MODULARITY; REAL DIVERSITIES OF NOTION

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ABSTRACT

MODULARITY; REAL DIVERSITIES OF NOTION

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Much academic work asserts a relationship between the designs of a complex system and the manner in which this system evolves over time. In particular, designs which are modular in nature are argued to be more "evolvable," in that, this evolution facilitates to make the future design and structure adaptations. In essence, modularity which is particularly important when a system must meet uncertain future demands creates "option value" with the respect to the new and improved designs.

It is important for an architect to understand the limiting factors that will affect the design of a modular building. The modular construction is a meaning of improving production efficiency and worker safety in the construction industry. It rises into question of the modular buildings design quality, and whether or not, the qualification of the building process is also captured from the perspective of the architect.

This study includes interviews with modular manufacturers and firms to extract information on the topic of innovation in the industry. Showing a case study project as a discussion platform, the opinions of experienced building professionals were explored to identify what is and what isn't possible.

Keywords: Module, Modularity, Prefabrication, Prototyping, Evolvable.

ÖZ

MODÜLERLİK; GERÇEK KAVRAM FARKLILIKLARI

GÜNAYDIN, Dilşa

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Bir çok akademik çalışmada, karmaşık yapıların tasarımı ile tasarım sürecinde izlenilen yolun zamanla gösterdiği değişim ilişkisi açıklanmaktadır. Bu değişimin esas kaynaklarından biri doğadaki modülerlik ve bu modülerliğin yapılara uyarlanarak çeşitli strüktürel sistemlerin tasarlanmasıdır. Özetle, öngörülemeyen gereksinimlerin sistem içerisinde biraraya getirilmesinde bilhassa önem arz eden modülerite, yeni ve gelişen tasarıma saygı göstererek 'seçenek değerleri' yaratır.

Modüler bir yapının tasarımına etki eden sınırlayıcı unsurların, mimar tarafından iyi anlaşılması önemlidir. Bu çalışmada da modüler kavramının piyasa ve tasarım alanlarında ki algısının doğruluğu tartışılıp, doğru olduğu ön görülen çalışmalarla modüler kavramı desteklenecektir. Modüler kurgu, inşaat endüstrisinde üretim veriminin artması, nakliye dez-avantajlarının ortadan kalkması, şantiyede geçirilen süre ve işçi kullanımında azalma olacağı için işçi güvenliğinin artması anlamına gelmektedir. Ayrıca bu durum, inşaa sürecinin nitelikleri mimar tarafından anlaşılsa da anlaşılmasa da, modüler yapıların tasarım niteliğinin sorgulanmasına neden olur.

Bu çalışmada, endüstrideki yenilikler hakkında bilgi almak, üreticinin ve kullanıcının bu konuyla ilgili bilgi seviyesini anlamak amacıyla modüler sistem üreticileri ve firmaları ile yapılan görüşmeler yer almaktadır. Modüleritede nelerin mümkün olduğu ya da olmadığını belirleyebilmek için deneyimli yapı firmalarının görüşleri karşılıklı konuşmalar yapılarak incelenmiş ve örnek çalışma olarak sunulmuştur.

Anahtar Kelimeler: Modül, Modülerite, Prefabrikasyon, Prototip, Gelişime Açık.

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LIST OF ABBREVIATIONS

BIM	Use of Building Information Modeling
NIST	The National Institute of Standards and Technology
CNC	Computer Numerical Control
2-D	Two Dimensional
3-D	Three Dimensional
3D-CAD	Three Dimensional- Computer Aided Design
CAM	Computer Aided Manufacturing
CAE	Computer Aided Engineering
SAP 2000	Integrated Structural Analysis and Design Software
PMC	Permanent Modular Construction

CHAPTER 1

1. INTRODUCTION

In this chapter, argument, objectives and disposition are presented together. Under the respective sub-headings, the argument for the investigation and objectives of the study being reported on here. Also, under the dedicated sub-heading, it continues with a brief overview of the general procedure followed in its conduct and ends with a sufficient description of what is mainly talked about in each of the continued chapters, under the sub-heading titled 'disposition'.

1.1. Argument

Modularity is the stage to which the components of a system may be separated and recombined from each other. This thesis argues that, modularity is a new and clear solution for todays' architecture and furniture design evolution and whether or not modular IQ totally complete and correct.

Knowledge and usages of modular construction can be questioned because of the lack of modular knowledge and the drowning knowledge of prefabrication. According to marketing, modularity is a part of prefabrication as Azari (2013) [1] states that; 'Modular prefabricated construction represents a specific type of prefabrication in which the module building components are assembled off-site. Modules are complete box-shaped units, containing walls, floor and roof with the interior space, which are built in the factory, shipped to the site, installed, and connected into a complete building'. As it appears above, the module is a part of the prefabrication for developing off-site construction systems but just as, modules creates prefabrication systems, also it can create modular system but it does not means that, prefabrication and modularity are the same thing.

After resolving this conceptual confusion, the argument continues with the identification of modular design perception. The author mentions that, if the lack of knowledge of modularity can be taken away, modularity notion can be applied for its own real notions and the benefits of modular construction can be quantified through a comparative analysis of selected buildings. The study of McGraw Hill Construction in 2011 'conducted among architects, engineers, contractors, and building owners supports the arguments that speed to completion, quality, and safety can be increased with modular construction, while overall costs, material waste, and the impact on the environment can be reduced'. (Bernstein, Gudgel, and Laquidara-Carr, 2011) [2]. As a result, as Haas (2000) [3] states that; 'The number of buildings incorporating prefabrication over the past 15 years has increased by 86%. '

In this study, the research of the issues which were mentioned and according to information from sources, it will be discussed that, do manufacturer and user know modularity enough? According to collected sources, especially in terms of manufacturer, modular concept sits on exactly the same task with prefabrication. However, prefabrication is not totally connected with the modularity but a part of module system. Also, by the users 'perspective, who are architects, designers and architecture students, thinks that modularity is not clear enough for them to use it efficiently. Because, while their educational life, modular knowledge is not a clear giving information for them. Thus, lots of them do not use modularity as a design solution for their works. With combining lack of modularity knowledge at the market, manufacturer and architecture cannot be come together for efficient works.

1.2. Objectives

Socially, not only in architecture, but also in other design terms, prefabrication and modularity notions are drawn to each other. With the help of researches and surveys, in some important titles, this study shows readers the real mean and notion of modularity. After clarifying modular architecture knowledge and prefabrication knowledge, real aim is to understand the real mean of modularity. As Gibb (1999) [4] says that; 'Prefabrication encompasses the construction of all building components that are a part of a larger final assembles'. As Haas (2000) [5] states that; 'Prefabrication is an offsite manufacturing process that takes place at a specialized facility in which various materials and building systems are joined to form a component or part of a larger final installation‘. Understanding the connection between modularity and prefabrication, industrial design needs to be understood clearly.

Thereon, first of all, this study aims to explain history of the modularity and the prefabrication to understand the usage notions of these two issues. Latterly, with the help of some design technics and procedures, it is aimed to differentiate the application of these two concepts from each other. Through differentiate and understanding of the modularity, some modular buildings and structures are being investigated for the understanding of real technic and benefits of modularity.

Some researches show that, who are manufacturers, mass customization is the most important part of industrial design. Furthermore, refabricating architecture is going to be a title for comprising modularity from the prefabrication. To distinct the prefabrication and the modularity from each other, it is aimed to come out some questionnaires to manufacturer to understand their understanding of modularity and prefabrication knowledge and how are they differentiate these two term to each other for their construction process.

After fully clarifying the modular complexness, this study aims to fit and sustain the manufacturers and the designers' perceptions of modularity into more solid foundations in the design process with the distinction of the prefabrication functionality from the modular systems.

1.3. Procedure

This study basically is planned as a case study. Inspiring from the social sciences, the case study technique is defined as an in detailed description and assay of a single information or phenomenon. It can be also descriptive or explanatory, with using any manner of data collection procedures. (with questionnaires).

This study used qualitative research, to reach direct answers and obligations from professionals and uncover the primary issues considered to be real diversities of modular notion in the ability of the industry to build innovative design projects. According to qualitative research, it emphasizes the influence of the researcher on the data collected. As Groat and Wang (2002) [6] mentioned that; 'Instead of interpreting data objectively without bias, background of the surveyor and point of view play into the presentation of the data and the structure of the investigation (the questions asked, and the level of interaction with the subjects)'. Qualitative research seeks the answer to 'why' and 'what' by obtaining unstructured data.

In this study, for using qualitative research, there are some questions prepared, which are aimed to reach to understand the knowledge of modularity and the prefabrication. 10 questions prepared to direct to manufacturers, professionals and students, who are related with the issue. 2 manufacturers (The firms that have their factory in Turkey), 4 professionals and 4 students participate to the research.

1.4. Disposition

There are four main chapters to this report. This first, containing the argument, the objectives and procedure of the research along with this disposition which sums up what follows in the remaining chapters, gives a broad overview of its most distinctive aspects.

The second presents a summary of literature of various aspects and identifications of modularity. What modularity refers, why modularity needed, why it becomes a question? These sentences are mainly talked in this chapter.

The third chapter is where a thorough description of study material as a modularity in the sub-headings under modular building structures and potential occupants and manufacturers of this issue. Together with the method, which used in first questionnaires to directly to students, manufacturers and colleagues and then in arriving the results. This chapter continues with, the specific results obtained from the analyses described in the preceding chapter and discusses these in light of its objectives and the reports in the literature.

While the fourth chapter sets out the study by summarizing its findings, evaluates the significance of these and offers convenient recommendations for future researchers.

CHAPTER 2

2. LITERATURE SURVEY

In literature survey, generally is talked about history of modularity, history of prefabrication and their evolutions and their actual stands under the same sub-headings. This chapter is composed of five major parts. First of all, for giving general information, history of modularity and prefabrication in design need to be explained. To clarify the details of these terms, the histories of the subjects should be examined. It comes with the modular design evolution in architecture to show the how modularity becomes useful in architecture and is it really necessary for architects and manufacturers. Because of the development of prefabrication was appeared simultaneous with the modularity, the usage of prefabrication is not old enough. Regardless, modules and the modularity are the initial point of the issue, chapter continues with the modular notions process. Has modularity some advantages? That question connects other sub-headings to each other.

2.1. History of Modularity and Prefabrication in Design

2.1.1. History of Modularity

In nature, modularity refers to the construction of a cellular organism by joining together standardized units to form larger compositions, as for example, the hexagonal cells in a honeycomb. (en.wikipedia.org)[7]. The honeycomb combination can be seen in the Figure 1 as below;

Figure 1. Honey comb is a good example of modular system at the nature. This example shows the minimal. Honeycomb that comes together and creates a modular shape. [8]

Originally, the term ‘module’ comes from ancient time, where the Latin word ‘modulus’ was a measure of length. Routio (1998) [9] mentioned in the article that; ‘it was described already by Marcus Vitruvius Pollio (Vitruve), who worked under the Roman emperor Augustus. He wrote in his ‘Ten books on Architecture’ (De architectura libri decem) about laws on proportions and symmetry in temples and columns.’ The module was a standard measure ensuring the right proportions.

In construction, modules are a bundle of redundant project components that are produced en-mass prior to installation. Using modules in products and utilizing the benefits from modular structures are solutions developed in practical design work in the industrial history of the 20^{th} century. As Lehtonen(2007) [10] states that; ‘In the practical industrial operations, modularity is not, of course, defined, but the word is used in connection with products with defined internal interfaces between assemblies. Occasionally, this has been associated with the idea of interchangeable modules and the configurability of the product, but it is not always the case. Also as Lehtonen (2009) [11] continues in the article as; ‘ Products labeled modular in the industry share the fact that they feature an internal division or divisions based on some more abstract reason than the general component structure’. This more abstract reason is more generally related to the organizing of production or to the life cycle or the configurability of the product’.

As Miller (2005) [12] states that;' Modularization is currently in focus as a means for increasing competitiveness of industrial companies. This is achieved by bridging the advantages of standardization and rationalization with customization and flexibility. But the phenomenon behind modularization itself is not very well described and understood in literature'.

Products can be found even in the remote history that features at least the ideas in the Baukasten system defined by Borowski. It may be impossible to indisputably show the first modular product in the world. For the scope of this dissertation, we do not need step back in time further than to the year 1939. At that time, a diesel engine with a modular architecture was introduced in an American patent. Baldwin Locomotive Works applied for a patent on 27 February, 1939 (U.S. Patent No. 2249628, granted 15 June, 1941) [13] for a 4,000hp diesel engine with six engine generator modules. It can be seen in the Figure 2 as below;

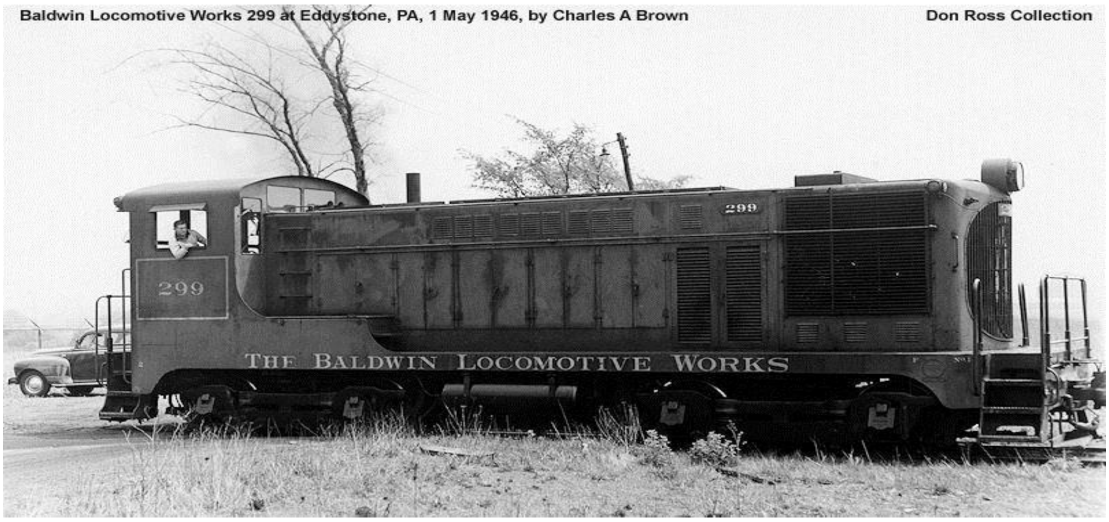

Figure 2.This figure is the first modular fabricated train which made at 1962 It was sold as Union Pacific 1250 in January 1948 and retired in August 1962. It was sold to Industrial Maintenance Service in July 1966 and to Electro-Motive. [14]

As Lethonen (2007) [15] states in the article that; 'Modularity as a phenomenon is divided into two categories; variation related modularity and modularity related to the life cycle of the product. With the identification of modules variations, both design and construction principles influenced from this consciousness and started to use and develop the modular knowledge.The first is traditional market variance how variety is needed on each customer concern, as measured by the variance from customer to customer, segment to segment, or brand to brand, for example. The second is usage variance how a product purchaser needs variety after the purchase is made'. As Jeffrey (2001) [16] mentions;' This variance, typically neglected in market science literature and research, is critical to understanding what product offerings are needed, be it multiple fixed product offerings, swappable modules on a standard interface, or an easily adjustable platform. The third influence is technology change—how fast the various modules change before a product design update is required. The last type of influence we call Design for X—how design, production, supply, and lifecycle criteria factor into consideration when determining product partitioning.'

2.1.2. History of Prefabrication

Prefabrication had been used from ancient times. As Martiini (2009) [17] mentioned that; 'From time predating humanity itself, it has been the chosen form of shelter for much of the natural world. The natural world, it turns out, is clever in that its citizens frequently rely on their neighbors or ancestors or their own biological functions to provide shelter (when there is any required)'. Also Martiini (2009)[18] gives some example for the prefabricate organizations as; 'Natural examples of site built housing abound (bird's nests, spider webs, ant hills, etc.) but even in these cases the tendency is to use materials that have already undergone fairly elaborate manufacture to bring them to their useful state (sticks, silk, sand, trees)'.

Arieff (2002) [19] states that; 'The earliest of such cases recorded was in 1624 when houses were prepared in England and sent to the fishing village of Cape Anne in what is now a city in Massachusetts'. As Smith (2009) [20] mentioned about the first transportation about prefabricated building as; 'The late 1700's and early 1800's was a time of Australian settlement of England. It is reported that the earliest settlement in New South Wales was home to a prefabricated hospital, storehouses and cottages shipped to Sydney arriving in 1790'. First portable prefabricate manufactures example can be seen in the Figure 3 as below;

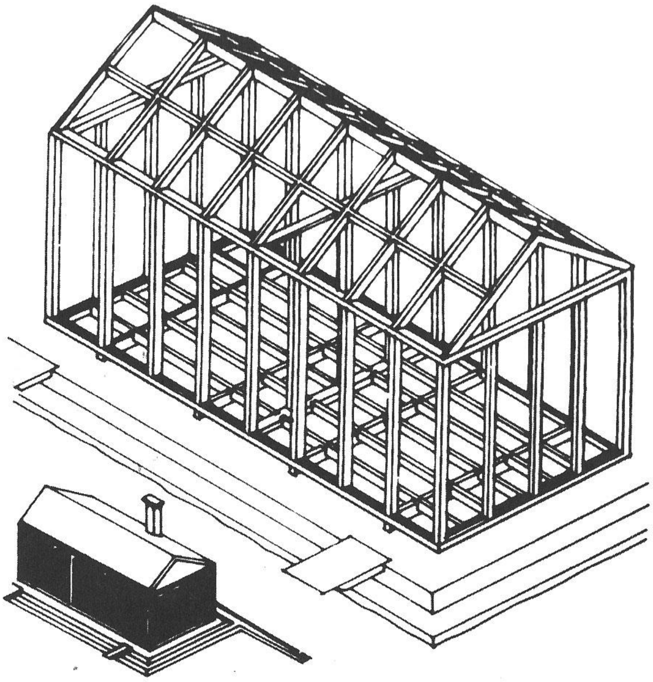

Figure 3. Manning Portable Colonial Cottage manufactured in Great Britain and shipped to colonies throughout the world. [21]

As being seen from the above part, prefabrication notion generally refers to housing. As Smith (2009, 1) [22] mentioned in the article History of Prefabrication: A Cultural Survey, that;

> ‘‘Prefabrication is a method of production in housing that has been harnessed to meet the needs and desires of different societies throughout the globe. Although the U.S. owns 26% of the prefabrication housing market, this is primarily due to the shear quantity of growth in the country. The UK, Scandinavia, and Japan control the majority of the innovations in which prefabrication constitutes a larger majority of the overall production of housing in these regions. This can be primarily attributed to the social and cultural contexts that give shape to the tradition of construction and knowledge base that make up these construction markets. This paper examines the history of prefabrication in these societies in order to identify how the U.S. might revaluate its construction ideologies, products and process in order to produce more affordable, higher quality housing.’’

It can be said that; modularity and prefabrication concepts are coming together under the mass customization title, except of principles of structural systems. Mass customization is defined in detailed by Kieran and Timberlake (2004) [23] in *Refabricating Architecture*. It is used effectively today in industrial design. Jacobs (2007) [24] states in article that;’ For example, Toyota automobiles, Dell computers, and Nike shoes divide the manufacturing process of their products into two primary parts: a base model with features included that are considered necessary, and auxiliary features that are available for inclusion based on the demand of consumers'. In the case of buildings, the structural skeleton acts as the canvas for architects to address issues of site, function, and the demands of a client. As Lu (2007) [25] stated that; 'The Sekisui house model in Japan, for example, is comprised of 30,000 components with more than 2 million available so that a high degree of customization is possible'.

Modularization generally refers to a process of breaking a complete building down into a series of smaller modules constructed offsite so that onsite construction is reduced to foundation work and module assembly. While the modular manufacturer has more control over quality and the production schedule, the major downside to modularization is the fact that shipping large empty volumes is costly. Also, to differentiate the knowledge, onsite and offsite construction are important terminologies for distinguished modularity from the prefabrication. In following lines, onsite and offsite construction terms are going to be identified.

As Schoenborn (2012) [26] describe in the article A Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction, that;

'.Onsite Construction

Stick built construction is used interchangeable with onsite construction and in-situ construction. The term stick built historically refers to dimensioned lumber construction, but it will be used here for any construction done onsite.

.Offsite Construction

Offsite construction includes prefabrication and/or preassembly away from the final building site. As Gibb (1999) [27] stated that; 'The term is traditionally used in the UK, where prefabricated components are instead categorized as 'non-volumetric offsite fabrications,' 'volumetric offsite fabrications,' and 'modular buildings'. In this study, offsite construction is used to describe the use of prefabrication and preassembly in generic terms which made at the factory and apply at the construction site.'

A modular product is an industrial innovation and as such at least 68 years old. There are different kinds of modularity depending on the respective aims of design, such as prefabrication. The existence of prefabrication basically depends on needs of housing. There exist companies and products whose success can be considered as a direct result of using modular structures.

2.2 Modular design evolution in architecture

As described above the understanding of the concept of modularity has evolved over time. The original geometrical definition is no longer valid. Ulrich & Tung mentioned their article that [28]; 'the original measurement module has been connected to the idea of industrial building blocks carrying functionality and also, in the later years, to immaterial things like software and knowledge. Therefore it does not seem reasonable to limit the definition of modularity to physical entities, as it is seen in large parts of the mechanical technical literature, e.g.'

According to the literatured surveys, if we back in time,the module was well known, even though the term was used in another meaning. In the beginning of the 20th century industrial building blocks were introduced in architecture, which gas influenced the understanding of the concept. Today it seems as if the concept is changing again. In the following some of the most important trends are described.

- **Bauhaus**

During the Bauhaus era (1919-1933) the German architect Walter Gropius for the first time combined the idea of standardization with functional thinking and industrial production in building construction. As Droste (1990) [29] stated that;'The module was linked to a building block concept (Baukasten), where the building blocks were functional units in buildings, e.g. kitchen, living room, sleeping room, etc. Under Bauhaus, the module kept the original meaning as a standard measurement,allowing combinations of many building blocks, inspired by children's toys. The purpose of the Bauhaus building blocks was to create buildings in a more rational way by standardization and prefabricated materials and to be able to make a more thorough and efficient planning.'

The functionality of the building block was not directly connected to the module at that time, as the module was only related to the geometry of the interface. The module as a standard measure of length is today still used in architecture and construction. In the Figure 4, the first example of industrialized building block builgings can be seen.

Figure 4. The Toerten houses in Germany (1926-28) is one of the first examples of industrialized building block buildings. [30]

Modularity in relation to Bauhaus buildings is often connected to monotonous container architecture and soulless giant constructions. It is true in some cases and is caused by a too radical and uncritical use of standardization and rationalization in areas, where the costs are huge measured as human uneasiness and alienation.

Drostes' following statement (1990) [31] shows an example, on how the rational line of thought was pushed too far: 'By the end of the year 1925 it was decided to introduce writing in sheer small letters [in the journal 'bauhaus"] and only use printed matters following the existing DIN-standards. On every sheet of paper it was now printed: “we write everything in small letters, because we hereby save time. furthermore: why two alphabets, when you obtain the same with only one? why write in capital letters, when you can’t speak in capitals?’.

- **Technical Building Block Systems (Baukasten)**

The concept of building blocks has been further elaborated in German, mechanical literature (in German: Baukasten). In the 1960’s it described the nature of different types of building blocks and attributes including guidelines for designing a technical building block system. As Borowski (1961) [32] states that; ‘The building blocks were physical, typically machine elements, and interfaces typically described by geometry’. The basic attribute of a building block system was described as the ability to create variety by combining and exchanging different building blocks.It can be seen in the Figure 5 as below;

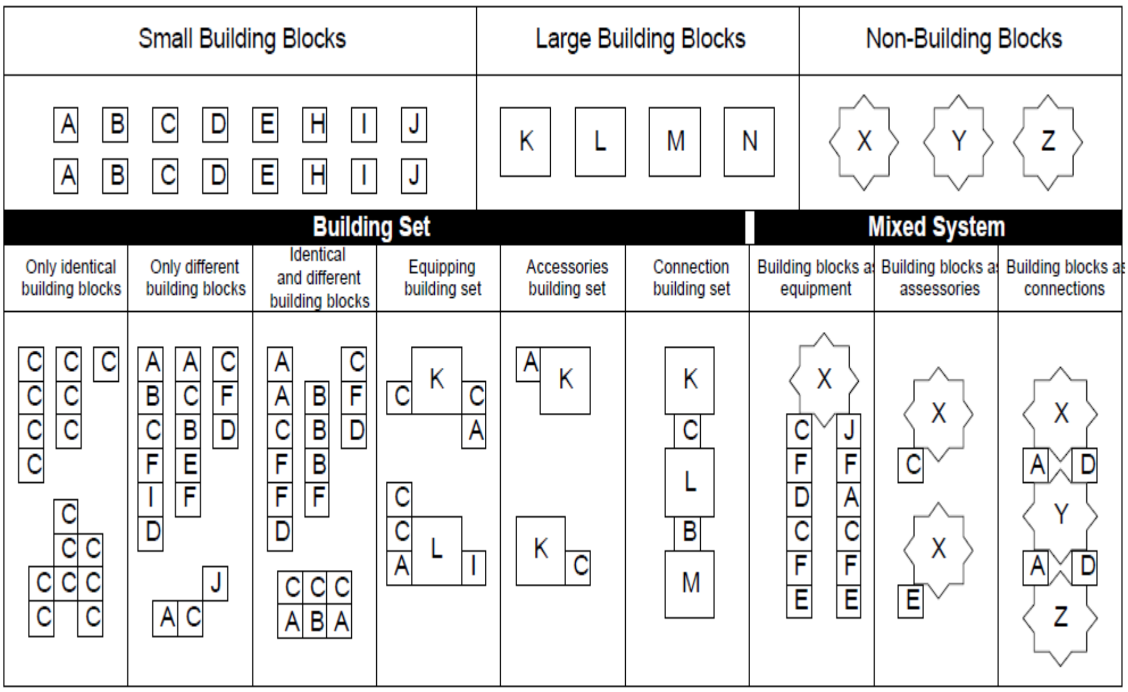

Figure 5. Different types of building block systems.The building blocks are mainly characterized by size. [33]

2.2.1. Perceived Benefits and Challenges of Modular Construction

There are lots of study made for clarify the modularity's perceived benefits and challenges. As Lu (2007) [34] mentions that; 'A study conducted at the Graduate School of the University of Clemson by Lu Na in 2000 [35] revealed the perceived benefits and limitations to using prefabricated components. 'The survey received responses from a mixture of 138 practicing architects, engineers, and general contractors in the U.S. The benefits associated with prefabrication revealed in the study included the following'.

1-Reduced overall construction time and efficient scheduling due to parallel production activities

2- Increased building quality and craftsmanship

3-Increased labor productivity

4-Increased labor safety

5-Reduced construction schedule disruptions due to the use of a weather protected work environment

6-The minimal environmental impact of the construction process on the site

As seen in the Figure 6, there is a chart which is related with the perceived benefits and perceived constraints of modular construction comparison can be followed as;

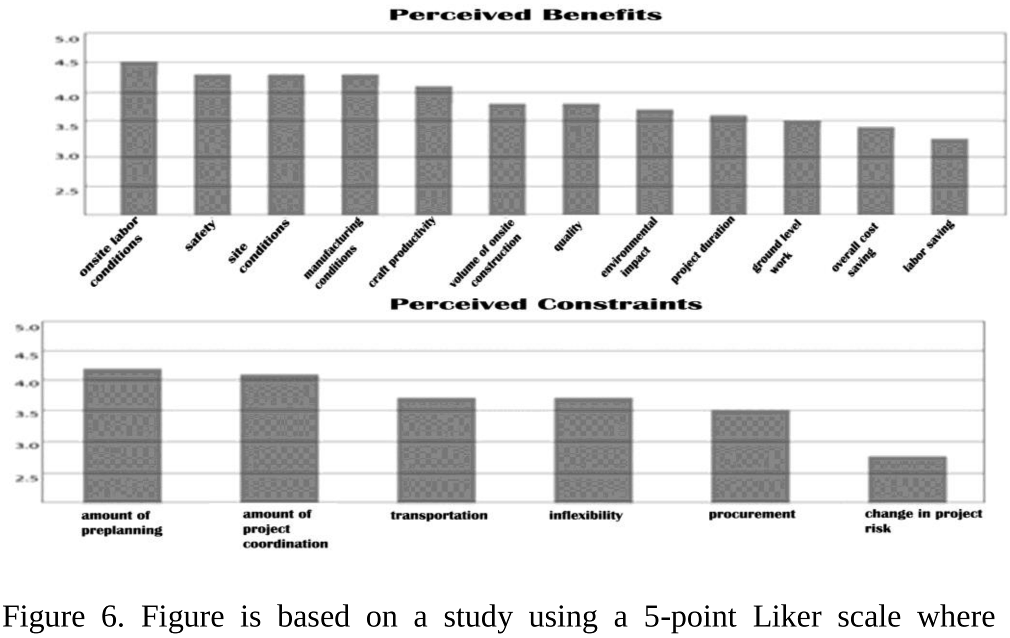

Figure 6. Figure is based on a study using a 5-point Liker scale where ratings between from 3 to 5 are considered advantages, and ratings from 1 to 3 are not considered advantages .[36]

Also Baldwin's theory of modular design and design evolution can be summarized as follows:

· Modularity creates options;
· Modular designs evolve as the options are pursued and exercised.

In general, modularizations serve three purposes, any of which may justify an investment in modularity:

· Modularity makes complexity manageable.
· Modularity enables parallel work.
· Modularity is tolerant of uncertainty.

In the chart below, it is shown that, when all options come together, with the sake of modularization, modularity creates lots of options.

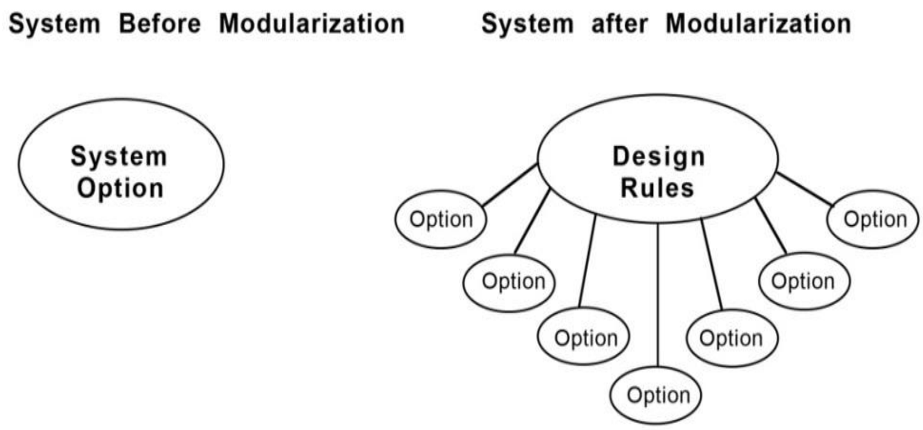

Figure 7. System vs. design rules options. (Baldwin and clark, 2000, p.237.) [37]

Thus, modular designs offer alternatives that non-modular ("interdependent') designs do not provide. Specifically, in the hidden modules, designers may replace early, inferior solutions with later, superior solutions. Such alternatives can be modeled as "real options."

2.2.2. Current Trends in Modular Construction

Modular components make a lot of sense in commercial building design of all kinds. A good trend that we hope will continue in future, are architects and engineers working with our industry more than ever to understand the current meaning of the word “Modular”.

As Schoenburn (2012) [38] states in the article; ‘Air flow in wall assemblies and the mitigation of moisture build up within structures. The codes are creating new air barrier requirements that are changing the way modular buildings will be designed and built.

There are some growing trends for modularity, due, in large part;

- Increased focus on sustainability and safety
- Use of building information modeling (BIM)
- Growth of modular construction in the healthcare industry
- Develop a modular construction system for outpatient facilities called “The New Model’’.

The National Institute of Standards and Technology (NIST) recommended an increased use of prefabricated components and preassembly as being one of the top five opportunities for breakthroughs in the construction industry (Improving Construction 2010)[39]. General contractors outsource prefabricated work because they require the following to be competitive (Chiang, Tang, and Wong 2008) [40]:

1. Market share
2. Know how
3. Financing

As Lu (2007) [41] states that; ‘While the benefits are currently known to both clients and general contractors, stick built construction is still used in 75% of new houses built in the US’. ‘Studies have shown that there simply is not a competitive marketing advantage to the use of modular construction over stick built construction'. (Chiang, Tang, and Wong, 2008) [42].

A 2007 article in *Building and Environment* [43] indicated that the following strategies are required in order for modular construction to be considered cost effective:

1. Complete mechanizing of the production process
2. Eliminating the amount of site work required as much as possible
3. Maximizing the usage of recycled materials for prefabricated building components.

As Haas (2000) [44] states that; 'prefabricated components are still used today in the majority of new building construction. The building trades that are identified as using prefabricated components most effectively were ranked as follows':

1. Piping
2. Mechanical
3. Structural assemblies
4. Equipment
5. Ironworks
6. Instrumentation
7. Welding
8. Electrical
9. Concrete
10. Insulation
11. Carpeting
12. Finishes
13. Furnishings
14. Masonry
15. Roofing
16. Plastics

And also as Haas(2000) [45] states that; ’ skill levels required for prefabrication is no different than that in traditional stick built construction, the cost of labor was shown to be lower’.

Meanwhile, the primary reasons for architectural integration of modular components into a project include the following:

1. Satisfying owner demand
2. Improving quality
3. Saving time

According to Bernstein, Gudgel, and Laquidara (2011) [46], the recommendations of the study include the education of clients on the productivity and business benefits of prefabrication, the development of BIM objects by the modular manufacturers to make it easier for architects to specify products in their design, and to promote the green benefits of prefabrication to make it stand out to both architects and clients as a positive alternative to onsite construction.

2.3. What does modular design consist of?

Before talking about the hole modular design principles, it needs to be known that, design is a big union for principles. With branches of design, every designer can create their own options, it named as ‘principles’. Because of the big principles hole, under this title, every title need to be clarified precisely and neatly.

Beginning with the modular design principles, firstly general design principles and elements need to clarify. Every designer sometimes disregards the principles of design. However, there is usually some equative virtue emerges.

As Lovett (1999) [47] states that; ‘the elements and principles of design are the building blocks used to create a work of art. The elements of design can be thought of as the things that make up a painting, drawing, design etc. The Principles of design can be thought of as what we do to the elements of design. How we apply the Principles of design determines how successful we are in creating a work of art.'

Afterwards, to apply all these principles as an architect, it needed to be known that, the construction technics are very important. Thus, whit in all these principles can be useless because of the lack of structural and constructional knowledge. There is a sub-heading included below to clarify some important construction technics.

2.3.1. Elements of design

There are some basic designs elements are existed to create or to guide for combining new designs. As Lovett (1999) [48] states that; 'The elements of design can be thought of as the things that make up a painting, drawing, design etc'.

These are;

- Line
  Line can be considered in two ways. The linear marks made with a pen or brush or the edge created when two shapes meet.
- Shape
  A shape is a self-contained defined area of geometric or organic form. A positive shape in a painting automatically creates a negative shape.
- Direction
  All lines have direction - Horizontal, Vertical or Oblique. Horizontal suggests calmness, stability and tranquility
- Size
  Size is simply the relationship of the area occupied by one shape to that of another.
- Texture
  Texture is the surface quality of a shape - rough, smooth, soft hard glossy etc. Texture can be physical (tactile) or visual.
- Color
  Also called Hue
- Value
  Value is the lightness or darkness of a color. Value is also called Tone

2.3.2. Principles of design

Although necessities creates design problems and this problems creates design solutions, there are some de-facto principles for design .This principles are generally just for providing more steady design but as known, however designers use these principles, every design has its unique features . Typical design principles graphic wich includes, space, function, form and technics, can be seen in the Figure 8 as below;

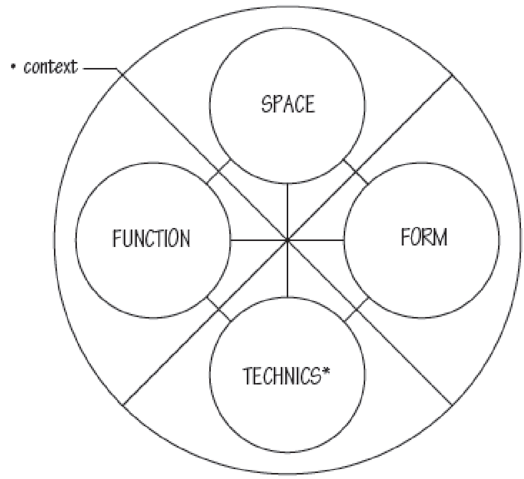

Figure 8. In this table, it's shown that space, function, technics and form creates contexts for principles. Technics refers to the theory, principles, or study of an art or a process.(Ching, 1943, 12) [49]

As Ching (1943) [50] mentioned in the book ARCHITECTURE form, space and order, that;

> ''The initial phase of any design process is the recognition of a problematic condition and the decision to find a solution to it.Design is above all a willful act, a purposeful endeavor. A designer must first document the existing conditions of a problem, define its context, and collect relevant data to be assimilated and analyzed. This is the critical phase of the design process since the nature of a solution is inexorably related to how a problem is perceived, defined, and articulated. Piet Hein, the noted Danish poet and scientist, puts it this way: "Art is solving problems that cannot be formulated before they have been solved. The shaping of the question is part of the answer.''

Thus, there is a common discussion between architects for understanding the design principles whether it is necessary or not. Besides this ideas, it need to be mentioned that principles as Lovett (1999) [51] also summarized below;

- Balance

Balance in design is similar to balance in physics

- Gradation

Gradation of size and direction produce linear perspective. Gradation of color from warm to cool and tone from dark to light produce ærial perspective. Gradation can add interest and movement to a shape. A gradation from dark to light will cause the eye to move along a shape.

- Repetition

Repetition with variation is interesting, without variation repetition can become monotonous.

- Contrast

Contrast is the juxtaposition of opposing elements e.g. opposite colors on the color wheel - red / green, blue / orange etc. Contrast in tone or value - light / dark. Contrast in direction - horizontal / vertical.

- Harmony

Harmony in painting is the visually satisfying effect of combining similar, related elements. e.g. adjacent colors on the color wheel, similar shapes etc.

- Dominance

Dominance gives a painting interest, counteracting confusion and monotony.
Dominance can be applied to one or more of the elements to give emphasis

- Unity

Relating the design elements to the idea being expressed in a painting reinforces the principal of unity.eg. a painting with an active aggressive subject would work better with a dominant oblique direction, course, rough texture, angular lines etc. whereas a quiet passive subject would benefit from horizontal lines, soft texture and less tonal contrast.

2.3.3. Construction Techniques

It is considered that ages ago, human being need to create and construct their shelters for living. Than they removed their shelters to move or to arrange it for larger spaces for their needs.Thus, the desire for better living was one of the most important issue for human being so, they started to create and develop some construction techniques.

All construction projects include some elements.To understand and use of these technichs prevends and takes away some negative results. These techniques are important for this survey because of the understanding of structural knowlegde of the modularity.

In the following part, the progress of various construction techniques are viewed.

As the Book ‘ Elements of Construction’ in chapter 8 [52] mentioned that;there are eight main techniques are need to known. These are;

• Footings and foundations;

A foundation is necessary to support the building and the loads within or on the building. The combination of footing and foundation distributes the load on the bearing surface, keeps the building level and plumb and reduce settling to a minimum.

• Concrete Foundations;

Concrete block foundations should be started in a full bed of mortar on a poured-concrete footing. A 1:1:5 ratio of cement–lime–sand makes a good mortar. The corner blocks should be carefully located and checked for levelness and plumb.

• Walls;

Walls may be divided into two types:

(a) Load-bearing walls that support loads from floors and roof in addition to their own weight and resist side-pressure from wind and, in some cases, from stored material or objects within the building.

(b) Non-load-bearing walls that carry no floor or roof loads. Each type may be further divided into external or enclosing walls, and internal dividing walls.

The term 'partition' is applied to walls, either load-bearing or non-load-bearing, that divides the space within a building into rooms.

• Floors;

Building floors may be as simple as compacting the soil present on the site before the building is constructed, or as complex as attractively finished hardwood parquet. A well-chosen, well-built floor offers protection from vermin and rodents, is easy to clean, and is dry, durable and a valuable asset to a building.

• Roofs;

A roof is an essential part of any building, in that it provides the necessary protection from rain, sun, wind, heat and cold. The integrity of the roof is important for the structure of the building itself, as well as for the occupants and the goods stored within the building.

• Doors and Windows;

Doors are essential in buildings to provide security and protection from the elements, while allowing easy and convenient entry and exit. Doors must be of adequate size. For use by people only, a door 70 cm wide and 200 cm high is adequate.

Windows provide light and ventilation in a building and allow the people inside to view the surrounding landscape and observe the activities in the farmyard. There are two main types of windows;

(a) Shutters: These are basically small doors and are constructed as unframed, framed or flush shutters.

(b) Glazed windows: Glazed windows are relatively expensive but are most practical in cold areas. When temperatures are low, the window can be shut while still allowing daylight to enter the room.

• Stairs and ladders;

Stairs can be designed as one straight flight, with a landing and a 90° turn, or with a landing and a 180° turn. The straight flight is the simplest, the least expensive and the easiest for moving large objects up or down.

Ladder-stairway: The recommended pitch for this type of steep, narrow stairway is 60°. The width is usually roughly the minimum of 600 mm. The size of the going (tread) is dependent on the pitch. Table 8.17 gives recommended values.

• Electrical installations;

Electrical energy can be put to many uses, and an increasing number of farms will benefit from electrification as the electrical supply network expands into the rural areas'.

2.3.3. Building Blocks versus Modules

The original building block idea (Baukasten) from Bauhaus has evolved in the later years with companies striving for combining the advantages of standardization and customization – mass customization. Today the original senses of the words module and building block have merged, so that a module is used for a building block containing specifications of both interface and functionality which can be combined with other modules. On the other hand, the contemporary meaning of a building block has lost some of its previous contents compared to the Bauhaus time.

As Miller (2005) [53] states that; 'A new difference has occurred between the module and the building block. A module has to posses a certain considerable amount of functionality compared to the final product. It can for example be a power supply module in a mechatronic product like a printer. In an industrial context, it is important that this functionality has to be sufficient for independent testing'.

The meaning of building block is on the other hand reduced to a more limited functionality compared to the final product.

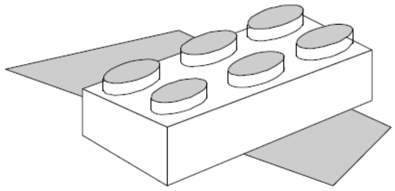

Figure 9. Lego-blocks are usually not modules as they do not posses a considerable amount of functional compared to the construction of which they are a part. But they do have a standardized interface allowing constructions by combinations. [54]

Following this line of thought, As it can be seen in Figure 9,Lego-blocks and traditional bricks are building blocks, thus usually not modules, as they don't posses any substantial amount of functionality compared to the construction of which they are a part. - The brick is neither kitchen nor living room and therefore not a module, though still a building block.

2.3.4. Modules Linked to Functionality

In the paper which written by Pahl & Beitz in 1996 [55], directly link the definition of modules to functionality and define different types of modules based upon a range of functions (basic, auxiliary, special, adaptive). A module is in this way the physical realization of a function. If an element does not relate to any of these functions, it is defined as a non-module. In this way Pahl & Beitz avoid that everything becomes modules. Furthermore, they categorize modules according to the following criteria: type of function, importance, complexity, combination, resolution, concretization and application. But the fundamental understanding of the concept behind modularity is not well founded, as for example, the whole interface problem is not approached.Fuction thypes which is related with the functionality of modularity can be seen in the Figure 10 as below;

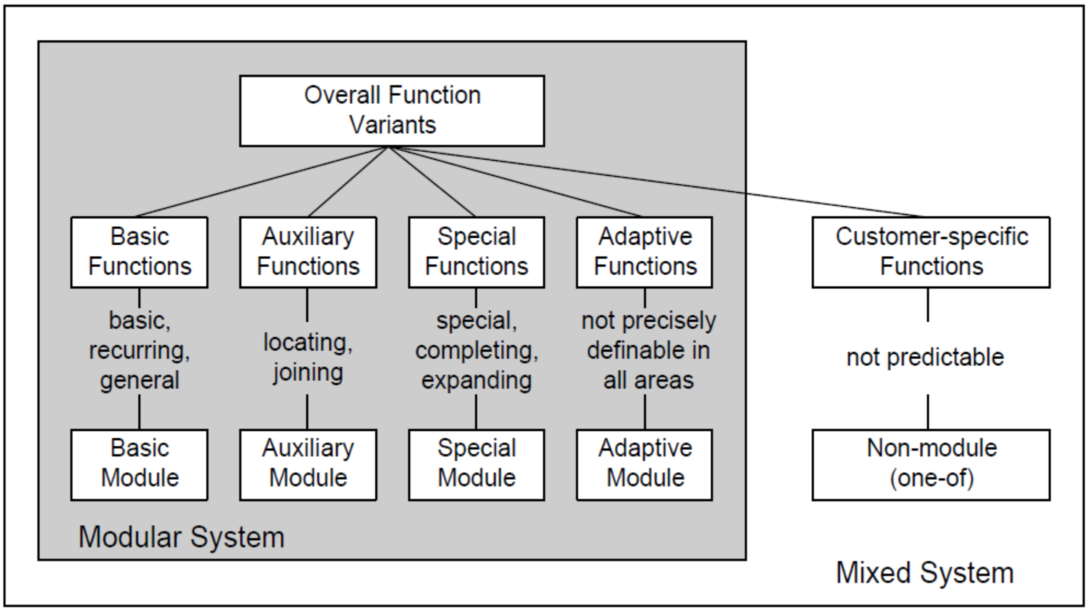

Figure 10. Function types and module types in modular and mixed product systems. [56]

2.4. Architectural design aspects for applications

With combining all of principles and elements of modular design, Applicational aspects are showing themselves more clearly. In fact, all new applications, based on some necessities, that cause on principles.

Ching (1943, 353) [57] mentioned in the book ARCHITECTURE form, space and order, to identify the principles of design as;

> ‘‘There exists a natural diversity and complexity in the program requirements for buildings. The forms and spaces of any building should acknowledge the hierarchy inherent in the functions they accommodate, the users they serve, the purposes or meaning they convey, and the scope or context they address. It is in recognition of this natural diversity, complexity, and hierarchy in the programming, designing, and making of buildings that ordering principles are discussed.’’

Except of common principles of design, as the author said below, there are some new necessities arise because of the development of technology and the change of expectations create some technological solutions and this solutions requirements.

2.4.1. Innovation in computer aided design

The contribution of technology to offsite manufacturing processes is expected to be considerable, yet it is unknown to what extent manufacturers are employing these tools in their processes. Prototype design demands highly detailed drawings because, as stated by David Denison of the Ohio Board of Building Standards, As Burns (2001) [58] mentions that;

> ‘‘It is one thing to have a dangerous condition in one house, and another to have it repeated a thousand times in an industrialized unit” .Kieren & Timberlake continues to support this idea that; ‘This requires the full modeling of components to effectively prove that all elements fi t together with acceptable tolerances and sufficient detail’. With the emergence of Building Information Management (BIM) tools, schedules and engineering data can be passed between consultants seamlessly, and joint details can be instantly modeled in 3-D. Computer Numeric Control (CNC) milling machines, 2-D laser cutting devices, and 3-D full scale printing procedures can remove.’’

Hand craft completely from the manufacturing process, eliminating the interpretation of drawings by the different design and construction disciplines. As CADeshack (2009) [59] mentions in the article that; ‘The advancements of technology most associated with building construction include the use of innovative building materials, internet based purchasing, 3D-CAD, computer aided manufacturing (CAM) tools, and computer aided engineering (CAE) simulation tools. 3DCAD software enables modeling with built-in databases that store building information (product information, assembly groups, dimensions, etc.). 4D-CAD software additionally stores scheduling and construction sequencing information, while 5D-CAD incorporates cost data’.

The depth of building information modeling allows compact data files to be passed seamlessly between designers, engineers, contractors, manufacturers, and clients. CAM tools today can pass building information directly between the designer and the machine, eliminating the chance for human error. For example Monolite (2011) [60] states that; ‘the aim of a system like D-Shape, being developed by Monolite, is to construct inhabitable space without involving any human intervention’. There is an example on the book Robot Crafted House (2006) [61] that; ‘Similarly, *Contour*

Crafting, a robotic arm concrete pouring system being developed at the University of Southern California, can produce a 30 foot slab on grade, and, with the foundation in place, the machine can erect detailed concrete walls that include omissions for door and window fabrications'. Some examples of drawing process and the results of using BIM programs can be seen in the Figure 11 as below;

Schoenborn (2012) [62] adds the information about CAE simulation tools as;

> ''CAE simulation tools like Autodesk Ecotect Analysis, used for studying the energy performance of buildings, and SAP 2000, used for structural analysis, interface with 3D-CAD tools. Eventually, a heightened accountability among disciplines may be the biggest contribution computer modeling tools have to offer to building construction, because no longer are construction documents intended as diagrammatic representations with a complete disregard to how systems relate to one another in 3-D space.''

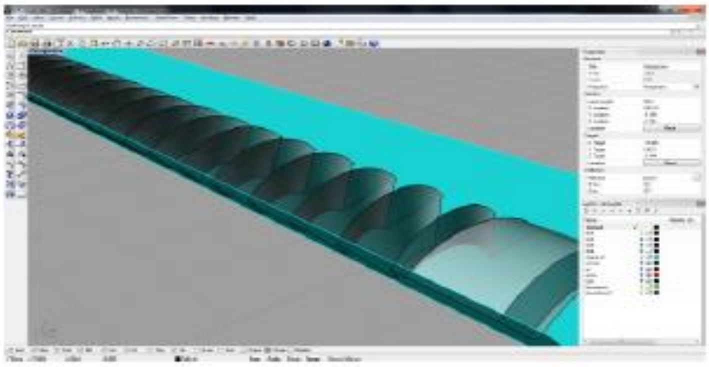

Figure 11. Example of a screw drawing using the 3-D based program called 'maya' That kind of programs provide user to draw one-to-one preview image before producing process. [63]

Figure 12. CNC machine (Computer Numerical Control) melting screw which data based from computer drawing. The drawing, which drawn before, can upload to machines storage and then the object can be produce easily. [64]

2.4.2. Prototyping

Before explaining what the usage of prototyping is, it needs to be known that what prototyping is.

A prototype is an early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. In PC Magazine, (2012) [65] it mentions that is a term used in a variety of contexts, including semantics, design, electronics, and software programming. A prototype is designed to test and trial a new design to enhance precision by system analysts and users. Prototyping serves to provide specifications for a real, working system rather than a theoretical one. Also Soares (2012) [66] mentions in the article; 'In some workflow models, creating a prototype (a process sometimes called materialization) is the step between the formalization and the evaluation of an idea'.

According to the Soares, there are some basic prototype categories,

• **Proof-of-Principle Prototype (Model)**

A Proof of concept prototype is used to test some aspect of the intended design without attempting to exactly simulate the visual appearance, choice of materials or intended manufacturing process. Such prototypes can be used to "prove" out a potential design approach such as range of motion, mechanics, sensors, architecture, etc. These types of models are often used to identify which design options will not work, or where further development and testing is necessary.

• **Form Study Prototype (Model).**

This type of prototype will allow designers to explore the basic size, look and feel of a product without simulating the actual function or exact visual appearance of the product. They can help assess ergonomic factors and provide insight into visual aspects of the product's final form.

In fact, there are some differences between prototyping and product design. İt can be clarified as below;

In general, prototypes will differ from the final production variant in three fundamental ways:

- **Materials**. Production materials may require manufacturing processes involving higher capital costs than what is practical for prototyping. Instead, engineers or prototyping specialists will attempt to substitute materials with properties that simulate the intended final material.
- **Processes**. Often expensive and time consuming unique tooling is required to fabricate a custom design. Prototypes will often compromise by using more variable processes, repeatable or controlled methods; substandard, inefficient, or substandard technology sources; or insufficient testing for technology maturity.
- **Lower fidelity**. Final production designs often require extensive effort to capture high volume manufacturing detail. Such detail is generally unwarranted for prototypes as some refinement to the design is to be expected. Often prototypes are built using very limited engineering detail as compared to final production intent, which often uses statistical process controls and rigorous testing.

Also if prototyping is an issue, it need to be clarified some characteristics and limitations of prototyping. Engineers and prototyping specialists seek to understand the limitations of prototypes to exactly simulate the characteristics of their intended design.

It is important to realize that by their very definition, prototypes will represent some compromise from the final production design. Due to differences in materials, processes and design fidelity, it is possible that a prototype may fail to perform acceptably whereas the production design may have been sound. A counter-intuitive idea is that prototypes may actually perform acceptably whereas the production design may be flawed since prototyping materials and processes may occasionally outperform their production counterparts.

In general, it can be expected that individual prototype costs will be substantially greater than the final production costs due to inefficiencies in materials and processes. Prototypes are also used to revise the design for the purposes of reducing costs through optimization and refinement.

It is possible to use prototype testing to reduce the risk that a design may not perform as intended, however prototypes generally cannot eliminate all risk. There are pragmatic and practical limitations to the ability of a prototype to match the intended final performance of the product and some allowances and engineering judgments are often required before moving forward with a production design.

Building the full design is often expensive and can be time-consuming, especially when repeated several times—building the full design, figuring out what the problems are and how to solve them, then building another full design. As an alternative, "rapid-prototyping" or "rapid application development" techniques are used for the initial prototypes, which implement part, but not all, of the complete design. This allows designers and manufacturers to rapidly and inexpensively test the parts of the design that are most likely to have problems, solve those problems, and then build the full design.

• **Dymaxion House**

It is important that; making an object model during the design process makes it more understandable for users. First and exact prototype was named as ‘Dymaxion House’ .The Dymaxion House was developed by inventor and architect Buckminster Fuller to address several perceived shortcomings with existing homebuilding techniques. As Sieden (2000) [67] states that; ‘Fuller designed several versions of the house at different times all of them factory manufactured kits, assembled on site, intended to be suitable for any site or environment and to use resources efficiently. A key design consideration of the design was ease of shipment and assembly. Fuller created the term *Dymaxion*, a portmanteau of the words dynamic, maximum, and tension, to describe many of his inventions’.

Patterson (2010) [68] adds the information about Dymaxions'construction phase as;

> ''The Dymaxion was completed in 1930 after two years of development, and redesigned in 1945. Buckminster Fuller wanted to mass-produce a bathroom and a house. His first "Dymaxion" design was based on the design of a grain bin. During World War II, the U.S. Army commissioned Fuller to send these housing units to the Persian Gulf.[2] In 1945, science-fiction writer Robert A. Heinlein placed an order for one to be delivered to Los Angeles, but the order was never filled.''

The Dymaxion House (completed as a one off built house named the Wichita House) was designed as a transportable kit that could be suitable for any building site.As Koch (1958) [69] states that; 'The geodesic dome of the house covers the maximum amount of space with the smallest amount of material possible. The façade is clad in repetitive aluminum panels, and the interior space is divided radially around a central mast structure'. It can be argued that the Case Study House Program (started in 1945 by *Art and Architecture Magazine* edited by John Entenza) was an example of prototyping at the scale of a completed home.

As Bergdoll and Christensen (2008) [70] mention that;' the intent of the program was to challenge the construction process by introducing a range of prefabrication components for custom buildings; the final outcome could have been marketed as a mass produced commodity'. Although it was ultimately viewed as an educational exercise, trying to push what is possible in single family house design, the Make It Right program being implemented today in New Orleans is being realized at a large scale. The homes designed for the program provides clients a range of predesigned houses to choose from.

The Dymaxion houses prototyping process can be seen in the Figure 13 as below;

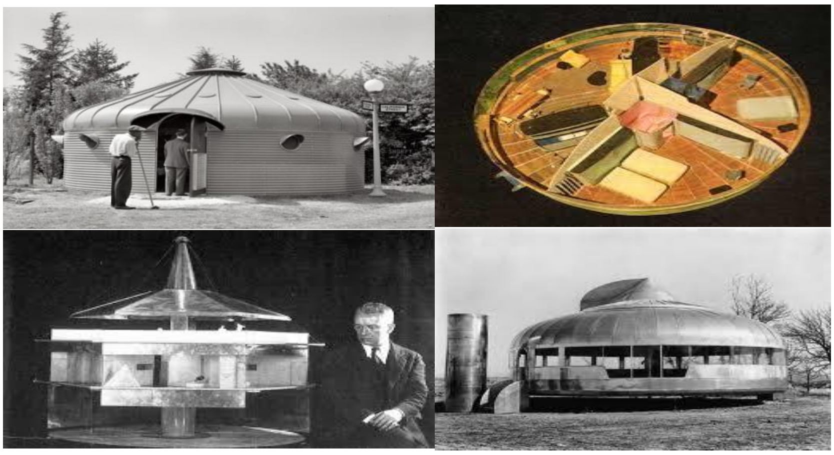

Figure 13. This figure shows that dymaxion houses plan and built process.Also in this visual two example which shown right side, are good prototyping examples of dymaxion house. [71]

2.2.3. Economic expedience

Lu (2007) [72] states in the article that; ‘While the benefits are currently known to both clients and general contractors, stick built construction is still used in 75% of new houses built in the US’. Chiang, Tang, and Wong (2008) [73] also mentions that; ‘Studies have shown that there simply is not a competitive marketing advantage to the use of modular construction over stick built construction’.

As Lu (2007) [74] states that; ‘this public perception was overcome by German manufactures through quality certification schemes, consistent promotional marketing of the benefits of offsite construction, and the standardization of components (increasing efficiency and productivity)’.

Itard and Klunder (2007) [75] mentions in their writing that;

> ‘‘Materials being specified by architects are taking into account the life cycle value of materials (durable) and components (reusable). Life cycle costs are attributed to the amount of energy and resources invested into materials and assemblies. This encompasses the goods and services used for the extraction of materials, their refinement and integration into components, the re-use of the components, the disassembly and recycling of materials, and their final disposal. The life cycle assessment method is the standard for comparing materials, components, systems, and entire buildings.’’

Changing design process time and time saving process can be seen in the Figure 14 as below;

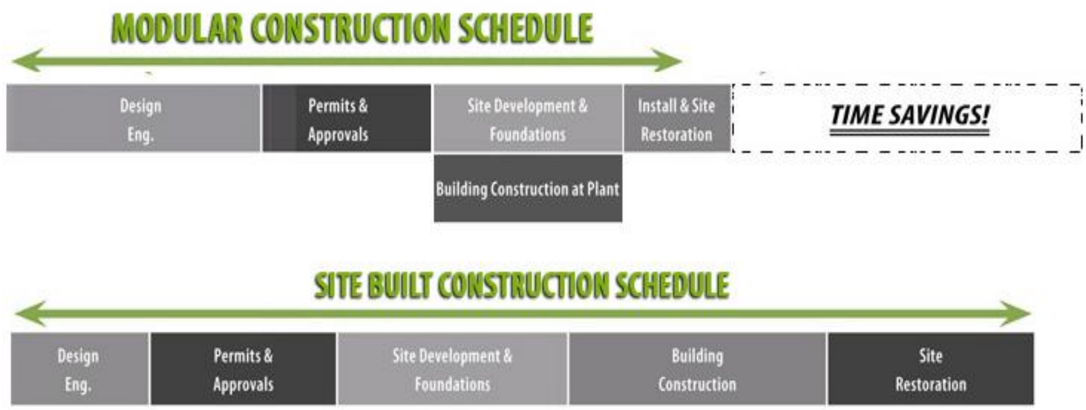

Figure 14. Comparison with modular construction and site built constructions time saving and money saving chart. [76]

This graphic shows that, using modularity rules, gave productive workers a lot of time saving. İt can be easily sat that; in constructional areas time saving is can be equal to money saving.

The life cycle value of material diagram can be seen in the Figure 15 as below;

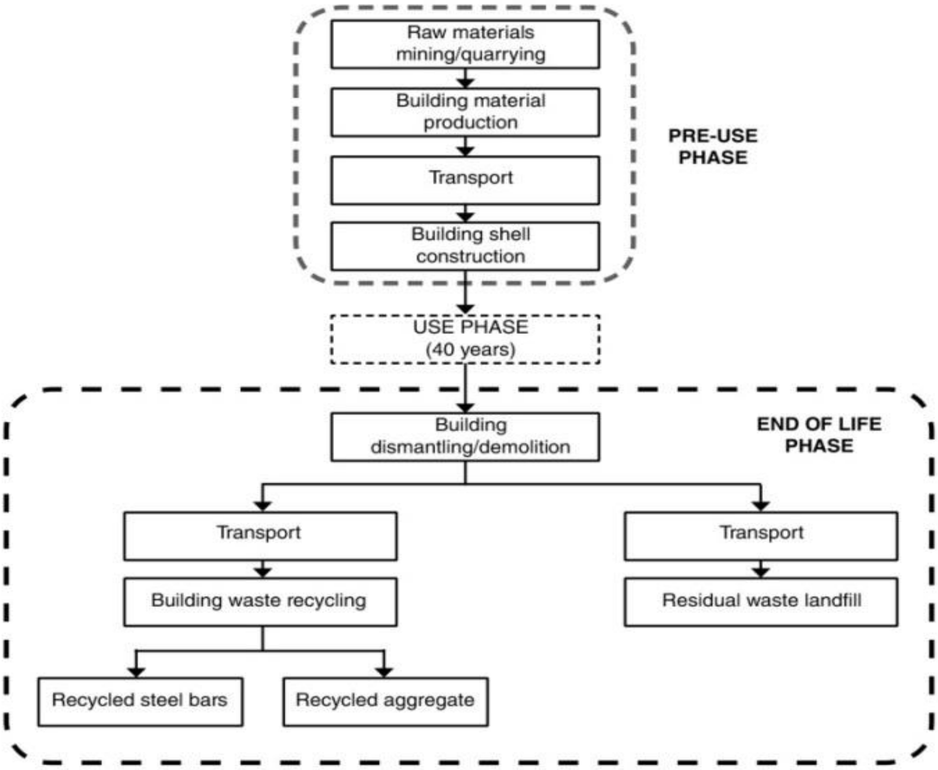

Figure 15. The life cycle value of materials. A demonstration of the effort and resources put into the life of a building from cradle to the grave [77]

Beyond quality management and improved completion time, modular construction offers numerous benefits to owners (Modular Building Institute, 2012) [78] these are;

• Less Site Disturbance;

On-site traffic is greatly minimized from workers, equipment and suppliers.

• Less Material Waste;

When building in a factory, waste is eliminated by recycling materials, controlling inventory and protecting building materials.

• Improved Air Quality;

Because the modular structure is substantially completed in a factory-controlled setting using dry materials, the potential for high levels of moisture being trapped in the new construction is eliminated

• Reduced Construction Schedule;

Because construction of modular buildings can occur simultaneously with the site and foundation work, projects can be completed 30% to 50% sooner than traditional construction.

• Elimination of Weather Delays;

60 - 90% of the construction is completed inside a factory, which mitigates the risk of weather delays. Buildings are occupied sooner, creating a faster return on investment.

• Built to Code with Quality Materials;

Modular buildings are built to meet or exceed the same building codes and standards as site-built structures, and the same architect-specified materials used in conventionally constructed buildings are used in modular construction projects – wood, concrete and steel.

• Better Engineered Building & BIM;

PMC relies on advanced BIM for visualization to assess the energy performance and identify the most cost-effective efficiency measures. PMC is ideal for the use of this technology where the construction process is already collaboration of systems, materials and people—much like the software itself.

2.5. Modular Structures

Modularity tends people to insert lots of object to their life easily. Not only in architecture, also in furniture’s, modular notion had become very useful.

• Habitat 67

Habitat 67 (a residential complex built for the 1967 International and Universal Exposition in Montreal, Canada) by Moshe Safdie successfully internalizes a suburban condition in an urban context. Also Safdie (1970) [79] states that; ‘The complex is an arrangement of a series of identical precast concrete volumes fi t together in a number of different arrangements to create a monolithic landmark for the city. Using about five different shaped module structures, each living unit (with a private garden) commands its individual presence despite the compact nature of the cluster of modules because of the interstitial spaces created by staggering their layout. Communal spaces including parks, shops, and even movie theatres are dispersed through the complex’. The constructional stage of Habitat 67 can be seen in the Figure 16 as below;

Figure 16. Construction process of Habitat 67. Modules inserted one by one to complete the whole building [80]

• MDU House

As Hartley and Blagden (2007) [81] mentioned that; ‘Modular construction would seem to be ideal for urban infill sites because onsite construction can be completed in phases allowing the surroundings buildings to be relatively undisturbed. The challenge, however, is that high-value “flagship projects” like large office developments would be undermined by the introduction of the limitations of modular construction’. But, though by no means prevalent, the challenge is being undertaken today by large architectural firms like SHoP Architects (Atlantic Yards in New York), or O’Connell East Architects (Victoria Hall in Wembley, UK). As Herbers (2004) [82] states that; ‘The New York based firm Lot-Ek, in particular, pushes the re-use of shipping containers as modular building blocks in urban environments. With their Container Kit project, complex building systems were divided into volumetric forms that protruded from the base container footprint, but could be pushed in to form a compact, transportable unit. The components contained different room functions – bathroom, kitchen, etc. In compact form, the building remains a standard container size’. The first example of The Container house can be seen at the Figure 17 as below;

Figure 17. The First example of container house, built by Mark Podlaseck and hispartner, Steve Bryant. Name is MDU House. [83]

This is a good example for modular structure and also it can be called the beginning of prefabrication. This MDU House project and its inventors were not aware that types of structural systems were going to be an inception of a new structural trend. Even though, container structural blocks are contemporarily being used for an urban site planning, shipping spaces, etc...

• EK's Nine Level Shipping Container Mall for New York City;

With the economy stalling, there are currently many empty lots or slivers of land sitting stagnant in the city. Shipping container malls could revitalize those unused spaces. Not only are they easier and in many cases cheaper to construct and uninstall than typical buildings, the natural curiosity they breed in. People make them a great tourist attraction which in turn bolsters the economy.

In the 5th Avenue shipping container mall, each module would serve to house one shop. A system of catwalks, elevators and stairs would sit between the containers and an adjacent building creating a way for people to travel through the mall as well as outdoor space to enjoy. To break up the facade, containers are removed in some spaces so that air and daylight can permeate the mall. The example of the Nine Level Shipping Container Mall can be seen as below in Figure 18.

Figure 18. LOT-EK's Nine Level Shipping Container Mall for New York City [84]

• The Term Terminal

The term terminal is also a good interior partition solution for loft spaces. For example, Terminal is the starting point in the spatial design process. It designed as a venue to guide the course of design journeys. Terminal presents spatial systems, unique products and solutions to meet the needs of commercial and cultural spaces, including offices, fair stands, shops and showrooms. With its dynamic design team to provide support, Terminal is a springboard for the spatial design process.

New style containers, partitions, stands and vans can also have terminal name.

• Containers; It can be seen as below in Figure 19.

Figure 19. Library container example which made with the idea of terminal. [85]

Here examples of new materials developed by the latest technologies throughout the world are on show, allowing architects and designers to touch, compare and choose the right materials for the right space.

• Partitions; (like insider containers.)

Terminal system presents flexible spaces capable of adapting to varying conditions. Open plan offices with flexible and uninterrupted structures are produced for lofts, industrial buildings or public spaces. The key is to develop the space so it can be used flexibly but still facilitate quality communication. This aim guides every stage of the creative process from concept design to budgeting, planning and installation. The design achieves ergonomic results with high quality acoustics by means of spatial systems that are compatible and consistent. It can be seen as below in Figure 20.

Figure 20. Meeting room divided from open plan offices with the system of terminal as partitions. [86]

Terminal usage not just provide semi-open spaces, also creates one direction walls and partitions to divide two spaces from each other.

• Stands and exhibitions.

Stands and exhibition spaces are just a part of architectural aspect but, also for interior architecture, designing exhibition areas are good branches. In this survey is generally depends on architectural aspect of titles but, it need to be mention stands in modularity title in general.

Whether designed for two-storey high spaces or the smallest of areas, Terminal is fully equipped to produce stand and exhibition designs which have their own distinctive character. The most flexible spatial solutions are achieved using a minimum of modules, enabling creative ideas to be put into practice with infinite variety. Sophisticated designs in which graphics and information find powerful expression reflect the aesthetic of austerity, so that a high standard is attained even in the smallest areas.It can be seen as below in Figure 21.

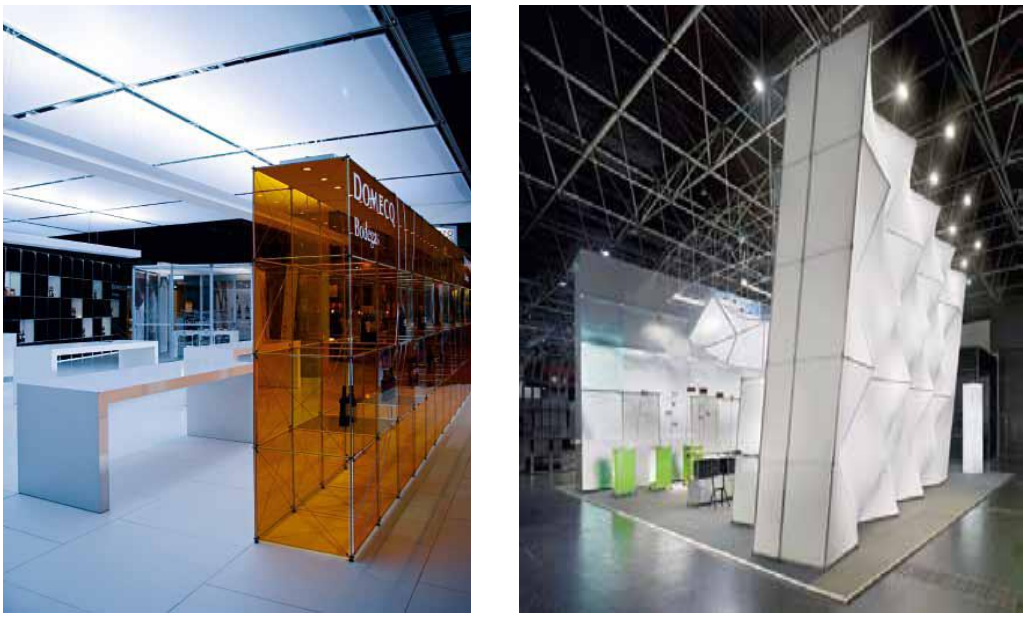

Figure 21. Exhibition stand examples built with the help of terminals as partition materials. [87]

2.6. Exemplifying the problem.

Much academic work asserts a relationship between the design of a complex system and the manner in which this system evolves over time. In particular, designs which are modular in nature are argued to be more "evolvable," in that these designs facilitate making future and structure adaptations, the nature of which do not have to be specified in advance. In essence, modularity creates "option value" with respect to new and improved designs, which is particularly important when a system must meet uncertain future demands.

It is important for an architect to understand the limiting factors that will affect the design of a modular building. The imposing of modular construction as a means of improving production efficiency and worker safety in the construction industry raises into question the design quality of modular buildings, and whether or not the qualification of the building process can also be captured from the perspective of the architect.

This study uses interviews with modular manufacturers and firms to extract information on the topic of innovation in the industry. Showing a case study project as a discussion platform, the opinions of experienced building professionals were explored to identify what is and what isn't possible.

Modularity has recently got a lot of attention. But the concept is not new at all. The observations show that, modularity conscious that relevant with the issue, such as architects, students or clients, is not accurate enough for applying modular solutions. The education in the schools doesn't provide the students to have enough skills for using 'modularity' to get the good design solutions in their career life. Since, the manufacturers and clients use the 'modularity' term in a wrong way. İs that possible to know and use modularity? Of course, it is not. This study is aimed to understand the real function and notion of modularity.

CHAPTER 3

3. MATERIAL AND METHOD

In this chapter, modular construction is used as material to show the problem solving of conceptual confusion of modularity. The people who fully understand modular consciousness, first examples of correct modular applications, current solutions and also interior solutions are given for clarify and orient the modular notion. The chapter continues with the methodical part. In this sub-heading, some questions and total surveys was directed to firms and according to collected data, firms modularity approaches were interpreted.

3.1. Material

As talked before; ‘Modular construction’ is a term used to describe the use of factory-produced pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building. The modular units may form complete rooms, parts of rooms, or separate highly serviced units such as toilets or lifts. The collection of discrete modular units usually forms a self-supporting structure in its own right or, for tall buildings, may rely on an independent structural framework. (Steelconstruction.info, 2013) [88]

3.1.1. Observed Data

For this study, differentiation of modularity and prefabrication is a material that already has some questions about its application and knowledge of usage. Thus, modularity as known by architectures and producers are drawn by mean to each other. This study aims to clarify the real notion and real function of modularity.

According to the collected data, professionals, who are interested in the modularity and the prefabrication, generally can differentiate the notions of the issues. However, professionals know what the module and modularity are and what is the difference between modularity and the prefabrication, manufacturer thinks that these two issues have the same meaning and application process.

3.1.2. Descriptions of Buildings

According to the researches, it is shown that; The Habitat 67 and The MDU House are good examples for understanding for the structural stage of modularity.

-Habitat 67;

According to the above parts, which included in Modular structures part, The Habitat 67 has some strict modular rules. Such as;

1. It originated from containers.
2. This container reminds the reader that; this container concept is related with the prefabrication.
3. It is a good approach to the issue, there are some specific and same module types that provides to container to become a modular part of a whole structure.
4. Every block has its union sitting plans as a house.
5. The sake of building-up process, every blocks are demountable so as this represents a good rule of modularity.
6. Every container has its own modules to create real module and also to create the whole structure.

The MDU House;

According to the above parts, this included in Modular structures part, also talked in detail about The MDU house.

1. The MDU house is also a good example for unique parts of structural systems.

2. Every container has its unique connection detail which provides to set up and remove.
3. It has unity.
4. It is also has some specific and same module types that provides to container to become a modular part of a whole structure.

According to the survey, professionals states that; this organization is the beginning of the prefabrication but the total organization is actually refers a good example of modularity, except of prefabrication because of the unity. This structural system would be an inception of a new structural trend. Such as; site planning, shopping spaces etc...

3.1.3. Description of Firms

In this study, I acted as the sole researcher who contributed to the design of the hypothetical project and was responsible for gathering information from modular manufacturers. Determined firms were being questionnared with the prepared questions.

Previously, there are some information about market approaches of firms and after these brief informations, In the appendix a part, there can be seen the answers of the manufacturers. After meeting face-to-face surveys to obtain the answers, the answers shows that, manufacturers are not in deeply have an acknowledge about the modularity and the prefabrication. According to the firms, modularity means prefabrication whether the constuctional confusion is important for them, they do not differentiate these two term from each other at the built-up stage.
The informations about firms and their market approaches are shown below;

- **Firm A Profile**;The hole informations are collected from their proffessional web page.Firm A, founded in 1989, is a Turkish General Contractor, with vast worldwide experience, providing Engineering, Procurement and Construction services for projects requiring high quality services in extreme environments.

Firm owns one of the largest prefabricated steel structure manufacturing facilities in the world. The manufacturing facility located in Ankara – Turkey, has 100.000 m^2 total area (55.000 m^2 workshop area)

Manufacturing Capacity:

- 160,000 m^2 Panelized Prefabricated Building Production per Month or,
- 3,600 Modular Units (Accommodation Containers) per Month or,
- 1,900 Tons production of Heavy Industrial Steel Buildings per Month

The Firm vision and values; Environmental sensitivity is a part of Firm's character. Firm guarantees that all raw materials, products and working environment of the corporation are environment- friendly and comply with international standards.

Occupational health and safety is very important for the firm during the production and montage works. It guarantees its conformity with laws and international standards.

The firm respects worker rights and human rights. Performance assessment of the workers is done professionally and special competency criteria are taken into consideration for task and working position.

The firm, constantly increasing its capacity for working harmoniously with the world's biggest and most esteemed firms and institutions, aims to increase its current market share in the fields of General Construction Business Services, turnkey type camp projects and modular prefab construction.

In their sector, where a high production rate in the short term and providing high quality services being considered a privilege, they shares desired work power with the world via Turkey, Kazakhstan, Iraq, Afghanistan, Qatar, Abu Dhabi and Libya.

- **Firm B profile;** The hole information was taken from their professional web page. Firm continues to be the leader company in the construction sector with its prefabricated building solutions since its founding in 1986. It started drawing international attention in its early years and firm's products now reached more than

70 countries. It is possible to stumble upon a firm product anywhere in the world. People calling a modular cabin "firm" out of Turkish borders prove that we are on the right path to achieve excellence. They, however, are aware that the world is changing all around us and they need to keep innovating and delivering better products inexpensively and faster.

Their greatest value is to have the brightest employees, who are experts in their specialties, and experienced personnel. They are a fast moving and teach company, who constantly listens to its customers in order to better address their needs. We manufacture prefabricated units that are compliant with international quality standards, energy efficient and suitable to be used in severe weather conditions. We carry out production in our modern facilities equipped with state of the art technology and located on 21,500 m^2 total area in Istanbul. They are conveniently located in a city enabling us to ship our products to anywhere in the world easily via alternative modes of transportation.

Their product portfolio and monthly production capacities are as below:

- Modular panelized buildings**:** 30,000 m^2/ month
- Mobile mono-block and flat pack containers**:** 400/ month
- Portable polyester cabins: 500/month
- Containerized residential and commercial facilities: 10,000 m^2/month
- Steel houses and villas**:** 10,000 m^2/month
- Pre-engineered steel structures**:** 10,000 m^2/month
- Polyethylene and fiberglass water tanks**:** 25,000/month

3.1.4. Description of Participants

In this survey, to understand and catch the real differentiates of the modular knowledge, there are some questions asked to people from different disciplines but from the same works spaces. There are two professionals and two students had been questioned from the prepared questions.

Professional ‘a’ is an architect and his job is related with the modularity subject. He is been doing his job for five years. He graduated from Gazi University.

Professional ‘b’ is an interior architect. Her knowledge of modular notion depends on her jobs but not frequently. She graduated from Bilkent University.

Student ‘a’ is an interior architecture student at Bilkent University.

Student ‘b’ is an interior architecture student at Çankaya University.

3.2. Method

In this survey, some questions and questionnaires were directed to firms and according to collected data of firms modularity approaches were interpreted. The interview as a research tactic was designed to capture the reactions of industry professionals regarding whatever topic was presented to them. The validity of their responses as data were contingent the credibility of the interviewer. This can be based on their experience, and on the ability for the responses to be corroborated by other evidence.

3.2.1. Questionnaire

Before preparing questions, some development processes were passed. The interview questions asked during the two face-to-face interviews included both questions specifically referencing conditions in the case study project, and general questions about the manufacturer’s process and the state of the industry. The challenge was extended to students from different disciplines (architecture, landscape architecture, and building construction). Questions about the project covered the following topics:

1) The Feasibility of the components to be fabricated
2) The ability for component productions to utilize from automation for manufacturers.
3) The sustainability and marketibility of the project.
4) The extent of a modular manufacturer’s involvement in design.
5) Transportation risks and limitations.
6) Whether or not life cycle costs are factored into building estimates.

3.2.2. Observation

In this study, as informed before, there are some confusions and some lack of knowledge about modularity and prefabrication. It could be the good way to obtain some defined questions to catch the real and known answers about the modularity and the prefabrication notions. Thus, some specific work areas and related persons chose to show the ideas of knowledge of professionals.

According to the collected answers of the survey, an architect requires knowledge about both the general process of modular construction and the manufacturer's production process to design effectively a modular building. There is lots of lack of knowledge to distinguish the modularity from prefabrication. According to the collected data, surveys show that, it needs to be more clarified and people need to be informed about these two issue. Also, increased interaction between the designer and the modular construction industry can best inform architects of what is and isn't possible, and provide manufacturers insight into the interests of the architect.

Even though the modularity is not a well-known issue at the market, financial issues are more important for the manufacturer. Although, manufacturers cares the financial and production side of modularity, designers thinks that; modularity is not a well-known subject to use in the market for using efficiently. Thus, except some designers, which are interested with the usage of modularity, designers avoid to use modularity efficiently for their works and they devoid of the benefits and facilitative ways of modularity.

3.2.3. Procedures and Findings

Data collected for this study were obtained through three interviews. Companies A and B were interviewed face-to-face, colleques and students were interviewed generally face-to-face some of them were interviewed by phone. Questions asked encompass the feasibility of the study project as it relates to each manufacturer's current process and factory arrangement, and concerns faced by the industry in general where design and production innovation are concerned. The interviews have been summarized in the following pharagraphes and total answers can be follow from the appendecies in appendix a part.

The information in this study is presented as a narrative. Since data collected came about through conversations with modular manufacturers only, the aspect of the architect was covered by the researcher. My aim was to relay everything that I learned about modular construction throughout this study. The objective is for this to be a tool primarily for design professionals that can help them to understand the challenges to modular building design. Summaries of all three interviews follow, and the conclusions enclosed contain the opinions of all involved in the study based on their experience in the industry and their school life.

The summary of interviews for Colleague A are as below;

'Colleague a' is generally defined modularity in a proper way. Because of the work type of 'colleague a', he has enough information about modularity. As the 'colleague a' mentions; 'Modularity is a configuration system which is formed with the components or the modules. It provides the varieties and the differentiation. More flexible, functional, easy and fast productions are possible by the help of modularity concept. The essentiality in modularity is the maintainability. If the components of a product do not have the ability of limitless assembling and disassembling, it cannot be called as a modular system. Mostly the modular system manufacturer and the firms make their production and application by ignoring this essentiality. Consequently, lots of products or buildings in industry do not have a real modularity notion. They just have the easy and instant application features'.

According to him, modular knowledge raises manufacturers gain and provides them easiness of transportation and decreases the production and the application. Also, 'Colleague a' believes that; 'an architect's involvement requires mostly in large scaled projects'. But in small scaled projects, interior designer or industrial designer need to be more active for the project because they are more capable to solve the problems that need more detail.

He thinks that, 'BIM' programs are very useful for especially modular design process because these programs help to see expected problems previously. Modular design process stuck with particular modules so, there is no need to draw something, permanently. Besides, with this easiness of design process provides to the designer can create lots of design varieties at the same time easily.

The summary of interviews for Colleague B are as below;

'Colleague b' is also defined the modularity as 'colleague a' mention as;

The information about modular notion is not enough for her to understand the real limits and usage of modularity. According to her, that ignorance is because of the lack of education. But if the design needs a modular solution, she uses her professional knowledge to solve design problems. As 'Colleague b' mentions that;
'I don't have much information about modular construction but with the help of my knowledge about modular interior design; I believe that modularity have specialties which are mostly preferred by both architects and clients. For the purposes of architects, modularity provides convenience in design process.'
'Colleague b' uses computer programs to finish her designs. However, she uses 'BIM' programs, at the beginning of the designing process; she prefers drawing sketches to create free images.at the end of the design process, to express the best style of the design, all BIM programs can be used.

Because of the lack of information for the modular utilities, manufacturer and architectures cannot make strong contact while they are working on a project. Manufacturer knows and defenses different ideas for modularity; architecture also defenses another idea so they cannot meet at the same side. As 'Colleague b' mentions that; ‘In general, designers do not prefer to collaborate with manufacturers during design process, but it would be a more efficient project if they did. Manufacturers and designers/architects have different professions and knowledge about construction and production issues. Collaboration between them could allow a project to be designed more suitable and straight for manufacture’.

The summary of interviews for Student A are as below;

‘Student a’ is generally defined that; modular notion is not enough from the beginning because according to colleague a, in Turkey, modular class that given at faculties, is not accurate for total knowledge. According to colleague a, because of the less of knowledge, even if at their career, modular notion is not clear enough thus some of these questions cannot be answered easily from the student. Also, BIM is a good technological solution for fabrication process but not design process. In sake of design process development, computer using has lots of advantages to the manufacturer and designer in terms of eliminating useless ideas and waste of time. Beginning with sketches is more useful and accurate for the development of design process for designer.

Continue with the transportation issue, the shipping is one of the most advantageous aspects for modularity because it leads to the offsite construction process modules to which provide large time savings. Construction phase of the installation also saves time. If a mishap in occurs during transport, new modules can be obtained from the factory easily. It cannot be denied that offsite construction from the time spent on the site also allows you to make a profit.

The summary of interviews for Professional A are as below;

‘Professional a’ is generally defend with the ideas that expected for the author;
‘Professional a ‘start the sentence as; Modularity is prefabrication. It is one of the most required manufacturing technics in the World. According to her, what is modular and what is prefabricated is the same thing. Thus, this is the one of the most specific problem for the modular identification of manufacturing areas. Because of the lack of knowledge of modularity, ‘Professional A’ thinks that modularity has the

same meaning and mission with the prefabrication. Whereas, Prefabrication uses modules to create prefabricate systems. Prefabricate systems wont continues with the modular systems.

Furthermore, architects expectations are not important for the manufacturer as the economic conflicts. The answer that ‘Professional a’ gave for the survey, defends this comment as; ‘the important issues in modularity comes from clients, selection of material, speed and architectural details’.

According to her, because of the limited work areas of the firm, architectural consultancy is generally needed for housing and hospital projects. Before installation process, architectural meetings are important for the firm. The firm is mainly thinks that, for the sake of economic conditions everything is possible. The conditions that is useful for installation process means to firm, time saving, and economic gain. Thus, All the BIM programs such as AutoCAD, Revit and 3ds max, etc... are useful for designing and manufacturing process.

CHAPTER 4

4. CONCLUSION

With this paper, I have sought to clarify the terms module, modularity and modularization. My starting point has been the evolution of the concept in a historical perspective from which we have derived the evolutional phenomenon. It is described how ‘the module’ has moved from being a geometric standard measure into being an industrial building block, and how this has further moved from being defined by its physical presence into being defined by functionality and is it valuable.

Also as a supporter idea, Baldwin (2002) [89] states modularity in the article ‘The Option Value of Modularity in Design’ as;

> ‘‘Modular designs create value in the form of valuable real options. But how will that value be realized? In Design Rules, we argue that the value of a modular system will be realized over time via modular design evolution.’’

After extricate all identifications of modularity, in this study, there are some distinction between modularity as people know and the real meaning and function of modularity. Under the title of conclusion, there are two subtitles for determining and summarizing total issue. After reading these two titles, it is aimed to be finished with the clean understanding and the real directed mean of modularity in architecture.

With the consistent idea of Miller (2005) [90], it can be support in the article Defining Modules, Modularity and Modularization, below;

> ‘‘Modularization is often mentioned as a means for handling these seemingly conflicting demands - and frequently in connection with the manufacturing concept of mass customization. The idea is that a broad variety of products can be produced by combining a limited number of modules. In this way

> modularity balances standardization and rationalization with customization and flexibility.''

Furthermore, better structuring and handling of tasks and knowledge are often mentioned as advantages.

Lehtonen (2007) [91] mentions with the supportive idea as;

- Modules need to be linked to functionality
- Balancing standardization and customization
- Work in parallel with mass production
- Needs better planning for better future
- Reduce risks by using well-known solutions
- Working faster and better by learning effects and supporting tools
- A Structuring Principle for Handling of Complexity.'

Miller (2005) [92] continues the idea as;'Over time the meaning of the term module has changed from being defined by the physical presence into being defined by structure and functionality. It is argued that modularity today is a combination of systems attributes and functionality of the module itself'.

Furthermore, modularization has evolved in an industrial context and there seem to be three basic drivers behind the desire for modularity: creation of variety, utilization of similarities and reduction of complexities.

As miller (1998) [93] states in the article 'for clarify modularity information', as;

> ''Modularity, as we use the concept today, has emerged in industrial context and is inextricably bound up with rationalization efforts. That is, the wish for utilizing resources in the most efficient way when a number of related tasks are to be solved or a range of related products is to be produced. Or in other words: modularity may be used to strengthen the business performance when families of related products are designed and manufactured.''

As a conclusion the total information and results can be shown in the graphic as below;

prefabrication		modularization	
	Mobility	*	Mobility
	Limitless repetition	*	Limitless repetition
	Reproducibility	*	Reproducibility
*	Using modules	*	Using modules
	It creates options	*	It creates options
*	Transportation easiness at the site process	*	Transportation easiness at the site process
*	Increased labor safety	*	Increased labor safety
*	Increased labor productivity	*	Increased labor productivity
	It enables parallel work	*	It enables parallel work
*	Use of building information modeling	*	Use of building information modeling
	It evolve as the options are pursued and exercised	*	It evolve as the options are pursued and exercised
*	Use of building information modeling (BIM)	*	Use of building information modeling (BIM)
*	Eliminating the amount of site work required as much as possible	*	Eliminating the amount of site work required as much as possible
*	Maximizing the usage of recycled materials		Maximizing the usage of recycled materials
	Modules need to be linked to functionality	*	Modules need to be linked to functionality
*	Increased building quality and craftsmanship	*	Increased building quality and craftsmanship

Figure 22. It can be seen the basic functions of prefabrication vs. modularization comparison from the above graphic.(Author, 2014)

After distinction of prefabrication complications, for understanding and differentiate of modularity development approaches also need to be known deeply.Traditional development approaches may prove insufficient when further integration between projects and products are needed. Eventually, modularity is a Structuring Principle for Systems which need to be apply correctly. Design tasks in companies may change when modularity is introduced to users in an appropriate way.

It is the hope of the author that the description of the concept of modularity and the suggested definitions may provide some clarification, when the overall business ideas of mass customization are to be transformed into guidelines to be used in engineering design departments and architectural design departments .

Furthermore, research in relation to design reuse, platform design and system architectures may provide some inspiration. This field deserves further exploration. With the combination of modularity and the prefabrication, construction techniques and detailed applications which applied to the buildings and site applications can deserve further exploration. Also for the real notion of modularity in relation to knowledge management and modules seen as knowledge carriers need further exploration.

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APPENDICES A

SAMPLES OF INTERVIEWS

- **Professional A Interview**

Q: What is the real mean and notion of modularity, and do you believe that it is really good on its notion?

A: Modularity is a configuration system which is formed with the components or the modules. It provides the varieties and the differentiation. More flexible, functional, easy and fast productions are possible by the help of modularity concept. The essentiality in modularity is the maintainability. If the components of a product do not have the ability of limitless assembling and disassembling, it cannot be called as a modular system. Mostly the modular system manufacturer and the firms make their production and application by ignoring this essentiality. Consequently, lots of products or buildings in industry do not have a real modularity notion. They just have the easy and instant application features.

Q: What is the driving force for interest in modular construction either interest coming from architects or clients?

A: The main reason of the modular construction being in demand is the maintainability specialty. Thus, it seriously decreases the production and the application cost both for the manufacturers and the clients. Besides this, forming the limitless products with minimum components provide the instant constructions in an easy way and to innovate in the sense of design with many variations.

Q: What types of projects require an architect's involvement for modular process?

A: An architect's involvement requires mostly in large scaled projects. But in small scaled projects, an interior designer or an industrial designer must play a role since their design ability of problem solving in details.

Q: At what stage of the design process should the manufacturer meet with the architect?

A: If it is possible, at the beginning of the project the architect and the manufacturer should meet. This will help to be estimated the possible problems from the beginning. Otherwise in the application project period, they must get in contact with each other.

Q: When or how often are advantageous changes to the manufacturing process pursued?

A: At every stage of the manufacturing the modularity advantageous affects the process positively.

Q: Is it advantageous to do finish work offsite, or do components run a risk of damage being accumulated during transport?

A: The transportations always have a risk of damage factor. However, if the components are designed according to the potential damage factors from the beginning, the risks will be minimized and the offsite production will become more advantageous.

Q: To what extent is BIM (3D-CAD) being used in the manufacturing process today?

A: BIM is used in manufacturing process for gaining the impeccable products in an easy and a short way.

Q: BIM is really usefull and necessary for modular design procces and what kind of benefits that you pursued?

A: BIM is really useful in the modular design process. It helps to be noticed the probable faults in advance and designed flexible, functional and applicative products. Besides all these, the designer can create lots of design varieties at the same time easily.

Q: How would it benefit the manufacturer to be included in the design development of a project?

A: Being a manufacturer included in the design process of a project, can prevent the probable difficulties in the production stage. Accordingly, the components and the project will run properly.

Q: What strategies are taken among manufacturers to either improve the public perception of modular construction or to promote its advantages to architects and potential clients?

A: I have no answer for this question.

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- **Professional B Interview**

Q: What is the real mean and notion of modularity, and do you believe that it is really good on its notion?

A: Modular components have to meet an expectation of faster manufacturing, transport easily to a site or a space and should be able to extend with its oriented components. Briefly it has to give a sense that it can be infinitive. A modular system can always be separated and recomposed again (so you can create different compositions if required) but it can also be in a different form if required. If these significant specialties can be implemented, it will be good on its notion all the time.

Q: What is the driving force for interest in modular construction either interest coming from architects or clients?

A: I don't have much information about modular construction but with the help of my knowledge about modular interior design; I believe that modularity have specialties which are mostly preferred by both architects and clients. For the purposes of architects, modularity provides convenience in design process. According to clients, modular components always make life more functional, practical and simple for interior spaces. Also the continuity, variability and transformation property of modularity, provide confidence to clients for possible future needs than stable components.

Q: What types of projects require an architect's involvement for modular process?

A: I don't have enough information about the types of modular construction, so it wouldn't be proper to make interpretation to this topic.

Q: At what stage of the design process should the manufacturer meet with the architect?

A: In our country, generally architects meet with the manufacturer at the end of design. Fundamentally, an architect should ask a manufacturer for advice at particular phases of design to conclude design process accurately.

Q: When or how often are advantageous changes to the manufacturing process pursued?

A: As I stated before, I don't have much information about architectural construction field of modularity, but as much I am informed the manufacturing process of modular construction is not on site. According to this knowledge, I can predict that the offsite period make clients or employers think that the deadline will not be on promised date. But after production of modules is finished and transported to site, construction process will be faster than accustomed techniques. At first, offsite processes can seem as disadvantage but construction period of modular construction has exact advantages.

Q: Is it advantageous to do finish work offsite, or do components run a risk of damage being accumulated during transport?

A: There may be some risks during transportation, but real modular products have perfect transportation techniques. I believe that modularity means, in one respect, transportation. Each modular component must have its own special transportation technique.

Q: To what extent is BIM (3D-CAD) being used in the manufacturing process today?

A: BIM is one of the essential equipment for lots of professions. In manufacturing process of construction or product, BIM is being used in a widespread manner.
Q: BIM is really usefull and necessary for modular design procces and what kind of benefits that you pursued?

A: At the very first stage of a design BIM should not be used, at least I don't, because I believe that it has delimitative effects in terms of creativity. After creative part of a design is finished, BIM should be use at this time to prepare a professional project. In terms of modularity, BIM has more eases. Simply, copy-paste command can be exemplified. In modular design drawing process it must be exhausting without BIM.

Q: How would it benefit the manufacturer to be included in the design development of a project?

A: In general, designers do not prefer to collaborate with manufacturers during design process, but it would be a more efficient project if they did. Manufacturers and designers/architects have different professions and knowledge about construction and production issues. Collaboration between them could allow a project to be designed more suitable and straight for manufacture.

Q: What strategies are taken among manufacturers to either improve the public perception of modular construction or to promote its advantages to architects and potential clients?

A: To promote its advantages, first of all manufacturers or relevant authorities have to know all details of modular construction and be able to express it to a client or architect. Then they can start to inform about the advantages what the potential client expect from a construction. Some clients/architects expect more cost effective construction; some of them expect it in less time.

- **Manufacturer A Interview**

Q: What is the real mean and notion of modularity, and do you believe that it is really good on its notion?

A: Modularity is prefabrication. It is one of the most required manufacturing technic in the World.

Q: What is the driving force for interest in modular construction either interest coming from architects or clients?

A: The important issues of modularity come from clients, selection of material, speed and architectural details.

Q: What types of projects require an architect's involvement for modular process?

A: Architectural point of view is needed in modular buildings. However hospitals and housing projects are top-priority.

Q: At what stage of the design process should the manufacturer meet with the architect?

A: Prior to manufacture and during the proposal stage architecture meetings are required.

Q: When or how often are advantageous changes to the manufacturing process pursued?

A: It can be done at every stage provided that the cost is not high.

Q: Is it advantageous to do finish work offsite, or do components run a risk of damage being accumulated during transport?

A: It is decided according to the Project and can be both in advantage and disadvantage according to conditions.

Q: To what extent is BIM (3D-CAD) being used in the manufacturing process today?

A: All BIM like CAD, 3D, REVIT can be used.

Q: BIM is really usefull and necessary for modular design procces and what kind of benefits that you pursued?

A: These programs are necessary and useful. The follow up can be easily done by these programs

Q: How would it benefit the manufacturer to be included in the design development of a project?

A: We make a difference by investing in human being, research and development and determine the right material.

Q: What strategies are taken among manufacturers to either improve the public perception of modular construction or to promote its advantages to architects and potential clients?

A: The cost need to be more preferable to point out clients cares.

- **Student A Interview**

Q: What is the real mean and notion of modularity, and do you believe that it is really good on its notion?

A: Modularity can be seen even in nature. So that, as a user and an interior architect, I can observe it in daily life experiences. To use modularity in construction is making our work easier and in developing world time is very important and modular construction saves time.

Q: What is the driving force for interest in modular construction either interest coming from architects or clients?

A: Actually I cannot easily understand or distinguish what is it modular or not. Because what we see in school is just a little part of modularity.

Q: What types of projects require an architect’s involvement for modular process?

A: In architectural field, modularity is using one single shape or object which based on a definite principle. Notion of this term is to simplify manufacturing, construction and usage. And I think it is good on this notion for example we can simply add or cancel ever single module.

Q: At what stage of the design process should the manufacturer meet with the architect?

A: After deciding the product, manufacturer should connect with the architect because design starts very beginning of the process.

Q: When or how often are advantageous changes to the manufacturing process pursued?

A: I am not a manufacturer so I do not have any knowledge about manufacture process. And I did not get any information about this issue in school.

Q: Is it advantageous to do finish work offsite, or do components run a risk of damage being accumulated during transport?

A: I do not think, problems which can occur while transporting would be so much important. First of all, because they are made of modules we can easily replace the damaged one. Secondly, there won't be loss of time because they are manufacturing, production will be quick. Most importantly, total of the product never gets damage at the same time. For example there is a transportation which is consists of 3 trucks, if one of them crushes and if the products get damaged, construction can still continue. However, this cannot be the same inside construction.

Q: To what extent is BIM (3D-CAD) being used in the manufacturing process today?

A: BIM is needed till the beginning of the construction.

Q: BIM is really usefull and necessary for modular design procces and what kind of benefits that you pursued?

A: BIM is the most fundamental equipment. Because it reduces the risk of error and it speeds up the production process.

Q: How would it benefit the manufacturer to be included in the design development of a project?

A: I do not use BIM in design process. I think BIM limits and draws borders in design. At the beginning of design, to understand and perceive the space or product as whole, designer should start with sketches. After finishing design BIM should be used.

Q: What strategies are taken among manufacturers to either improve the public perception of modular construction or to promote its advantages to architects and potential clients?

A: Modular course should be given accurately in faculties. Current courses are not enough for students; they do not give satisfied information about this term. To reflect the term correctly to costumers, sufficient information and practice should be given in term courses.

APPENDICES B

CURRICULUM VITAE

PERSONAL INFORMATION
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Date and Place of Birth: 12 May 1986, Trabzon
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EDUCATION

Degree	Institution	Year of Graduation
M.Sc.	Çankaya University, Interior Architecture	2014
B.Sc.	Bilkent University, Interior Architecture and Environmental Design	2010
High School	Tevfik Serdar Anatolian High School /Trabzon	2004

WORK EXPERIENCE

Year	Place	Enrollment
2012- Present	Deb Design Studio	Project Manager
2012 July-2013 August	Hacettepe University High School/ Endustrial Product Design	Teaching assistant
2011-12 July	TEPE Holding/TEPE Home Furniture/Base Factory/ Main Center.	Interior Architecture
2010 July	BOYDAK/ Yön A.Ş.	Interior Architecture

FOREIN LANGUAGES
Advanced English, Beginner Italian.

HOBBIES
Dogs, Swimming, Volleyball, Playing guitar, Teaching, Designing, Driving.