Client-oriented Building Mass Customization (CoBMC)

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Abstract. Although much later compared to other industries including aerospace, automobile, oil and gas etc., digital technology development has been cresting towards an exponential curve in the construction industry. Technological diversity and abundance change the game from “what you can” to “what you want”. Society is changing at an unprecedented rate. Consequently adaptability will be crucial. This research paper explores the integration of digital adaptive technologies that transform the construction industry from the mass production to that of a possible client-oriented mass customization. The focus on the design, construction and performance stages of a building project, currently undergoing major overhaul faces a paradigm shift globally that will impact and compel attention for the next three decades with viable solutions such as Building Information Modelling (BIM) to manage massive data cum information. Customization maximizes clients’ participation during the design process thereby achieving greater effective value and higher satisfaction. A study between customized and standardized examples will investigate how adaptive customization will shift the design paradigm from cost to value centric. This action research will explore different aspects of emerging innovative systems already in place pushing the edge of frontiers, and transforming the building industry landscape whether micro or giga, to compliment new technologies to create an unprecedented exhilaration of freshness over the mundane, routine and mediocrity. Three identified fundamental aspects that are instrumental to Client-oriented Building Mass Customization (CoBMC) are design option visualization, parametric product information and n-dimensional modelling. The study concluded that a paradigm shift is therefore inevitable for every stakeholder including clients who will need to re-examine their roles, capabilities, and competencies in preparation towards challenging future.

1. Introduction
Client or customer satisfaction is always the ultimate factor for business success. This is no exception for the construction industry as purported by The Latham Report of 1994, which specifically recognized clients as the driving force: “Implementation begins with clients. Clients are at the core of the process and their needs must be met by the industry. But clients are dispersed and vary greatly” [1]. Every client certainly will have his or her own distinct requirements, specific concerns and unique preferences. Is it possible to create a typical planning, design and construction that fits all, while achieving excellent client-satisfaction [2] [3] at the same time? Customization is a useful tool to satisfy client requirements that is unique in the construction industry. Whilst customization empowers clients to make micro decisions that will trim the gap between their expectation and the final construction outcome, this will
lead to the “I designed it myself” effect [4] and directly increase client satisfaction. The idea of custom-made buildings is not new. It is of intrigue to look at speculations in relation to how the construction and housing industry evolved since the year 2000:

“By 2015, savvy well-capitalized companies from outside of the housing industry have taken over the market, and speculative developers have all but vanished. A young couple looking to build a new home begins the process at one of a number of internet home sites, where they play design games and select from options presented to them. As the system begins to understand their needs and values, proposals are produced for their evaluation - which then, in turn, leads to additional designs. In the process, they find that there has been an explosion of creative activity as dozens of young architects and industrial designers develop and license systems to integrators - based on new industry-wide standards for both physical building components and digital technologies.”

- Larson, K. [5]

Obviously, such speculations did not materialize, at least not on a massive scale. This is possibly due to factors such as evolving technology, statutory regulations, lack of skilled human resources, escalating cost and stakeholders’ perception, etc. However, continuous research towards custom-made buildings has not stopped by exploring through the means of integrated system [6] and information technology [7]. As Building Information Modelling (BIM) [8] implementation matures, there is great potential in realizing mass customization of the built environment in an unprecedented scale. This research is a conceptual study about the possible Client-oriented Building Mass Customization (CoBMC) via BIM or Virtual Design and Construction (VDC).

1.1. Client-Oriented Process
There are many labels such as “client”, “customer”, “service user” or “consumer” depending on business types and disciplines, which describe not of a person, but of inter-relationships [9]. It is a widely accepted fact that a client-oriented approach through collaboration [3] and integration [6][10] that will strengthen the client relationship. Non-construction products have ventured into “design by customer” interaction [11] achieving the next level of client-oriented processes. Customization allows personalization and innovation which are not achievable with mass production. As client requirements and construction industry expectations broaden and deepen, creative approaches will inevitably and earnestly be adopted to enhance client-oriented processes. Buildings are one of the most expensive products one would purchase and own for a relatively long period of time. It is only logical that clients of the construction industry have access to a mass customization process to meet their own needs.

1.2. Building Mass Customization with Building Information Modelling
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Mass customization for building refers to both the number of buildings being customized and number of customizations being made in a single building. Earlier study on parametric space configuration, for example, the Palladian grammar [12] is significant to later building mass customization research like Siza’s houses at Malagueira[13]. After that, computer systems were developed integrating 3-dimensional
computer aided design (CAD) and spreadsheets to facilitate [6] building design. Such computerized framework required the designer to create a system, rather than a specific design. However, this is time consuming and costly when compared to traditional approaches. The balance between the customizable flexibility level and customization complexity will be a determinant to achieving successful building mass customization. As technology advances, the obstacles towards a practical building mass customization solution will be collateral a greatly transformed entity.

Building Information Modeling (BIM) is about an integrated approach to design, construction, and facility management [14]. Such an approach is considered “new” when compared to the traditionally perceived 2-dimensional Computer Aided Design (CAD). BIM framework is introduced later to better understand and integrate the relevant fields such technology, process and policy [15]. It also spells out “what is” and “what is not” BIM by clearly defining the stages namely, object-based modelling, model-based collaboration, and network-based integration. BIM adoption and implementation will be easier by deliberately developing all the matrix components with a holistic approach [16]. Research also shows that majority of construction industry stakeholders agree that greater use of BIM will improve construction best practices [17]. Powerful information systems [18] will manage the increase of information [19] that supports the growth of customization heterogeneity. BIM offers an efficient way to integrate the massive information [20] generated for optimization [21] during the mass customization process.

2. Methodology
This is a conceptual action research [22] type study with no collection of hard data, but BIM model outputs for examination and exploration. Action research is known for uncertainty and complexity, which is suitable to explore evolving research directions. The study collaborates with highly experienced practitioners [23] in the building industry including architects, engineers and quantity surveyors. The study explores and predicts how the building industry will transform from industry-oriented mass production to client-oriented mass customization from various significant aspects.

3. Significant Aspects Of Client-Oriented Building Mass Customization (CoBMC)
There are a few aspects that will make mass customization more feasible than before by using BIM, namely design option visualization, digital product information and n-Dimensional modelling. Some may argue that such aspects are available even without BIM. However, the advancement in computer hardware and software capabilities has critically enhanced the quality and quantity of these aspects. The first aspect is design option visualization. Without BIM, the number of design alternatives is limited, however, it is now feasible to have hundreds of design alternatives explored and visualized once it has been set up. The second aspect is BIM provides parametric product information for almost every types of building components thereby making actual construction true to its intentions. The third aspect is n-dimensional modelling that integrates the information of time, cost and quality for efficient decision-making.

3.1. Client-Oriented Building Design Process
Written project brief and 2D layouts certainly are essential to communicate with clients. However, 3D visualization is the key for mass customization as it enables clients to see promptly instead of imagining the construction outcome. Design option visualization is enhanced by the 3D modelling efficiency which reduced the gap between imagination and visualization as shown in Figure 1 and Figure 2. This action research learned that even on the same structural system, design option visualization makes a lot of difference in communication with the client.
Design option A as shown in Figure 1 is designed based on the client’s requests for a transparent double volume living room, playroom with good sound insulation at level 1, and some green plants at level 2. Design option B as shown in Figure 2 is a variation when the client requested for a sheltered balcony, an external curved staircase going up to level 1, and an enlarged master bedroom at level 2. Client’s requirements are being scrutinized at the design stage through various high level considerations. Mass customization with design option visualization will increase client’s satisfaction, thereby encouraging green construction by reducing waste, rework and renovation after initial construction.
3.2. Parametric Product Information

Parametric product information provided by manufacturers is a significant enabler for mass-customization, as now designers can “plug and play” with existing building products including finishes and fittings such as, facade panel, furniture, light fittings, sanitary fittings, etc. This action research exercise found that mass-customization can be done by exploring numerous combinations of two different parametric products as shown in Figure 3.

Figure 3 shows that the two parametric products namely (1) umbrella shaped steel structure, and (2) curtain panel, under mass customization with the combination of both products, the variance in height, width, thickness, material, and colour etc., clients can customize the final outcome to their unique preference instead of the compulsion to select mass-produced elements. The example demonstrates the “I designed it myself” effect that consequentially enhanced client’s satisfaction.

3.3. N-Dimensional Modelling

Management tools such as the Gantt chart and the S Curve chart are useful to visualize and correlate different information such as cost and time. BIM’s n-dimensional modelling drastically enriched such
tools to highlight the impact of various customized designs in real-time to the clients for pertinent decision-making as shown in Figure 4, which able to identify the detail information of every single curtain panel in the building.

![Figure 4. Information of different dimensions in an integrated model](image)

This action research found that by utilizing the function of automated quantity extraction from n-dimensional model shown in Figure 4, clients are able to participate proactively even in the most detail stage of the design. Any impact such as surge in cost or time delay communicated graphically to the client to suit personal or organizational considerations is interactive. On-going changes are adeptly automated to cater for prompt updates.

4. Conclusion

Clients’ requirement and expectation are becoming higher over the years, and this is an irreversible trend. A paradigm shift is therefore inevitable for every stakeholder including clients who will need to re-examine their roles, capabilities, and competencies in preparation towards challenging times. This action research presents a fresh approach for building mass customization by featuring the significant aspects including design option visualization, digital product information and n-dimensional modelling to spearhead a much-needed change. These aspects are instrumental for any building research, innovation and development from not just the technological perspective, but also address the client’s behavior. The research is timely to explore the transformation for building development from industry-oriented mass production to client-oriented building mass customization to infuse personality and preferences in an ever-depersonalized world. Further research shall investigate the compounding effects of other technological advancements within the Client-oriented Building Mass Customization such as 3D printing, computer numerical control (CNC), reverse engineering, cloud computing etc.
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