Mass customization limitation and guidelines in prefabricated construction

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Purpose In the start of 20th century, most economies in the world were industrialized economies. This industrialization introduces the mass production concept along with other strategies like mass distribution, mass marketing and mass media. Mass production covered most industries in our life and one of the newest industries which adopt mass production strategy is building construction industry. However, a combination of advances in information and technology (Robotics and advanced equipment) is making the production increasingly possible to mass customize - to rapidly respond to consumers with customized products at mass production prices. Mass customization in prefabricated building construction industry is a new strong tool based on integrating organizational structure over the whole value chain corresponding with information flows between enterprises product, machinery, robots, customer and all complementary sub-processes but in the other hand this mass customization should be controlled by some guidelines depending on some aspects like the type of building (wood, brick or concrete), architectural aspect, location and climate where the products are targeted. Method By studying and analyzing the different types of prefabricated building construction methods (linear production, 2D production, 3D production) which apply the principle of mass customization production the author presents the degree of customization for each method. The type of relationship between the factory and the customer and the rules which control this relation. Results & Discussion After studying and analyzing those methods of prefabricated construction and the relationship between the customer and the factory, the author considers a set of general guidelines for building design should be adopted as standards in building mass production industry according to all the data and information acquired in this research and with the respect of architectural and civil engineering standards in construction along with the costumer needs, moreover the guideline will redraw the role of the architects in building production industry.

Keywords: Industrialization, Mass Customization, prefabrication, building production, Mass production, guidelines.

INTRODUCTION
The industrial revolution(1750-1850) made a big changes in the world economy, because it almost effect all industries in every person life start from food and agriculture industry ends with transportation, by innovating a new technologies and machines which enhancing the performance of productivity in all of these fields, this improvements could be seen clearly in manufacturing industry, before the revolution, manufacturing was depending on tools and human labor and it was so slow and costly for both side the manufacture and the customer, after the revolution and the integration of new technology and machines the flow of work start to be faster because it start depending on machines, tools, and human labors in that order and of course the products efficiency was improved. After 1850 the market demand for products start to increase and add more pusher on the factories because of the increasing number of population specially in cities after the immigration of the people from superb to the cities this immigration is conceder as one of the result of industrial revolution, so they started to adopt a new strategy which called “mass production” this strategy aim to product a large amounts of standardized products, including and especially on assembly lines, this concept had its maximum popularity in 1910 establishing the first moving assembly line by Henry ford which reduced the production time for model T cars from 728 hours to 1.5 hours. Some of the manufactures start to add more value for their products by introducing the custom made products, this marketing strategy makes the customer to pay more for getting the product which satisfying his exact needs but in the other hand it will cost more and not all of the customers will afford it, from this point most of manufactures start to think more about the customer needs and step by step the customers start to be a part of the production progress then the mass production market moved toward new strategy which called mass customization, is fast emerging as a popular business strategy which aims to also cater to individual expressed needs of end users at prices closely comparable to mass produced items. This strategy covered most of industries in the world economy and had a great feedback from the customers.
industries which adopt mass customization strategy is prefabricated building construction.

Fig.1. Henry ford first moving assembly line for ford for model T cars (1913)

Fig.2. relationship between degree of customer adaption in production progress and the cost of the product.

This paper studying and analyzing the different types of prefabricated building construction methods (linear production, 2D production, 3D production) which apply the principle of mass customization production the author presents the degree of customization for each method, the type of relationship between the factory and the customer and the rules which control this relation.

**Prefabricated building construction methods**

There are three types of prefabricated building construction methods each one of them is specify for different kind of materials, these types are:

1. Linear production (brickwork).
2. 2D production (wood and concrete work).
3. 3D production (steel frame units).

**Linear and 2D production:**

In this type to design, build and market a home requires consideration of both products and services. A building consists of many components, which can be considered as ‘products’, while design, construction and marketing are usually regarded as ‘services’. To generate a housing development, these two aspects are again involved with housing materials and systems as the products and the design and construction of these homes as the services. When viewed as a ‘system’ for designing, producing and selling a product, “mass customization” is impossible without customizable products or communication services. In this case the services are where the customers can interact with the factory to help them customize an end product. At the design stage the customer should determines the configuration of their home from choices given by the factory by using a selection catalogue to enable clients to easily choose from the many options. Basically the customer can choose colors of the walls, materials which are used in the house, kitchen, toilet, lighting doors, windows and all other details which provided by the factory with full consulting service from the architects. After that all of these data transport to construction and civil engineers who will decide how many prefabricated building components (product) they going to need and what size of this components. In addition to that they provided a customer relationship management which aim to strengthen its continuous contact with its long-term customers, and warranty for their houses which could reach up to 25 years.

Fig.3. The customers with the architect in the design stage (Baufritz factory)
3D production:
In this kind of building prefabrication production, Japan is taking the lead as the most advanced and industrialized fabrication systems in the world. Prefabrication companies like Toyota Home is the best example to describe mass customization in 3D production.

Toyota’s innovation a new manufacturing process shortly after the Second World War. Many of Japan’s industrialists were impressed by America’s speed in which they could build aircraft and vehicles utilizing the Ford mass production model of automation, assembly line, and economies of scale. In starting a new with these processes, they could evaluate the shortcomings of the Ford model, with a new critical eye and develop their own process known as the “Toyota Production System” or TPS. This system has been highly praised and received awards around the globe for its focus on people through mass customization and utilization of economies of scale and made an extension of conventional marital information flows “Push production” in to a new concept based on current demands “Pull production” this new concept aim to make the factory output to be pulled by the customers instead of pushing, so it will give the chance for the customers to have a complete synchronization between production progress, materials suppliers and the customer demands and needs.

Several industries, other than the automotive sector, have been using this production model as a basis in which to ground their own practice. Toyota Home saw the housing industry as no exception to the principles of TPS. Toyota has taken 5 of its 14 principles used in automating and applied them to the prefabricated housing market.

The basic tenants include:
1. Just-In-Time
2. Jidoka
3. Heijunka
4. Standard Work
5. Kaizen

Fig. 4. Toyota home logo

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Fig. 5. How the push/pull production works.

Fig. 6. Toyota production system

The Heijunka principle is giving customer the ability to customize facilitates both customer predictability and product variety. Toyota Home keeps inventory low and in constant supply. Toyota accomplishes this by manufacturing directly to customer order. Standard work allows for Toyota Home to keep a well-stocked supply of raw materials. The future owner of a home will go to the Toyota home park where they may browse many of the options and select specifics. The Toyota home website allows patrons to virtually apply a variety claddings, colors, exterior/interior ornament in a customizable environment to suit their needs and tastes. All of these options are based on the same raw materials kept in stock so when the order is issued, they can be pulled off the shelves and go through the process of assembly to component to module to whole house erection on site. Not all of the elements that are compiled to make the Toyota Home modules and finally the completed structure are customized. From the decades of producing automobiles, Toyota understands the principles of utilizing standard components and systems make the drive towards efficiency much simpler. Each year a handful of car models are produced, many of which are modifications of the previous year’s production. A basic model with minor modifications over several years allows Toyota to understand the core structure of the automobile, and thereby produce the part with greater effectiveness and reduced cost. Therefore, the modules are standardized with customization built into the configuration and relationships between modules. The Toyota Home models: Vietrois, Smart Stage, and Espacio Mezzo are made unique by the modules
that make up the final house. There are 12 modules to a home, depending on the size requested by the owner. The modules themselves are built with a steel frame that can be easily adapted to the often-varying lengths of modules. Each of the modules’ steel frames is specifically designed for Japan's seismic activity. When the Toyota's modules are locked together, the structural frames of the modules in tandem create a rigid structure. The spaces inside the modules may be delineated by interior partition walls or may be defined as needed. Standard work allows the manufacturer and consumer to be extremely confident that the product they produce and receive will be of the utmost practiced quality. Toyota's confidence is expressed in offering a guarantee of up to 60 years on the life of the prefabricated house.

Fig. 7. Module fabrication at Toyota Home factory in Japan.

GRIDLINES AND CONCLUSION
Mass customization covered most of industries in the world economy and had a great feedback from the customers, especially in prefabricated building construction industry, because of the integration of advanced information and technology in prefabricated building construction industry (Robotics and advanced equipment). After studying the three types of prefabricated building construction methods and the degree of customization for each method, the type of relationship between the factory and the customer and the rules which control this relation, the Author come out with some general guidelines to control this relation. these guidelines are:

1. Each prefabricated building construction methods have its own elements like main structure, components and main frame or skeleton all of them related to the main core of the building these elements are designed, manufacture, examine and testing by architect, civil engineers, construction engineers and mechanical engineers from factory itself to provide highest level of quality and comfort for the product ( building ) and maximum efficiency of load bearing, and climate resistance, these elements are the only things cannot be customized in the whole production progress in the other hand the customers can control only the visual aspects ( color and texture )of this element.

2. At the design stag the architects should have the main role, they will provide for the customers two options, to choose one of the readymade modules which provided by the factory then add some changes by the customer to meet his own demands with total support from the factory architects or ask the architects to make a new design for them and provide them with some their detailed information which help the architects to come out with best design which meet the customer specific needs. This design will be presented to the customer, get there feedback and comments then modify it regarding these comments. the changes in the design should not have any conflict with architectural aspect and standard.

3. The factory should provide for the customer all the support which he will need to select his options by affording a full details catalogs presented in very attractive way ( computer or physical version), this catalogs should have a variety of options for each elements and detail of the building which can be customized with the help of the factory architects. This step will save a lot of time for both sides ( customer and the factory).

Fig. 8. Rendering of one of Toyota customizable home designs.

4. After completing the designstag starting with production progress the factory should keep the customer updated in all production steps and keep ready for and kind of modification from the customer, also they should give him exact date of handover.

5. With handing over the factory have to give quality certificates and warranty To prove performance, quality and durability of the house and its sub-systems to the customers. and providing for the building regular inspection and long term maintenance.
References


5. R Balamuralikrishna, KA Rosentrater, M Rajai, Mass Customization and Its Curricular Implications, 2006, for Four-Year Degree Programs in Manufacturing Technologies.


