# BIM as a global configurator for facilitation of customisation in the AEC industry

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## Abstract

In under a decade since Building Information Modelling (BIM) was first introduced to the Architecture, Engineering and Construction (AEC) industry, it has gone from a buzzword to the pivot point of all AEC technologies. The actual benefits of BIM along with its visual realisation capabilities have now started being comprehended and utilised to the best benefits of all stakeholders of a construction project. BIM's potential capabilities in offering real-time cross-sectional nD design have introduced 'integrated project delivery' approach as an unprecedented concept in the AEC industry.

One of the substantial challenges facing the AEC industry in its post mass production paradigm has been the market size, the diversity of the customers – their needs, requirements and preferences – as well as the challenge of achieving the economies of scale for personalised end products. This has made customisation and personalisation very difficult tasks to achieve. Although emerging strategies and technologies, which mostly originate in manufacturing industries, have come to help the AEC industry to respond to this challenge, the technology infrastructure has not yet been up to the challenge. BIM as a novel technological tool, environment and more importantly a platform can facilitate this approach.

This paper investigates how the introduction of BIM in the AEC industry – whether as a tool, an environment or a platform – can facilitate mass customisation (MC) in the AEC industry. We start with a brief introduction to MC in the AEC industry followed by a targeted investigation of BIM. At next stage we will initiate a match-finding exercise through a case study, superimposing the context requirements with the tools/means capabilities. Finally we will provide some suggestions to investigate other benefits of BIM to offer a fully customisable layer in a building – in this study a curtain wall façade system – and with potential possibilities to develop it further into a web-based or standalone application with a user-friendly GUI.

**Keywords: BIM applications, Configurators, Mass customisation, Modularity, Personalisation, Product families**

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# 1. Mass Customisation

The term mass customisation denotes an offering that meets the demands of each individual customer, but that can still be produced with mass production efficiency (Piller *et al.* 2006). Pine (2007) defines mass customisation as the low-cost, high-volume, efficient production of individually customised offerings. Stan Davis, who coined the term 'mass customisation' in 1989, states: 'The general message is, the more a company can deliver customised goods on a mass basis, relative to their competitors, the greater is their competitive advantage' (Davis 1996).

## 1.1. Modularity, Standardisation, Product Families and Configurators

According to Pine (1993) modularity is a key to achieving mass customisation. It provides a means for standardisation of repetitive components. Ever since customisation started diverging from mass production and was acknowledged as a paradigm shift in the manufacturing strategy, product configuration and product families have formed important topics in this area (Joergensen *et al.* 2011).

## 1.2. Variety and Complexity

As the variation grows, the complexity of the design and manufacturing raises exponentially, thereby increasing the complexity of process and product (Forza and Salvador 2007, Hvam *et al.* 2008, Hvam and Pape 2006). Blecker and Abdelkafi's (2006) study on complexity and variety in customisation suggests 'variety management strategies' at product and process levels (See Figure 1).

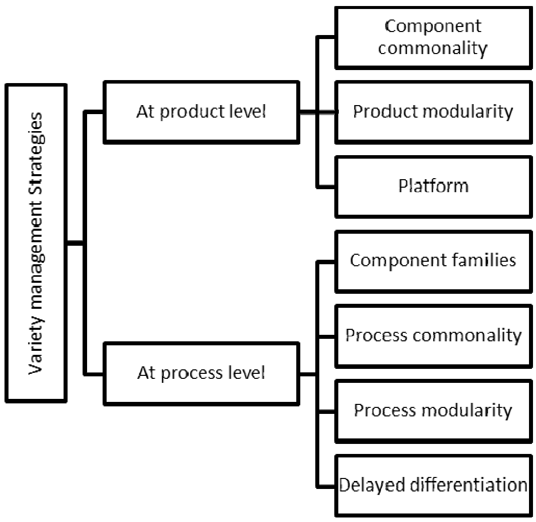


***Figure 1: Variety management strategies at the product level and at the process level (Blecker and Abdelkafi 2006)***

### 1.3. Platform Design

Designers are able to handle variety within a platform through modular-based design or scale-based design (Simpson 2004). There is a significant difference between the concepts of a platform even between different members of a manufacturing sector, for instance between Ford and VW both as car manufacturers (Dahmus *et al.* 2001). The role of a platform in facilitating customisation, however, should not be considered confined to physical platform only. Web 2.0 applications have introduced virtual platforms for participation in content development since buyers and sellers are actively involved in value [co-]creation (Helms *et al.* 2008). Emergence of BIM as a virtual platform has been a major turning point with outstanding implications to facilitate customer-centric, object-oriented approach to design and delivery in the AEC industry.

### 1.4. Technological Requirements

As Pine (1993) suggests: '…to mass customise, a firm must excel in either the right technology or the right people skills, or more likely the right mix of technology supporting people…', the right (level) of technology was not available in the construction industry until recently. Dating it back to first introduction of ArchiCAD or AllPlan, some may have argued that BIM has a history of 30 years or so in the AEC industry. However until quite recently neither the ICT technology, nor the people (work-culture wise) were yet up to challenge to facilitate the collaborating working processes as an underlying principle of BIM.

## 2. BIM

Building Information Modelling (BIM) is an ICT 'hub' to facilitate integration of information pertaining to a building throughout its lifecycle, in form of parametric nD data – whether geometrical or tabular, generated by an array of stakeholders into one centralised, real-time and interactive environment through collaborative working processes.

The US National BIM Standards (NBIMS) define a building information model as:

> 'A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability' (NBIMS 2007: 149).

### 2.1. BIM as a Culture

Expectations of BIM vary across disciplines, as shown in Figure 2. For design disciplines, BIM is an extension to CAD, whereas for non-design disciplines such as contractors and project managers, BIM is more like an intelligent data management system (DMS) that can quickly take off data from CAD packages directly (Singh *et al.* 2011). However this fragmentation of views does not seem to be of any help to stimulate the cultural change required for a full adoption of BIM in the AEC industry.

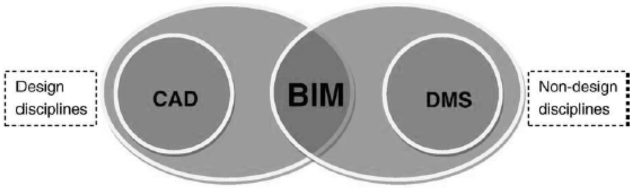


***Figure 2: Disciplinary backgrounds and differences in expectations from BIM-servers*** **(Singh *et al. 2011*)**

Jung and Joo (2011) define three dimensions including ‘BIM technology’, ‘BIM perspective’, and ‘construction business functions’ and six categories to address the variables for theory and implementation of BIM (See Figure 3). This, if employed and disseminated strategically, may introduce the driver of a continuous change towards collaborative working in the industry.

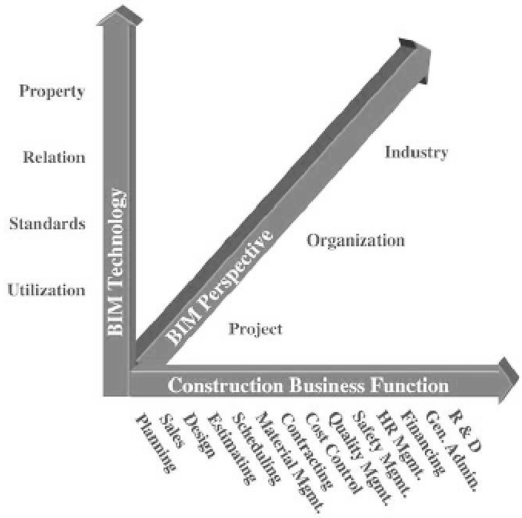


***Figure 3: BIM framework (Jung & Joo 2011) [Construction business functions defined by Jung & Gibson (1999)]***

## 2.2. BIM Benefits and Hurdles

The impact of BIM on design can be mostly detected in the conceptual phase of a project because it supports greater integration and better feedback for early design decisions, followed by the construction level modelling including detailing, specifications and cost estimation, then the integration of engineering services and supporting new information workflows, and last but not least collaborative design-construction integration (Eastman *et al.* 2011). They go further into defining 19 benefits in 4 different stages of the construction process of which:

- Improved collaboration using integrated project delivery (Preconstruction stage)
- Earlier collaboration of multiple design disciplines (Design stage)
- Better implementation of lean construction techniques (Construction and fabrication)

are the most closely related ones to customisation. This indicates that although many BIM advocates have unanimously called for a change in the culture within the AEC industry, this change has not necessarily been perceived yet in the same way as in manufacturing industries.

Although BIM applications are supposed to improve (collaborative) working processes which can potentially alleviate complexity and consequently facilitate customisation, in reality this has yet got a long way to go. Gu and London (2010), for instance, point out some expected implications of BIM from the literature and indicate that BIM is expected to envision efficient collaboration, improved data integrity (Ellis 2006), intelligent documentation (Popov *et al.* 2006), distributed access and retrieval of building data (Ibrahim *et al.* 2004) and high quality project outcome through enhanced performance analysis, as well as multidisciplinary planning and coordination (Fischer and Kunz 2004, Haymaker *et al.* 2005, Haymaker and Suter 2006). However their survey shows that '…in most common practices [in Australia], collaboration is still primarily based on the exchange of 2D drawings, despite most disciplines are now working in 3D environments…' (p. 989) and '…in numerous occasions, participants confirm that both technical as well as process/method related issues are key[s] to the development and implementation of BIM, especially important for project collaboration…' (p. 992).

Barlish and Sullivan (2012) analysed over 600 sources of information of which they found 21with some information regarding the benefits gained from BIM utilisation, but in general terms. They classify these 21 as case study, quantifiable findings, model or process, survey, theory and general assumption. Out of the 18 benefits of BIM which they address in those 21 sources, almost none is sensibly correlated with customisation.

FMI/CMAA Eighth Annual Survey of Owners (2007) in the United State gives a clearer understanding of what the process change involves, if a successful adoption of BIM is facilitated. According to them BIM benefits (extrapolated to customisation) are:

- Improved communication and collaboration among project participants
- Easier to achieve process standardisation
- More reliable compliance with specification and regulations
- Greater productivity from labour and assets
- Broader strategic perspective and innovation

- Decreased labour costs

Likewise hurdles on the way which may have a negative effect on customisation include:

- Greater system complexity
- Lack of industry standards
- Poor integration with existing systems
- Different needs across stakeholders (which is the core purpose of customisation)
- Unclear business value and ROI

In the UK on the other hand, although it may be down to the UK Government Construction Strategy's requirement which calls for fully collaborative BIM level 2 (with all project and asset information, documentation and data being electronic) as a minimum by 2016 (Cabinet Office 2011), the response of the professional practices to BIM seem to have been improving as indicated in the NBS National BIM Report 2012 (Malleson 2012).

### 2.3. Attempts on Facilitating BIM

Early attempts on quantifying the most important features that can portray BIM as a real process facilitator for customisation, thereby measurable benefits for customisation can be perceived, have not yet had been very promising. According to Howard, R. and Björk, B. C. (2008) in the mid 1990s the product modelling standardisation for the building domain was taken over by an industry consortium called the International Alliance for Interoperability (IAI). The first version of the industry foundation classes (IFC) was issued in 1997. These have been tested in a number of pilot projects (Kam *et al.* 2003). However neither the standards nor the product modelling/product families are widely used in practice. Nevertheless most recently top-down push measure mostly by the governments and bottom-up pull demands from the industry's non-professional stakeholders have begun to be introduced, whose success is yet to be quantified. In addition bottom-up approaches have been taken by major component and system providers in the UK (and other countries including Germany, the Netherlands, France and Scandinavia) which have shown promising. Those component/system suppliers have taken initiatives in developing their own product families which can be downloaded for free, recalled, inserted and used in BIM applications.

## 3. Research Methodology

In this research first of all a comprehensive literature review was carried out to establish the most significant associations between mass customisation as a manufacturing strategy in the AEC industry, on one hand, and BIM as a facilitating platform of effective deployment of MC strategy, on the other. At the second stage we developed a global case study to explore different categorical variations on form, materials, openings, and relative locations to the structural system in a customisable curtain wall façade system. We then developed a BIM family to demonstrate how those principal requirements of a customisable façade system can be addressed using that product family in the BIM application. This model is still under development and at this stage just includes the basic form of the curtain wall façade system which can vary from a 2D plane surface to a 3D single or double-curved surface.

## 4. Development of the Case Study

A case study of analytical design typologies was developed and an industry standard BIM application was utilised to respond to the variation requirements of a customisable curtain wall façade system. Variations which need to be covered were classified under three systemic levels starting from:

- The 'super-system' as the building where the curtain façade system will be applied,
- The 'system' which consists of the façade itself, and
- The 'sub-system' level which consists of the façade components and materials which form the façade.

The focus of this study is on system level and upwards (see figure 4).

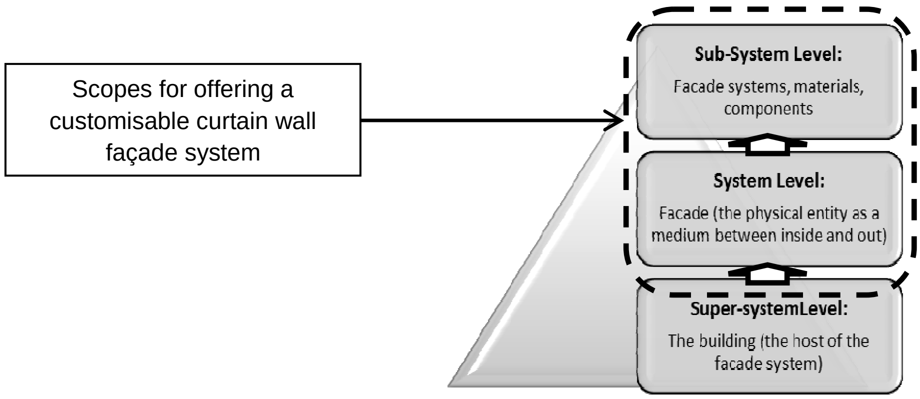


***Figure 4: Possible scopes for applying customisation on a curtain wall system***

The system level variation on the form of the curtain wall façade is shown in Figure 5.

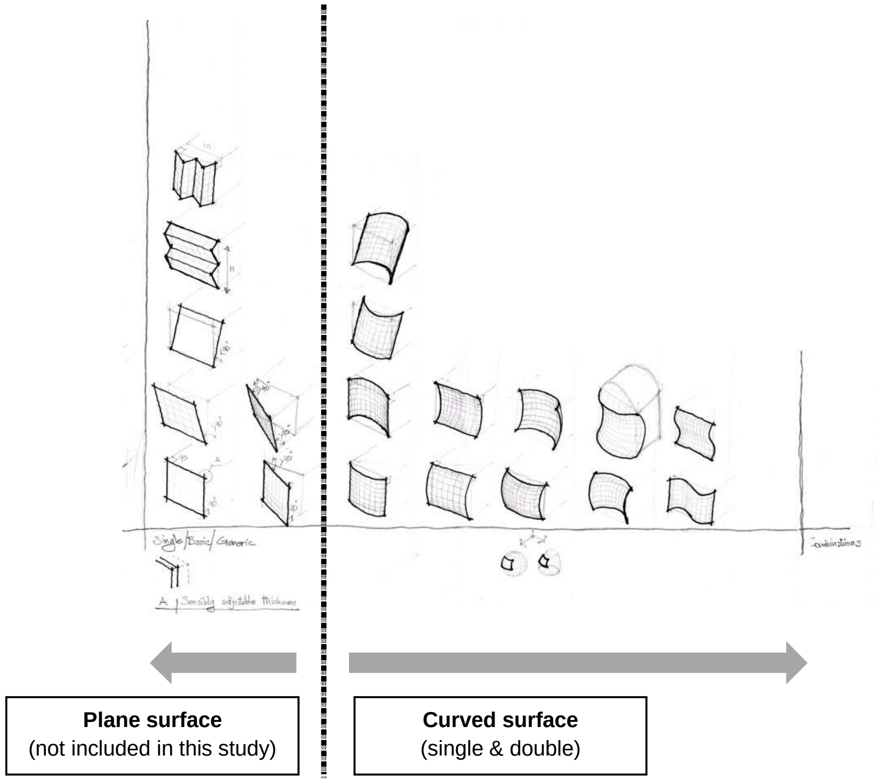


***Figure 5: Variation of form at system level***

Study of form variation commenced with a plane surface with different values for projection and different angels of rotation around axes X, Y or Z or a combination of two or three in a local coordinate system. To cover these variations a very basic family could have been developed. This was deemed very straight-forward hence was excluded from this study. The family developed in this study will cover curved surfaces – both single and double – with different parameters and future possibilities to add on both projection and rotation values as explained for plane surfaces. Potential opportunities were also discussed to develop the family into a web-based or a stand-alone application.

The geometry of the family which responds to this variation initially consists of three splines each of which comprises three points on different height levels, to obtain a double curve host. When joined together, three splines on various height levels create a form which can accommodate a single- or double-curved form (See Figure 6).

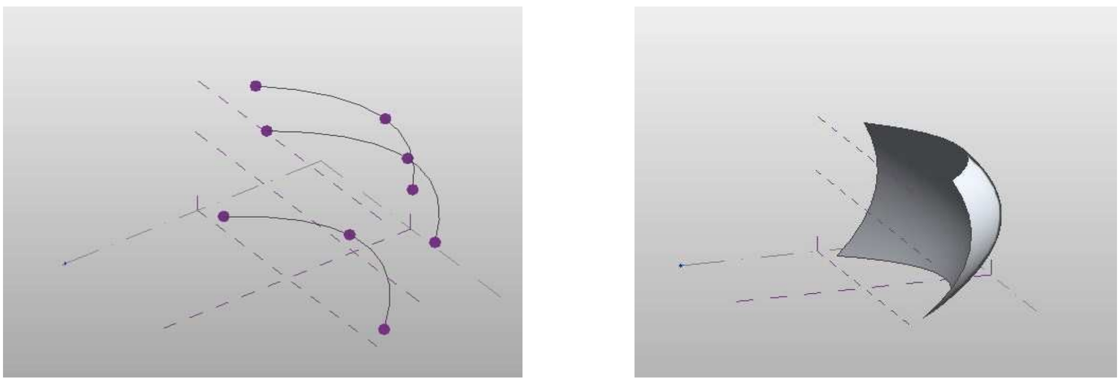

***Figure 6: Basic geometry of the product family***

To respond to variation requirements of a fully customisable façade, the values of each point were assigned ‘configurability’ of end point depth (2 points), apex offset and apex depth as well as width and height of each spline level including the base level to allow for offset of the base (see Figure 7).

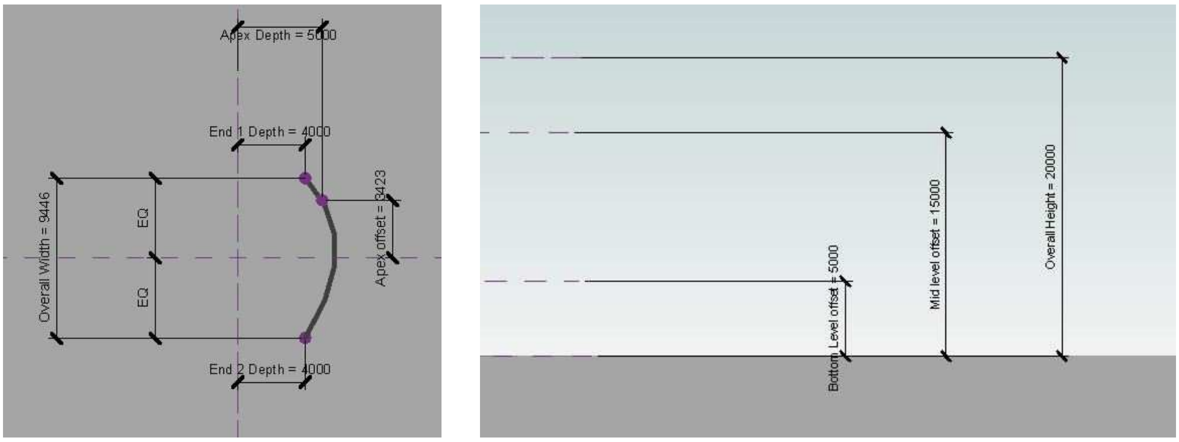


***Figure 7: Defining configurators for family of the forms***

Using this geometry, parametric values were then created which can be changed in both project and family environments (See Figure 8).

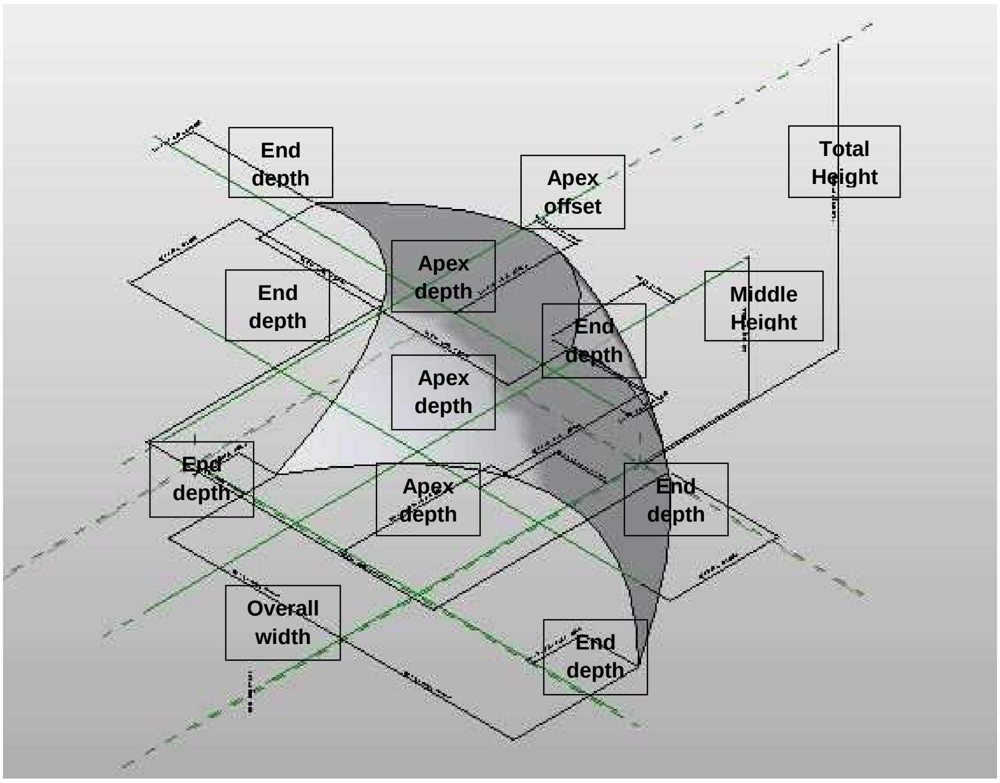


***Figure 8: Parametric values to configure the geometry of the façade***

This family can then be used as a host for a curtain wall. A mesh example of a representative variation of this product family is shown in Figure 9.

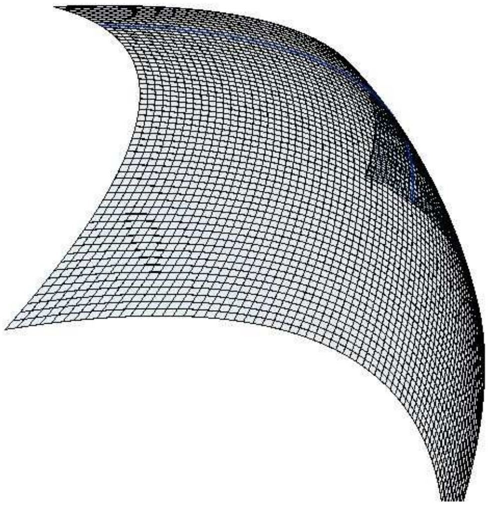

***Figure 9: A representative mesh example as a product of the family created of the customisable curtain wall façade***

## 5. Conclusion and Future Research

Mass customisation has a proven record of value-added in manufacturing industries. Despite this fact, it has not yet been fully and completely deployed in the AEC industry. This is partially due to the nature of the AEC industry and fragmentation in the supply chain in this sector. However, this has also arguably been because of the lack of proportionate ICT infrastructure to fully facilitate the change and provide a dynamic real-time push/pull mechanism in the market as a cause for this change. BIM applications can potentially provide the ICT required for this change. Mass customisation and BIM applications were separately discussed with an emphasis on the most relevant features of each which can either facilitate the other's, or be facilitated by the other's. Deploying the highlighted concepts from the literature, then a case study for a mass customisable façade was developed and partially tested through development of a product family using an industry standard BIM application. It was shown that the most challenging requirement of providing a mass customisable curtain wall façade system i.e. variation of non-planar form can be offered using parameters built into the family to act as configurators to customise the façade at system level.

It is envisaged that future work at this level is also required to help elaborate on:

- Incorporating configurators for variations of height for individual points on the generating splines
- Creating unlimited number of points within each generating spline
- Provision of indefinite number of splines;

The study is in progress to develop the configurator(s) at system level further to accommodate:

- The structural system
- The location of the curtain wall relative to the structural system
- The interface system

And also at sub-system level where, in addition to the form of the host, the following configurable parameters will be addressed to enable full customisation of the curtain wall system:

- The materials,
- The components, and
- The elements;

Subsequently, at service level the research will also need to address:

- Integration of levels of automation for curtain wall panels
- Investigations into interfaces with, and links to XML/HTML files and/or SQL databases and/or spread-sheets/data-sheets to create a web-based or standalone application with an easy-to-use and user-friendly GUI for mass customisation of façades.

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