The Concept of Customization and the Evolutionary Path of Industrialized Architecture in the Twentieth Century

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Abstract. Industrialized Architecture in the twentieth century was affected -directly and indirectly- by the Mass Production Paradigm that appeared in industrial products, and due to the nature of architecture in combining creative and craft design and industrial production on the one hand, and to preserve the economic, social and demographic aspects on the other hand, major changes appeared in dealing with Mass Production. As a result, features of the concept of Customization emerged, which means the merging between Craft production and Mass production, constituting the contemporary Manufacturing Paradigm. The research problem crystallized in the change in the embodiment of the Mass production Paradigm in Industrialized Architecture in the twentieth century. The research assumes: the concept of Customization has a time depth whose features appear in the evolutionary path of Industrialized Architecture in the twentieth century. The research dealt with the theoretical side to reveal indicators that clarify the features of the concept of customization in Industrialized Architecture in the twentieth century, to be tested in the practical side, with the aim of verifying the hypothesis.

Keywords: Industrialized Architecture, Customization, diversity, individuality

1. Introduction

This paper attempts to investigate and highlight the architecture in the twentieth century that dealt with industrialization in different forms, trends and phenomena. Its development coincided with the fundamental changes in the industrial revolutions, which reflected -directly or indirectly- industrial concepts and technologies at every stage of its development. The prefabrication technology gained aesthetical interest and a wide area of application in the period of Modern architecture in the twentieth century.

Fuller wrote his famous equation in 1923 which stated: Science + Art + Industry = Universal Architecture, thereby emphasizing the role of industry in achieving global architecture, as manufacturing became a symbol of modernization, which had its effect on the whole world [1]. As a result of the fusion between modern technology and architecture, Mass Production Paradigm that appeared in industrial products influenced architectural trends in various aspects such as:

- Architects’ ideas towards modern architecture.
- The need for buildings that keep pace with modern technological developments.
- The need for mass-produced buildings. [2]
Mass Production Paradigm provided low-cost, large-scale industrial products, but the number of varieties offered by this Paradigm was very limited, as evidenced by the statement issued by Henry Ford: "Any customer can own a car dyed in any colour as long as it is black." [3] This Paradigm was distinguished by:

- Interchangeability: the ability to choose parts and assemble them together, which made it essential in the introduction of assembly lines at the beginning of the twentieth century. Parts were individually manufactured in large quantities and their assembly was controlled in a desired order and performance to achieve economy of scale.
- Moving Assembly Line: First released by Henry Ford in 1913, and start-up.
- Specialization moving assembly line into the division of work by focusing on some specialized repetitive tasks for each worker, which represents a qualitative increase in productivity.
- Scientific Management: A theory founded by Fredrick Taylor was one of the first attempts to improve economic efficiency and in particular work productivity.
- Tradition of mass production: The main goal of mass production is the pursuit of productivity, as manufacturers designed products with limited inputs, forgetting consumer's desire, which led to a deterioration in product quality and an increase in storing. [3]

Due to the nature of architecture to combine creative design with craftsmanship or industrial production, architects pushed to find ways and means to apply industrial concepts. The ideas of ready-made structural parts appeared and considered them a fundamental tributary of the growing human settlement on the condition that the architect intervenes in the formulation of its vocabulary and makes it practical, beautiful, and in line with the need and desire of customers.

In 1925 Gropius published his famous book "Global Architecture" and stressed through his writings on the human role that must be given the large and important space, in addition to the concept of regional and cultural specificity that starts from residence and ends in the region.[4] Architecture can mix different manufacturing paradigms such as craft production and mass production together to preserve the economic, social, demographic and creativity aspects. This is confirmed by the concept of (Customization) in contemporary manufacturing paradigms such as mass customization and personalized production that appeared in many fields, especially technical and industrial fields, according to a group of propositions:

- **Stanley Davis** (1987) stated in his book 'Future Perfect' "It is possible to reach the same large number of consumers in the quantitative markets of the industrial economy, and at the same time to deal with them individually as in the case of markets customized to pre-industrial economies". [5]
- **Joseph Pine** (1992) defined it as "It is a combination of the craft and the elements of mass production", [6] (See figure1) and in (1993) he defined it as "Developing, producing, marketing and providing goods and services at reasonable prices with sufficient diversity and customization so that almost everyone will find what they want". [6] (See Figure2)
- **Tseng & Jiao** (2001) defined it as “It is the techniques and systems to deliver goods and services that meet the needs of individual consumers with virtually mass production efficiency”. [7]
- **kaplan & Haenlein** (2006) defined it as “Mass Customization is a strategy that creates value through some form of interaction between the company and consumers at the design stage at the process level to create customized products, following a hybrid strategy that combines cost leadership and differentiation”. [8]
- **Reichwald & Piller** (2009) defined it as “Mass Customization is described as the production of goods and services for a relatively large market in which the individual needs of each consumer are met. In an interactive co-design process, products and services are defined by consumers, these products are offered at similar prices that the consumer can purchase at the equivalent cost of the measured product”. [8]
- **Modrak** (2017) defined it as “It is the marketing and manufacturing techniques that combine personalized customization with mass production”. [9]
Figure 1. Mass Customization is a mixture between craft production and mass production. [10]

Figure 2. Product diversity increases in contemporary manufacturing paradigm (mass customization and personalized production) compared to mass production [11]

These propositions emphasize two main indicators of the concept of customization, which distinguish it from mass production:

- Diversity in the product.
- Individuality of the consumer.

Therefore, the research problem appeared in the change in the embodiment of the Mass production Paradigm in Industrialized Architecture in the twentieth century. The research put the following hypothesis: the concept of Customization has a chronological depth whose features appear in the evolutionary path of Industrialized Architecture in the twentieth century. The aim of the research is to uncover indicators that clarify the features of the concept of customization Industrialized Architecture in the twentieth century.

2. Methodology
The research relied on the descriptive analytical approach in describing and analysing 5 projects as case studies that were adopted on the basis of clear foundations drawn from the content of the research to achieve its objectives and to verify the research hypothesis.

3. Features of Industrialized Architecture in the twentieth century
Due to the divergence of trends in dealing with the concept of industrialization and mass production in the architecture of the twentieth century in terms of direct inspiration, formal or indirect influence, which means merging industrial concepts with architectural thought, which affected the embodiment of the thought of Industrialized Architecture in that period. Therefore, the research seeks to clarify these trends according to a set of architectural vocabulary and concepts that enhance the nature of Industrialized architecture and embody a change in the prevailing Mass production Paradigm, as follows:

- The Prefabricated elements.
- The Free- plan.
- The Modular System.

3.1. The Prefabricated elements
Mass production imposes the concept of repetition on the industrial product in general, which is not commensurate with the different needs of mankind. However, there are attempts to make the
Industrialized Architecture stand alone in order to suit the needs of the human being according to his demographic and social nature. There architectural trends are as follows:

- Gropius emphasized the various configurations of housing and a wide freedom by adapting prefabricated elements in a manner that could avoid the risks of mechanical repetition, the main goal of prefabricated items is not to recreate and replicate a typical kind of boring housing. The audience always disagree with mechanical attempts that are against the characteristics of human life. But manufacturing operations will not stand as an obstacle to solving this problem, especially since there is no choice except to accept the challenge of the machine in all fields of production so that a person can employ and volunteer it to serve his biological needs. Thus, gradually, the construction operations will depend on the workshops that produce the building parts on the one hand and the method of assembling them on the site on the other hand. And that the trend here is to grow the process of developing prefabricated elements to function as parts of the structure and in a variety of configurations instead of producing fully manufactured residential homes.[12] He also stressed the need for concerted efforts to achieve the various requirements of those who inhabit it, as it requires standardization of building units for industrial production, and that the vital problem of mechanical parts in neglecting individual needs and the difficulty of producing solutions that can meet various human requirements.[13] He also claimed: “The limitations of quantitative production will not completely limit personal expression because by manipulating the measured elements that undermine individualism, architecture can achieve diversity.”[7] Its impact was on understanding the role of architecture in society during industrial design and construction processes that can satisfy the public’s desire for individuality and allow the customer to enjoy personal choice [7]. In 1911, he became a member of the German Workers’ Association, which aimed to combine creative design with artisanal or industrial production, and here the ideas of prefabricated structural parts emerged and were considered a basic tributary to the growing human settlement provided that the architect intervenes in the formulation of its vocabulary and makes it practical and beautiful and keeps pace with the need and desire.[4]

- Wright spoke in 1932 about the idea of an “Assembled house”. This house consisted of measured units that became spatial building blocks that defined various spaces. These units are a set of Kit-of-Parts that can be added to and taken from. He did not want to produce houses according to the mass production, but his architecture depended on the customer and the location in the first place, and the technology in the second place. [2]

3.2. The Free-plan

It is the tool that the architects used in modern architecture in the more flexible organization of the spaces within the building instead of the fixed arrangement of spaces, in line with the development in the technology of that period. So, the architects relied on the free-plan in arranging the spatial formations as a result of the connections related to the social and functional context. The modern architecture program was designed through the free plan that provided flexibility, as the construction of the structural frame freed the walls from the responsibilities of the loads and could organize the partitions to facilitate the job. There architectural trends are as follows:

- Mies van der Rohe proposed (the free plan), which reduced the use of divisions between spaces, regardless of the necessities of service and private spaces. He then provided a large, light and airy space open to movement and flow of functions. He rejected the idea of solutions based on the centre of the building and the traditional four-wall rooms as a spatial arrangement, and appreciated the flexibility as multifunctional unlike the functions included in heavy hard boxes.

- The free plan is one of the points that Le Corbusier identified, as a design formula, which he implemented in designing homes that became like products that have an assembly line, each of which has its own shape and identity but consists of a specific set of components. [14]
3.3. The Modular System

The Module is a basic and independent functional unit in itself linked to the product that it is a part of. The standardized unit in the system has standard interfaces and interactions that allow the formation of products by the assembly unit. [16] In the early twentieth century it was characterized by mass-produced housing units, military kiosks, and emergency housing. There architectural trends that follow the modular systems are as follows:

- Jean Prouve designed the modular units liftable, consisting of a structural frame to be filled with panels and manufacturing systems in the off-site factory. He also designed residential homes as temporary, lightweight, prefabricated solutions for post-war housing. [2]
- Buckminster Fuller in 1936 designed a modular prefabricated bathroom unit for a residential home. (See Figure 3) In 1940, he designed Dymaxion Deployment Units (DDU units) a repeatable army housing unit (emergency housing), which were characterized by round-shaped units, raised from the ground, containing a central mast from which the walls were suspended. They were made of galvanized corrugated iron instead of aluminium, (the same material used to make aircrafts, and were manufactured in the same factories as combat aircraft and bombers). They were characterized by being inexpensive, fast to construct, and light enough to be shipped across the country on board plane (See Figure 4). [16]

In the mid and late twentieth century, architects were interested in how to develop future architecture for the twentieth and twenty-first centuries, as the architectural discourse shifted from functionalism to what is called (aesthetic awareness). It was a period of transition, characterized by the search for a variety of creative languages with the help of advances in architectural materials and building techniques. [18] A new thought was developed for the future of the new architecture to embody the possibility of change, movement and mobility to meet the changing and continuous needs of man, as dictated by the nature of change that accompanied the new technological thought that was applied in most other industries. Significant contributions to unique architectural models emerged in which prefabrication and mass production paradigm played a major role, such as Archigram and Metabolist Group.

Among the most important and distinguished concepts that were developed by them:

- Movement and flow.
- Possibilities of change and replacement.
- Consumer choice and individual emancipation. [19]

The modular system in the Archigram series features replaceable units within the building. It is characterized by a flexible infrastructure represented by a network in which the relationships between the shape and the structure are arranged with the associated function, through which units or parts can be integrated. These replacement units are loaded on a giant megastructure of concrete or steel structure. These units have an expiration date and are designed with a short life span. Therefore, it needs constant replacement that it is capable to suit future generations. [20]
The group urged that “more people in the technological community will play an active role in defining their individual environment and in determining their own way of life” [14]. They suggested parts that are subject to change or exchangeable depending on individual needs and preferences, along with specifications for mass production and the openness of architecture to other disciplines. [14]. The idea of introducing a mass production Paradigm into society was considered because it was “a product of an advanced consumer society”. [20]

The modular system in the Metabolist group resulted from the perception of the building as a kind of synthesis of the organism and the machine. The analogy of the building to the cell, whereby the building consists of a group of semi-autonomous components, yet it can be replaced as needed in a similar way to the parts of the machine. [21] Metabolite designs are often characterized by a combination of a massive structure that acts as a permanent base, and many individual modules attached to the structure that undergo replacement. [22] The balance between high-tech infrastructure and individual freedom is achieved through an architecture made up of custom cells and adaptive temporary configurations such as residential units. It can expand and contract as needed in order to balance change and persistence. It is expressed in the design of the different life cycles of infrastructures and individual cells, the permanent and resilient parts of the urban system. [18] The group has dealt with the building by always intentionally leaving it open for addition and modification. [20]

4. Case studies
The research chose 5 projects as case studies that were selected on the basis of clear foundations drawn from the research content to achieve its objectives:

- Prefabrication played a major role in the chosen case studies.
- They were designed in different periods of the twentieth century (projects were presented according to their design chronology).
- Each case study had a distinct intellectual and formal characteristic during that period.

4.1. Dom-Ino by Le Corbusier in 1915
Le Corbusier designed a repetitive basic unit in groups represented in a building, which consists of 6 columns bearing three concrete tiles, to form the idea of free space and to give freedom and flexibility in interior designs by abandoning most of the load-bearing walls. [23] The Skelton system, reduced the inclusion of architectural components in any order required by the specific context, this approach was an evidence of contemporary scientific design. (See Figure5) [14]

4.2. Dymaxion house by Buckminster Fuller in 1928
Fuller obtained a patent in the design of the house, which was considered as a modular unit, with an assembly line in the factory that resembled a metal circus tent, with a mast shaped like an airplane and a construction system with a cable, [2] reflecting a number of innovative features:

- Inexpensive, quick to construct, and light in weight (interchangeable triangular panels were made of aluminium which was light -easy to carry- and flexible at the time, and were used to build the ceiling, floor and walls).
- The outer walls were unloaded and suspended by cables from the central mast anchored deep into the ground. The living area itself had been suspended and its function was to protect residents from the effects of “fires, floods, hurricanes, earthquakes, and electrical storms”.
- High flexibility in designing customizable units with all the amenities included in Al Sari, the homeowners have been free to transform the indoor living space to suit their needs. (See Figure 6) [16]
4.3. Jacobs House in Madison by Frank Lloyd Wright in 1932

Wright was interested in rational construction logic and consideration of cost through the use of the structured network, standard materials, and prefabrication capabilities. The heart of the house was built from reinforced bricks units, which included services such as a bathroom, kitchen and stove, representing the lateral stability of the house. He used plywood interior partitions and chipboard for the exterior, which made the house very tailored. (See Figure 7) [2]

4.4. Living pod project by David Greene (Archigram Group) in 1965

The project design indicated the relationships between activities, compared to a list of requirements, including actual dimensions, the following has been replaced:

- Inflatable cutter instead of wall.
- Inflatable seats instead of living.
- The dining machine instead of the kitchen.
- Study machine instead of the office.
- Wash units instead of the bathroom.

All are parts of the design that are not static and stand-alone "plug". The wall contained multiple pods, grouped together on a vertical axis. Compartments (pods) can be moved, removed or added to by jacks according to the user's wishes. The pods and the independent structure devoid of public facilities are connected with each other by means of flexible units that allow the replacement and movement of the pods used for assembly and forming the structural form and installed according to a mechanical system.

Each pod contains anchor points for attaching to the tire, which would be flexible and recalibrate the pods (which is very similar to a car suspension). Regarding changes in weight, arrangement and to allow maximum freedom with respect to any pod, the total load did not exceed 10,000 pounds (or the weight of a three-small car). The individual housing units moving together formed the multi-height block, meaning that the shell wrapped around the entire structure and this is similar to contemporary examples. (See Figure 8) [20]
4.5. The Nakagin Capsule Tower in Tokyo by Kisho Kurokawa (Metabolist Group) in 1972

This project was considered one of the masterpieces of modern architecture in the post-war period in Japan, as this building displayed the basic ideas of metabolism in adaptation and the possibility of replacement with the concept of instability and mobility that affected every step of the design and construction of the tower. According to the different "metabolism cycles", the building had been divided into three basic components:

- The permanent structure (two central parts of iron concrete and the steel frame that are 11 and 13 stories high, respectively).
- The mobile component (144 capsule-shaped units).
- The service equipment (utilities).

Designed on the basis of different life spans, the capsules were arranged in a random shape, indicating a continuous process meaning the column could grow, and more capsules could be stacked. [22] According to the metabolism concepts of continuous growth, setting a life span for the capsules commensurate with the thought of societal change, where the capsules are replaced from 25 to 35 years), then the life span of the concrete core parts is more than 60 years.

The design was for the future, keeping in mind the Japanese history of capsule design with exclusive modular ratios. [26] As Charles Jencks noted in his introduction to Kurokawa's book 'Metabolism in Architecture', that the capsules embodied futuristic technology and ideas with the proportions of traditional Japanese space. He declared that in the future, human condition will be measured by mobility rather than by plot size. [18] Each capsule represented a housing unit the size and shape of a shipping container with dimensions (7.5 feet x 12.5 feet x 7 feet), which were fixed to the towers with flexible joints (high-tensile steel nails with four high-tension screws only, two on the upper and lower sides independently on the concrete pole), so as to replace it without affecting other capsules, the distinctive capsule shape has a round window glass. [22] The interior of the capsules was designed using industrial technologies. The goal was to provide an essential space to ensure the living conditions and individual freedom of modern man in the city as a small living space, designed primarily for relaxation and sleep. A variety of built-in furniture and appliances have been built (a bed under the 4-foot circular window, appliances and cabinets along the other wall including a colour TV set, refrigerator, kitchen stove, air conditioner, telephone, stereo, air cleaner, table light, clock, and office calculator) with an integrated bathroom unit in the corner. [26] It only included the construction of the two towers and other space and equipment on site. The capsules were pre-fabricated and assembled by railway vehicle and ship manufacturers in other cities. It was lifted by means of a crane and anchored to the concrete pillars, starting from the bottom up. Each capsule was independently sealed and isolated from the column so that any capsule could be removed perfectly without affecting the other. The entire construction took only one year. (See Figure 9) [22]
5. Analysis of the case study results

After analysing the five projects and adopting the descriptive analytical approach, it became clear that the concepts of diversity and individuality existed. They were dealt with according to the vocabulary of Industrialized Architecture in the twentieth century in terms of prefabricated elements, free plan, and modular system as follows: (Table 1)

- **Customization indicators in Project 1** are achieved by the free-plan:
  - Diversity in the form of internal spaces, which varies according to the internal divisions.
  - The freedom of the individual in the internal divisions and giving the residents flexibility in determining the internal spaces.

- **Customization indicators in Project 2** are achieved by the Prefabricated elements:
  - Diversity in the shape of the interior spaces and the flexibility in the design of the modules vary due to their ability to be customized by standard prefabricated elements.
  - The individual has freedom in internal divisions and freedom in determining the sizes and shapes of spaces.

- **Customization indicators in Project 3** are achieved by the Prefabricated elements:
  - Diversity in Standard interior partitions design and tailored for home.
  - Individual choice in designing partitions inside the house.

- **Customization indicators in Project 4** are achieved by the free-plan and the Modular System:
  - Diversity in Change in free-space segmentation in a single capsule, and Capsules are moved and repositioned, and designed as interchangeable and replaceable parts consistent with the principles of useful life.
  - Individual freedom to return, change and replace furniture because it is not fixed parts, and moving rooms to remove or add to them according to the user’s desire. The individuality is achieved in giving each capsule its facade expression

- **Customization indicators in Project 5** are achieved by the Modular System:
  - Diversity in the dynamic shape in the distribution of capsules with the possibility of achieving change, continuous growth and instability by expanding and increasing the number of capsules and replacing them. That ensures suitability for continuous changes.
  - Individuality is achieved in giving each capsule its expression at the Facade with the idea of replacing selected parts that fit with the ongoing changes in societal contexts.

This is what fulfills the research hypothesis which states that the concept of Customization has a time depth whose features appear in the evolutionary path of Industrialized Architecture in the twentieth century.
### Table 1. Features of the concept of Customization in Industrialized Architecture in the twentieth century.

| No. | Case study                        | Year | The Prefabricated elements | The Free-plan | The Modular System |
|-----|-----------------------------------|------|----------------------------|---------------|-------------------|
|     |                                   |      | Diversity                  | Diversity     | Diversity         | Diversity          |
|     |                                   |      | Individuality              | Individuality | Individuality     | Individuality      |
| 1   | Dom-INO by Le Corbusier           | 1915 | -                          | -             | -                 | -                 |
| 2   | Dymaxion house by Buckminster Fuller | 1928 | The shape of the interior spaces and the flexibility in the design of the modules varies due to their ability to be customized by standard prefabricated elements | The individual has freedom in internal divisions and to determine the sizes and shapes of spaces | - | - |
| 3   | Jacobs House in Madison by Frank Lloyd Wright | 1932 | Standard interior partitions design and tailored for home. | Individual choice in designing partitions inside the house. | - | - |
| 4   | Living pod project by David Greene (Archigram Group) | 1965 | Change in free-space segmentation in a single capsule. | Individual freedom to return, change and replace furniture because it is not fixed parts. | Capsules are moved and repositioned, which are designed as interchangeable and replaceable parts consistent with the principles of useful life. | Moving rooms to remove or add to them according to the user's desire. The individuality is achieved in giving each capsule its facade expression. |
| No. | Case study                                                                 | Year | Customization indicators                                                                 |
|-----|---------------------------------------------------------------------------|------|------------------------------------------------------------------------------------------|
| 5   | The Nakagin Capsule Tower in Tokyo by Kisho Kurokawa (Metabolist Group)    | 1972 | authenticity of housing units on the main structure, such as dynamism, change, growth and instability. |

6. Conclusions

- The customer role varied in the architectural formation according to the concepts of mass production and giving freedom and exclusivity, from the level of internal divisions of space in the early twentieth century, to control and choice at the level of the residential unit. Focusing on the individual cell component, or capsule and the principle of freedom, in the mid- and late-twentieth century.
- The concept of diversity was confined to the size and distribution of internal spaces in the early twentieth century with the help of measured prefabricated elements. While the technological development in the structure in the middle and end of the twentieth century helped in promoting the concept of diversity in the architectural form through a set of concepts in the distribution of housing units on the main structure, such as dynamism, change, growth and instability.... etc.
- The individuality is achieved in giving each housing unit its expression, the facade, which made the area ratios in the housing unit (the capsule) less than the average, which means that it is less than the economic area.
- More people in the technological community play an active role in defining their individual environment and in defining their own lifestyle by changing or replacing parts according to individual needs and preferences along with the specifications of mass production and the openness of architecture to other disciplines.
- Attempts at customization in the twentieth century in prefabricated parts, flexibility in internal divisions, and the principles of the patterned system in observing individuality in design, made them catalysts for the emergence of a contemporary manufacturing paradigm.
- The form of Industrialized Architecture has been affected by technological development, which has changed from simplicity to complexity and from stability to dynamism, diversity and flexibility, and it is the concepts of the contemporary manufacturing paradigm that deals with customization.
- The idea of replacement of selected parts is commensurate with the continuous changes in societal contexts, materials and technologies, as it connects the idea of transformation and renewal with contemporary architectural culture, and the potential future of architecture, which gives a diversity of form in terms of one's freedom of choice.
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