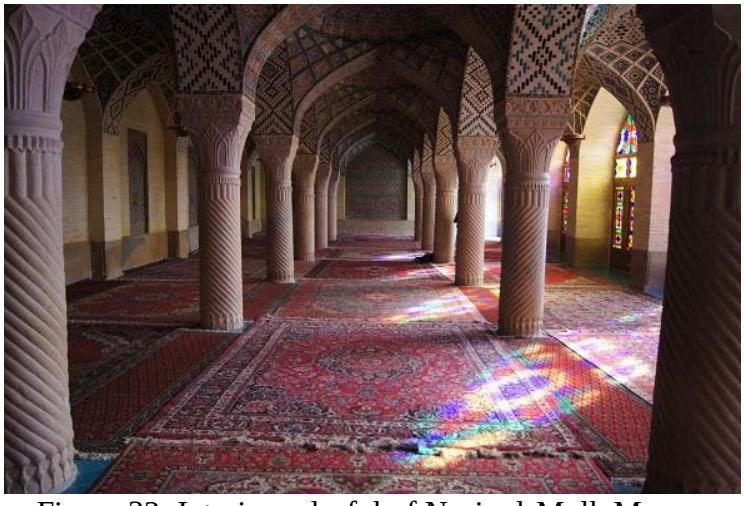


Figure 32: Interior colorful of Nasir al-Mulk Mosque

4.2 Modernity in Persian Architecture

Habibi and Hosaini (2010) add the contemporary or present-day Persian architecture as another style to the two above-mentioned classifications. This addition continually rejects recognizable forms with familiar symbolic forms of particular culture by particular people using modern building techniques. The dawn of Iran's modern architectural development, according to Diba and Dehbashi (2004), started around 1800s due to country's increase in communication with Europe and European art and architecture. In this period, modernity in Persian architecture, manifested itself in palaces' classical plans, entrances and roofs combined by traditional symmetrical spaces in windows, decorations and elevations. The former royal Qajar complex in Tehran, or the Golestan Palace constitutes one of the best structures of this period (Figures 33 and 34).

Figure 33: Mian entrance of the Golestan palace complex

Figure 34: Internal view of Golestan palace and its mirror works

In this era, the first House of Technology known as Dar ul-Funun established in 1851 replaced the traditional architectural training method (pupilage/master) mainly based on oral communication (Figure 35).

Figure 35: Entrance of Dar ul-Funun historical school

Continued to be infatuated by the West, Pahlavi dynasty (1925-1979) was another era in Iranian history, with a great deal of influence on Iran's culture, economy and architecture. As a result of industrialization, according to Diba and Dehbashi (2004), for the first time in Iranian history, Reza Shah, then the King of Iran, invited western architects to design new buildings or infrastructure such as railway stations, cinemas, hotels, and factories. As a result of these interactions, traditional design of many cities changed significantly with the entry of new construction techniques and building materials like steel, cement and glass. The University of Tehran exemplifies

modernist architecture during the first two decades of this era (Figure 36). French architects Roland Dubrulle and Maxime Siroux, Swiss architect Alexandre Moser, as well as Andre Godard, Nicolai Markov and Mohsen Foroughi designed Tehran University's campus buildings.

Figure 36: Main designed gate of University of Tehran, Iran

From 1941 to 1979, the country experienced social and economic changes influenced by industrialization, which is why Iran was more influenced by modern western architecture. This modernization process negatively affected almost all governmental and commercial buildings in major cities like Tehran, Mashhad Yazd and Kerman. According to Diba (2012), vernacular architecture almost ignored local factors and climatic zones, and developers built numerous uniform residences with a minimum number of materials irrespective of their location. Closely modeled after the École des Beaux-Arts in Paris, one positive legacy of this era though was the establishment of the Tehran University's Fine Arts faculty in 1940. This new faculty was formed by merging the School of Applied Arts and Crafts with the School of

Architecture as directed by French architect Andre Godar. Going through radical changes following the American pattern in 1963 and influenced by the last dean of the faculty who had studied in Italy, Ardalān, (1986, p. 353) noted that "the dominant cultural force in Iranian schools of architecture and engineering shifted from French domination to an Anglo-American bias with some Italian influence." The distinct presence of international modernism can be seen in work of well-known Iranian-Italian architect, Jahangir Darvishbani, who designed Takhti Stadium in Tehran (Figure 37).

Figure 37: Modern designed Takhti Stadium in Tehran

Despite the strong influence of Modernism encouraged in architectural schools, many Iranian architects including Houshang Seyhoun tried their best to keep the ties to their cultural identity. This can be seen in Avicenna's mausoleum in Hamadan (Figure 37 & 38), which was designed by Houshang Seyhoun.

Figure 38: Contemporary designed, Avicenna Mausoleum, Hamedan, Iran

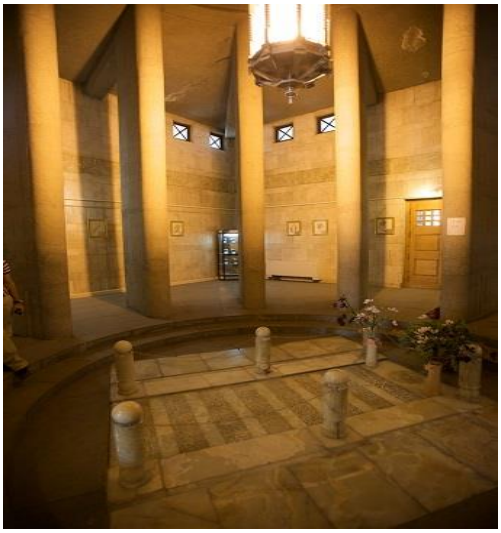


Figure 39: The interior Avicenna's Mausoleum in Hamadan

Despite their efforts, other faithful architects to their past (e.g. Kamran Diba, Hossein Amanat and Nader Ardalan) could not save the country from the influence of western modern design. Hence, as Diba and Dehbashi (2004) argue, Iran's architecture turned to the inharmonious combination of the western-style architecture and developers' build-and-sell architecture.

Two other major events had significant effects on Iran's architecture and urban planning. The establishment of the Islamic Republic of Iran in 1979 was the first one

was when the new regime overthrew the last king of Iran, and abolished monarchy. The economic and social consequences of 8-year war between Iran and Iraq created the second one, which not only led to a strain on the job market, especially architectural firms, but also forced many architectural elites to flee to other countries. Because of all this, Iran faced a new self-made organization called the Jihad of Construction (Jihad e sazandegi) which addressed poverty through rural development and construction (e.g. building schools and health services), agricultural growth and self-sufficiency.

The 1980s and 1990s witnessed the revival of the Iranian traditional architecture. Giving more attention to religious places such as mosques resulted in keeping the Islamic spirit alive by using materials such as tiles and bricks and ornamental elements like molding and calligraphy. Thus, *Iranian-ness* and religion blended as a result of which the Islamic-Iranian architecture emerged. The Holy Shrine of Emam Khomeini designed by Mohammad Tehrani, and the mosque of Sharif University in Tehran sketched by Mehdi Hojat exemplify distinct examples of this trend. The Shrine of Emam Khomeini has a gold dome sitting on a high drum, surrounded by four free-standing minarets. This shrine is surrounded by a large rectangular plaza which has been designed to hold vast numbers of visitors.

Fortunately, at this time, the repetition of traditional Iranian elements slowly made a comeback, but unfortunately, this revival was "at the cost of a surprisingly eclectic fusion" which led to a clumsy, worthless housing construction with its limitation towards technology, rules and regulations (Diba and Dehbashi, 2004, p.35-36). Blindly trying to copy works of famous architects such as Zaha Hadid, Peter Eisenman, Daniel Libeskind, these kinds of buildings are nothing but 3-dimensional computer images which are detached from time and place (Diba and Dehbashi,

2004). Bani Masoud (2014) calls this the "superficial orientation" towards western architecture which was derived, at the time, from fancy architectural magazines and formal imitations as well as superficial adaptation from postmodernism and deconstructive architecture mainly practiced by not very professional architects. During three decades after 1979 revolution, Iranian architecture also bore other tendencies towards high-tech (high technology) and eco-tech styles (technology green), which led to the arrival of new materials and new building systems mainly based on eco-efficiency energy (Bani Masoud, 2014). The neomodern architecture which rejected classical decorations and ornamentations was yet another new trend. This was followed by computer-aided design (CAD) period based on architectural advanced programs mainly present in the projects of 3rd generation of Iranian architects currently study at architectural universities in Iran.

4.3 The Essence of Iranian Contemporary Architecture

As previously discussed, after Iran's revolution in 1997, Islamic-Iranian architecture was given more attention and as a result religious places and sacred atmospheres were became a key focus in contemporary Iranian architecture. In Islam, mosques are built for more than merely worshipping God and praying. In fact, they are also used for mass therapy, religious meetings and congregations and places where priests address a large mass of people. In some countries like Iran, mosques also allow meetings which are utilized for health education or for community involvement. What follows is the introduction of one of the contemporary mosques which its unique concepts have been incorporated with appropriate actions suited with the needs of the community and its religion. This place is a prayer room (Namaz Khaneh) at Laleh Park in Tehran (Figures 40) which was designed by Kamran Diba.

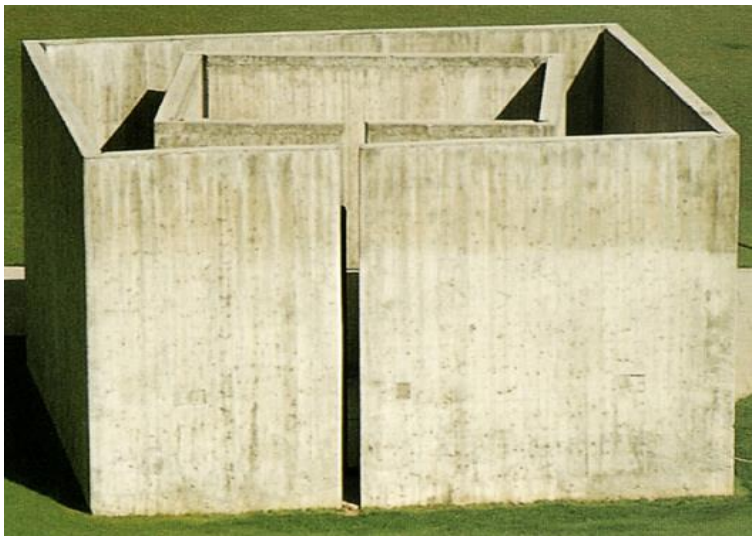


Figure 40: Namaz khaneh at Laleh Park

4.4 Iranian Projects

Each of the following case studies represents various ideologies and schools of thought of experienced architects who have accomplished a great deal of respect in their professional practice. As mentioned earlier, purposive sampling helped carefully select top professional architects to participate in this study. The snowball sampling method helped identify these experts and collect their project samples. These potential architects were interviewed, during which, they introduced their selected projects. This chapter introduces their related pictures, drawings and official project descriptions. The following table provides additional information about the architects' names, projects' names and their location.

Table 5: Selected architects and their Projects' information

	Architect	**Project**	**Location**
1	Farhad Ahmadi	*Embassy of Iran*	Seoul, South Korea
2	Catherine Spiridonof	*Mellat Park Cineplex*	Tehran
3	Hosein Diba	*Unknown Martyrs Monument*	Ardakan, Fars
4	Esfandiar Abdeshah	*Roya House*	Shiraz
5	Alireza Emtiaz	*Namak Restaurant*	Shiraz
6	Zhila Norozi	*Sacred Defense Museum*	Tehran

7	Sorosh Saberi	*Tagh Kasra Building*	Shiraz
8	Mehrdad Iravanian	*Textile Museum*	Shiraz
9	Ali Sodagaran	*Tourism Information Center*	Shiraz
10	Morteza Adib, Maryam Yousefi, Farzad Daliri	*Bam Land*	Tehran
11	Kamran Diba	*Namaz khaneh*	Tehran

4.4.1 Embassy of Iran, Seoul

Figure 41: The entrance view of the Embassy, Exposed structure and columns

The volume of project (Figure 41) consists of four towers enclosing an open space in the lower part of the sunken courtyard and above, in an atrium, a suspended court with glass surfaces on top and bottom. The whole building is hanging from four towers to give the opportunity to increase the open space at the ground level. The rising towers manifest the transcendental tendency of the earth, and diagonal glass floor of atrium symbolizes the descent of heaven into the earth. The height of four exposed concrete towers is approximately 15m. Three volumes such as the bridges connect these towers by exposed steel trusses. The elevator and the staircase are

located on the forth side to cut the natural ventilation, and send it up to the atrium while the front side is open to the air current (Figure 42). The sunken courtyard is the continuity of the ground level into the earth passing through a stone gate and partially covered by water, providing access, light and air to the underground spaces while reducing the temperature in high season. Materials used in the project (mainly concrete, steel and glass in the facades, marble and wood on the floors) are exposed and present their original identity. The project is very minimal, modest, the purity and simplicity could feel in this introverted building.

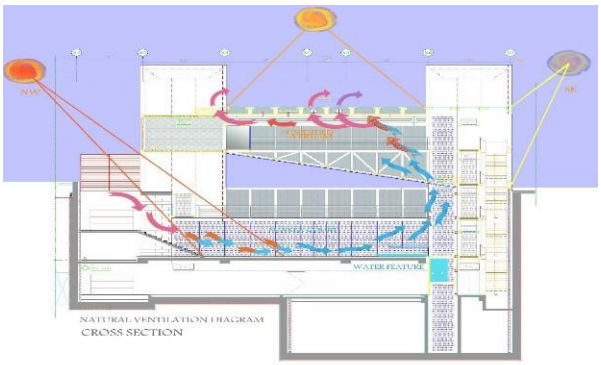


Figure 42: Cross Section of the building

Figure 43: The Project Plan

Figure 44: Central Internal Space of the building

Figure 45: Internal Elevator of the building

Figure 46: Perspective of the Cineplex

4.4.2 Mellat Park Cineplex

The Mellat Park Cineplex is located on a rectangular 3,000 m2 land, at the western edge of Mellat Park. The project borders the park on the north and east sides, and is

adjacent to Niayesh Freeway on the south, and Enghelab Sports Complex on the west side. The plan included 4 movie theatres, each with an occupancy of 250, a smaller theatre with an occupancy of 30, gallery spaces, restaurant, coffee shop, bookstore, office spaces, and service spaces, with a total area of approximately 15,000 m2. Given the green spaces adjacent to the project, as well as the views of Mellat Park, the concept was to design a concrete core (where the movie theatres were located), floating within a glass envelope. By pulling up the center of the form and separating it from the ground a large “eyvan” allows direct access from the park to the city and vice versa, essentially transforming the project from a wall, into a gateway. In addition to providing natural ventilation inside the building, the large terrace also serves as a place for exchanging ideas and holding various cultural events (Figure 46). Locating the gentle circulation ramps against the glass enclosure provides direct views of the park inside the building. The overall structural design uses deep concrete beams to support the theatres, circulation spaces, as well as the large terrace, giving the project a uniform identity.

Figure 47: Top view of the site

Figure 48: Side view of the building

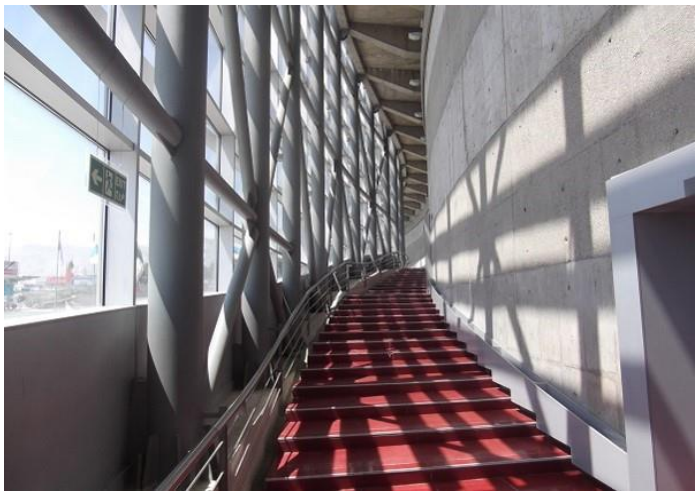


Figure 49: Side internal steps

Figure 50: Cinema Space

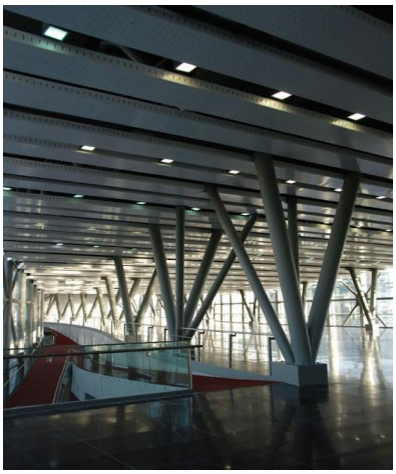


Figure 51: Interior of building

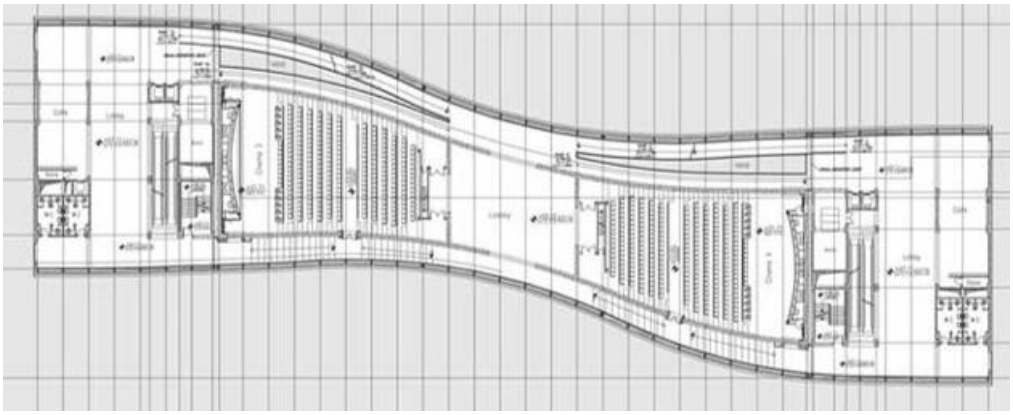


Figure 52: Floor plan of the cineplex

4.4.3 Unknown Martyrs Monument

Promoting and celebrating the greatness of the martyrs constitute the main goal in designing this monument. As such, the architect attempted to design the building volume to symbolize the Zagros mountain. With its firm base, this consideration also complied with the climatic characteristics of Ardakan city where it is located. Ascendance of the volume ends up reducing its thickness as observed in a mountain peak. The architect has adopted an octagonal geometry (Shamseh in Islamic architecture) which refers to the sacred eight years' war with Iraq. As such, the centralization of the plan evokes the sense of unity.

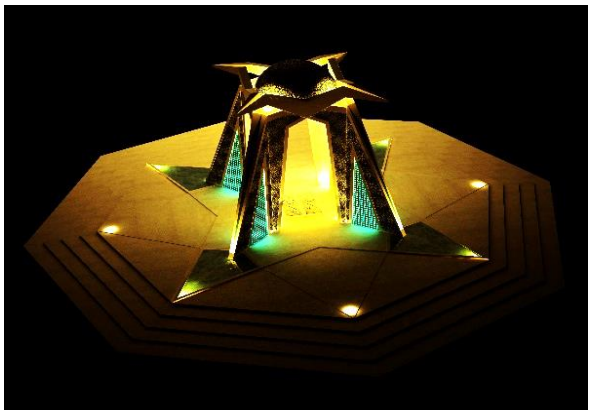


Figure 53: The aerial view of the monument

Figure 54: Elevation of the Monument

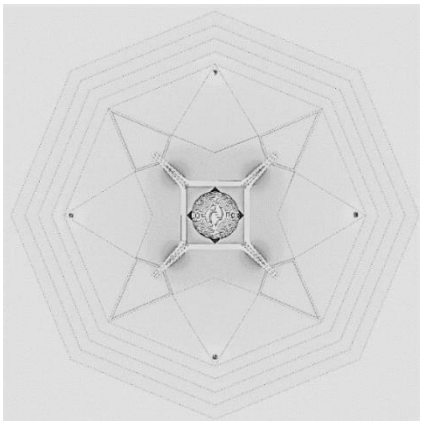


Figure 55: Plan of the Monument

Each column in this monument is a metaphor of human form raising his or her hands toward the sky as a symbol of freedom (Figure 53). Repeating these columns together evoke four humans who tie their hands with each other, and attach their

heads with each other at the same time. These four symbolize the followers who believe in their sacred goals and ideals. Floating wings which on top of the building, according to their form, evoke a sense of flight and ascendancy. Also, the high height of the monument is to show the vastness and strength of the martyrs.

4.4.4 Roya House

As a quintessential goal, since the beginning of history to date, humans created shelters for their security, peace and comfort. Dreams and imaginations, have always been attractive to humans. Separating humans' daily and normal lives from a world of dream and fantasy, the architect created a sense pleasure by combining layers of folding architecture. The folding architecture consists of layers and concepts for architecture based on the project functionality.

Figure 56: Façade of the house

Figure 57: Interior design of the house

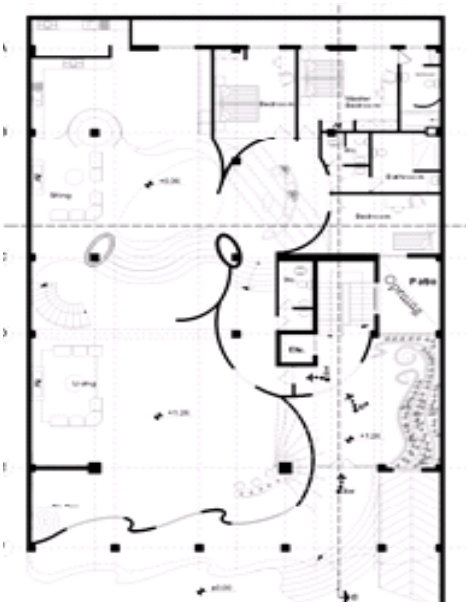


Figure 58: Floor Plan of the house

Figure 59: Interior Design of the house

Figure 60: Façade of Restaurant

4.4.5 Namak Restaurant

With its disinfectant character in most dietary products, the salt symbolizes an interesting concept behind the design of this project (Figure 60). Its white color shows desirable and pleasant images of cleanness in a shop or a restaurant in mind. This design, with making a space look like salt cave, invites people to it with the least cost and accessible in any place and any time; its image serving as a reminder for the viewer in mind. Based on semi-commercial fabrics of the site, the designer attempted to create an iconic external form to reinforce the area. The design also continues the external into the internal skin. Shaping organic forms not only inspires from the instinct of the materials, but also provides identity and attracts people. To comply with nature and be more sustainable, the design of this restaurant includes materials of steps, entrance door handles, and chairs, from the melting of irresolvable garbage like aluminum cans of soft drinks from other restaurants.

Figure 61: Interior view of the restaurant

Figure 62: Interior view of the restaurant

Figure 63: Designs of Chairs and tables

Figure 64: Perspective of the sacred defense museum

4.4.6 Sacred Defense Museum

The idea behind this building (Defa Moghaddas), symbolizes one of the main goals of the sacred defense which protects the land and physical and spiritual values of it from enemies. Therefore, the building does not dive into the hill (site topography) but like camouflage mesh shades rolls on the hill. The hill as metaphor has positioned inside of the museum and inspired by the wrinkles of the hill, the floor plans, and the ceiling as its canopy have hidden the building. The rolling hills have shaped the museum's architecture. The layers of site's topography inspired the design of the floor plans and divisions of galleries as well. The concept of Persian gardens has inspired the project landscaping by memorializing nature into the layers of the topography.

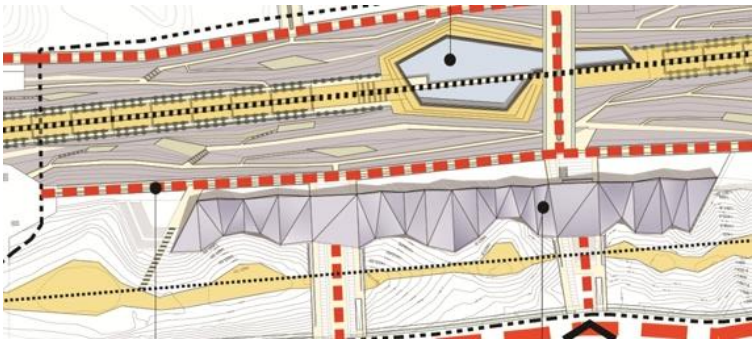


Figure 65: Site Plan of the museum

Figure 66: Elevation of the building

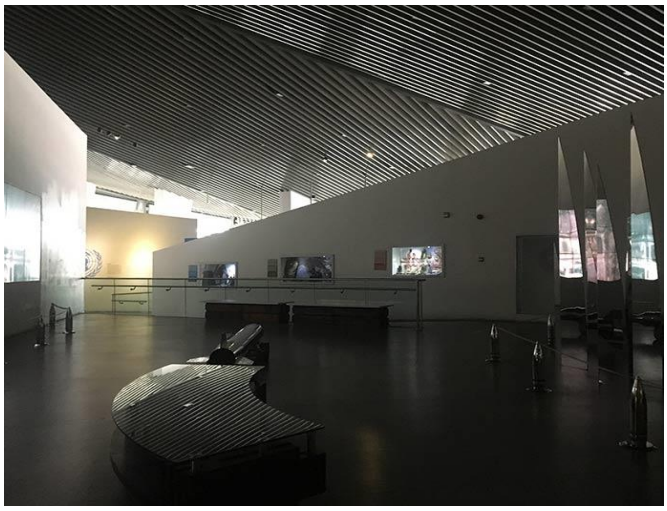


Figure 67: Interior design of museum

Figure 68: Landscape of the project

Figure 69: The main façade of the building

4.4.7 Tagh Kasra Building

Located at the edge of street and alley, the project juxtaposes the commercial and residential components. The building's main elevation is a big truss vault inspired from the ancient *tagh e kasra* palace located in Iraq today. The top level of the vault positions the administrative section, which is accessible by staircase and lifts through the pillars of the vault. Trusses support the weight of this floor, which makes it a real working vault. There designer wanted to show this floor floating in the facade and the exposing structure be visible for viewers. In general, the idea was to combine the Persian architecture and modern architecture.

Figure 70: Some details of the building facade

Figure 71: Perspective of the project

Figure 72: First floor plan of the building

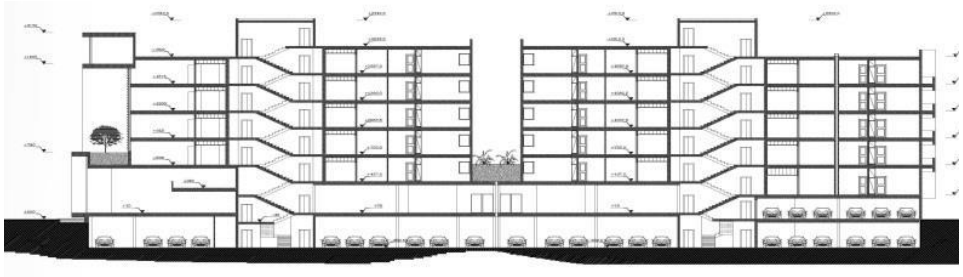


Figure 73: Section of the complex

Figure 74: Side elevation details

Figure 75: Residential section entrance

4.4.8 Textile Museum

Figure 76: Main façade of the museum

This building was originally a textile factory built during the Pahlavi era, with Qajari architecture traits expressed in its brickworks. Then at the end of the Pahlavi period, it became abandoned, and gradually demolished except for some external walls. The architect redesigned and revived this building. To repurpose the original factory into a textile museum, the design involved the reuse of some of the original elements to the textile process and production (Figure 76). Metal cables are used in

different parts to not only connect architectural elements, but also to show the schematic production process. Structures similar to scaffolding and parts of destroyed walls provided stability for the building, and made a visually coherent whole. It epitomizes a somewhat hi-tech architecture with the use of organic elements such as remnants of timbers from the original building. The main structure of the building is covered by the new one, and tries to celebrate the glory of the demolished factory morphing into the new building.

Figure 77: Perspective of the textile museum

Figure 78: Central space of the museum

Figure 79: Central space design

Figure 80: Internal gallery

4.4.9 Tourism Information Center

Figure 81: Façade of the information center

The floating volume in this space provides the possibility of continuity of marginal park in order to invite passers to visit the building. With its specific color and in contrast with its background, this architecture plays a key role as an urban symbol. As such, the most important point is that as an iconic building, it wants to function as an urban furniture. Colorful curtains in contrast with the green color of the area's vegetative cover, are not only indexing the volume of the project, but also with their 45-degree orientation, prevent direct sunlight in hot seasons into the inside space. It also guides the sunlight into the internal spaces during cold seasons. The challenging aspect of design in this project was to direct the volume of light in the park, so in this way, crooked columns are used to show the more floating character of the building.

Figure 82: Perspective of the center

Figure 83: Entrance of the building

Figure 84: Interior design


Figure 85: Interior structure

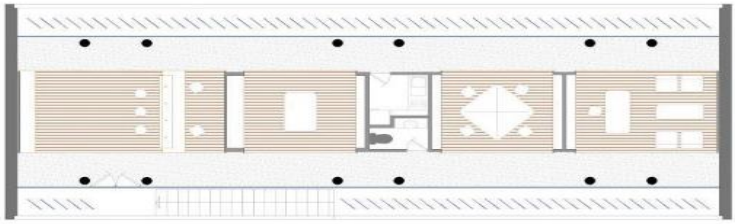


Figure 86: First floor plan

4.4.10 Bam Land

As a commercial and recreational complex, the Bam land is located at the stretch of Chitgar lake shore in Tehran where the residential and the urban fabric meet. This project consists of restaurants and other recreational spaces orientated based on the local sunlight and local prevailing wind direction. Buildings are detached and are only connected to each other by spaces like courtyards (important Persian traditional architectural elements) and *Ravaaghs* (traditional connector space), all combined into the landscape. The design of these buildings, incorporates proportions rooted in the

historic Persian architecture. These elements like courtyards are formed in modern frames based on the transparency in providing views to the lake. As another important design idea borrowed from the traditional Persian architecture, wind towers help move and channelize desirable and cool breezes from the lake into the buildings' interiors. Using bricks on the façade and water features in the landscape are other related traditional elements of Persian architecture which could express Persian gardens in different geometry.

Figure 87: Aerial view of the complex

Figure 88: Façade view

Figure 89: Section-elevation of the complex

Figure 90: First floor plan of the complex

Figure 91: Perspective of the buildings

Figure 92: Elevation of the restaurants

4.4.11 Namaz Khaneh

This site was originally vacant and people prayed to protect the area from wrongful ways. The architect decided to design a simple space for this site to provide a calm space for people. As shown in Figure 93, this place consists of two nested cubes located harmoniously. An external cube which relatively represents Kaaba also known as Ka'aba (the Sacred House for Muslims), is in perfect harmony with the one inside located along south-west which is Muslim's Quibla (the direction that should be faced when a Muslim prays). Cubic architectural forms create a peaceful and sacred atmosphere used for centuries in many civilizations, especially for designing mosques. The other fascinating features of this place include two slits in the bodies of these nested cubes as the only apertures towards the outside world. Artistically designed, when one stands to pray, he or she also faces the most significant symbolic icon of Shia, الله or God which mounted on the 4-meter bar exactly leveled out with one's eye. This can be seen in the left side corner of Figure 94.

Figure 93: Side view of the building

Figure 94: A 4-meter bar to represent Shia's symbol

4.5 Summary

A background about the Iranian architecture started the section on reviewing the Iranian projects including the pre-Islamic architecture focusing mainly on the Achaemenid and Sassanid architecture. The post-Islamic era of Iran, mostly witnessed the majesty of religious buildings like mosques. The contemporary architecture of Persia started during the Qajar period that coincided with interactions with European nations. Gradually, the traditional architecture was forgotten and mainly modern architecture arrived and dominated Iran. This changed the identity of Persian architecture too. In Pahlavi and after revolution era, some efforts have done

to produce architecture with some elements and characters of Persian art. This part followed the case studies of a select few of Iranian projects, along with official descriptions, pictures and drawings. There are various types of projects on this list, from different architects located in different cities of Iran to a wide variety of building types in the reviewed projects.

Chapter Four talked about Iranian architecture background and Introduced Iranian projects. The next chapter, discusses Interviews and Iranian projects following by analysis of them.

Chapter 5

DATA ANALYSIS

Chapter Four focused on the background of Iranian architecture and review of Iranian selected projects. This chapter discusses the analysis of interviews' data (based on Inductive analysis) and also 11 case studies selected for this research (based on Abductive analysis). First of all, inductive reasoning is used for data gathering and analysis of interviews. Inductive analysis is kind of approach that mainly uses detailed readings of raw data to get concepts and themes via interpretations done from the raw data by a researcher. Data analysis is conducted by evaluation objectives (to configure investigated domains) and findings are directly made from the analysis of raw data, not primitive expectations or models. Findings are formed by the experiences and assumptions of evaluators. (Thomas, 2006).

The goals of using inductive analysis are condensing varied raw data into the summary format, making clear links between objectives of research and findings of summary, and developing of model about fundamental elements of experiences and processes which are obvious in raw data. Most inductive studies reached to a model that has three to eight main categories in the findings. (Thomas, 2003) The inductive analysis strategy includes the following steps: initial reading of text data, recognition of specific text parts related to the objectives, tagging the parts of the text to create categories, decreasing overlap and abundance from the categories, and making a model combining most important categories. Findings in inductive approach are

started from the frequent and important themes and are trying to only present and describe these themes. (Liu, 2016).

5.1 Inductive Analysis of Interviews

Table 6: Interviews' most important and specific texts according to objectives

Projects	***Specific Text Parts Related to the Objectives***
1- Embassy of Iran, Seoul	I have some principles and concepts which are formed visually in each project; in lower part placed sunken courtyard and on above, an atrium, a suspended court with glass surfaces; whole of the building is hanging from these four towers; to give opportunity to increase the open space at the ground level; diagonal glass floor of atrium symbolizes the descent of heaven into the earth; Steel and concrete structures are combined with each other in this project to increase the structural and architectural efficiencies, and also provide better stability and strength for the building; the bridges connect these towers by exposed steel trusses.
2- Mellat Park Cineplex	Based on the characteristics of the site and building function; By pulling up the center of the form and separating it from the ground, a large "eyvan" was designed; Given the green spaces adjacent to the project, as well as the views of Mellat Park, the concept was to design a concrete core, floating within a glass envelope; mostly contextual types; by analysis of the context and the site; Stable structure, material strength, naturalizing idea, making a place; Structural design of this building has overall flexibility to the site and surrounding characteristics to provide more architectural and structural efficiencies; The architecture and structure are tried to be integrated well in order to create more spatial potentials.
3- Unknown Martyrs Monument	This building is formed on the octagonal geometry; Centralization in plan is been to evoke the sense of unity. Each column of this monument is a metaphor of human form who get his or her hands toward the sky as a symbol of freedom; In design of the volume, it is tried to consider architecture and climatical characteristics; The structure should show the beauty and the stability together and could transfer the meaning of design to the viewer. In design, I try to show some parts of the structure exposing. In this project, it is tried to have façade only as a skin on the structure and the general form of the structure be kept; Specific steel structural design in this project which provide supporting in different angles, creates more structural efficiencies.
4- Roya House	It can have specific form from aesthetics and functional point of views; The subject of dream and imagination, always have been attractive for humans; My metaphor and analogy are inspired from the nature; Based on the function of the building, metaphor and analogy of structure are imagined in my mind; Structure and idea in architecture must be designed together to not get problem after the design; we can implement a design that has not any concept but helps the surrounding from aesthetics point of view.
5- Namak Restaurant	This design, with making a space like salt cave, could invite people to this kind of cave; Based on the semi-commercial fabric of the area of the site, it is tried to create an iconic external design to reinforce the area; Shaping organic forms not only are inspired from the instinct of the materials but to provide identity and to attract people; I am not searching for strange things which could not be connected to audience; the public audience, make faster and better contact with analogy because of its more obvious language; The best analogy and metaphor for structure during design, is depending on kind of design, function and concept.
6- Sacred Defense Museum	Usually it is followed by site configurations; like camouflage mesh shades on the hill; inspired from the wrinkles of the hill; The layers of the topography of site were inspiring the design of the flooring and divisions of galleries; The landscape of the project, got idea from the Persian garden; Most structural elements which are considered in this building, have suitable efficiencies as can be seen in steel load-bearing walls, trusses, cables and bracings, to provide enough strength and stability; structure should be viewed as architecture to share their beauties together; Structural components, themselves, as aesthetics objects, could be exposed in different ways.
7- Tagh Kasra Building	the weight of this floor is actually supported by the trusses, so it is a real working vault; There is wanted to show this floor floating in the facade and the exposing structure be visible for viewers; The main elevation of the building is a big truss vault inspired from the ancient tagh kasra palace; consider relations and aesthetics of the volume of the building; Analogy and

	metaphor in a structure of a building, depends on the function of it, so in different buildings, structure are different from each other; Architecture and structure should be combined effectively and be expressed integrative; structure is part of architecture and form is combination of structure and surfaces; Based on the concept, different functional steel trusses are applied to support an upper big space (regarding strength and stability) and also to provide other workable spaces.
8- Textile Museum	an architect needs to make his or her architecture mysterious; this building redesigned as textile museum to revive the original factory, with using of some related elements to the textile process and production; Metal cables are used in different parts to not only connects architectural elements but to show schematic production process; Destroyed walls were rebuilt to provide stability and strength of the building and to make visual coherence for the building too, by the help of some structures similar to scaffolding; It is kind of hi-tech architecture; Architecture has also a series of hidden layers; we could answer new structural needs and grow the structural efficiency.
9- Tourism Information Center	Mostly I inspired from the surrounding of my work; Floating volume in this space, provides the possibility of continuity of marginal park in order to invite passers to visit the building; This architecture with its specific colour plays a role as an urban symbol; crooked columns are used to show more floating character of the building; View of each person is different with other one and the eye of human is scanning.
10- Bam Land	Always we are following imagination of different forces which are existed in site; context has vital role in forming of our designs; This project consists of some restaurants and other recreational spaces which are orientated according to the local sunlight and local dominant wind; Buildings are detached and are connected to each other by some gathering spaces like courtyard (as important Persian traditional architectural element) and Ravaagh (as traditional connector space); In design of these buildings, some proportions are used which has roots to the historic Persian architecture; using of some kinds of windtowers which have roots to the traditional Persian architecture; Using of brick on the façade and water features in the landscape are other related traditional elements of Persian architecture; geometric or functional meaning in their background; Structure is inseparable part of architecture; We like exposing structures that show the method of load transferring; Recognizing the kind of structure, somehow, is coming from the architecture logic; Modular structures provide the possibility of growth and development with specific and repetitive regularity.
11- Namaz Khaneh	In my designs, I get metaphors from the surrounding of the site and its context; Namaz Khaneh is got to my mind when people have prayed in this site in the park, incorrectly; I decided to design a calm and quiet space for them to pray in right way and in good atmosphere; Simplicity and purity in forms; Simplicity and modern ideas; Most of concepts are coming from metaphors or analogies; It depends on the type of using of them and depends also on the type of projects; According to design situation, in any stage, metaphor or analogy could be used; Simple and original structure; According to the subject of design, and simple structure of the Kaba; In design process, all needed factors should be considered and analyzed to get an acceptable result.

Table 7: The most repeated and important codes in interviews' texts

Codes	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Nature		×	×		×	×			×	×	
History	×		×		×	×	×	×		×	
Function	×	×	×	×	×	×	×	×	×		×
Context		×				×			×	×	
Site		×				×			×	×	
Flexibility	×	×	×	×	×	×	×	×	×		×
Facade	×	×	×	×	×	×	×	×	×	×	
Creativity	×	×	×	×	×	×	×	×	×		×
Plan		×				×				×	
Structure	×	×	×			×	×	×	×		×
Form	×	×	×	×	×	×			×	×	×
Symbol	×		×	×	×	×	×	×	×		×
Attraction	×	×	×	×	×		×		×	×	×
Visual Effects	×	×	×	×	×	×	×	×	×	×	×
Exposed Structure	×	×				×	×	×	×		×
Structural Beauty	×	×				×	×	×	×		×

Building Envelope				×	×					×	
Structural Efficiencies	×	×	×			×	×	×		×	×
Stability	×	×	×	×		×	×	×	×		
Strength	×	×	×	×		×	×	×	×		
Structure as Form	×	×	×			×	×	×	×		×

Table 8: Similarities and links between resulted codes of tables 6 and 7 refine codes

Codes		***Similar or Linked Codes***	***Refined Codes***
A	***Nature***	C D E F K L N O	
B	***History***	A D E G K L M N O Q R U	
C	***Function***	D E G I J K L N O P Q S T U	
D	***Context***	A B C E F J L M N O P R T	
E	***Site***	A B C D F G J K L O P S T U	
F	***Flexibility***	A C D E I J K L N P S T U	**Flexibility**
G	***Facade***	B C D E I J K L M N O P Q R S U V	
I	***Creativity***	C D E F G J K L N O P Q R S T U	**Creativity**
J	***Plan***	C E F G I K L O P Q S T U	
K	***Structure***	A B C E F G I J L N O P Q R S T U	
L	***Form***	A B C D E F G I J K M N O P Q R S T U	
M	***Symbol***	B C D G L N O Q R U	
N	***Attraction***	A B C D E F I J K L M O P Q R U	
O	***Visual Effects***	A B C D F G I K L M N P Q R S U	**Visual Effects**
P	***Exposed Structure***	A B C D E F G I J K L M N O Q S T U	
Q	***Structural Beauty***	B C D E F G I J K L M N O P S T U	
R	***Building Envelope***	B C D E G I J K L M N O S T	
S	***Structural Efficiencies***	A B C D E F G I J K L M N O P Q R T U	**Structural Efficiencies**
T	***Stability***	A C D E G J K L P Q R S U	**Stability**
W	***Strength***	A C D E G J K L P Q R S U T	**Strength**
U	***Structure as Form***	A B C D E F G I J K L M N O P Q S T	**Structure as Form**

According to analysis of raw data of interviews through tables 6, 7, and 8, some important codes are concluded. These are results of detailed readings and comparisons between all text parts of interviews responses. Some codes could be considered more architectural and some others structural.

visual factors in architecture have positive and negative potentials that needed to be analyzed and considered according to the thinking of designer and characteristics of a project. Colors, signs, symbols, paintings, materials, and details, as some visual elements could have significant impressions on audience of a building in order to invite them to visit the building.

Creativity and imagination will aim designer better to shape the concept strongly and beautifully at the same time. Without creativity, design product will be boring and repetitive. Good architect uses suitable skills and knowledge in creative ways to treat the selected concept. Architectural design has a powerful relationship with creativity in all aspects, because an architect must face the design problem differently case by case, so it is needed to consider design factors in new ways for each project specifically.

Other essential factor in design is flexibility that architects should behave with it seriously. Today, it is expected to create a design according to all aspects of site including climate, context, conditions, people, and other elements of surrounding environment. Therefore, design of building should be flexible to site characteristics as it possible. Building could get the form of the site, face the views of the surrounding, integrate with climate, integrate with adjacent sites and buildings, not disturb the local flow and many other issues. Considering flexibility, consciously or unconsciously, give the power and many positive potentials to the building design, and invite local people to the project smoothly and respectfully.

From structural point of view, as basic consideration, the building should have stability and strength together. Stability is one of the most important points which catches the mind of designer and architect, is the structural stability of the building. It is checking that if the proposed idea and concept can provide a structure which not

only forms the base of the concept but holds the building too. Stability is concerned with the ability of a structural arrangement which is in equilibrium to accommodate small disturbances without suffering a major change of shape. Other important factor is structural strength. The influence of load to a structure makes internal forces in the components and external reacting forces at the foundations, and the components and foundations should have enough strength and rigidity to resist these. It is about the ability of the building to keep its physical unity. Structure is the building part that answer the requirement for the strength. Foundations and structural elements must not be deflected under high loads, so loads, stresses, and forces should be controlled and checked to be at acceptable ranges.

The third structural aspect which could be discussed widely, is efficiency. This point is considered by designers and engineers from different views and at different levels. One view is relationship and integration between structure and architecture. Level of this connection could show the level of structural efficiency. If the structure has close integration to architecture, structural requirements and their technical logics are well combined with architectural design, so the structure not only could be visual but could be technical and efficient. Therefore, this point can be very effectively influence on use of structure, so high integration of structure and form includes more analogical characteristics because of deeper, more functional and more structural relationships between design concepts and structural design.

In continuation of integration discussion, it is essential to discuss about the conditions and knowledge of architects and engineers as agents of architectural design and structural design. Their relations and skills directly influence the integration between structure and form, thus could increase the structural efficiency. One thing is that how the architecture and its form relates to the structure, according

to new technologies and developments. Structure, could be at the service of the form and vice versa. Structure can follow the main form of the building, functionally. We could call structure as form, while structure and building form, integrated with each other in functional and influential ways. Architect and engineer have this opportunity to perceive their thinking and proposals artistically and technically in order to coordinate related concepts and create the shape of the building according to real working structure. In this way, selected type of structure could follow the architectural form beautifully.

Secondly, abductive reasoning is applied for analysis of selected projects of architects. Abductive analysis emphasizes mainly on the domain of the theoretical background that a researcher brings to research. Therefore, based on the literature review of the study (theoretical backgrounds, metaphorical and analogical definitions) and based on the primary description of selected project and project facts by architect (in interview), analysis will be done. An abductive conclusion includes making a primary guess according to the interaction between existing theories and data. This approach emphasizes on the development of unique and new experimental findings. (Timmermans & Tavory, 2012) In this way, according to considered objectives (regarding conceptual design and structural design), and according to definitions in literature review, set of conclusions will be done for each selected project of architects. Modern researchers mostly consider abduction as a process of finding a best explanation for a set of observations. (Wang & Sun, 2012) Reasoning is abductive in its nature which in that many conclusion steps use regulations to introduce possible guesses rather than introducing fixed conclusions. (Meadows, Langley, & Emery, 2014) Based on the structural focus of this study, for each project, structural analysis (information and conclusions) will be introduced and

described. Then, integration of structural design and architectural design in each project will be assessed. After that, conclusions and analysis of all projects will be reviewed to explore main themes and categories by data summarization. Finally, findings of abductive analysis (projects) will be compared and matched to findings of inductive analysis (interviews' data) in order to reach to the final categories, keys and possible models.

5.2 Abductive Analysis of Projects

5.2.1 Embassy of Iran, Seoul

Figure 95: External Analysis of the Embassy. Exposed concrete towers and its connecting exposed steel trusses as semi efficient structure.

Metaphorical concept of form of this project includes the four big columns as symbols of four columns of the universe (figure 97) with just surface and relational similarity that is organized in initial stage of design process. (Hey, 2008) On the other hand, the design of this building can be referred to the historic Persian mansions in the middle of the garden which stimulates people. Users of the building in an amazing way, passes the spaces by lift from the parking area to the semi-courtyard space (passing water feature as important Persian element) and then to the upper spaces. It can be imagined by them that they are passing from the dark side to

the lighter sky and this way of design with using of mostly transparent walls could provide more energy for the users and visitors.

Also the structure of the building has its stability parallel to exposing design of it, in most of spaces. Some architects are aware of potentials of exposed structure to enrich architecture. Here, it has aesthetical and functional effects. This kind of structure in this project helps an architect to provide more transparent and glazing walls and spaces, and also to provide better air ventilation. Two different structural systems which are reinforced concrete and steel have integrated with each other helpfully and technical efficient elements are used in most of spaces. Therefore, from one side it could be structure as form, internally and externally. From another side, the exposed reinforced concrete towers and steel trusses which connect each other, as efficient elements, could be called form-active structure. These types of structures have relational and functional similarities to considered concepts (Persian palace) to form analogical use of structure. (Charleson, 2005) (Macdonald, Structural Design for Architecture, 1997).

Figure 96: Interior Analysis of the Embassy that shows exposed surfaces with visual and functional influences.

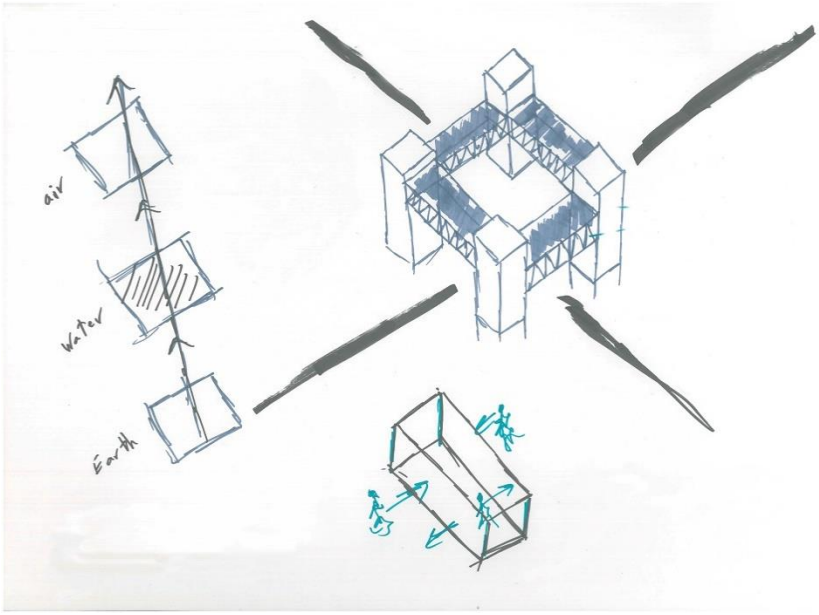
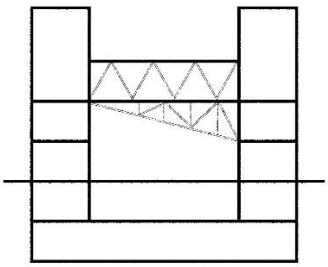


Figure 97: Sketch of the architect

Table 9: Analysis of embassy of Iran in Seoul

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Embassy of Iran	*Seoul, South Korea*	*Farhad Ahmadi*	*Metaphor (Columns of Universe)*	*Initial*	*Analogy (Persian Palace)*
Objective 1					
At one side, a meta-physical concept considered for this project in a way that the four big columns as symbols of four columns of the universe, are used in project as metaphorical issue, with just surface and relational similarities to the concept and is organized in initial stage of design process. Usually, at this stage, similar ideas have formed in the minds. On the other hand, the design of this building can be referred to the historic Persian palaces in the middle of the specific garden which attracts people and provides Persian sense that also this idea could be metaphorical concept of form which has appearance similarity to original Persian palaces. (Casakin, 2003, 2006)					
Objective 2					
Material	Concrete – Steel				
Column	Reinforced Concrete - Steel				
Beam	Reinforced Concrete - Steel				
Slab	Reinforced Concrete - Steel				
Wall	Non-load bearing				
Bracing	Steel I beam				
Cable	-				
Structural Requirements	This integrative structural system which includes concrete and steel elements, provides mutual supporting conditions. While the whole building structure has related balance, the four huge concrete volumes have the important role of keeping the stability of building in conditions of different loads and forces. It cannot be forgotten that the strength of reinforced concrete which is the main structural component, is helpful for overall stability of building. Other structural components which are mostly from steel, provide suitable strength and stability in connection to each other and in connection to glazing elements, by the help of bead				

	and screw system. (Lin & Zhen, 2016) (Macdonald, 1997)
Structural Arrangements (Basic Geometry)	We could see combinatory structural system in this project. Using of reinforced concrete structure in four main blocks of the building, provides flexible components. On the other hand, applying steel structural system for the rest of building parallel to steel bracing and trusses, give effcient elements in case of external and internal forces. This steel structure is connected to the glazing surfaces in the form of steel joints, and steel trusses hold bridge-like connections between concrete blocks. Therefore, technical logics and flexibility can be seen more than visual characters which it could be called full-form-active structure.
	 Reinforced concrete post-beam structure has connected to steel structure (I beam steel bracing system) (steel truss structural system), all have joined through steel hinges.
Use of Structure	The structure of this project includes combination of two different structural systems by using of various concrete and steel components in aesthetical and functional ways. Spaces are formed and connected applying mostly efficient workable steel elements in kind of complex systems. There are technical visible components such as trusses and bracings well joined with glazing surfaces. Thus, this system of structural design which could be called structure as form, also form-active type of it, make analogical use of structure. (Lin & Zhen, 2016) (Casakin & Goldschmidt, 1999)
Relationships between Structure and Architecture	
However, in most of current global projects, it is tried to design independent structure, but the professional, technical and aesthetical issue is that interrelation between architecture and structure provides more opportunities and design potentials. In this project, the technical and efficient ways are followed as the main structures could be seen from outside and inside. Steel structures and components are well integrated with glazing surfaces to provide and show different ideas. Hence, all elements are working and can be considered as visual characters and designs. (Dutton, 2000) (Uihlein, 2014)	

5.2.2 Mellat Park Cineplex

One of the pioneer projects in Iran, is this naturalizing complex in Tehran (Figure 98) which considers the surrounding context by transmitting surrounding lines into the site to form the shape of the building naturally and in fact, not only respects the surrounding natural environment but the surrounding urban environment (Figure

100). This metaphoric architecture which its concept follows visual and relational similarity to the surrounding environment (Hey, Linsey, Agogino & wood, 2008), has shaped attractive and unique soft design for passing users of surrounding roads and users of adjacent park to reach to the placemaking project. “Placemaking derives meaning from the qualities of a location and its surroundings”. (Menin, 2003, p. 144) The combination of this building design and the surrounding environment, as a cultural space, provides interesting place for gathering and meeting.

Figure 98: Site analysis, architectural and Structural influences by site and surrounding context

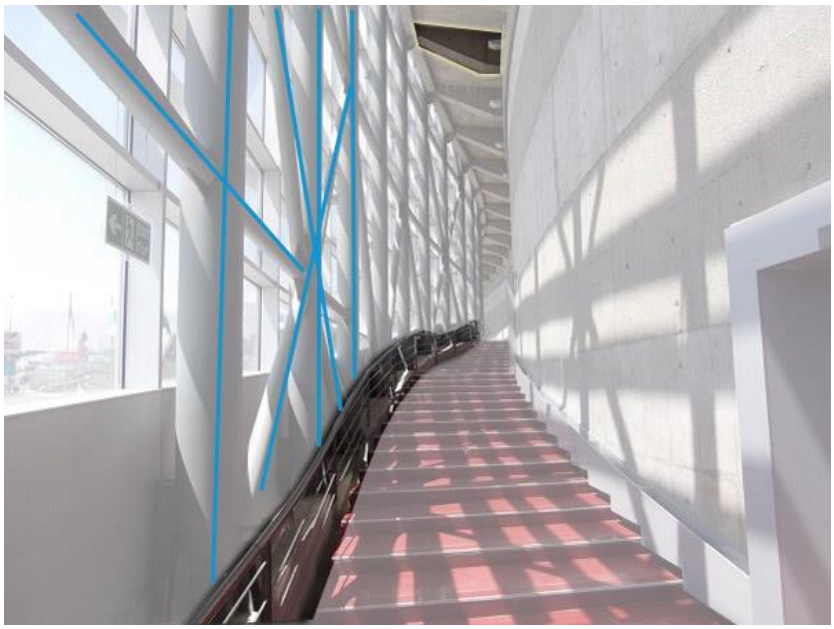


Figure 99: Internal Analysis, glassy surfaces supported by some steel exposed bracings

An architect, regarding the structure, has considered all concepts including surrounding natural and urban environment and used their contextual lines to not only form the building design but to form the building structure. Therefore, the main curvy body of the complex shaped with functional concrete walls and beams and some additional steel elements were used connected to the main body. The glassy surface of the building is also supported by some steel cylinderical bracings which like other structural elements of the building, are exposed and could be called high-tech design. This structural design and arrangement with high efficiency according to site and surrounding (figure 100), and with specific and complicated structural shape, can be considered as form-active structure. In the same way, structural efficiency and performance of this project and less using of ornamental elements, form structural arcitecture type. Therefore, we can say that the structural and relational similarities to concepts (natural and contextual and form-active), shape analogical use of structure.

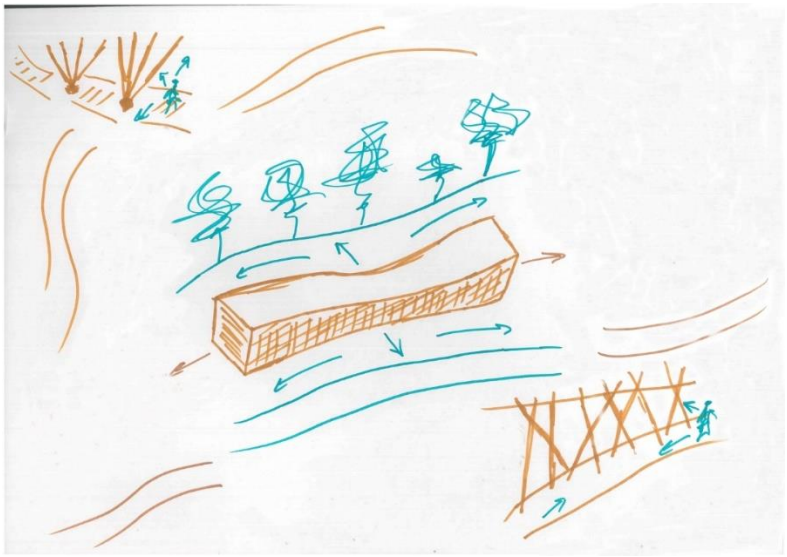
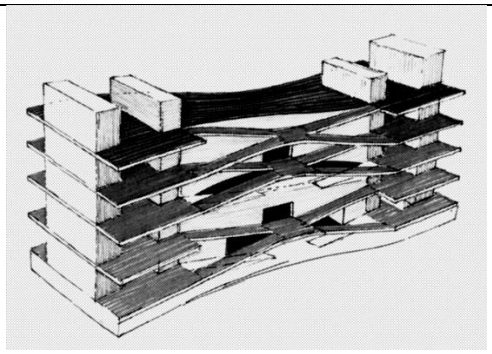


Figure 100: Sketch of the architect

Table 10: Analysis of mellat park cineplex

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Mellat Park Cineplex	*Tehran, Iran*	*Catherine Spiridonof*	*Metaphor (Surrounding Environment)*	*Initial*	*Analogy (Site)*
Objective 1					
This design considers the surrounding context by transmitting surrounding lines into the site to form the shape of the building naturally and in fact, not only respects the surrounding natural environment but the surrounding urban environment. This metaphoric architecture has concept which follows visual and relational similarities to the surrounding environment. (Hey, 2008)					
Objective 2					
Material	Concrete				
Column	Cylinderical Steel				
Beam	Reinforced Concrete				
Slab	Reinforced Concrete				
Wall	load bearing (reinforced concrete)				
Bracing	Cylinderical Steel				
Cable	-				
Structural Requirements	A structural engineer considers the issue of ensuring that a building structure, is enough (regarding strength, stability, cost, etc.) for its intended use. This structure not only follows the site characteristics but uses integrated reinforced concrete in most of parts of the building to provide high tension and compression and other forces resistance (stability and strength) by well passing of loads, which are supported by different steel bracings. (Garrison, 2005)				
	Special structural requirements and needs of long spans, has formed full-form-active structural arrangement. Using of new types of steel bracings and integrated curvy concrete walls are some signs of these kinds of form-active systems. (Macdonald, 1997)				

Structural Arrangements (Basic Geometry)	 Reinforced integrated concrete structure joined to concrete foundation and multiple steel bracing by hinges.
Use of Structure	Full-form-active structure of this complex provided more structural efficiency for designer to freely play with spaces according to the functions of them. The structural design followed the overall lines and characteristics of the site as considered concepts too, to make structure as form. Therefore, we have structural and relational similarities of structure to concepts that forms analogical use of structure. (Songel, 2010) (Hey, 2008)
Relationships between Structure and Architecture	
Functionally, the architectural and structural design of this complex, integrated beautifully and softly in new ways. Unified curvy form of the building is supported well by reinforced concrete system to have all structural requirements together and also to show this attractive unity externally and internally. (Dutton, 2000)	

5.2.3 Unknown Martyrs Monument

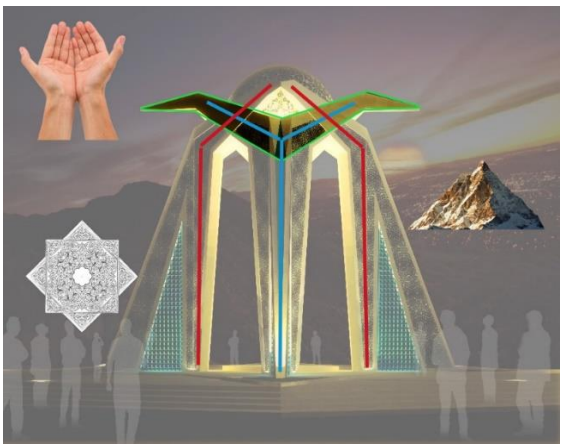


Figure 101: Elevation Analysis, combined relational concepts are used in this design and structure of monument metaphorically

These kind of space as their cultural value in Iran, could be considered by an architect as placemaking design, because of their regular attraction and gathering.

“The architect creates a culture’s image”. (Tuan, 2002, p. 164) This symbolizing multi-conceptual stable building (figure 102) not only could transfixes people but could stimulates them to visit the place. A designer has used purified various ideas in this monument that can be seen in elevation and other views. Combined different concepts (unity, praying) which used here, processed in concept generation stage of design process, are also only have appearance and relational similarities to the main sources, so form metaphoric architecture. (Hey, Linsey, Agogino & wood, 2008)

Also a scaled mountain is considered here as a symbol of powerful and stable structure. The main structure of the monument is steel type, with the support of steel buttresses or bracings, and covering of concrete material. It is tried to design this structure according to site topography and local characteristics including the earthquake. It is understood that this type of structure has full efficient structural steel elements which are well integrated with each other, by hinges and joints, so create full-form-active structure. These elements are covered in a way to visualize the concepts but hold their main structural form and stability. Therefore, they help the architectural design, and structural efficiency too and provide structural and relational similarities, so create analogical use of structure.

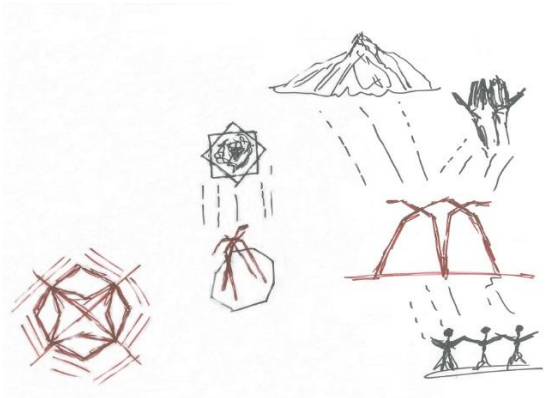
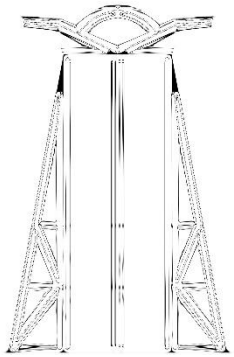


Figure 102: Sketch of the architect

Table 11: Analysis of unknown martyrs monument

Project	Location	Architect	Concept of Form	Stage	Use of Structure
Unknown Martyrs Monument	*Ardakan, Iran*	*Hosein Diba*	*Metaphor (Unity, Praying)*	*Concept Generation*	*Analogy (Mountain)*
Objective 1					
Combined different concepts (praying, unity) which are used here, processed in concept generation stage of design process, only have appearance and relational similarities to the main sources, so form metaphoric architecture. (Hey, Linsey, Agogino & wood, 2008)					
Objective 2					
Material	Steel				
Column	Steel				
Beam	Steel				
Slab	-				
Wall	Concrete				
Bracing	Steel				
Cable	-				
Structural Requirements	During schematic design, overall stability of the structure must be checked. The design of this monument is in way that all steel components connected well together by hinges and support of steel bracing to provide strength and stability of structure. (Lin & Zhen, 2016)				
Structural Arrangements (Basic Geometry)	Well connected steel elements with aim of some bracings or supporting components, mostly in crooked conditions, in this structure, make full-form-active structure. This structural design improves the structural efficiency too. (Macdonald, 1994)  integrated steel structure joined to concrete foundation and multiple steel bracing by hinges and joints				
Use of Structure	As architectural and structural point of views, the design of this monument has formed mostly according to its considered structure, so could be named structure as form. Also, efficiency of structure is considered well in structural design and materials of this building, by using of steel and concrete and their supporting elements, to create full-form-active structure. Thus, we have analogical use of structure, which includes structural and relational similarities to the concept (mountain). (Smith, 2016) (Songel, 2010)				
Relationships between Structure and Architecture					
For integrated design, a key feature is that structural engineers include architectural design objectives in their work. Therefore, we can see this point in this project that overall form of the structure, not only follows structural efficiency, but follows the general forms of concepts. This is one of the effective points in integrated design to get high quality design and attractive building. (Uihlein, 2014)					

5.2.4 Roya House

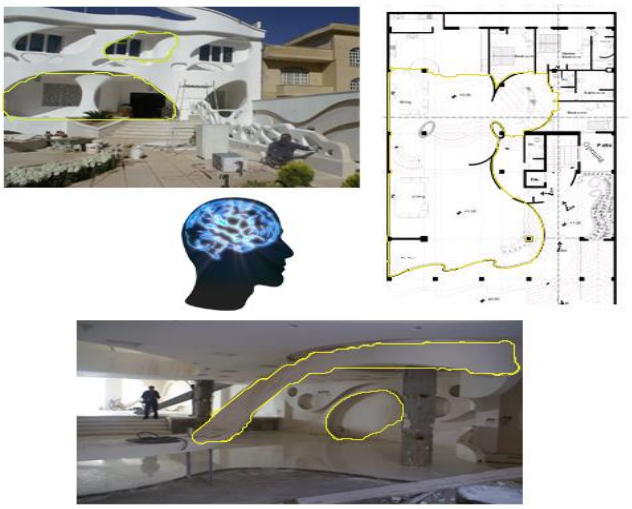


Figure 103: Roya house analysis, Curvy unique house structural design should be efficient and workable to be form-active type of structure.

This attractive and transfixing house in Shiraz, has designed in a way that evokes the dream (figure 104) and freeness from the regular life. Designer has tried to simplify the dream concept, in initial stage of design process, as some simple curves which stimulates the user, not only by the façade design and interior design but by the plan design. “The architecture expresses senses and values in the material”. (Hojat, 2010, p. 58) This is essential that how an architect could uses these kinds of metaphor in the form of physical, real, stable and material structure, so the user of the house could get the sense of dream when looking at the interior and exterior curves. It is the metaphoric design as translation of dream, without functional similarity. (Hey, 2008) .

The structure of building also must holds the loads parallel to keep the conceptual design. This concrete structure has created combination of post-beam structure and semi-complicated curvy structure. Some elements can be considered as efficient structures and provide some openness and diversity internally and externally. This

semi-form-active type of structure has good potentials for architect to create unique conceptual spaces. However, some parts are working functionally but some other parts are mostly tending toward ornamental design. The rhythmic and curvy form and design of this house, not only must be workable but should be continuous external elements to internal elements efficiently. Thus, this metaphorical use of structure (dream) has only visual and relational similarities to the source of concept.

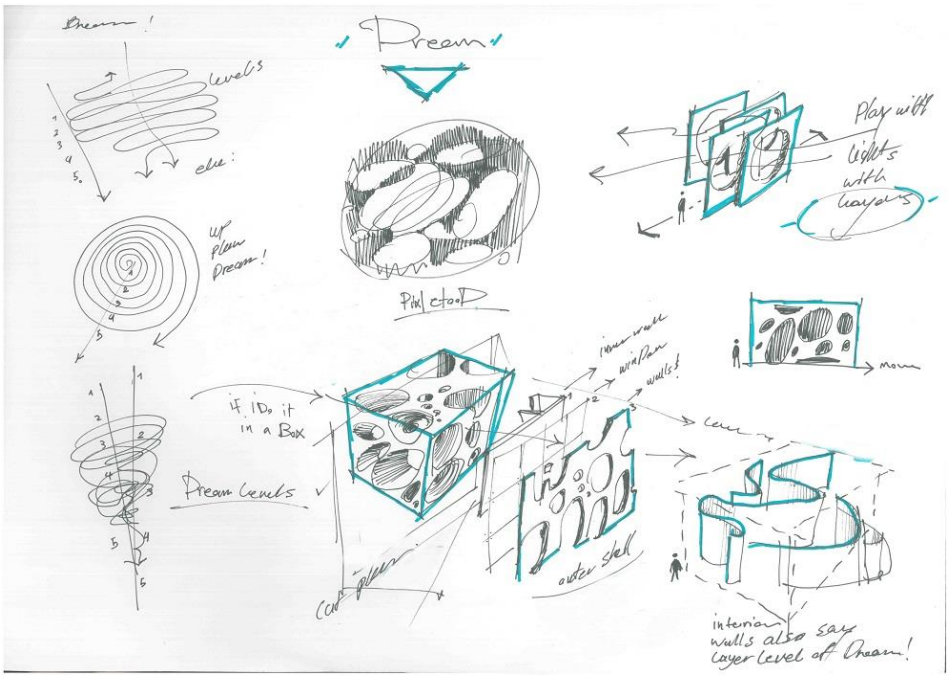
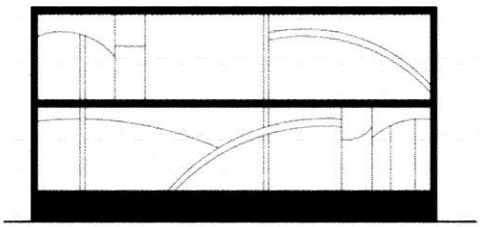


Figure 104: Sketch of the architect

Table 12: Analysis of roya house

Project	Location	Architect	Concept of Form	Stage	Use of Structure
Roya House	*Shiraz, Iran*	*Esfandiar Abdeshah*	*Metaphor (Dream)*	*Initial*	*Metaphor (Dream)*
Objective 1					
Designer has tried to simplify the dream concept, in initial stage of design process, as some simple curves which stimulates the user, not only by the façade design and interior design but by the plan design. (Hey, 2008)					
Objective 2					
Material	Concrete				
Column	Reinforced Concrete				
Beam	Reinforced Concrete				
Slab	Reinforced Concrete				
Wall	Non-load bearing				
Bracing	I beam Steel				

Cable	-
Structural Requirements	Reinforced concrete provides high strength and stability by the help of composing steel mesh and included materials. Loads and forces must be resisted by reinforced concrete foundation according to its rigidity and strength. (Farrelly, 2007)
Structural Arrangements (Basic Geometry)	The structure of this house is not simple post-beam type and it includes steel bracings. It also contains some semi-functional curvy structural elements. Therefore, the structure has more efficiency and more spans. (Macdonald, 1997)
	 Reinforced concrete structure joined to concrete foundation and steel bracings by hinges and joints
Use of Structure	Structural design of this house consists of semi-form-active system which has semi-efficient components as reinforced concrete, steel bracings and some functional elements. However, it can be said that the external and internal designs, mainly, are visual elements to be consider the structure as ornament. Overally, the use of structure can be named as metaphorical (dream). (Hey, 2008)
Relationships between Structure and Architecture	
Using of visual structural elements should be functional, useful and meaningful. In design of this house, this point is not completely considered and designer should think about it seriously that elements must be designed and used effectively and naturally, in architectural and structural domains. (Charleson, 2005)	

5.2.5 Namak Restaurant

This naturalizing designed restaurant inspired from the salt and its natural form, transfixes people by its attractive façade. An architect has tried to transmit the soft form of the façade to the inside of the building to keep the natural sense of design and concept. Most parts of this restaurant has tried to be designed softly and in respect to the main concept which stimulates customers to eat better. Relational, surface and functional similarities to the natural salt cave (figure 105) to evoke this kind of place when you are sitting there, forms analogical conceptual building. (Casakin, 2006b)

The main body of structure is from wooden and metal cores which are covered with natural gums and salty compositions. This type of structural design could not be fully efficient (semi-form-active) and has not deep similarities to the natural salt caves (figure 105), however, architect has tried to use some sustainable materials. It is tried to create symbolical visual structural form in order to follow the main concept and attract people. The structural use of this project is not in the way of technical logics so it is looks like some attractive cover than flexible functional structure. Hence, its use of structure, with just surface similarities, presents metaphoric use of structure.

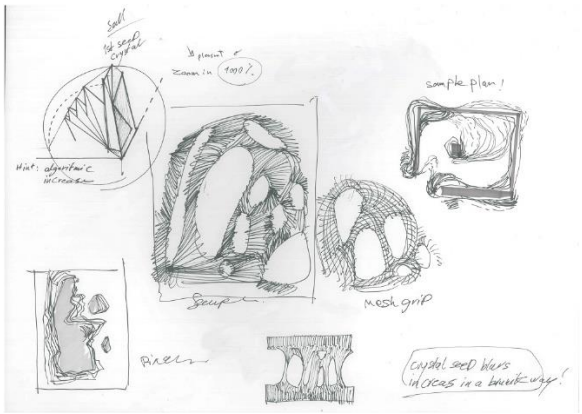
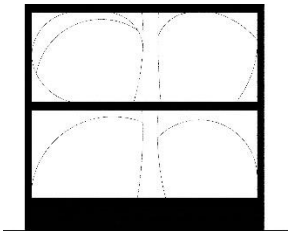


Figure 105: Sketch of the architect

Table 13: Analysis of namak restaurant

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Namak Restaurant	*Shiraz, Iran*	*Alireza Emtiaz*	*Analogy (Cave)*	*Concept Generation*	*Metaphor (Cave)*
Objective 1					
Relational, surface and functional similarities to the natural salt cave to evoke this kind of place when you are sitting there, forms analogical conceptual building. (Casakin, 2006b)					
Objective 2					
Material	Steel				
Column	Steel				
Beam	Steel				
Slab	Masonry				
Wall	Non-load bearing				
Bracing	I beam Steel				
Cable	-				

Structural Requirements	Again steel in selected in this project for structural material to its better properties like high strength in different loads and forces and also better transferring of loads to the foundation as stability. (Sun, 2014)
Structural Arrangements (Basic Geometry)	This structure includes only steel post-beam system followed by steel bracing and some non-structural wooden and metal elements which are not covering specific space, so semi-form-active structure created in this project. (Macdonald, 1997)
	 Steel structure joined to concrete foundation and steel bracings by hinges and joints
Use of Structure	This type of structural design could not be fully efficient (semi-form-active) and has not deep similarities to the natural salt caves, however, architect has tried to use some sustainable materials. It is tried to create symbolic visual structural form in order to follow the main concept and attract people. The structural impression of this project is not in the way of technical logics so it is looks like some attractive cover than flexible functional structure. Hence, its use of structure, with just surface similarities, presents metaphoric use of structure. (Casakin, 2006b)
Relationships between Structure and Architecture	
The design of this restaurant is trying to evoke the natural salt cave and some wooden and metal components are used in this way, but they are not efficient and technical, so could just be considered as apparent tools to attract and stimulate people. Designer can create something which is more real and more structural to increase the structural efficiency. (Songel, 2010)	

5.2.6 Sacred Defense Museum

Figure 106: naturalizing external form and structure according to the site characteristics

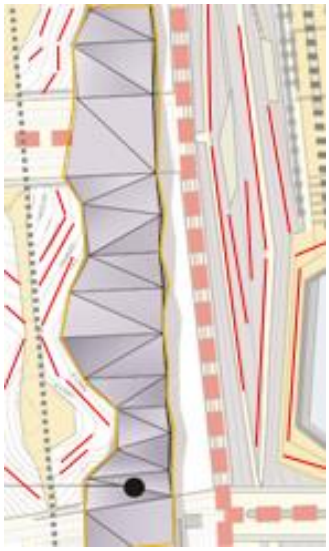


Figure 107: overall building form and plan according to the site topography

This museum is designed very similar to the organic style of architecture which can be called naturalizing architecture. The design of museum pursuits the topography of the natural site to be formed in a way to encompass the hill, not into the hill. This style of design not only holds the stability of the building but transfixes people and visitors from different angles of views. The sacred defense (figure 108) characteristics as one of the important national symbols of any country, are considered as concepts of this project, so with only relational and surface similarity to the concepts, the metaphorical architecture has shaped. (Casakin, 2003)

The structural design of this building followed the steel structure type which overally is full-form-active structure. The main walls have irregular form and design according to the natural form of the site (figure 108) which made up from steel materials and they are load bearing, so could be considered full-form-active. Columns are also by steel and some surfaces are used efficient steel cable and bracings. The ceiling of the project is made by light steel and has efficiently structural form which has tried to express topographic condition of the site.

Therefore, in this analogical structural design, we see technical logics and the structure is trying to follow the architecture and its concepts.

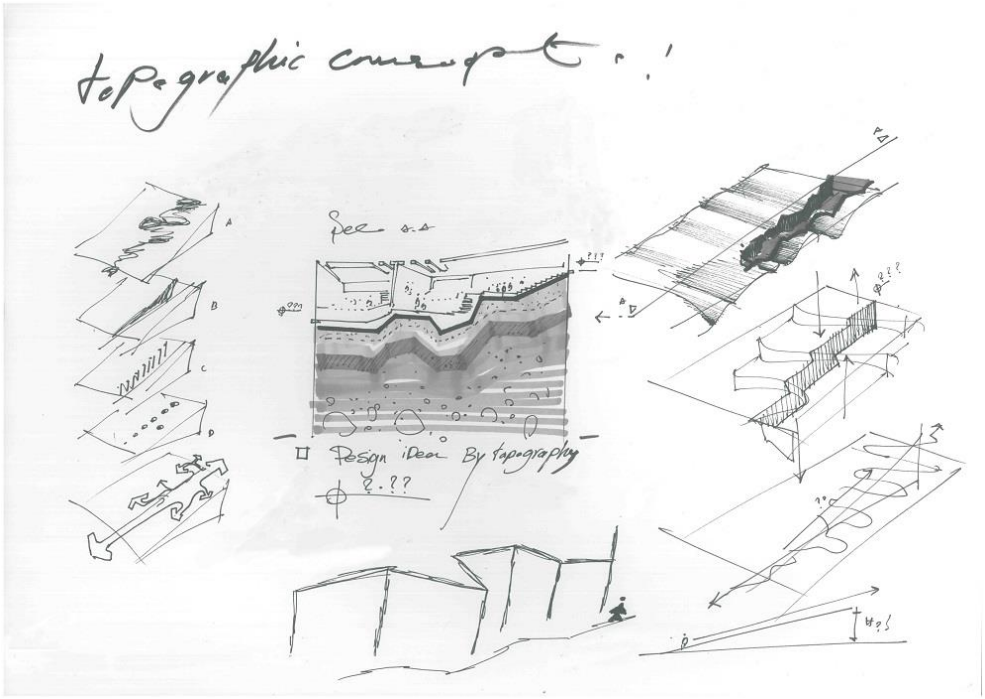
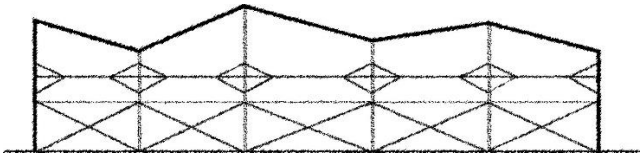


Figure 108: Sketch of the architect

Table 14: Analysis of sacred defense museum

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Sacred Defense Museum	*Tehran, Iran*	*Zhila Norozi*	*Metaphor (Sacred Defense)*	*Concept Generation*	*Analogy (Site)*
Objective 1					
The sacred defense characteristics as one of the important national symbols of any country, are considered as concepts of this project, so with only relational and surface similarities to the concepts, the metaphorical architecture has shaped. (Casakin, 2003)					
Objective 2					
Material	Steel				
Column	Steel				
Beam	Steel				
Slab	-				
Wall	load bearing				
Bracing	I beam Steel				
Cable	Steel				
Structural Requirements	The steel structural design of this museum, has used the benefits of steel material strength in compression and tensile forces, aligned with using of steel bracings and cables and trusses to provide needed stability of building. (Farrelly, 2007)				

Structural Arrangements (Basic Geometry)	According to specific structural needs in this project such as wide spans, light ceiling, and specific wall forms, full-form-active system is used here. As technical logics, steel bracings, cables and trusses are used to improve the structural efficiency. The main steel walls are also load bearing. (Macdonald, 1997)
	 Steel structure joined to concrete foundation and steel bracings and steel cables by hinges and joints
Use of Structure	Applying efficient steel elements to have light and specific structure and long spans, created full-form-active structure. On the other hand, form of the structure is following the overall form of the architecture of the building and there is less ornamental elements. In this way, analogical use of structure is made.
Relationships between Structure and Architecture	
In semi topographic condition of this project, steel structure and elements are used to form organic-like architecture. However, the applied materials are not organic and natural, but the structural efficiencies are considered in different parts of the building as steel components have played important roles in main walls, ceiling and big columns. (Uihlein, 2014)	

5.2.7 Tagh Kasra Building

Figure 109: Façade analysis, its form-active structure has efficient side and top trusses which are technically and visually working

One of the interesting projects in this research, is this commercial and residential complex, with unique façade design. Saberi as an architect, not only has tried to revive the famous ancient vault (Tagh Kasra) in the façade design (figure 110), but to evoke floating stable floor, with the help of exposing trusses. Also it is tried to use

some traditional elements like netted window and brickworks to complete the concept of Persian traditional art and architecture (Figure 109). Combination of these different concepts and interpretation of them as semi-modern designed façade, creates attractive metaphoric architecture which has relational and appearance similarities to the concepts, considered in initial stage of design process. (Gentner & Markman, 1997)

Here, while the whole structure is steel with bolt joints, the inspired truss supported floor, is the interesting efficient structural design of this project. The main volume which is located at the façade of this complex, from sides and upper level, is supported by some trusses effectively and efficiently. At the side the trusses provide spaces for lifts to work easily. At the upper level, the weight is supported functionally by the help of trusses and bolt joints. Therefore, the form-active structure is formed here. The structural design mainly at the façade, is in a way that combined technically and visually with architecture. The analogical truss structure (appearance, relational and functional similarities to the main concept) is modernized working real vault (figure 110) to hold the administrative floor above the main entrance. “The analogy has two distinct kinds of interpretation, the one to do with visual appearance or composition, the other functional-although the two are interrelated”. (Steadman, 2008, p. 8) With this kind of reasoning, designer could create functional and meaningful structural elements at the same time.

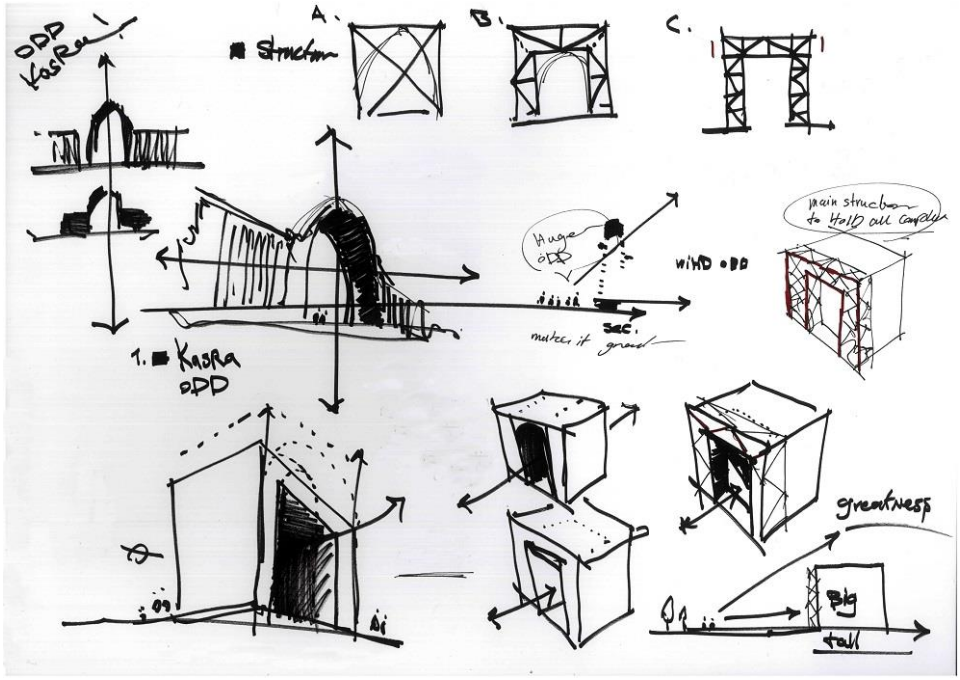
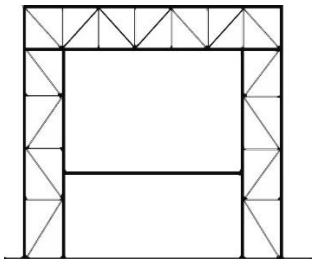


Figure 110: Sketch of the architect

Table 15: Analysis of tagh kasra building

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Tagh Kasra Building	*Shiraz, Iran*	*Sorosh Saberi*	*Metaphor (Ancient Vault)*	*Initial*	*Analogy (Vault)*
Objective 1					
Combination of different concepts (ancient vault) and interpretation of them as semi-modern designed façade, creates attractive metaphoric architecture which has relational and appearance similarities to the concepts, considered in initial stage of design process. (Gentner & Markman, 1997)					
Objective 2					
Material	Steel				
Column	Steel				
Beam	Steel				
Slab	Masonry				
Wall	Non-load bearing				
Bracing	I beam Steel				
Cable	-				
Structural Requirements	Not only steel structure and its characteristics, provide suitable efficiencies for this structural design, but its used steel trusses are covering large spans and support stability of the upper spaces and also enough strength. (Garrison, 2005)				
Structural	Structural efficiencies of used elements in this design include steel structure completed by steel bracings and different trusses which are functionally and technically support large spans. This structural design is not using simple components but is supporting functional upper spaces as complicated system, so we can see full-form-active structure. (Macdonald, 1997)				

Arrangements (Basic Geometry)	 Steel structure joined to concrete foundation and steel bracings and steel cables by hinges and joints
Use of Structure	Here, while the whole structure is steel with bolt joints, the inspired truss supported floor, is the interesting efficient structural design of this project. The full-form-active structure of this design, also has suitable relationship with architecture, especially on the main elevation. The analogical truss structure (appearance, relational and functional similarities to the main concept-vault) is modernized working real vault to hold the administrative floor above the main entrance. (Gentner & Markman, 1997)
Relationships between Structure and Architecture	
Designer of this project used unique way in order to have effective and functional structure which forms considered architecture too. In this way, trusses are playing important role to evoke lightness of design in main façade and to express the floating space as considered ceiling of ancient vault. (Sun, 2014)	

5.2.8 Textile Museum

Figure 111: Elements analysis, Contrasts of original brick masonry structure and other efficient and non-efficient structural elements are visualized and expressed in unique ways.

One of the other unique projects which is assessed in this research, is this museum. Some designers, instead of concentrating of finding solution, for reaching to the better realization of problem, are playing with ideas (Lawson, 2005). Here, designer in a way of vitalizing the old textile factory (figure 112), has considered different ideas parallel to the renovation of the building. (Figure 111) Demolished building is designed and constructed again to keep the stability of the project, by pursuit of the original design and by the help of some exposing elements related to the old factory and its function. These relational, functional and structural elements, similar to the main concept of the project, are used even without any touch to evoke the textile function and production process, to create analogical architecture (Gentner, 2001).

However, the project has some additional visual not efficient structural elements, but it is tried to renovate and revive the main structure of the original building with the original materials. This original structure is masonry system made by bricks and some few steel elements and steel cables are used in different parts of the building to reinforce the main structure. Therefore, this renovated masonry structure which enriched by some efficient steel cables, could be regarded as full-form-active structure. It is also can be concluded that this integrated brick and cable structure, creates the main body of the architectural design and has appropriate relationships with its architecture. Therefore, this building, also with its relational, functional and structural similarity to original structure (figure 112), forms analogical use of structure. This semi hi-tech architecture, not only provides structural concepts for designer, but enhances the aesthetics qualities of the façade and other surfaces, from internal and external point of views.

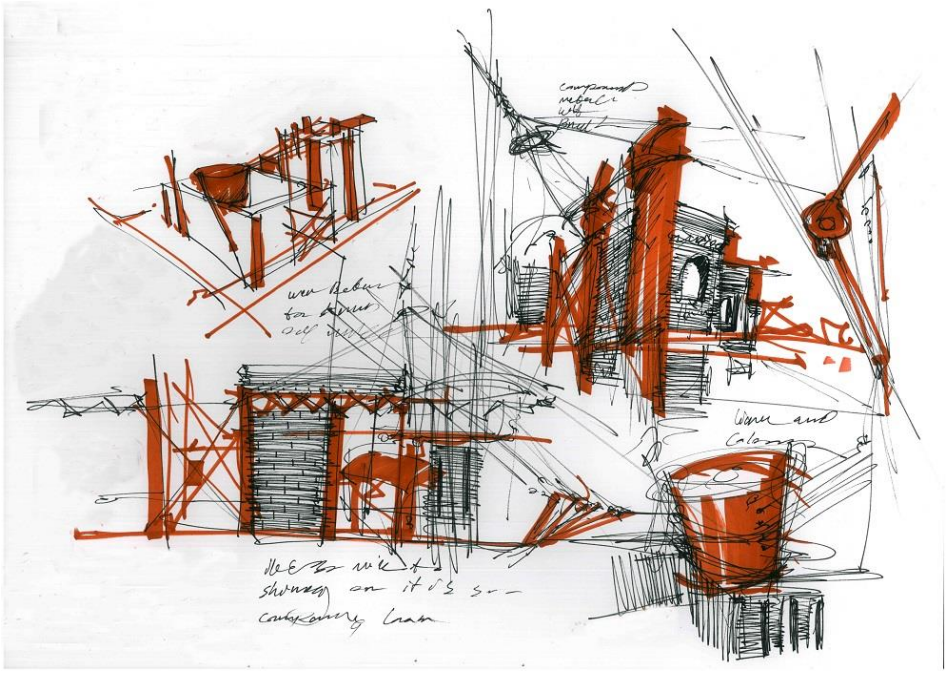


Figure 112: Sketch of the architect

Table 16: Analysis of textile museum

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Textile Museum	*Shiraz, Iran*	*Mehrdad Iravanian*	*Analogy (Factory)*	*Concept Generation*	*Analogy (Factory)*
Objective 1					
Relational, functional and structural elements, similar to the main concept (old factory) of the project, are used even without any touch to evoke the textile function and production process, to create analogical architecture. (Gentner, 2001)					
Objective 2					
Material	Masonry				
Column	Masonry				
Beam	Masonry				
Slab	Masonry				
Wall	Load bearing				
Bracing	Steel Cable				
Cable	Steel				
Structural Requirements	Masonry structure, itself, has low properties like strength and stability, but here, it is powered by using of steel cables to provide more stability and strength according to the characteristics of steel and cables. (Farrelly, 2007)				
	However, the original structure is masonry and it is tried to be kept and renovated, but efficient steel elements which are steel cables are used in different parts to increase the technical roles of the masonry structure. Hence, spans could be larger, and spaces could be diverse and free, so full-form-active system will be seen in this project. (Macdonald, 1997)				

Structural Arrangements (Basic Geometry)	 Masonry structure joined to concrete foundation and steel bracings and steel cables by hinges and joints
Use of Structure	This renovated masonry structure which enriched by some efficient steel cables, could be regarded as full-form-active structure, and it is well integrated with architecture. Its structural and functional similarities to original building (factory), make analogical use of structure. (Gentner, 2001)
Relationships between Structure and Architecture	
In this specific situation, the original building is not demolished but repaired to be expressed by itself. In this way, its architecture and structure is tried to be original and just some technical and visual steel element added to them to fortified it more, so we can see strong relationship between architecture and structure, in new way. (Uihlein, 2014)	

5.2.9 Tourism Information Center

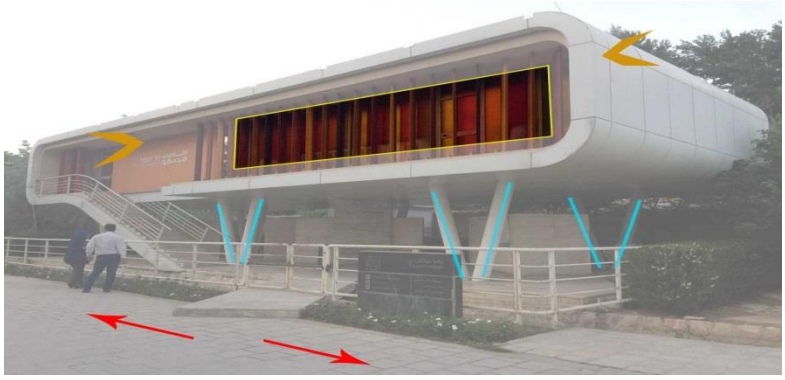


Figure 113: Design analysis, Angular columns of this center are the result of trying of an architect to influence on local passers with sense of floating and weightless.

Making contrast in architecture is one of the interesting and attractive design ideas. Architect of this center also has followed this method to design this colorful building in contrast with its surrounding natural green environment in order to have a transfixing design which can absorbs passers to the center. A building is designed like a balloon (figure 114) which is light-weight to express the light character of it, with least interference to its site. Thus, the building is designed with least crooked exposing stable columns which pursuits the passing way and without the ground floor to be shown as a flexible volume in the place. Also some naturalizing ideas are considered here by the help of colorful orientated curtains according to the seasonal sun diagram. As it explained here about this architecture, the appearance and relational similarities to concepts can be seen in this metaphoric design (Gentner & Markman, 1997).

This building includes kind of unified steel structure with some flexible columns. These semi efficient crooked columns could be acting as effective visual elements and at the same time, they can induce the sense of floating structure. Also the building internally has some steel bracings which are essential to provide stability of this semi-floating building. This semi-form-active structure is not designed fully technically and there could be other options for its structural design and system so we kind of ornamental structure. Therefore, its expression of structure is also metaphoric kind because of the surface and relational similarities to considered ideas.

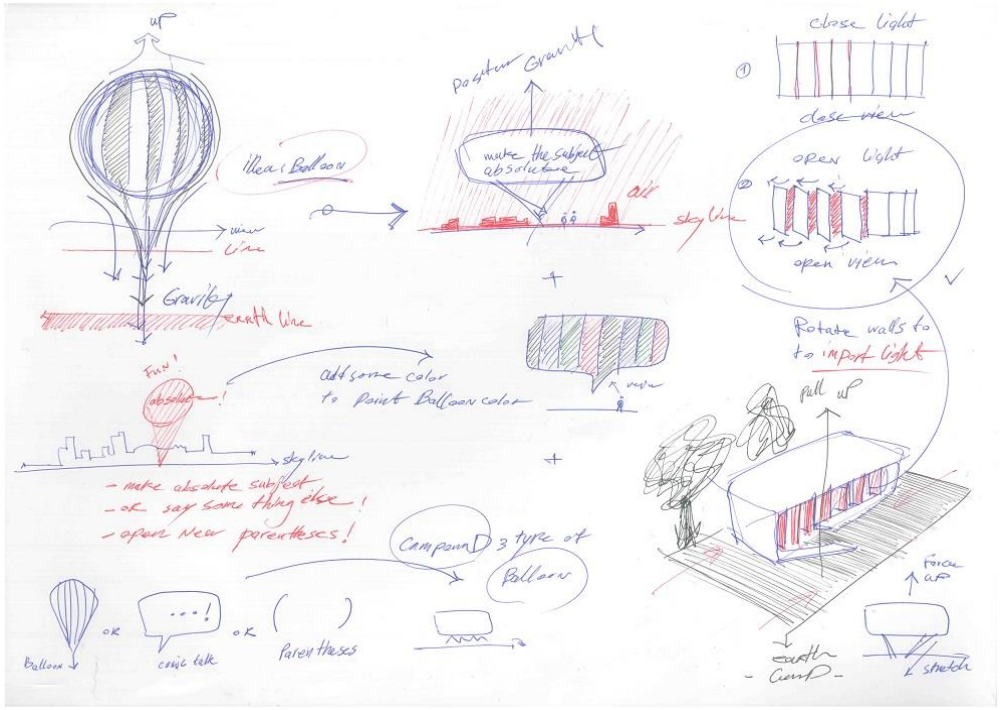
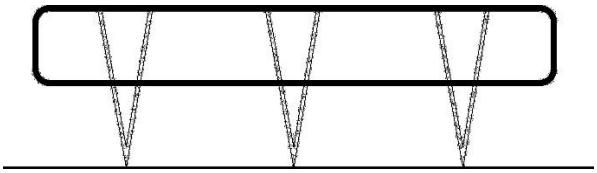


Figure 114: Sketch of the architect

Table 17: Analysis of tourism information center

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Tourism Information Center	*Shiraz, Iran*	*Ali Sodagaran*	*Metaphor (Balloon)*	*Initial*	*Metaphor (Balloon)*
Objective 1					
As trying to show the lightness of building like balloon, so the appearance and relational similarity to concepts can be seen in this metaphoric design. (Gentner & Markman, 1997)					
Objective 2					
Material	Steel				
Column	Steel				
Beam	Steel				
Slab	Masonry				
Wall	Non-load bearing				
Bracing	Steel				
Cable	-				
Structural Requirements	High properties of steel caused use of it in this project to ensure enough strength and stability of the building. The specific steel columns with help of steel bracings, transfer the loads to the concrete foundation effectively. (Macdonald, 1997)				
	Crooked columns and bracings, are designed to improve the structural efficiencies, however, it is not completed well and it is not made unique form. Therefore, semi-form-active structure can be seen here.				

Structural Arrangements (Basic Geometry)	 Steel structure joined to concrete foundation and steel bracings by hinges and joints
Use of Structure	This steel structure can be considered as semi-form-active structure as there is not large spans or unique shape in this building design and from another view, there is not simple post-beam structure. Also, we can not call it structure as form, because some elements like bracings are hidden and crooked columns are not related well with the main architectural form. Thus, there is surface similarities to the main concept (balloon) and we have metaphoric use of structure. (Gentner & Markman, 1997) (Smith, 2016)
Relationships between Structure and Architecture	
Although the design is guided to be unique and structurally but it is not combined with architecture in technical way. In this project, crooked flexible steel columns are trying to integrate with the site but columns could have effective roles to form main architectural body, not only from structural point of view but from environmental point of view. (Charleson, 2005)	

5.2.10 Bam Land

Figure 115: Façade analysis, using traditional and historic symbols and elements without any structural logic, provide less resistant and meaningful buildings.

This complex located at the shore of the famous lake in Tehran, includes various concepts in order to vitalize pre-Islamic and Islamic Persian architecture in different ways and forms. Team of designers decided to stimulate local and other visitors to visit the place, to gather (placemaking) and to enjoy the restaurants with the unique

views, by the help of design combination of traditional and ancient elements (Figure 115). These elements are used in simplified ways and in different scales and proportions as evoking of ancient Persian arches and vaults and other details, plus some other naturalizing elements such as traditional windtower (figure 116), positioned on the traditionally proportioned buildings. “The mystery of architecture is hidden in geometry and proportion” (Tavasoli, 2004, p. 87). The application of some elements with appearance and relational similarities to the concept (history) express the metaphorical architecture (Casakin, 2003).

Regarding the structure of the buildings, the complex includes simple concrete post-beam system of structure which provides simple building forms and plans. Some wooden elements and details are used in this project on the façades or terraces which all of them have not any structural function or efficiency. If we want to use some traditional elements to attract people, or if we want to provide meaningful historic elements, it is more useful, effective and functional to use related modernized structure. It means that the resulted structure must be a good and efficient combinations of traditional and modern elements. Hence, buildings of this complex are using structure as ornament which try to have some influences and symbols just visually not deeply (figure 116). The appearance and relational similarities to concepts (history), express the metaphoric use of structure.

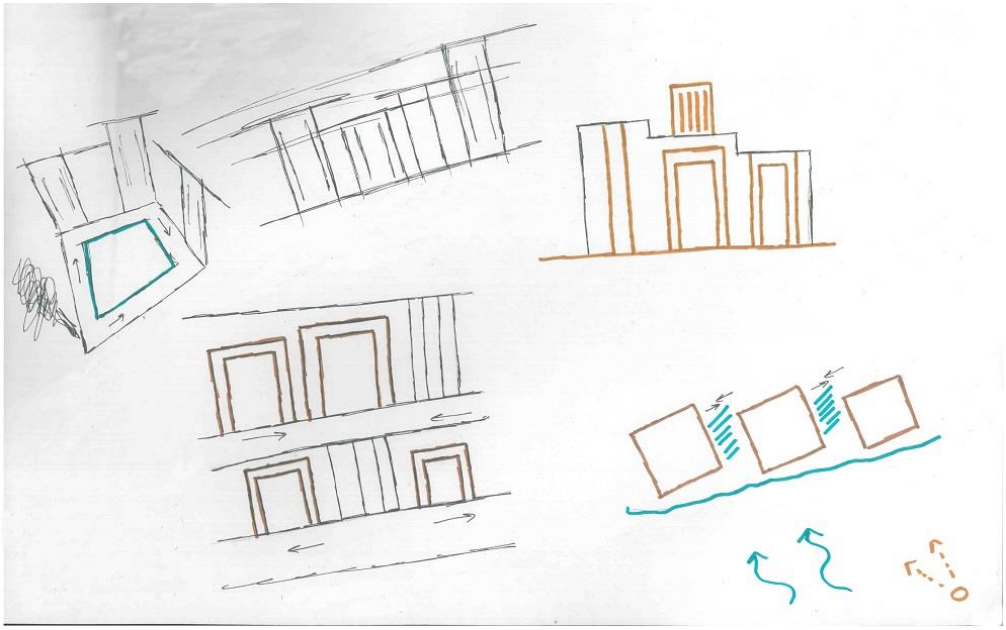
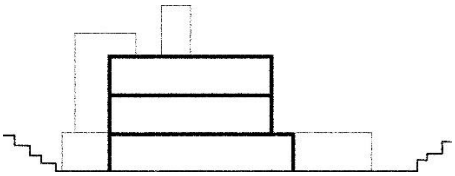


Figure 116 : Sketch of the architect

Table 18: Analysis of bam land

Project	Location	Architect	Concept of Form	Stage	Use of Structure
Bam Land	*Tehran, Iran*	*Morteza Adib, Maryam Yousefi, Farzad Daliri*	*Metaphor (History)*	*Initial*	*Metaphor (History)*
Objective 1					
The application of some elements (windtower, building proportions and frames) with appearance and relational similarities to the concept, express the metaphorical architecture (Casakin, 2003).					
Objective 2					
Material	Concrete				
Column	Reinforced Concrete				
Beam	Reinforced Concrete				
Slab	Reinforced Concrete				
Wall	Non-load bearing				
Bracing	I beam Steel				
Cable	-				
Structural Requirements	The strength of reinforced concrete and its resistance against different conditions are good but still it depends on the amount of loads and its exposure. Suitable connection of it to concrete foundation, surely, provides better transferring of loads and forces, and therefore, stability of building. (Smith, 2016)				
	Although, concrete could be formed easily by today tools, but this project has simple post-beam system with just additional steel bracings, that create semi-form-active structure. There are no light structural elements and no wide spans. (Macdonald, 1997)				

Structural Arrangements (Basic Geometry)	 Reinforced concrete structure joined to concrete foundation and steel bracings by hinges and joints
Use of Structure	Steel bracings in this concrete structure, made it to be considered as semi-form-active structure, and on the other hand, there is only visual structural elements such as woods and frames, and we cannot see structural similarities to concepts, so metaphorical use of structure is shown. (Casakin, 2003) (Charleson, 2005)
Relationships between Structure and Architecture	
In this multi-conceptual design, however, the architecture is considered stronger by using of different ideas, but the structural design is not well regarded and most of elements are visually not logical or technical. Wooden elements could be combined with architectural design in efficient and environmental ways effectively. Also ancient frames can be positioned on the openings to be structural, to better evoke the sense of concepts. (Songel, 2010) (Sun, 2014)	

5.2.11 Namaz Khaneh

In this cuboid building, the rotation of one cube within another cube is also another metaphoric concept of Tawaf, the circumambulation around the Kaaba in a counter-clockwise direction (Figure 117). On the one hand, the space between the two cubes represents the momentum and mobility; on the other hand, the space within the smaller cube represents immobility and stillness. Indeed, in religious beliefs, “pause” creates tranquility and peace.

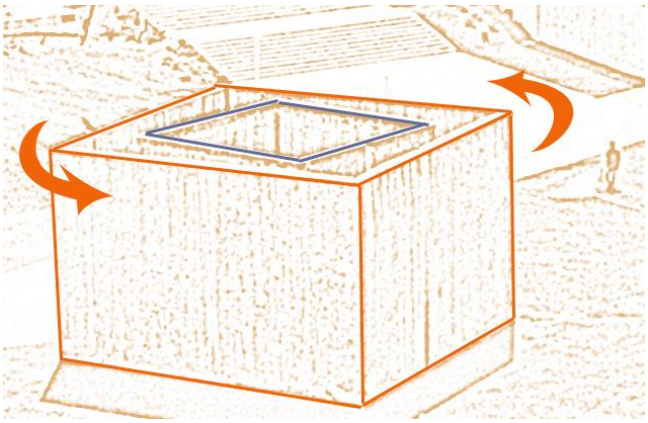


Figure 117: The rotation of one cube within another cube

Another fascinating feature of this place is that this prayer room lacks roof. The absence of ceiling allows direct sun light and rainfall, two purification agents among most religions including Islam. According to Bani Masoud (2014), the design of this prayer room can be considered as one of the most flourishing designs in the realm of the sacred spaces of the modern world with its both traditional and modern approaches. Therefore, the surface similarity to the concept (house of god) is created the metaphoric building but the relational and functional similarity of structure to the source domain (house of god), is created analogical use of structure in this project. (Hey, Linsey, Agogino & wood, 2008)

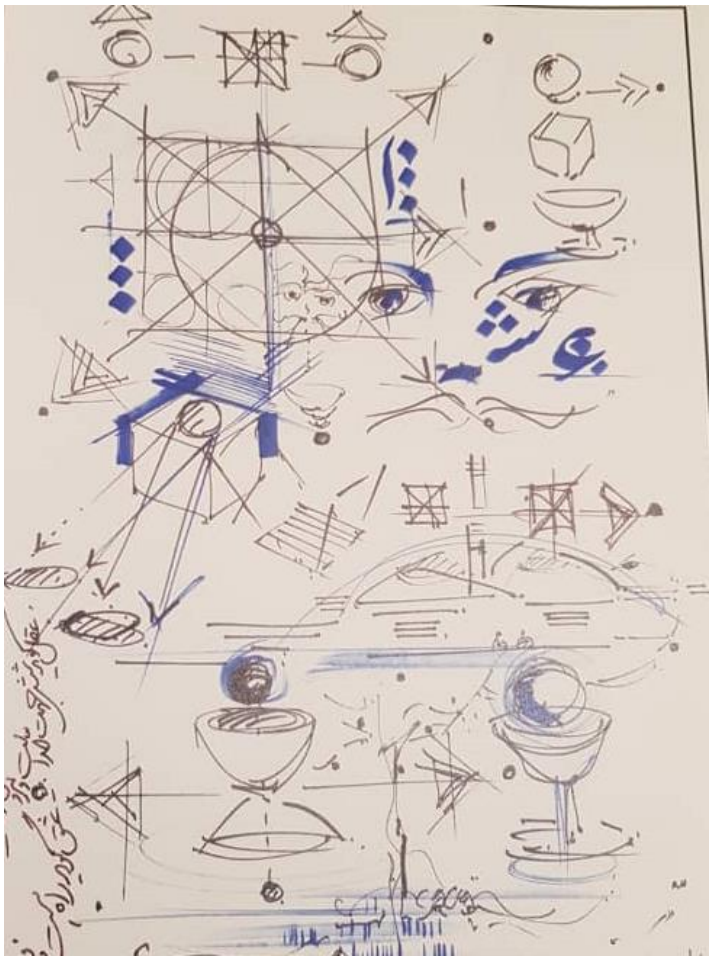


Figure 118: Sketch of the architect

Table 19: analysis of namaz khaneh

Project	**Location**	**Architect**	**Concept of Form**	**Stage**	**Use of Structure**
Namaz Khaneh	*Tehran, Iran*	*Kamran Diba*	*Metaphor (Kaba)*	*Concept Generation*	*Analogy (Kaba)*
Objective 1					
Two simple cubic spaces with surface similarities to the main concept (house of god), provide metaphoric building form.					
Objective 2					
Material	Concrete				
Column	Reinforced Concrete				
Beam	Reinforced Concrete				
Slab	Reinforced Concrete				
Wall	Non-load bearing				
Bracing	-				
Cable	-				
Structural Requirements	The strength of reinforced concrete and its resistance against different conditions are good but still it depends on the amount of loads and its exposure. Suitable connection of it to concrete foundation, surely, provides better transferring of loads and forces, and therefore, stability of building.				

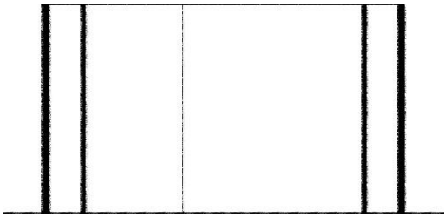
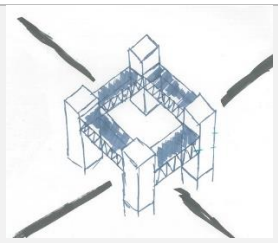
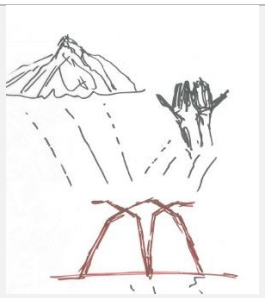
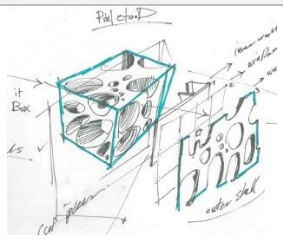
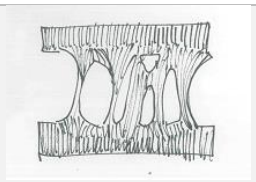
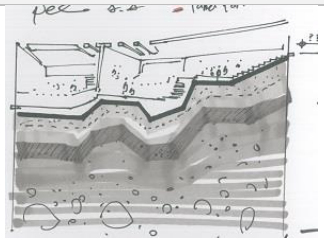
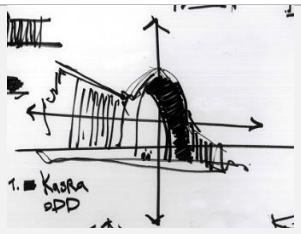
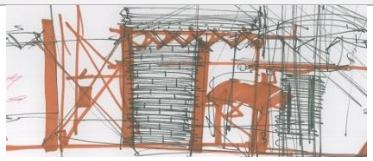
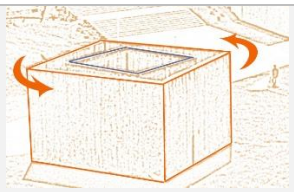
Structural Arrangements (Basic Geometry)	Although, concrete could be formed easily by today tools, but this project has simple post-beam system with just additional steel bracings, that create semi-form-active structure. There are no light structural elements and no wide spans.
	 Reinforced concrete structure joined to concrete foundation and steel bracings by hinges and joints
Use of Structure	simplicity in this concrete structure, made it to be considered as efficient type of structure as needed walls and spaces. These concrete walls have relational and functional similarities to the structure of the main concept (Kaba) in order to create analogical use of structure. (Casakin, 2003)
Relationships between Structure and Architecture	
However, the building has purity and high simplicity, but as essence of architecture meaning, designer has used this purity as main concept for praying space by using simple cubes and real wall to integrate architecture and structure in new way. (Songel, 2010)	

Table 20: Summary of projects analysis

Projects		***Metaphorical Concept of Form***	***Analogical Concept of Form***	***Drawing***
1	***Embassy of Iran, Seoul***	Columns of Universe		 Originality, Persian Garden, Symmetry
2	***Mellat Park Cineplex***	Surrounding Environment		 Context, Site Form, Views

3	***Unknown Martyrs Monument***	Unity, Praying		 Mountain, Unity, Praying
4	***Roya House***	Dream		 Dream, Imagination
5	***Namak Restaurant***		Cave	 Originality, Cave, Natural Form
6	***Sacred Defense Museum***	Sacred Defence		 Topography, Site Form
7	***Tagh Kasra Building***	Ancient Vault		 Ancient Palace, Technology
8	***Textile Museum***		Factory	 Originality, History, Factory

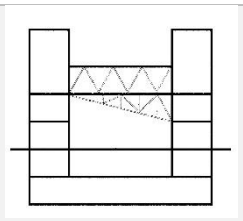
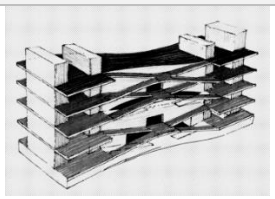
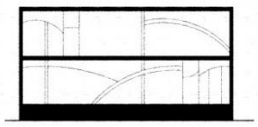
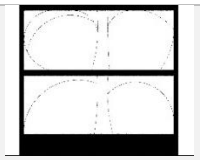
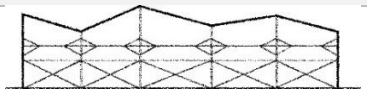
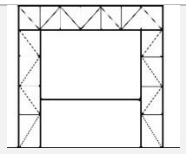
9	***Tourism Information Center***	Balloon		 Balloon, Flexibility
10	***Bam Land***	History		 Windtower, Ancient elements, Tradition
11	***Namaz Khaneh***	Kaba		 Simplicity, Purity, Originaity

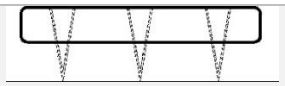
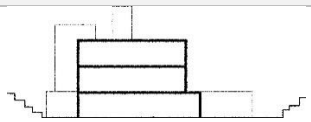
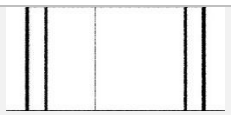
As analysis of projects and specificying the conceptual points of each of them, it can be said that natural and historical concepts are used more than others, in metaphorical thinking. Nine projects have used metaphorical concept of form. These metaphors refer to nature, history, originality and site. As analogical concept of form, one other project has applied salt cave as natural feature in order to evoke the food characters of salt, based on the function and character of restaurant. Other project has tried to revive the old factory. Therefore, the site and originality are the most important points which could be realized from this analysis.

The site of the project could provide various potentials for designers. First, the considered building could make strong connections with surrounding sites and buildings. These relationships with surrounding can be made more smoothly and peacefully. It is kind of respectful design that consider the context of the site, and this respect could be in terms of façade, plan, planning, function and other architectural elements. From structural view, the site could influence the type of structure based on the site form and condition. The site form could guide an architect and an engineer effectively and rightfully to form the building and its structure efficiently. This action can be done from the first stages of design process by effective cooperation of both architect and engineer.

Some architects consider originality of the concept in architectural and structural design of their project. Originality includes main characteristics of the concept. It could provide some opportunities for designers in order to catch the views of people based on the culture, traditions, and conditions of the site surrounding. From another view, originality could help architects to create analogical form of building.

Table 21: summary of projects analysis

Projects		*Metaphorical Use of Structure*	*Analogical Use of Structure*	Drawing
1	***Embassy of Iran, Seoul***		Persian Palace	 Steel Truss, Floating, Efficiency
2	***Mellat Park Cineplex***		Site	 Form, Integration, Beauty
3	***Unknown Martyrs Monument***		Mountain	 Design, Efficiency, Stability
4	***Roya House***	Dream		 Ornamental, Curves
5	***Namak Restaurant***	Cave		 Materials, Visual Effects
6	***Sacred Defense Museum***		Site	 Efficiency, Form, Beauty
7	***Tagh Kasra Building***		Vault	 Floating, Function, Form, Stability

8	***Textile Museum***		Factory	 Originality, Stability, Beauty
9	***Tourism Information Center***	Balloon		 Beauty, Design, Form
10	***Bam Land***	History		 Ornamental
11	***Namaz Khaneh***		Kaba	 Originality, Function, Beauty, Form

According to structural analysis, most of selected projects, include analogical use of structure. Their concepts of form are mostly metaphorical but in field of structure, deep relationships between concept and target, have considered. Beauty and form are two influential factors which are focused more in analysis of these projects, from structure point of view.

Form could be the most challengeable thing in architecture design and today, even in engineering design. Form of building is significant point in building design. The form could be inspired from anything, metaphorically or analogically, depending on the tastes of designer, audience, client, or related conditions. Architectural styles, arts, context, site, needs, climate, and many other factors could influence the design of the building form. The best and most effective kind of facing to these factor is considering all of them in integrated pack. In this way, the design product and its form, can be enriched and multi-dimensional.

It is essential that how we define a beauty in the architectural design and structural design. Each designer has specific definition about beauty and may treat it differently in design process. Beauty may be considered as more abstract meaning than its normal understanding, in design and engineering process. Others may consider it more real and visually. It is essential to say that most of people understand the beauty more visually, so many architects use metaphoric concepts to consider beauty. Beauty is part of visual effects in architecture and design. Visual elements in architecture have long history and wide discussions. Thinking in this field includes different opinions and styles. One of the most effective issues, is using of metaphor and analogy which are defined according to visual characteristics. The building form could be similar to the concept more apparently or deeply. From structural point of view, beauty has been considered seriously, as independent design style in contemporary era. In Hi-tech style of design, the structure features expose to audience as technical and structural beauty.

5.3 Summary

Analysis of interviews and case studies done separately by inductive and abductive reasoning. As results, different themes and codes discovered and each one of them described. Flexibility, creativity, visual effects, structure as form, strength, stability and efficiency, concluded from interviews. Site, originality, beauty and form concluded from selected projects. These keys are important and arguable which should be suitable models for architects and engineers in building design process. About the findings of this analysis, some recommendations will be introduced in the next chapter.

Chapter 6

CONCLUSION

This dissertation focused on metaphorical and analogical reasoning based on evidence provided by a select number of Iranian architects and their projects. While studies on these themes exist, the bulk of them however, concentrate on either metaphor or analogy, but not combined. Very few of these studies discuss metaphor and analogy from a structural engineering and not solely an architectural angle. To fill a gap in the literature, this research explored the extent to which architects' familiarity with and utility of metaphor and analogy in design affected their projects. The conclusion sheds light on four inter-related points on design process, metaphor-analogy, case studies and recommendations.

Design process: The first part of the conclusion revisits the gaps identified in the literature review, with some recommendations on the architects' education. The second part focuses on the findings from the case studies. First, design gives birth and identity to an idea. Designers engage in these creative activities in different ways, and under different circumstances. Design theory explains the design process and the paths to get there. Understanding this process and differentiating it throughout the design process, therefore, has important implications. While sometimes architects think they design something theoretically and in abstract terms, it may not actually turn out that way in practice. Design could conceivably happen in one's imagination and thinking and under different conditions.

Architectural design ending up with a building as the byproduct of a designer's imagination is a typical case in point. Architects adopt different approaches or artistic and presentation styles toward building design and creative thinking. As such, architecture becomes a sign or symbol depending on the site, context and other conditions. Architectural symbols and products communicate visual and cultural messages to their audience both directly or indirectly, and, for different purposes. These signs and symbols, however crude or broad they maybe, are subject to different assessments and evaluations criteria in debates surrounding architectural criticism. On the other hand, architecture provides an ideal physical milieu for people based on the site's visual and geological specificities and affordances. Reaching a sustainable level of equilibrium that creates a balance between the natural and the built environment constitutes an optimal solution. The design process, therefore, aims to undergird and address sensitive factors that come into play in building design.

The design process consists of three stages: The Generator stage involves thinking and selecting a concept; the Conjecture stage addresses working on design according to the selected concept, and analyze and complete the design outcome through critical evaluation and thinking. Architects also apply imagination, reasoning and potential creativity to realize the conceptualized or idealized form. The designer alone, cannot resolve this challenge or problem. Engineers, among others, play key roles in solving potential problems. The architect identifies, reviews, evaluates and analyzes the problem to clarify what or how to define the optimal formal solution. Thus, conceptual and structural aspects of building design certainly influence the architectural design process. Potent concepts definitely enrich and strengthen buildings, while structural concepts could simplify complex and technical features if

they effectively integrate with the design concepts. This is how the visual or aesthetic and technical features of a building can join forces, and as such serve the final outcome.

Architectural semiotics play another role in architectural discourse. Semiotics essentially addresses how design communicates certain messages, meanings, and signs to audiences and users. The whole or parts of a building could convey signs or symbols to an audience. The interface between form and sign, form and function, or form and space play important roles in transferring or communicating certain messages through signs. These conditions lend themselves to a holistic or separate assessed or analysis. Reading, experiencing, and understanding the unfolding messages from buildings or built artefacts to people make up different methods of conveying signs in semiotics.

In that sense, the design process influences the structural and conceptual aspects of building design. Structural concepts encompass a wide range from structural forces found in nature to aesthetics features such as proportion or rhythm. Design concepts, however, predominantly associate with visual themes and characteristics. Using of cognitive tools helps architects and engineers to relate to both approaches. Metaphors and analogies mediate and function as conduits for facilitating this understanding and imagination of relevant concepts. These tools could not only influence our routine and daily activities, but also help engineers and architects to reconfigure, and communicate their design solutions to others semiotically. Metaphors cover surface and relational similarities of source and target domains while analogies include functional and structural similarities of source and target domains. Based on their visual attributes or structural systems (form-active, semi-form-active or non-form-

active), structural concepts or uses of structure, resonate both with the metaphor (visual, and semi or non-form-active) and analogy (technical, and full-form-active).

Metaphor-Analogy: Second, architects use metaphors or analogies to define, solve, or share design problems in different ways. They believe that these two cognitive tools have improved not only the quality of their designs in general, but how to communicate them with others in particular. Metaphors address public problems or concerns, and may not only offer solutions to particular design problems, but share or express them publicly. Public taste affects and mediates the way in which they appreciate architecture and aesthetics. Metaphor and analogy are dynamic ingredients, that might shift and transform into each other from time to time. Time will really tell. Metaphors and analogies reflect deeply personal values too. A particular metaphor to one architect might mean quite the opposite to another architect. Metaphors and analogies can be effectively used to communicate, but they can also be confusing at times too if used improperly. Metaphors matter in associating with abstract concepts and qualities. When we cannot express the reality directly, metaphors could help by defining, framing, or design a concept, and specifying certain goals. Metaphors facilitate at the starting point of the design process where primitive or premature decisions make it difficult to see the results all the way through.

Analogies communicate higher order relationships and characteristics. Appropriate analogies could solve difficult design and structural problems during the design process. Visual and functional or structural characteristics typically represent two interrelated interpretations in analogy. analogical thinking makes unknown or complicated concepts easier or more familiar for an audience—sometimes even

better or more practical than using metaphors. That is when people better connect to more clear concepts, if analogy ends up working better than a metaphor.

Site turns out to be the point of departure for architects in a design team. The site analysis or survey reveals its inherent characteristics, limitations and potentials. From an analogical point of view, designers can integrate the site with building—both conceptually and structurally. Site's topographical features, and its surrounding context, the site's geological make-up, views, nature, and many other factors could theoretically (directly or indirectly) intervene or interfere with the design process.

There should be enough flexibility between building and the site and its surrounding area. Integrated concepts, and the site and structure dynamic relationships create flexible building designs which invite people move to the building. Creativity both in site design and conceptual thinking and form design, help to analyze and create interesting design products. Therefore, designers should not neglect, undermine or downplay the role of creativity in integrating the site characteristics into building design and its related functions.

Efficiency in architectural design has already become quite sensitive due to climate change, unsustainable building and design practices, and environmental sensitivity. Selecting construction materials, meticulous site analysis, types of structures, structural design, design concept development, and using relevant technologies create effective ways toward sustainable design. Concepts relevant to form and structure must comply with these conditions. building form and structure serve each other mutually. Designers could replace metaphorical concepts of form to analogical by seeking to find practical ways of using the original features of a particular concept. However, building form, sometimes depends on the designers' taste, while some other designers consider not only their own tastes but those of users

and various audiences. Concepts like beauty of aesthetics vary from person to person, or as the saying goes “beauty lies in the eye of the beholder.” But the point is to safeguard, protect, or cherish concepts such as identity or design originality.

It is necessary to emphasize that the architects’ and engineers’ familiarity with metaphors and analogies and their facilitators, dates back to their educational training. Students of architecture and civil engineering should have enough interactions and relationships through joint workshops, courses, conferences, lectures, and researches. They could be introduced with skills of each other and even learn them as needed for future professional designs. As findings of this research, there are wide domain of metaphorical and analogical concepts and codes. In order to produce high quality designs in the future, requires that students know and practice them in these fields. Single and group related tests and surveys provide the necessary tools to introduce students with better team works, and better conceptual forms and structural thinking.

Case Studies: Third, the conclusion gleans some lessons learned from the case studies based on the data from the in-depth interviews with a number of well-known Iranian architects. The emergent themes from content analysis of the interviews included flexibility, creativity, visual effects, structural efficiencies, stability, strength and structure as form. Analyzing the unique features of the architectural and structural characteristics and concepts of the selected projects resulted in additional codes that facilitated the selected architects’ designs. These additional themes include beauty, form, originality, and site.

In most of projects, sites guide designers to successfully integrate their buildings’ unique functions into their surroundings. In each case, architects used their creativity to face and overcome design problems and challenges. Flexibility in the design

process, on the other hand, applied to all the potential aspects of each particular project. Building stability turned out as another key consideration in any type of building and irrespective of its functionality. The types of structures chosen in each project adhered to the concepts and building characteristics. That is, the building structures have close ties with the building form, function and design.

While building forms play important roles in architectural creativity, design concepts exert powerful influences on them. Visual elements such as symbols, and styles and signs could effectively attract any audience or users to buildings. As such, design outcomes while potentially beautiful to some, might seem otherwise to others. Some designers seek contextual and conceptual originality in their design outcomes, and believe in its prowess, and as such, aim to enhance building popularity by creating the right identity.

Analyzing the selected projects revealed interesting features: The Namak Restaurant and textile museum applied analogical concepts in giving form to architecture. In that sense, the salt cave served as a natural feature to create good relations with the restaurant's visual character and function. Furthermore, the museum concentrated on the history of its designated site and revived its original function. Both of these projects sought to create close relationships with their concepts through analogical thinking. The other nine projects used metaphors in form creation based on crude and abstract ideas. Metaphors such as universe, prayer and balloon have more abstract roles in these debates.

Examining the results of structural analysis on each project reveals different observations seven of which designed structures through analogical means. These designs emphasized structural, functional, originality, and efficiency characteristics in their pertinent concepts of respective structural designs. For example, the sacred

defense museum used efficient structural elements to provide flexible building form based on the site's topography. Also, the Tagh Kasra building considered its historic vault to apply modern efficient trusses to hold space as the functional vault. The other four projects like the dream house, used dreaming as an abstract idea to visualize the structure albeit not functionally.

Recommendations: Fourth, considering the structure in the design process implies gaps between architectural and structural design. Contemporary technical advancements in structural engineering, new trends in the construction industry, and separated educational approaches, have intensified this important chasm between architecture and structural engineering. Architects seem to be less familiar with structural concepts, as structural engineers know less about architectural design. If architects give due attention to structural concepts from the get-go, it would pave the way for a smooth, more efficient process all the way through, which is why cooperating between them becomes imperative.

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APPENDICES

Appendix A: Architecture and Structure

Relationships

Always, there must be motivation to keep creative relations between architecture and engineering. Sometimes, structure is assumed to be a regulation for architecture. This is important to consider structure in new ways to define a space. Balmond (2002) believes that architecture elements have not hierarchy but have interdependency, so these related ideas could be called informal. Structure and architecture should be integrative with close identities. Structure must enter more emotional fields and on the other hand, architecture must be beyond its ornamental status. Structural and spatial ideas should be challenged. Same as high-tech movement, structural expression could be a beautiful thing. Sometimes, engineer should have enough skill and creativity, to express the structure in a way of architectural ideas. Structure should be considered as generating path, not as unthinking normal grid columns.

Architecture derived from structure. Architecture, firstly, should make an outward form according to structure. Adrian Forty (2000) defines structure as the system of support of a building or it is a design which through it, the building become perceptible. There are some signs like volumes, spaces, masses and interconnection systems, which provide cause for the perception of structure. Architecture is the result of the needed structure. The building form could be an expression of structure. The structure could be inspired from the nature. The structure is not just construction but it is related to mechanical aspects too, as support system. Some theorists believe that the general task of architects is to provide a warm and livable space. In initial

stages, the structural planning is not an immediate priority, but it becomes important when the project is being realized.

Structure System

As today complexity of architectural design, there are new problems of adapting technological advances with architecture. One complex problem is consideration of economical, creative and imaginative structure in design process. Engel (2007) says that structure occupies in architecture a position that both give existence and sustains form. Structure is the primary and single instrument for generating form and space in architecture. Structure in its relationship to architectural form, presents wide area for interpretation. It personalizes the creative purpose of the designer to unify form, material and forces. Technically, there are some typical mechanisms (structure systems) to deal with acting forces and for example, redirecting them: *Form-Active*: structures acting mainly through material form, and systems in single stress condition (compressive or tensile forces)

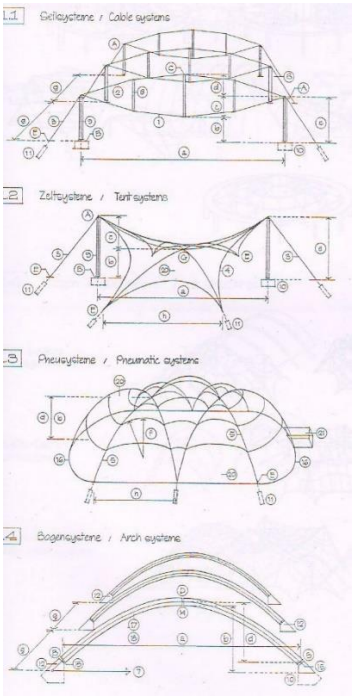


Figure 119 : Form-active structures (Engel, 2007, p. 59)

Vector-Active: structures acting mainly through composition of compressive and tensile members, and systems in coactive stress condition (compressive and tensile forces)

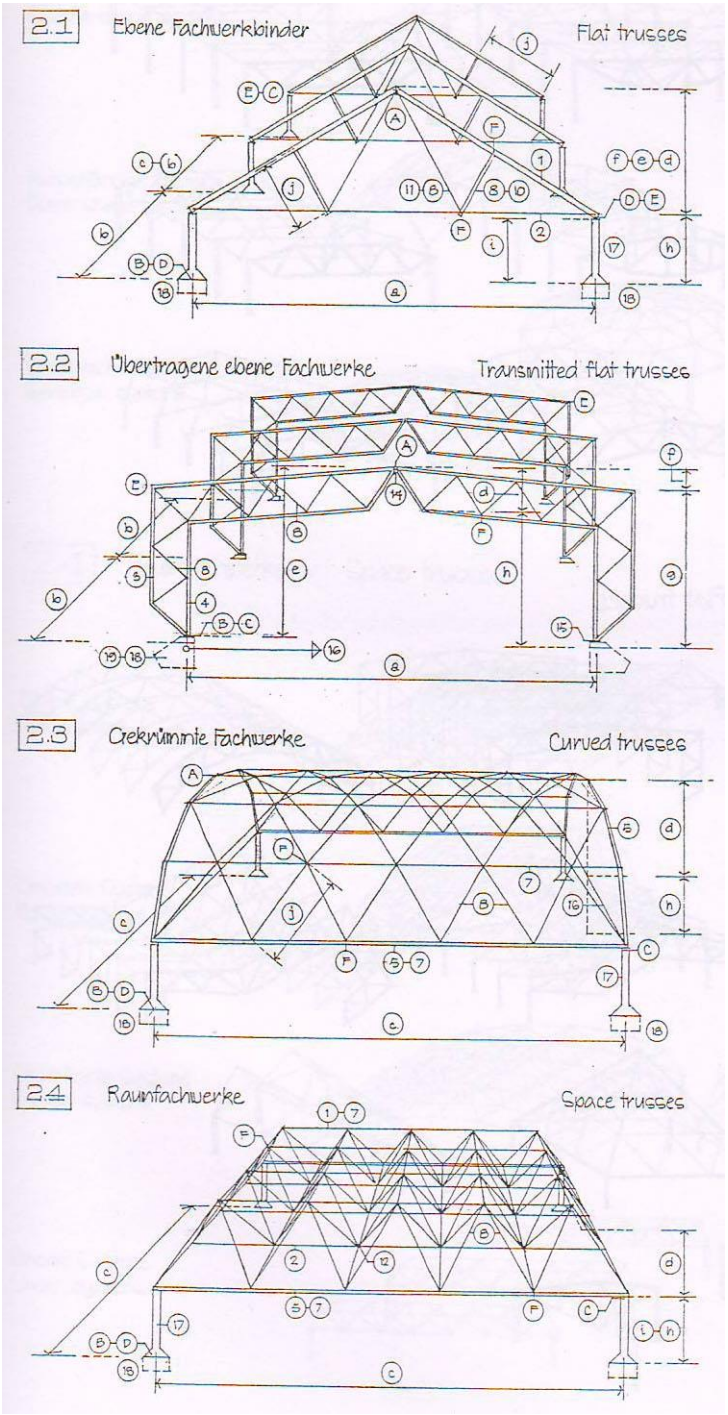


Figure 120 : Vector-active structure system (Engel, 2007, p. 135)

Section-Active: structures acting mainly through cross section and continuity of material, and systems in bending stress condition (sectional forces)

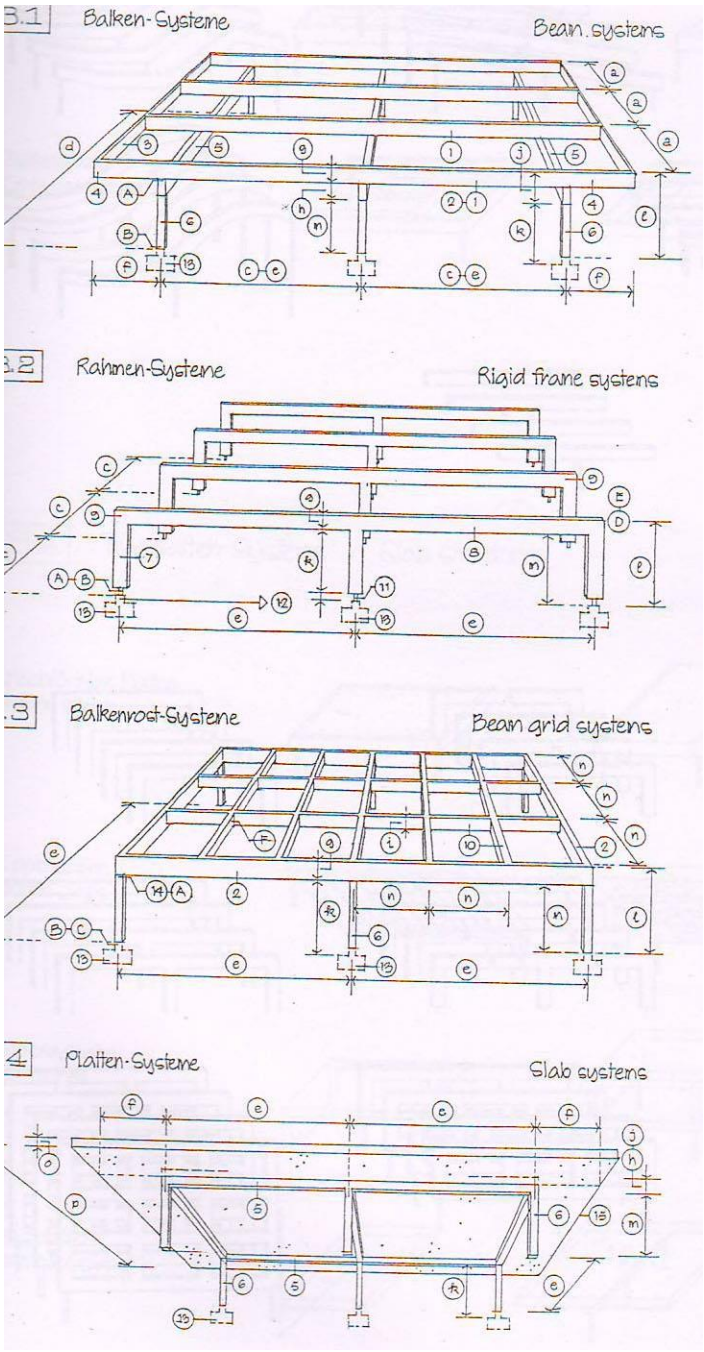


Figure 121 : Section-active structure system (Engel, 2007, p. 173)

Surface-Active: structures acting mainly through extension and form of surface, and systems in surface stress condition (membrane forces)

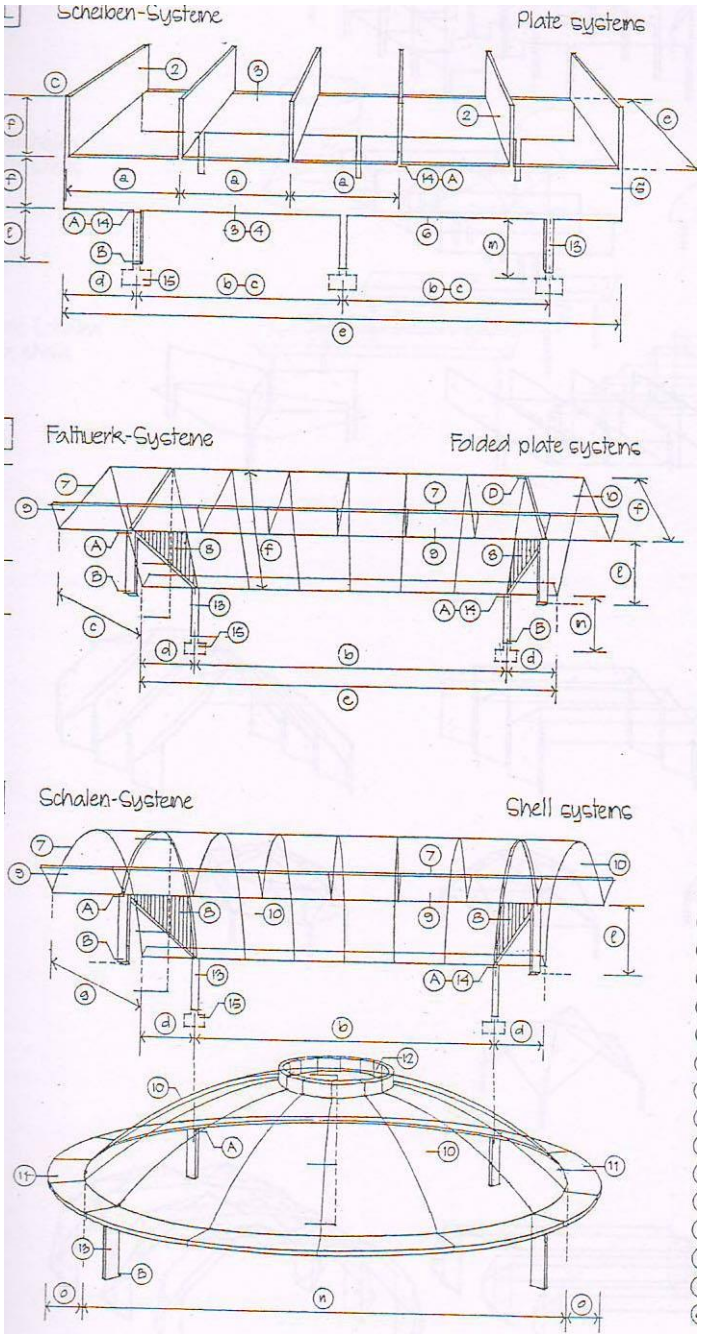


Figure 122 : Surface-active structure system (Engel, 2007, p. 213)

Height-Active: structures acting mainly as vertical load transmitter, and systems without typical stress condition

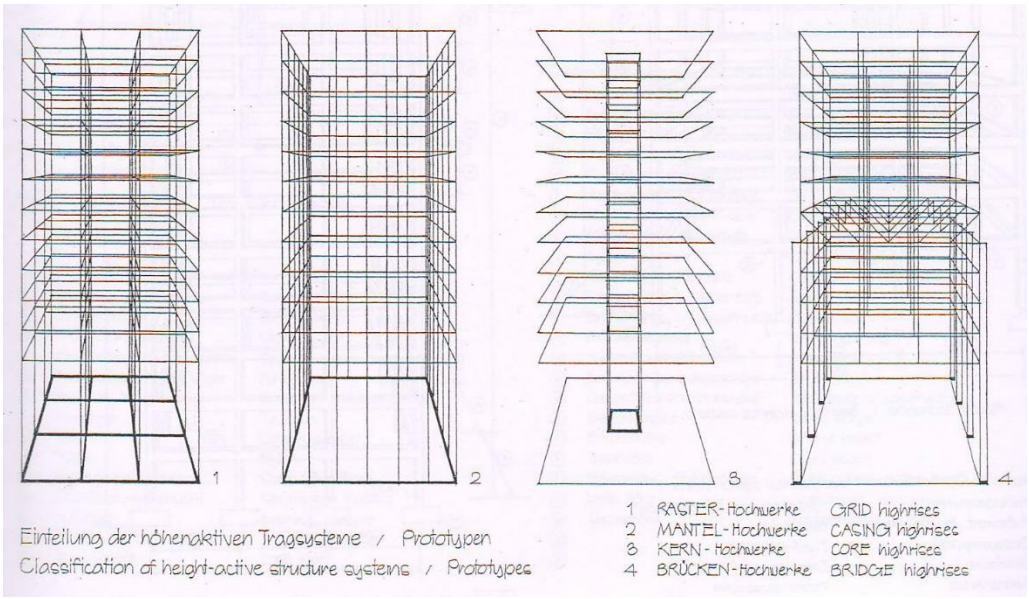


Figure 123 : Height-active structure system (Engel, 2007, p. 269)

Structural Engineering

Structural engineering is the art of materials application that have characteristics which could only be guessed, to make real structures that could only be almost analyzed, to sustain forces that are not exactly known, so that our liability with respect to public safety is done. Thus, "structural engineering is the combination of technology (mechanics) and art (aesthetics)" (Lin & Zhen, 2016, p. 16). It is the total of all structural systems that are solid, able to bear force, and unveil in varied formations and in the goal of bettering the living situation of human beings. Applied experience and theoretical mechanics are bases of structural engineering. Structural engineers and architects must ensure about the validity of structure which is designed by them, technically. At the same time, it is needed to realize aesthetics and functional issues artistically. In other words, with the assurance of structure validity, a creative role is also given to the art in design. Also, requirement of sustainable development must be considered in this way (Lin & Zhen, 2016). Big creativity was needed on the part of the structural engineering team to make a structure which had

an acceptable technical function while at the same time becoming to be that which it was not (Macdonald, Structure and Architecture, 1994). The skilled person concerning the structures is the structural engineer. The problem of certifying that a building or any structural element, could be resisted for its considered use, is solved by structural engineer. Usually, a structural engineer is not alone in his or her work. He or she is part of a team of professionals. The structural engineer is responsible for certifying that the building could safely bear all the forces to which it is maybe to be faced, and that it will not bend or break suddenly in use (Garrison, 2005).

Structure Type

In architecture terrain, which in that gravitational loads are generally the most important, three primary arrangements are existed: Non-form-active or post-beam, form-active and semi-form-active. Post-beam structures are combination of vertical and horizontal components; fully form-active structures are perfect structures that their geometries follow the form-active shape for the main applied load; Structural arrangements which are not considered in mentioned groups, are semi-form-active.

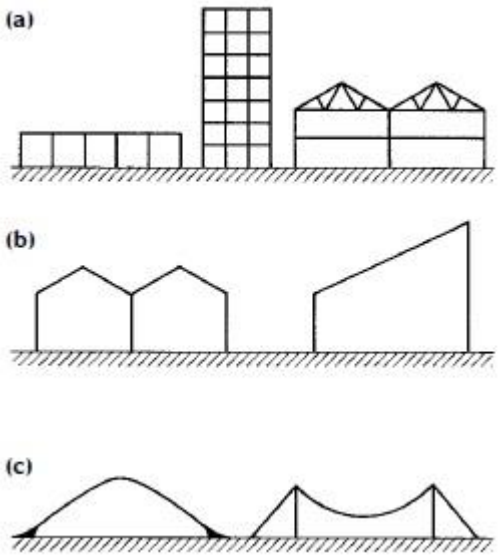


Figure 124: The three categories of basic geometry: (a) Post and beam. (b) Semi-form-active. (c) Form-active. (Macdonald, Structure and Architecture, 1994, p. 47)

The periodic loadbearing wall shape is a very basic type of structure in which the most primitive kinds of bending (non-form-active) components, with solid and simple, cross-sections, are used. They have low efficiency and their disadvantage is that the needs of the structure constrain in fair way intense limitations on the designer's freedom to plan the shape of the building.

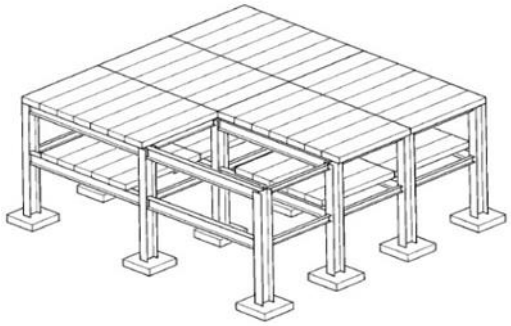


Figure 125: typical multi-story frame structure in which a skeleton of steel beams and columns supports a floor of reinforced concrete slabs. Walls are non-structural and can be positioned to suit space-planning requirements. (Macdonald, Structure and Architecture, 1994, p. 51)

Semi-form-active structures include shapes that their geometry is not post-beam or form-active type. Therefore, the components include all types of internal force (like shear force, axial thrust and bending moment). This type of structures is generally used as support elements for buildings because of one of two reasons. They may be selected because it is essential to get bigger efficiency than a post-beam structure will permit, because a wide span is included or because the used load is light.

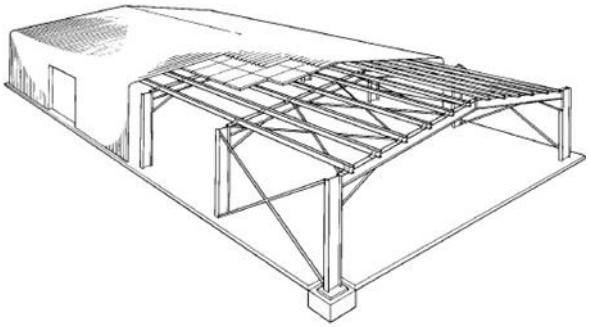


Figure 126: A typical arrangement of semi-form-active portal frames forming the structure of a single-story building. (Macdonald, Structure and Architecture, 1994, p. 56)

Complete form-active structures are generally applied just in conditions that a special structural elements are needed to get a high level of structural efficiency, because the span included is very big or because a structure of specifically light weight is needed. They include geometries which are more complex than post-beam or semi-form-active kinds, and they make buildings which have different shapes. Involved in this type are tensile cable networks, air-supported tensile-membrane structures and compressive shells, and. (Macdonald, 1994)

Figure 127: Barton Malow Silverdome. A very large span is achieved here with a cable-reinforced air-supported membrane, which is a tensile form-active structure. (Macdonald, Structure and Architecture, 1994, p. 58)

Building structures may be categorized as three groups of Full-form-active, semi-form-active and non-form-active. In domain of gravitational loading, which is the main form of load in most architectural structures, post-beam structures are non-form- active and could be more divided into the two groups of loadbearing wall structures and skeleton-frame structures. It is from this restricted range of probabilities that the building structure should be chosen. Within each group, approximately unlimited diversity of structural probabilities exists, however, based on the kinds of component which are determined and the way in which these are related together. Any type of structure which is not completely form-active or not completely non-form-active, will support load via the mixed influence of axial and bending action. Mentioned structures have characteristics which are middle between those of the post-beam order, which is not efficient but easy to erect, and the vault, arch, or cable net, which have high efficiency but complex to erect. Therefore, mixed-action structures are applied in conditions in which middle levels of efficiency are needed, like in the medium-span domain. They are mostly positioned in the form of skeleton-frame orders. (Macdonald, 1997)

Figure 128: Palmerston Special School, Liverpool, England 1973-76 (demolished 1989). Foster Associates, architects; Anthony Hunt Associates, structural engineers. Semi-formactive portal frames of steel hollow-section are used here as the primary structural elements in a multi-bay arrangement with relatively short spans. The moderately high efficiency of this type of structure has permitted very slender elements to be adopted. (Macdonald, Structural Design for Architecture, 1997, p. 12)

With span growth, the number of various kinds of structure that would be suitable reduces. At the very wide span (about 200 meters), just the most efficient form-active kinds, like steel cable nets or thin concrete shells, are suitable. Therefore, from the designer point of view, the selection of structure kind is wide, if the span is limited and will be gradually more restricted as the span grows. Those which got pure tension by stress, are the most efficient types of structure. The cable structure by steel, that the primitive supporting load components are transformative cables working in complete tension, is an example of this kind. Because of high efficiency of these structures, they are able to use for very wide spans. The key element of cable structures is high flexibility which permits modifies in geometry to happen in response to variations in load and keeps the condition of completely tensile stresses. Reinforced concrete is also suitable for the making of form-active or semi-form-active kinds of structure like vaults, domes and arches. Hence, Reinforced concrete introduces the architect very wide open hand regarding the form. (Macdonald, 1997)

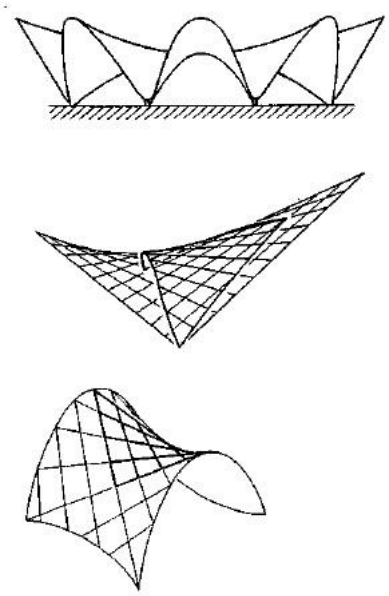


Figure 129: Reinforced concrete lends itself to use in compressive form-active structural elements. The great efficiency of this type of structure allows the strength required for long spans to be achieved with very thin shells. (Macdonald, 1997, p. 146)

Appendix B: Mansillas's Questionnaire

Mansillas's Questionnaire before adaptation

Appendix: Questionnaire

DEPARTMENT OF APPLIED LINGUISTICS:
SCHOOL OF ARCHITECTURE,
POLYTECHNIC UNIVERSITY OF MADRID

The following questionnaire is part of a PhD work, and its results will be considered for the design of an English course for students of architecture in the School of Architecture in the Polytechnic University of Madrid, Spain. The objective of this questionnaire is to obtain information on the use you make of metaphors in working situations; I am specially interested in categories such as a city and a building. Please try to answer each question, by ticking , filling in the blanks, or answering as needed.
Thank you very much for your help!

0. What is today's date? _____

1. Personal Profile

1.1. Are you an architect? ☐ Yes ☐ No
1.2. Are you an engineer? ☐ Yes ☐ No Speciality:_____
1.3. How many years have you been working as such?_____
1.4. What is your gender? ☐ Male ☐ Female
1.5. What is your age? _____

2. THE CITY

2.1. What is your image of a **city**? Please write down some expressions.

2.2. When you talk about **a city** at work, do you ever refer to it as a living organism?

☐ Yes ☐ No

2.2.1. If your answer is **no:** how do you refer to it ?

2.3. In which sense do you use it? In a negative or positive way?

2.4. Can you remember and write down one or more of such specific living organisms you use?

2.5. Do you think people understand you better by using such analogies? ☐ Yes ☐ No

2.6. How do you use the expressions?

☐ unconsciously

☐ intentionally for each particular situation, from a set you have previously heard or read

☐ intentionally for each particular situation, just inventing them at the moment

2.7. Please tick the percentage of use (# of times you refer to the CITY as a living organism over # of times you refer to the CITY):

☐ 0%-10% ☐ 10%-20% ☐ 20%-40% ☐ 40%-60% ☐ 60%-80% ☐ 80%-100%

3. THE BUILDING

3.1. What is your image a **building**? Please write down some expressions.

3.2. When you talk about **a building** at work, do you ever refer to it as a living organism?

☐ Yes ☐ No

3.2.1. If your answer is **no:** how do you refer to it ?

3.3. In which sense do you use it? In a negative or positive way?

3.4. Can you remember and write down one or more of such specific living organisms you use?

3.5. Do you think people understand you better by using such analogies? ☐ Yes ☐ No

3.6. How do you use the expressions?

☐ unconsciously

☐ intentionally for each particular situation, from a set you have previously heard or read

☐ intentionally for each particular situation, just inventing them at the moment

3.7. Please tick the percentage of use (# of times you refer to the BUILDING as a living organism over # of times you refer to the BUILDING):

☐ 0%-10% ☐ 10%-20% ☐ 20%-40% ☐ 40%-60% ☐ 60%-80% ☐ 80%-100%

4. OTHER ANALOGIES

4.1. Apart from the previous analogies mentioned, can you think of other analogies you make in other areas of your work or from everyday language? Please name a few of them:

5. THE SPEAKERS

5.1. Please grade the frequency of usage of metaphorical expressions depending on the people who are involved in the communication:

(1: very seldom.....5:very often)

a)	When a client speaks to an architect:	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
b)	When an architect speaks to a client:	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
c)	When an architect speaks to an employee:	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
d)	When an architect speaks to an architect:	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
	Others. Name please:	
e)	_____	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
f)	_____	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
g)	_____	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
h)	_____	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

6. USE OF METAPHOR IN ARCHITECTURAL PRACTICES

6.1. What does the use of metaphor imply, convey, impress, or/and bring in, in your profession?

If you need some help for filling out this questionnaire, you can get in contact with Mrs. Úbeda in the telephone number or email address provided below. Please, when the questionnaire will be completed, send it back as soon as possible by fax, mail or email to the following address:

Paloma Úbeda Mansilla. Departamento de Lingüística Aplicada a la Ciencia y Tecnología
ETS de Arquitectura de Madrid. Avda. Juan de Herrera nº 4. Madrid 28040. ESPAÑA
Email address: pubeda@aq.upm.es

THANK YOU VERY MUCH FOR YOUR COOPERATION!!

Appendix C: Interviews

- These questions aimed to meet the research objectives by asking subjects to describe the ways in which they used metaphors and analogical reasoning of structure:

1. Do you usually use metaphors or analogies in your conceptual design thinking?
2. If yes, in what ways (i.e., sketches, photos, or words)? Give up examples from your own designs.
3. Describe your selected buildings either by sketch or writing.
4. What was your conceptual idea of this building in the design process?

5. What kind of metaphor or analogy do you usually use? Would you please give an example.
6. In case you do not use metaphor or analogy in your designs, what other cognitive tools do you use to visualize your design ideas?
7. Do you ever use any metaphors or analogies in describing your designs to others? If yes, give examples.

8. In what ways in your opinion, metaphor and analogies have facilitated your design process?
9. Where in design process do you usually use metaphor or analogy?
10. What was the most important metaphor or analogy expression of structure while you were designing this building?

11. Which one (analogy or metaphor) was used to express structure in your selected building?

12. How structure is used in generating the architectural idea?

13. Would you like to share other comments regarding your design experience?

Embassy of Iran, Seoul

1.

Yes

2. I have some principles and concepts which are formed **visually** in each project.

3. The volume of embassy of Iran in Seoul consists of four towers enclosing an open space that in lower part placed **sunken courtyard** and on above, an atrium, a **suspended** court with glass surfaces at the top and bottom. In fact, whole of the building is **hanging** from these four towers; to give opportunity to **increase** the open **space** at the ground level.

4. The rising towers manifest the **transcendental** tendency of the **earth** and diagonal glass floor of atrium **symbolizes** the descent of **heaven** into the earth.

5. **Meaningful** and **amphibological** kinds

6. All concepts are kinds of metaphors or analogies.

7. Yes, it is more effective and **attractive** to describe projects by the help of metaphors and analogies.

8. In different ways and it depends on the **situations**.

9. **Initial** and concept generation stages of design process

10. Steel and concrete structures are combined with each other in this project to increase the structural and architectural **efficiencies**, and also provide better stability and strength for the building.

11. Analogy.

12. Whole of the building is hanging from these four towers; to give opportunity to increase the open space at the ground level. The height of four **exposed** concrete towers is approximately 15m; three volumes such as the bridges connect these towers by exposed steel **trusses**.

13. Architecture is a **continuous**, smart, soft or hard skin to create safe space and to include different programs.

Mellat Park Cineplex

1. Yes.

2. Based on the **characteristics** of the **site** and building **function**.

3. The project borders the park on the north and east sides, and is adjacent to Niayesh Freeway on the south, and Enghelab Sports Complex on the west side. The program

included 4 movie theatres, each with an occupancy of 250, a smaller theatre with an occupancy of 30, gallery spaces, restaurant, coffee shop, bookstore, office spaces, and service spaces. By pulling up the center of the form and separating it from the ground a large "eyvan" was designed that allowed direct access from the park to the city and vice versa, essentially **transforming** the project from a wall, into a gateway. In addition to providing natural **ventilation** inside the building, the large terrace also serves as a place for exchanging ideas and holding various **cultural** events.

4. Given the green spaces adjacent to the project, as well as the views of Mellat Park, the concept was to design a concrete core (where the movie theatres were located), floating within a glass envelope.
5. mostly **contextual** types
6. by analysis of the **context** and the **site**
7. Yes.
8. **Stable structure**, material strength, **naturalizing** idea, making a place, and other things.
9. **sometimes initial** and sometimes **concept generation** stage
10. **contextual** type. Structural design of this building has overall **flexibility** to the **site** and surrounding characteristics to provide more architectural and structural **efficiencies**.
11. Analogy.
12. The overall **structural** design uses deep concrete beams to support the theatres, circulation spaces, as well as the large terrace, giving the project a **uniform** identity. The architecture and structure are tried to be **integrated** well in order to create more spatial **potentials**.
13. The building should respect the **site** and **surrounding** area and also should **break** the **norms**.

Unknown Martyrs Monument

1. Yes.
2. by sketching
3. Whatever the volume goes up, its thickness reduces such as peak of mountain. This building is formed on the octagonal geometry (Shamseh in Islamic architecture) which is referring to the **sacred** eight years' war with Iraq. Centralization in plan is been to **evoke** the sense of **unity**. Each column of this monument is a **metaphor** of

human form who get his or her hands toward the sky as a **symbol** of freedom (Figure 172). Repeating these columns together is **evoking** four humans who tie their hands with each other and attach their heads with each other too. These are a group which follow a goal and believe in that. Floating wings which are staying on top of the building, according to their form, **evoke** kind of flying **sense**. Also the high height of the monument is to show the vastness and strength of the **martyrs**.

4. The main goal of design of this monument, was to show the **greatness** of these martyrs. In design of the volume, it is tried to consider architecture and **climatical** characteristics of Ardakan city, so the formed volume is a **symbol** of Zagros mountain, with bases which are stayed on the earth firmly
5. According to the subject of design and its function, I make an idea for example in this design, based on the subject, I have tried to show the **symbol** of **freedom** and **stability**.
6. I try to use existed elements in the area and **local** architecture like mountain and water and …, and the formed design be similar of these elements.
7. It dependes on the design subject. Some projects are designed for public like residential building but some designs such as martyrs monument, must be tried to transfer its message conceptually. Also the perception of people is important in this way. The perception of a professional person is different from the normal person.
8. Metaphor and analogies cause the formation of the process and primitive **scenario** in my mind.
9. From the **beginning** to the **end** of the work
10. The **structure** should show the **beauty** and the **stability** together and could **transfer** the **meaning** of design to the viewer. In design, I try to show some parts of the structure **exposing**. In this project, it is tried to have façade only as a skin on the structure and the general form of the structure be kept.
11. In my opinion, both of them could be together or separated are used, depending on the design subject. In this project, based on considered definitions, this structure could be analogical.
12. In most of times, in making an idea, **type** of structure could have a big **help** to the formation of considered idea. **Specific** steel structural design in this project which provide supporting in different angles, creates more structural **efficiencies**.
13. In design, it must be tried to combine the volume and space in a way that the formed design could create an engagement between itself and audience. Also, structure could be designed in a way to be as considered architecture usefully.

Roya House

1.
Yes, but not in all my designs.
2.
Necessarily, I not use the concept for design. Architecture of each place, necesasarily must not has **specific** meaning and concept. It can have specific form from **aesthetics** and **functional** point of views, but for designs that I want to use concept, I reach to it by studying and sketching.
3.
Human from the first of the history until today, has needed a place and a shelter for security, peace and comfort, which is one of the most important places for human. The subject of dream and **imagination**, always have been **attractive** for humans, so I gave their life the **sense** pleasant, to separate humans from their daily and normal life, with a specific design as **combination** of **folding** architecture and dream concept. Folding architecture is the architecture of layers and concepts for architecture are forming based on the project function.
4.
dream and imagination, to separate humans from their daily and normal life
5.
My metaphor and analogy are inspired from the **nature** but necessarily this is not followed in all my designs.
6.
I will consider the **beauty** and the **function** of that space
7.
No, because it is not pleasant for me. In my opinion, each design must present and **evoke** the concept and idea itself. The **perception** of each person is different.
8.
As I said, metaphor and analogy are things that formed in the **mind** of each person during the design according to the previous information and study.
9.
In **any stage** of design, the metaphor and analogy could be sensed and used. It cannot be said exactly in which stage.
10.
Based on the **function** of the building, metaphor and analogy of **structure** are **imagined** in my mind.
11.
Both of them could help audience to **percept** the **structure** and geometrical **relations** in a building. This house is constructed by reinforced concrete.
12.
Structure and **idea** in architecture must be designed **together** to not get problem after the design. Although the structure could limit our design, but we try the most to have least influence of it on design.
13.
In architecture design, in contrast to some thinkings, the concept is not necessary for design. A design could be a good solid **combination** with help of geometric forms and just have a nice shape. We must not consider the design with complicated meaning and philosophy which most of them created after the finishing of design. I am not saying that the **conceptual** architecture is bad but we can implement a design that not has any concept but helps the **surrounding** from aesthetics point of view, because all geometric forms have specific shape but do not have meaning loneliness and must combine with each other to be beautiful.

Namak Restaurant

1. Yes.
2. Anything could be inspired.
3. Because of the white color of the **salt**, it shows **desirable** and **pleasant** image of cleanness of a dietary shop in minds. This design, with making a space like salt **cave**, could **invite** people to this kind of cave with least cost and **accessible** in any place and any time, and **remind** this image in the mind of viewer. Based on the semi-commercial **fabric** of the area of the site, it is tried to create an **iconic** external design to reinforcement the area. Also it is tried to **continue** the design of the external skin to the internal skin. Shaping **organic** forms not only are inspired from the instinct of the materials but to provide **identity** and to **attract** people. Also in design of this restaurant, for **compatibility** to nature, the chosen materials of steps, entrance door handle, and chairs, it is tried to use from the melting of irresolvable garbages like aluminium cans of soft drinks of other restaurants.
4. According to the disinfection character of the salt, from the past until today, and also using of it in dietary products, the salt is chosen as the concept of this project.
5. Generally, there are no specific metaphors or analogies for my works. Each work is a dependent project.
6. The method of my work is searching for an idea in nature and I am not searching for strange things which could not be **connected** to audience.
7. I use analogy. Generally, the public audience, make faster and **better contact** with analogy because of its more **obvious** language. It means that the **perception** of analogy and its meaning is easier than metaphor for audience.
8. For example, in this example, salt as the primitive idea is considered and then in **growing** stage of an idea, the scale is choosed and therefore the idea of salt cave is formed as an analogy.
9. In **idea choosing** stage but this not cause to keep it as general idea, and the analogy has moved until the **details** stage.
10. The best analogy and metaphor for structure during design, is depending on kind of design, function and concept.
11. This could be metaphoric type of structure that contains steel structure.
12. It is used in **organic** form based on the salt cave as concept.

13.

The important point that I consider it in my designs, is that in my opinion, the eye of human, percepts curvy angles easier and more perceptible unconscious because the eyes are scanning everything which seen always. Therefore, I have tried to use curvy forms in my designs to **engage** more with audience. The considerable point is that in my opinion, today buildings not only must provide their functions but must response to **environmental** issues to solve today human problems.

Sacred Defense Museum

1)
Yes.
2)
Usually it is followed by site configurations.
3)
The building is not dives into the hill (site topography) but like **camouflage** mesh shades on the **hill** and the hill as metaphor of the land has positioned inside of the museum and infact forms the floor of the project and the ceiling as canopy on it, inspired from the **wrinkles** of the hill, has hided it. The **layers** of the topography of site were inspiring the design of the flooring and divisions of galleries. The landscape of the project, got idea from the Persian garden, has formed with **combination** of nature, organized based on the layers of the topography.
4)
The idea of this building (Defa Moghaddas), has shaped according to one of the main goals of sacred defense which was **protecting** the land and physical and **spiritual** values of it. The architecture of the museum has shaped inspiring from the wrinkles of the hill which positioned on it.
5)
Natural and contextual kind
6)
Site **analysis** and local studies
7)
Yes.
8)
Naturalizing topographic design **pursuitting** the site
9)
Concept generation stage
10)
Natural and topographic points.
11)
Analogical expression of structure.
12)
According to the site characteristics and **landform**. Most structural **elements** which are considered in this building, have suitable **efficiencies** as can be seen in **steel** load-bearing walls, trusses, cables and bracings, to provide enough strength and stability.
13)

Design of anything should consider all important and effective factors in design process. Also, structure should be viewed as architecture to share their beauties together. Structural components, themselves, as aesthetics objects, could be exposed in different ways.

Tagh Kasra Building

1)
Yes.
2)
I use all issues for concept.
3)

This commercial and residential project is located at the edge of street and alley which the street side is the **commercial** section and the alley side is the residential section. In the top level of the vault, the administrative section is located that is accessible by the staircase and lifts through the pillars of the vault and the weight of this floor is actually supported by the trusses, so it is a real working **vault**. There is wanted to **show** this floor **floating** in the facade and the **exposing** structure be visible for viewers.
4)

The main elevation of the building is a big truss vault inspired from the ancient tagh kasra **palace** in today Iraq. In general, the idea was to combine the **Persian** architecture and modern architecture.

5)
I try to inspire from concepts which are familiar to me from before. Then I will work on it. Finally, I will use my skills to make good compositions.
6)
If I not use metaphor and analogy in my designs, I will just consider relations and aesthetics of the volume of the building. Some works have strong metaphorical points and some works are just abstract form which aesthetics aspects are more considered in that, and in some works, no ones are existed and it is just functional.
7)
Yes, it is not the main cause. An audience percept our opinion when we select a related topic and work on it because the perception of audience from design, is different from each other.
8)
As I said, when I started to make idea, I get help from my past mental things and I try to make a relation between concepts and topics which I familiar with them from before, and a topic which is considered now for design. The creative mind of an architect could act creative when could make a logical relation between them.
9)

I can sense metaphor and analogy in primitive stage of design when I make an idea.
10)
Analogy and metaphor in a structure of a building, depends on the function of it, so in different buildings, structure are different from each other.
11)
Analogy. Architecture and structure should be combined effectively and be expressed integratively. In my opinion, both of analogy and metaphor could help to percept the structure and geometric relations in a building by audience.
12)
In one sentence, we can say that structure is part of architecture and form is combination of structure and surfaces. Based on the concept, different functional steel trusses are applied to support an upper big space (regarding strength and stability) and also to provide other workable spaces.
13)
To have a new idea, we must get help from our past mental images, and could integrate it with current world concepts.

Textile Museum

1)
Yes, an architect needs to make his or her architecture **mysterious**. Metaphors could do this and produce mystery and new **meanings**.
2)
Its media is different like book, film, text. This could be anything such as accident, memory or **reviewing** of a story. The scope of it is vast and tools of using it are wide. So we can see that various **medias** for reproduce of it, are produced like music, painting, and different types of art.
3)
This building, in fact, was a textile **factory** which was built in Pahlavi era, with trends to the **Qajar** architecture, **expressed** by brickworks. Then at the end of the Pahlavi era, it became abondened and gradually it is demolished except some external walls. Therefore, this building **redesigned** as textile museum to **revive** the original factory, with using of some related elements to the textile process and production. Metal cables are used in different parts to not only connects architectural elements but to show **schematic** production process. Destroyed walls were rebuilt to provide **stability** and strength of the building and to make **visual** coherence for the building too, by the help of some structures similar to **scaffolding**.
4)
It is kind of **hi-tech** architecture with using of some **organic** elements such as remained timbers of **original** building. Actually, the main **structure** of the building is covered and it is tried to show the glory of factory demolition and it is not always bad.

5)
Analogy.
6)
The material itself could **resemble** for example wherever we want to consider luxury in design, may we use a shiny metal like bronze or gold. This is an analogy that

guide our thinking to this direction. In a way that we engage with **artistic** work, the architecture is also the same. Architecture has also a **series** of hidden **layers**.

7)

Yes.

8)

These are tools that we are using them and naturally could be effective.

9)

Sketching is part of design but some part of design is not **visualized** on the paper and happens in the mind. Naturally in this section, the metaphor is useful because the design process has some issues. Sometimes, it is design and sometimes it is concept making and even **presentation** is made. Metaphor or analogy could be mental or meaning base of work so they will be running to end of the work.

10)

Keeping the **originality**.

11)

Analogy. It is tried to revive the original structure of the building and also to support and enrich it by using new structural steel elements like cables, so we could answer new structural needs and grow the structural efficiency.

12)

Structure has important role because of its limitations. Maybe the most regular and **challengeable** issue in design, after the economic and client issues, is the frame of the work. The structure is **dependent** on many elements like client **needs**, **cost** of client, economic **justification**, climate and kind of function, therefore it has not reasoning itself.

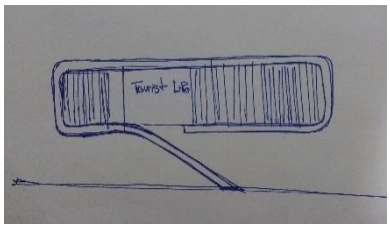
13)

When you choose the path of be designer in your life, you will different engagements with design. Sometime you design more but have less results and vice versa. Most of the analysis will be happened in your mind and the final result will be formed. Sometimes you need to sketch for **qualitative** evaluation of design and then compare it and it has not **predefined** method. Sometimes it is coming with mental storms or in **presentation** of your work, new design will come to your mind and you could go back in your path. Whatever is important in design, is the management of design. It means that you notice that in what way you must design and manage to be centralized and has design factors and provides the **needs**. Sometimes the management of design is more important than the design itself.

Tourism Information Center

1. Yes.
2. Mostly I inspired from the **surrounding** of my work.

1.



Floating volume in this space, provides the posbility of **continuity** of marginal park in order to **invite** passers to visit the building. This architecture with its specific color plays a role as an urban **symbol**, in **contrast** with its background, so the most important thing is that the building is **iconic** and wants to be as an urban furniture. Colorful curtains in contrast with green color of the vegetative covering of the area, are not only indexing the volume of the project but with their 45-degree orientation, prevent direct sunlight in hot seasons into the inside space and also guide the sunlight into the internal spaces in cold seasons.

2. The most important thing in this project was designing light volume in the park, so in this way, **crooked** columns are used to **show** more floating character of the building.

3. In most of works, I have tried to design something that is metaphor or analogy of surrounding **nature** but simple.

4. The method of my work is to try to inspire from **surrounding** nature of my project.

5. Yes.

6. Respecting the local **historic** and natural characteristics as materials, colors and forms

7. I have tried to use my idea **to end stage** of my project.

8. **Light** structure.

9. Metaphor.

10. According to the site **characteristics**, the related structure could be selected. In this way, crooked columns are selected for this building to have free site movement and sense of floating.

11. I have tried to use simple designs. View of each person is different with other one and the eye of human is scanning.

Bam Land

1)

Always we are following **imagination** of different **forces** which are existed in **site**, in our design. These forces are coming from **topography**, site morphology, **climatic** forces, social forces such as daily people life and their movement, and **cultural** forces from the place of design. Therefore, **context** has **vital** role in forming of our designs specially designs which are shaped in wide and open spaces.

2)

In design process in architecture office, primitive sketches and meaningful diagrams are used as main tools of showing these forces and meanings which are coming from the context, however, the texts are used as the help to make **contact** with other teams and specially the client.

3)

Bam land as commercial and recreational complex is located at the **stretch** of Chitgar **lake** shore in Tehran which residential and **urban** fabric reach to the lake at this point. This project consists of some restaurants and other recreational spaces which are **orientated** according to the **local** sunlight and local dominant wind. Buildings are detached and are **connected** to each other by some **gathering** spaces like courtyard (as important **Persian** traditional architectural element) and Ravaagh (as traditional connector space), all **combined** with the landscape.

4)

In design of these buildings, some **proportions** are used which has **roots** to the **historic** Persian architecture according to the courtyards but are formed in modern frames based on the **transparency** need to provide **views** to the lake. Another idea was using of some kinds of **windtowers** which have roots to the **traditional** Persian architecture in order to transfer the desirable and cool breeze of the lake to the inside of the buildings **functionally**. Using of brick on the façade and water **features** in the landscape are other related traditional elements of Persian architecture which could express Persian gardens but in different geometry.

5)

Usually, in designs, we are chasing metaphors and analogies which have geometric or **functional** meaning in their background.

6)

Meaningful using of water and other materials in design.

7)

Audience of architects are two groups of **public** people and **skilled** people. Kind of metaphors which are used for each group are different. Sometimes public people is looking for the first meaning that is **evoked** for them and will ask designer for confirmation. But regarding the description of design for skilled people specially architects, metaphors maybe explained **deeper** and more exact.

8)

Thinking regarding this issue could be with architect from the first stages to construction stage.

9)

Structure is **inseparable** part of architecture. We like **exposing** structures that show the method of load **transferring** but because of some reasons, still we have not built a project that shows this our **desire** clearly.

10)

Recognizing the kind of structure, somehow, is coming from the architecture logic. **Modular** structures provide the possibility of growth and development with specific and **repetitive** regularity, however, it is not meaning that the whole project is similar to each other.

11)
Metaphoric structure which expressed by concrete structure.
12)
In this project, using of modular structure, had a big help to space **management** and construction speed.
13)
Always we consider the architecture and landscape with together and complementary. Landscape is booster and provider of required **infrastructure** for **functionality** meaning in building

Namazkhaneh

1)
Yes.
2)
In my designs, I get metaphors from the surrounding of the **site** and its **context**.
3)
Namaz Khaneh is got to my mind when people have prayed in this site in the park, incorrectly. Then I decided to design a calm and quiet space for them to pray in right way and in good **atmosphere**.
4)
Simplicity and **purity** in forms
5)
Simplicity and **modern** ideas
6)
Most of concepts are coming from metaphors or analogies
7)
Yes.
8)
It depends on the type of using of them and depends also on the **type** of projects
9)
According to design **situation**, in any stage, metaphor or analogy could be used
10)
Simple and **original** structure
11)
analogy
12)
According to the subject of design, and simple structure of the Kaba
13)

In design process, all needed **factors** should be considered and analyzed to get an

acceptable result.

Appendix D: Architects and their Contacts

Table 22: List of architects and their contacts

	Architect	Project	Contact
1	Farhad Ahmadi	*Embassy of Iran, Seoul*	00989121033469
2	Catherine Spiridonof	*Mellat Park Cineplex*	info@fma-co.com
3	Hosein Diba	*Unknown Martyrs Monument*	00989171871376
4	Esfandiar Abdeshah	*Roya House*	http://abdeshah.com
5	Alireza Emtiaz	*Namak Restaurant*	00989173135356
6	Zhila Norozi	*Sacred Defense Museum*	00989121879959
7	Sorosh Saberi	*Tagh Kasra Building*	00989171117015
8	Mehrdad Iravanian	*Textile Museum*	inf@mehrdadiravanian.com
9	Ali Sodagaran	*Tourism Information Center*	00989173117734
10	Morteza Adib, Maryam Yousefi, Farzad Daliri	*Bam Land*	farzad.daliri@yahoo.com
11	Kamran Diba	*Namaz khaneh*	00982188675682