Mass Customization in construction industry

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Abstract: In recent years, industrialized construction (IC) has pushed the construction industry to incorporate modern manufacturing technology into offsite construction and factory component assembly procedures to boost productivity and efficiency. The ability to provide mass customization and mass production concurrently, which is only achievable in a highly flexible manufacturing system, is the key to success in an industrialized construction company. The use of such technology can lower construction costs and project duration. The primary aim of this study is to identify customer needs and learn about current residential market practice through a questionnaire survey, as well as to determine the minimum room dimension based on which the two generalized layouts of a twin dwelling house with the same structural layout were prepared, so that cost comparison between cast-in-situ construction method and precast construction method.

Index Terms **– Mass Customization, Industrialized Construction, Flexible Manufacturing, Precast Construction, Construction Technologies.**

1 INTRODUCTION

Mass customization is a business approach that combines the opposed manufacturing theories of mass manufacturing with personalization. In the 1910s, Henry Ford pioneered the notion of mass production for the production of the Ford Model T. Mass production, also known as serial production, was founded on the standardization of components and the systematization of processes. The concept of mass production offers new opportunities to companies by combining a mass production tradition with a high level of customization, allowing them to maintain high efficiency while offering highly customized products.

1.1 Mass customization in construction industry

At present mass, customization has not been widely researched in the construction industry. Therefore, the only partial theoretical background is available for the implementation of mass customization. Mass customization has the volume to deal with unique products at a huge scale. Besides it is about evolving, manufacturing, promoting, and distributing custom-made products and services with the adequate variety that customer requirements are fulfilled. A fact about industrialized strategy is that it can positively influence construction projects and organization in terms of productivity of labours & equipment, timely completion of the project, safety of workers, and quality of products. Due to factory-made products, the construction process on-site is shortened, hence the difficulty of the projects tends to be high in the industrialized environment due to some factors like conflicts between different trades on-site, construction product supply chain, interdependence on various vendors, etc. One of the major causes for the construction industry's limited amount of industrialization is that it operates in opposition to the standardized product that serves as the foundation of the industrial revolution.

1.2 Need for study

The aim of the study is to point out the key advantages of mass customization like saving in money and time by using factory-made products having higher quality while also meeting the unique needs of each consumer and to know current market practice and analysis of the future requirement of locals receding in Ahmedabad city. The research in this sector has just reached the theoretical idea stage, much more research is required before this technology can be implemented by the construction industry.

1.3 Objective

The primary objective of the research is to investigate current market practices as well as analyse future requirements of people receding in Ahmedabad city. And secondary objective is to conduct a construction cost and duration comparison study for twin dwelling house considering mass construction, built using two different methods traditional construction method and Precast construction method.

1.4 Methodology

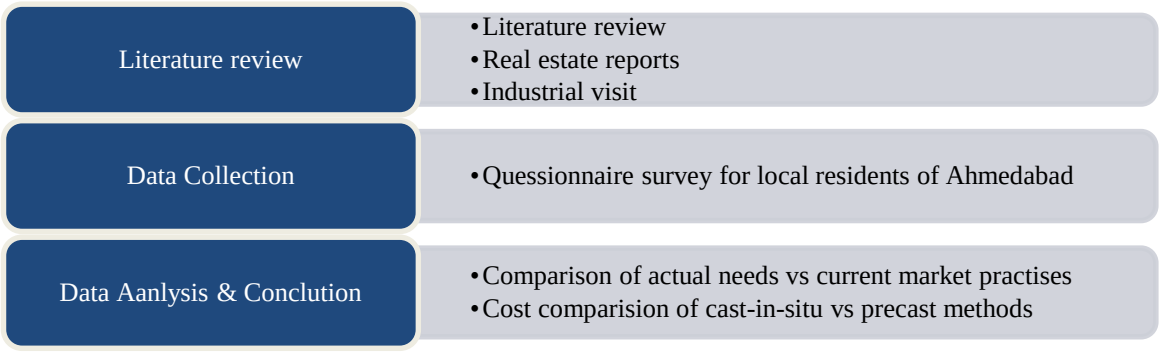

Figure 1 Methodology flow chart

2 LITERATURE REVIEW

Using mass production to reduce the unit cost of product while at the same time permitting individually customized products will depart in the scale of finance. For achieving results regarding the increase in productivity, lowering the cost, and reduction in construction time industrialization in the construction industry needs to increase. There are some component manufacturers such as door and window, modular kitchen, readymade furniture, etc. who offer customization in their products with the highly automated and flexible production system. The current research on mass customization was studied by (Stoettrup , Schioenning , & Li, 2019), defined the four main characteristics of mass customization namely (1) Mass customization in the house building industry, (2) Modular and off-site construction, (3) Construction supply chains, and (4) Customer satisfaction. (Daniela, Viana, Tommelein , & Carlos, 2017), discussed about importance of modularity in the construction industry, the role of modularity in the management of the complex system, and the prefabricated building system. It also illustrates that how modularity can reduce the complexity of Engineered to order industrialized building systems, in companies that adopt a mass customization strategy. By using an industrialized building structure, the on-site production processes are simplified. The important issues of mass customization in Engineer to order are investigated and addressed by (Thomassen & Alfnes, 2017), the practical consequences of implementing mass customization in engineer-to-order manufacturing are tested by setting the principles of mass customization. The major factor affecting were related to designing and operation, followed by logistics and procurement. (Kjeld , Brunoe, & Noergaard, 2017)focuses on three fundamental capabilities of mass customization, Solution space development, Choice navigation, and Robust process design, the two case study are explained where Case A: A door and window manufacturing company approached mass customization strategy, but their focus was mainly on robust design with an automated process. Due to which they were unable to cope with the other two fundaments of mass customization namely solution space development and choice navigation which resulted from them in heavy use of resources while processing orders. Where as in Case B: A similar door and window manufacturing company's main was to fulfill customer's needs. They also used automated processes so that they benefited from the necessary use of resources while processing. But through their journey of mass customization, their document management process was slow due to hand-carried documents which increased the cost. Danish construction market was analyzed by (Jensen , Kjeld, & Brunoe, 2016), which concludes that using standardized modules, flexible production which enables individual tailored product at low cost.

With the help of case studies conducted in China and Hong Kong by (Elena , Generalovaa , & Generalova, 2016), puts light on methods of using modular units in construction and advancement in the technology for the construction of modular buildings. We all know that modular construction helps in shortening the project design and engineering time, reduce costs and improve construction productivity and they are also cost-efficient, safe, and eco-friendly. (Lee, Kyoung-woo, & Lim, 2014), focuses on the use of prefab structures which enable to minimize the construction waste at project sites. The main component taken here is the floor structure which is prefab and methods were identified focusing on the quality of construction. (Benros & Duarte, 2009), gave an idea of mass customization by developing the framework for the same and focusing on how to design, build and produce so to reach the end-user and also to know the end of life management of the system. A 3D model is developed for the easy accessibility for designer and client to see the drawing in the software and whatever changes required can be directly modified in the computer system developed giving immediate results. Due to this the production system also works smoothly as the things which are required are produced as per requirement and just-in-time(JIT). As pre manufactured products are made in factory and transported to site, (Nasereddin , Mullens, & Cope, 2006), emphasizes the use of model making using different software like ProModel and Visual Basic which helps in making the production process easy and effective to use for the actual site. With the help of model development, the time for the production process can be reduced from months to weeks. If merged with mass customization, the process of simulation model making and customizing the same simultaneously can make the process all the more effective and useful for the end-users as it can lead to methods that can help improve various factors like time, cost, and quality. (Bock & Linner , 2010), stated that Automation in the construction industry is going to be a major contributor in the field in every aspect. As in India automation and industrialization technology are not currently popular but in coming future it will be adopted and beneficial for sustainable development.

3 DATA COLLECTION

The crucial information gathering portion of the exploration used an experience-based feedback (quantitative technique). As a result, this paper uses a questionnaire survey method to test a reasonable model of factors influencing customer's needs in India's construction industry, which are limiting growth. In this, the data from the real estate report (first quarter 2020) is also studied to know the current housing trend (source; - Knight frank). A quantitative questionnaire was used to collect data regarding local requirements of people. The process used for the data collection was as followed Set functional requirements, which is done by performing a questionnaire survey among the residents to know their living requirements. A questionnaire survey was carried out using google form. The first survey was for Residential requirements for locals particularly Gujarat state with a 95% confidence level. Secondly, Check Design Parameters, this step is performed by knowing the types of products available in the market**.** Products for mass customization are categorized in various filed like Structural element such as precast column with corbel, prestressed beam, precast staircase etc. as well as some services like Aluminum, wooden, Upvc door and window, readymade and customizable furniture, modular kitchen. And lastly by Setting-up design matrix, in this designing and selection of products is done according to the requirement of your building plan.

3.1 Informational Demographics

While Ahmedabad is one of India's most cheap marketplaces, it has been negatively hit by the ongoing recession in the Indian residential market. The industry had only just adjusted to the broad regulatory changes of RERA, GST, and the state government's Online Development Permission System (ODPS) for providing building approvals to real estate developers when the financial problem worsened in 2019. The COVID-19 epidemic, which hit full force in the second quarter of 2020, has only aggravated an already grim situation. However, after five successive half-yearly periods of modest but positive growth, sales in the Ahmedabad market plunged by 69 percent year on year to a decadal low of 2,250 units during H1 2020. Even in the first quarter of 2020, the economy's slowing and the housing market's downturn influenced homebuyer inquiries. The extraordinary disruptions created by the pandemic forced a lockdown in the economy and a total suspension of all activity in the real estate market, resulting in sales

falling to near insignificant levels in Q2 2020. Innovative marketing plans, such as online presentations of residential projects, and aggressive sales strategies, such as allowing refundable deposits on booking and facilitating homebuyer financing, helped top-tier developers salvage some sales at the end of the quarter in an otherwise disastrous quarter for the market.

3.2 Sample size calculation

$$a = \frac{z^2 * pr * (1 - pr)}{er^2} \quad \textbf{Eq. (1.)}$$

Where,
a = Sample size of unlimited respondents
z = Static value for the Confidence level (refer table 3.3)
pr = Estimated respondents Proportion (50%)
er = Margin Error

$$r = \frac{a}{1 + \left(\frac{a-1}{B}\right)} \quad \textbf{Eq. (2.)}$$

Where,
r = Sample size of limited respondents
B = Sample size of available respondents

From this calculation, we can conclude that the minimum sample size for Survey-1 should be 132 numbers sample so that a confidence level of 95% can be achieved with a marginal error of 5%. Considering this questionnaire of survey-1 is floated among 200 respondents from which 137 responses were achieved. The categorization of all the respondents was shown in table 1.

Table 1 Respondents distribution

Occupation	Count
Student	65
Employee	48
Business	17
Homemaker	7

4 DATA ANALYSIS

From the survey, we were able to know the current type of living and future requirements and current ongoing market practice to fulfill the future requirements. Respondents were asked where they now resided and whether they lived in an apartment or a bungalow. According to the data from the survey, 59.9 percent of respondents live in an apartment, while 40.1 percent live in a bungalow. Public requirement vs current market practices The current living of respondents concerning the number of BHK is shown in fig 2. As per the data collected most of the locals are residing in 3 BHK particularly of Ahmedabad city area parallel current market practice is also as per the customer's requirement.

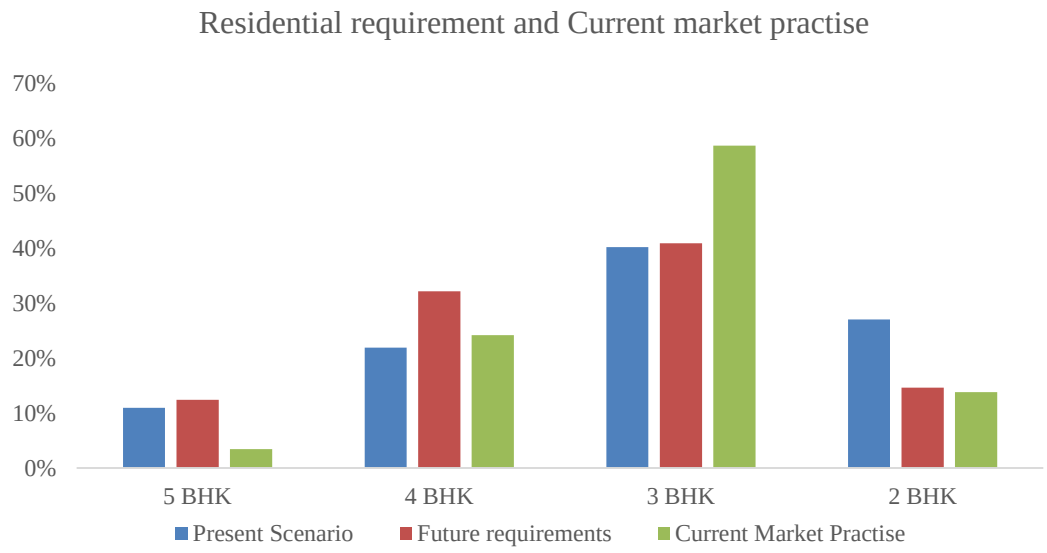

Figure. 2 Overall scenario of requirements and market practisce

In the survey respondents were asked to select the minimum size of living room, Kitchen and bedroom required. They have to select the room size from the predefined list provided in the questionnaire survey so that was irregular and improper room size can be avoided and to give the prior idea to respondents for generally available living room size. The response for living room of size 13'0" x 17'0" was maximum then followed by sizes 12'0" x 15'0" with, 14'0" x 14'0". Similarly, for kitchen the response for size 11'0" x 12'0" was the highest, followed by sizes 13'0" x 10'0" and 11'0" x 11'0". Likewise, for minimum size of bedroom required was 15'0" x 11'0" and followed by sizes 12'0" x 10'0", 12'0" x 12'0", 13'0" x 11'0". As per the study, we can conclude the minimum requirements of different room sizes which are shown in the table below.

Table 2 Room categories and their defined sizes

Room category	Minimum required Size
Living room	13'0" x 17'0"
Kitchen	11'0" x 12'0"
Bedroom	15'0" x 11'0"

4.1 Planning of twin dwelling unit

According to the response a double dwelling unit is envisaged. It is designed in such a way that two different plan layouts can be made using the same structural plan and configurations, giving clients multiple options based on their demands which is the basic idea for mass customization. This unit is built using two separate methods: cast-in-situ and precast in huge quantities. A cost and time comparison analysis for a single unit, ten units, and fifty units is also covered. That explains the advantages of widespread customization with the open housing concept.

For the twin dwelling unit, two different layouts were prepared as shown in fig 3. In layout-1 the arrangement of room was like the very first room was the living room at the entrance then the bedroom and at last kitchen. Here the bathroom area was allocated by offsetting bedroom space. Where as The room layout of layout-2 was as follows: the first room was a living room near the entryway, followed by a Kitchen, and finally a bedroom. Offsetting kitchen space was used to apportion the bathroom area in this case.

Table 3 Layout plan dimensions

Layout-1	Layout-2
Plan dimensions Living room: - 11' x 15' Bedroom: - 11' x 8'7" Kitchen: - 11' x 11' Bathroom: - 6' x 5'	**Plan dimensions** Living room: - 11' x 15' Bedroom: - 11' x 11' Kitchen: - 11' x 8'7" Bathroom: - 6' x 5'

Figure. 3 Layout considered for cost calculation

4.2 Cost comparison

The cost comparison was done for the upper layouts of twin dwelling unit. The cost of construction by two different methods is calculated for cast-in-situ and precast. Here by cost comparison we are able to know the utilization of modular construction elements for mass production of customizable housing scheme. The cost for one dwelling unit, 10 dwelling unit and 50 dwelling unit was calculated. The below table 4 and 5 shows item wise cost calculation for cast-in-situ and precast construction method respectively. The cost of electrical, plumbing work, painting is considering same for both construction methods. It is considered by assuming percentage of total cost of civil work. The cost of transportation and erection is not included in cast-in-situ however additional 15 percent and 12 percent of total civil work is assumed for transportation and erection**.** As when a product is bought in bulk there is benefit in terms of discount similar theory is applied in precast as the precast elements are ordered in bulk a discount is offered by manufacturer about 1.5% is considered as shown in table 5.

Table 4 Cost comparison of cast-in-situ 10 units

Cost for 10 twin unit		Cast-in-situ				
Activity	**Item**	**Quantity**	**rate**	**unit**	**number**	**total cost**
Design	Structural design	891	25	Sqft	1	22275
Production	precast Column					
	precast beam	-	-	-	-	-
	Precast slab	-	-	-	-	-
	Precast wall panel	-	-	-	-	-
Construction	Excavation	20.16	67.80	Cum	10	13671
	Backfilling	14.52	45.20	Cum	10	6562
	R.C.C	27.60	5167.61	Cum	10	1426006
	Masonry	32.62	4256.48	Cum	10	1388268
	Internal Plaster	333.14	457.64	Sqm	10	1524562
	External plaster	146.29	509.62	Sqm	10	745543
Finishing	Flooring	76.64	1748.00	Sqm	10	1339711
	Electrical, Plumbing	-	-	-	-	765692
	Paint	479.43	67.06546669	Sqm	10	3215326
Miscellaneous	Transportation	-	-	-	-	-
	Erection	-	-	-	-	-
Total cost						**10,447,615**

Table 5 Cost comparison of precast 10 units

Cost for 10 twin unit		Precast				
Activity	**Item**	**Quantity**	**rate**	**unit**	**number**	**total cost**
Design	Structural design	891	50	Sqft	1	44550
Production	precast Column	27.60	5178.91	Cum	10	1429124
	precast beam	4.45	5393.61	Cum	10	239834
	Precast slab	8.34	5506.61	Cum	10	459155
	Precast wall panel	32.62	5047.71	Cum	10	1646329
Construction	Excavation	20.16	67.80	Cum	10	13671
	Backfilling	14.52	45.20	Cum	10	6562
	R.C.C	5.60	5280.61	Cum	10	295894
	Masonry	-	-	-	-	-
	Internal Plaster	-	-	-	-	-
	External plaster	-	-	-	-	-
Finishing	Flooring	76.64	1748.00	Sqm	10	1339711
	Electrical, Plumbing	-	-	-	-	613585
	Paint	479.43	69.19	Sqm	10	2045284
Miscellaneous	Transportation	-	-	-	-	452933
	Erection	-	-	-	-	566166
Total cost						**9152799**
		Discount	1.5%			**56617**
		Net Cost				**9096182**

4.3 Cost comparison-overall summary

According to the cost calculation of twin dwelling unit by different methods the table 6 shows the overall cost comparison. Here cost of one, 10 and 50 twin dwelling unit constructed by two different methods is discussed. While constructing only one twin dwelling unit the preferred method is cast-in-situ because it is cheaper than precast method. While constructing large no of units the precast method is more economical as there was saving of 15 percent for 10 units and saving of 35 percent for 50 units respectively.

Table 6 overall cost comparison

Twin units	Cast-in-situ	Precast	Benefit of precast for mass production	
Units	**Cost**	**Cost**	**Saving**	**% of saving**
1	Rs. 775,429	Rs. 782,622	Rs. (7,192)	-1%
10	Rs. 10,447,614	Rs. 9,096,182	Rs. 1,351,432	15%
50	Rs. 116,455,485	Rs. 86,114,040	Rs. 30,341,444	35%

4.4 Duration comparison

The table 7 shows the duration of construction of one twin dwelling unit comparison by cast-in-situ and precast construction method. As shown in table 7 the designing phases of this building for two different methods is same. The foundation work like excavation, levelling, footing, backfilling etc. consist of same number of days. But the major benefit in construction using precast method is in superstructure construction in which factory made elements are only needed, and to be erected on site where in cast-in-situ all these elements are casted on site and have higher interdependence of each other so the construction duration increases.

Table 7 Overall Duration comparison

Twin units	Cast-in-situ	Precast
Design	5 Days	5 days
Production		10 Days
Construction	36 Days	6 Days
Finishing	12 Days	12 days
Transportation		2 days
Erection		2 Days
Total Days	53 Days	31 Days
Reduction in days	16 days	
% reduction in days	30%	

5 Results and Discussion

As per the analysis conducted the results justify that future requirement for 2 BHK is fulfilled, while on the other-side requirement for 3 BHK are overestimated and certainly for 4 BHK are underestimated. From the survey carried out, as per the respondent's requirement minimum sizes for the kitchen, Bedroom, and Living room was evaluated. According to its plan for twin, dwelling house was prepared with customizable layouts and the cost of designing and constructing was calculated which resulted in to decrease in cost and time when customized mass production strategies were utilized. For single twin dwelling units, the total cost for precast construction was 1% higher than Cast-in-situ, whereas constructing this unit with precast construction method in mass (50 units) the Saving in cost was up to 35%.

5.1 Future Scope

This study can be expanded to a real construction site for a different type of construction project such as commercial, Infrastructure (road, bridges). Further study for the application of smart energy, wearable technologies, etc. can be done.

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