ABSTRACT

Home building industry industrialization to allow customer choices in home plans, elevations and interior fit-ups are currently offered using web based tools by some production home builders integrating sales through production and occupancy processes. Historically, component shapes and forms in home building industry were limited by the physical limits on construction workmen. But with the advent of digital tools based design and production processes provide a marketplace for production home builder to increase the degree of customization options. The current degree of customization options by production home builders support only a limited number of options for the buyer led changes to floor plans, elevations and interior fit-ups. Production builder are faced by decision making issues to allow new custom options both internal (within builder) and external (outside builder domain of control). In this paper a literature review is conducted to study the decision making issues and the current degree of
customization in residential industry. A product based definition for mass customization for production home builder is articulated. Future research on the decision making issues are discussed based on the literature review.
“A building begins as an idea in someone’s mind, a desire for new and ample accommodations for a family, many families an organization or enterprise” (Allen and Iano, 2004). To convert all personalized home building ideas of the home-buyers into reality in an industrialized and affordable mass production set-up is the primary research area of this paper.

The following is a brief timeline of industrialization in residential construction industry-

**Timeline: Industrialization in Residential Construction Industry**

A brief timeline of industrialization in housing industry attempts made by industrialists and entrepreneurs saw mixed success in the last century as shown below:-

1795  Nail Making Machines [Jacob Perkins]

1832  Balloon Framing [George Snow]

1851  Crystal Palace, U.K.

[Joseph Paxton and John Henderson developed systematic steel framed assemblies for reducing time and increasing efficiency]

1861  Skillings and Flint Modular Buildings

1870  Col. Lyman Bridges and Hodgson sectionalized homes.

1880  A Lindbad Portable Homes

[Folding Structure limited to octagonal configurations]

1908  Sears Kit Homes:

[Most successful in terms of the scale of production 70000 homes produced from 1908-1933) but could not sustain the interest rates of accumulated debt during depression after world war.]

1910  Le Corbusier Visions “Machine for Living”

[Application is limited mainly toward low cost housing]
1919  Platform Framing Ray Bennett Lumber Co.
1934  Forest Products Lab develops SIPS panels
1937  Wrights Usonian Automatic Houses Vision
       [Failed attempt of using concrete blocks for variations]
1941  Walter Gopious’s Panels
       [Gopious and Washman tried to venture General Panels prototype housing systems but
       after 10 years of research studies because the costs of panels were higher than site built
       construction]
1946  Buckminster Fuller’s Wichita House
       [Despite potential prospective investor’s and buyers of Fuller’s Wichita House
       prototype industrialization the concept for industrializing was stalled.]
1949  Jean Prouve’s Tropical House
       [The French Govt. and Architect Jean Prouve’s concept of producing mass produced
       vacation homes did not see much success beyond prototype testing for reasons of radical
       design and cost]
1949  Charles Eames House, USA
       [Modernist home completely made from off the shelf mail order components,
       however, principles not embraced by the industry and public did not like materials ]
1950  Lustron Corporation
       [After completing 25000 homes in 1950 the company could not reach the planned scale
       of production of 50 houses a day to break even. Subsequently the corporation has
       accumulated debt of the order of 38 Million dollars.]
1947-1951  Levittown
[Reverse assembly lines and specialized tasking by workers moving from house to house for rapid production process for the “Budget Homes”]

1963 Japanese Prefabricated Construction Suppliers and Manufacturer Association and projects “House 55”.

1969 Operation Breakthrough

[Failed federal Govt. initiative for low cost efficient housing]

Habitat 61 Prefabricated Concrete Modules

1976 Misawa Homes O’Model

[Successful in providing more customer choices in prefabricated homes (Ishawita 1990)]


[National home builder investing in plant-based modular production home building is facing current market slowdown in Northern Virginia]

2000- Mass Customization and Industrialization University Research Projects [MIT’s House_n Chassis + Infill; USC Contour Crafting; Virginia Tech HUD Process Mapping for Industrializing Residential Construction Sites etc.]

Historical Lessons and Contemporary Issues of Industrializing for Production Home Building:

Construction industry as a whole and residential construction specifically has been described as "laggard" and resistant to change relative to innovation in building practices (Koebel C. T. and Cavell M., 2006, Koebel, 2003). Some of the above innovation related efforts in industrializing the residential construction processes were unsuccessful. Research projects in
residential industry show some of the reasons as - industry fragmentation, limited R&D, Government regulations, complex supply chain management, information and communication errors, AEC cultural barriers, other typical challenging issues for home buildings like logistics, lack of options/choices for buyers from the factory-made homes, financial mismanagement, market slowdown etc. (Kieran and Timberlake, 2003). Many of these reasons are non-technical and highlight the management of complexity of information generation and distribution at the production builder’s enterprise level to digitally support sales through production processes of customer led changes (Wakefield et al., 2001). Information bottlenecks from sales through production are affecting industrializing and innovation of residential construction sites. Additions, modifications and change orders do not get digitally integrated from sales office to the construction site for factory based production home builders (O'Brien et al., 2002). The parametric modeling tools used in home building industry like Revit, Argos BDS, Graphisoft, Digital Project etc. are still in the development phase for the construction industry (Eastman, 2004, Mitchell et al., 2001). In the future, to efficiently use the digital parametric modeling tools and numerically controlled machines for supporting customer led changes in residential homes design and construction, the customer and builder's sales force should be able to visualize product, measure performance parameters and execute production process in small batch sizes to serve “Markets of One” (Pine and Gilmore, 2000). To address these issues, a decision making framework is required that articulates variables of a new creative home model and analyzes the performance parameters for the builder. Historically, in the home building industry construction components have been limited by the physical limits of the workmen but with industrialization the limits are now human physical capacity and machine limits CNC machines. The enterprise level management of production related information of the increasingly larger modular
components incorporating new systems in the structural enclosures of the house is a challenging the production home building industry. Home as a product and process shows a dichotomy in the nature of the complexities. Whereas the product is a highly complex assembly of parts and systems, the processes producing of those parts and systems go through similar repetitive processes (Schodek D. et al., 2004). Historically, home building has seen major additions in system utilities but the structure as a whole is still built the same way (stick built) with similar materials as used a century back (O’Brien, 1999). The existing industrializing efforts show some serious information related bottlenecks across factory production and on-site assembly for panelized housing (O’Brien et al., 2000). CAD and other BIM based IT tools enabled mass customization model for the home building industry thus could focus on eliminating these information related bottlenecks both at the processes and at enterprise level to bring owner, buyer, consumer all to the same platform for information visualization, generation and sharing (Beliveau, 2004). Also, IT tools like F-CIS, VIRAPS etc. based mass customization model were able to bring the home buyer closer to designers and builders. The resulting structured increase in the number of choices to customize apartments and provoke the need for further research to integrate the supply chain into the planning and control of production process (Frutos and Borenstein, 2003).

The major research thrust and interest in residential construction is shown by research institutions and industry to be focused on innovation, mass customization and industrialization for production home builders in the last decade. This is seen in the increasing number of research publications, university projects and R&D journals (Larson K., 2002, Koebel C. T. and Cavell M., 2006, O’Brien et al., 2000, Khoshnevis 2004). Traditionally, the financial incentive for product innovation for homes has been shadowed by the construction profits accrual from land
acquisitions rather than product innovations for the developers. The innovations efforts for newer methods of production like contour crafting, digital manufacturing techniques etc. are some research directions towards innovation over stick built construction. The most recent studies of innovation for US home builders (Koebel 2006) shows that large production home-builders seem to be more innovative than small builders and may drive research towards offsite modular mass customization business model. Large organization is more aggressive in reducing purchasing, design, and marketing departments’ approvals/ influences on innovation in these firms. Sensitiveness to the customer creative preferences and organizational culture can drive builder to be innovative. Developers have typically profited more from land acquisitions than the product itself. This may have impacted on the need and urgency of innovation of the product. But as a cyclical nature of industry, companies who take innovativeness in their product design usually sustain low market demands.

Production home builder’s digitally enabled industrialization is in its early growth stage and a offsite production model and IT enabled data driven manufacturing have a great potential to efficiently improve process, and reduce errors, data redundancies and process bottlenecks (O'Brien et al., 2000). Researchers in housing industry also foresee a change in construction contracting from design-bid-build to design-build etc., production oriented 3D modeling and data integration technology systems from schematics to realization e.g. BIM, CAD based systems etc., new fabrication processes (dependent on detailing and collaboration between architect and builders etc. (Eastman, 2004, Mitchell et al., 2001). To make these strides toward industrialization, decision support tools are required for organizations to best optimize their products and variables under the influence of – technological dependencies, design/ pre-
construction, regulatory approvals, market requirements, and overall organizational culture complexities arising from mass customization (Blecker, 2005).

Also, currently the number of choices for factory based production builder as seen as an application of mass customization range from choices in floor plans to additions and deletions of fit-ups as shown in figure-1 (Pulte Home Science, 2007). Mass customization can be seen either to increase or decrease complexity for the organization depending on the application strategy and management of information. The complexities usually associated for organizations that allow mass customization are classified as internal or external (Blecker, 2005). The literature regarding the how a new option is managed at the production homebuilder enterprise level is a new area of research. Especially, with industrialization, and innovation in offsite production components the Design-Fabricate-Assembly is a new paradigm for production homebuilders.

Homebuyers usually try to personalize aesthetic appearance, functional requirements pertaining both to cosmetic and core features of a house. Industry is currently providing web based IT enabled solutions similar to preference engines (Larson K., 2001), F-CIS (Frutos and Borenstein, 2004), VirApps, etc. to buyers to work with the architects, sales team and designers to select their home model and incorporate their specific preferences in it. However, there are several internal manufacturing-assembly related challenging issues for production homebuilders in terms of managing the complexity in providing options without sacrificing quality and efficiency. Just by
sheer numbers a home model with minimum elevation options, square footage additions in floor plans, and interior variations lead to million possibilities. For e.g. a large production home builder allows 5 alteration to floor plans, 10 alterations to elevation and 15 interior fit-up options then the mathematics of the total possible choices would be of the order of 5! Times 10! Times 15!. In order to manage such complexity in production, the decision makers in production home building industry face with issues of increasing the extent of providing options to the home buyers and integrating options related information from sales to production to assembly. In the following section we shall explore the existing literatures on the following two areas in home building: a) Definition of Mass Customization for production home builders based on home as a product, and b) enablers, drivers and barriers for a builder to increase the level of customization.

**Definition of Mass Customization for Production Home Builder:**

The following table highlights some of the key definitions of Mass Customization across industries and academic disciplines. However, a definitions need to be articulated from a Production Home Builder’s standpoint of homes as a product incorporating production process and parameters specific to residential homes.

<table>
<thead>
<tr>
<th>Source Field</th>
<th>Author Year</th>
<th>Definitions/ Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td>(Duray, 2002)</td>
<td>Mass customization is a combination of craft manufacturing and mass production offering unique products in mass produced low cost high volume environments.</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
<td>(Davis, 1987)</td>
<td>Mass Customization was first coined in this book. Business like everything else in the universe is influenced by time, space and mass. In the product space to fulfill whatever wherever is a future reality and today’s challenge for several industry.</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>(Pine, 1999), (Pine and Gilmore, 2000)</td>
<td>“Producing in response to a particular customer’s desires.”... Customers do not want choice; they just want exactly what they want”</td>
</tr>
<tr>
<td>Business</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The definition focuses on meeting the demands and needs of the buyer and the relevant distinction between variety and tailored products or services.

<table>
<thead>
<tr>
<th>Business</th>
<th>Piller 2005</th>
<th>“a customer co-design process of products and services which meet the needs of each individual customer with regard to certain product features”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>(Svensson and Barfod, 2002)</td>
<td>Customization adds value to product than a mass produced product as it fulfills the needs of buyers.</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>(Blecker and Friedrich, 2006, Blecker, 2005)</td>
<td>Customization should define whether it is applied to physical products or service,</td>
</tr>
<tr>
<td>Home Building</td>
<td>(Frutos et al., 2004, Frutos and Borenstein, 2003, Frutos and Borenstein, 2004)</td>
<td>Web based object oriented modeling framework for increasing customer company interaction was developed primarily focusing on the interior of an apartment building in an urban location.</td>
</tr>
<tr>
<td>Home Building</td>
<td>(2006), (Schodek D. et al., 2004)</td>
<td>The Architectural Skylight company successfully customizes skylights based on 5-10 configurations and shapes with durable high-end structural materials for a mass market through web based tools. The options seem to be based on optimization research on the sure winner models types for the mass market.</td>
</tr>
<tr>
<td>Home Building</td>
<td>(Larson K., 2001)</td>
<td>The customization for home building here focuses on adaptability of home floor plans for dynamic changes for future use through conceptual chassis+ Infill systems. For e.g. a day time living room could be modified into a bedroom some other time.</td>
</tr>
<tr>
<td>Home Building</td>
<td>(Friedman et al., 1994)</td>
<td>The concept of Customization through Row houses was introduced.</td>
</tr>
<tr>
<td>Innovation</td>
<td>(Hippel and Sloan School of Management, 1999)</td>
<td>Democratizing innovation through customer involvement design and production innovation.</td>
</tr>
</tbody>
</table>

**Figure 1 - Definitions of Mass Customization**

Though the definitions and application methods in industries like computers (Michael Dell and Catherine Fredman ), automobile (GM, NBIC bicycles), electronics (Black & Decker, Ross Valves), apparel (Levi Strauss) etc. have differing application parameters and models, a common thread in all the above definition is the need to improve the production process agility to support customer specific non-standard high quality product at mass produced prices and
efficiency. Meeting customer expectations to drive changes in a standard mass produced product on a mass scale is a step beyond adding product varieties (Pine, 1993). It includes customer as an active designer and developers of the product to incorporate expectations of customer. Before, proposing a definition for mass customization model and its application parameters, attributes and requirements; it is important to identify the audience for the proposed research. The audience for the research is primarily targeted toward factory based production home builders who are either progressing from a mass production to mass customization model or trying to set up a new factory to industrially mass produce wood frame custom homes in Northern Virginia USA. The factory based production builder is defined as a construction company that uses off-site industrialized methods of production including non-volumetric modular panels, and undertakes the majority of the work in a controlled factory environment, governed by stringent single family codes similar to the International Residential Code and International Building Codes. Assumptions include – (1) structures are primarily wood framed homes up-to three levels, (2) The mass markets for home with a median price of 400 thousand dollars, and range of 300 thousand dollars to 2 million dollars.

In Home Building industry, this new strategy is a challenging area for researchers and builders to provide solutions for progressing from mass production toward higher customization production model. The following sections summarize and define digitally enabled mass customization in residential construction.

Mass Customization (for a factory based production builder) is a marketplace where customer’s creative options are leveraged by –
a) Standardized production process: to create component modules not limited by standard options transforming into customer specific configurations (floor plans), permutations (house elevations) and variations (interior fit-ups) for single family wood frame detached homes and

b) Digitally Production Integrated Marketplace of all available choices: A marketplace where a two-way integrated information exchange exists between the buyer-builder-supplier to increase the degree of options for buyers aiding in a dynamic production related communications of sales, production and construction for the builder both within and outside the builder’s enterprise.

The distinguishing factors of this definition when compared with the earlier definitions used in the home building/ construction industry are - a) It focuses on the off-site production and on-site assembly process of a complete house and not one component or part in it, b) It is focused on the production process and supply chain for production builders. This process is made possible by a digitally enabled flexible and agile manufacturing process for a factory based production home builder.

Literature Review on Mass Customization in Residential Industry

A literature review of journal papers, university research projects and industry application of Mass customization in home building and construction industry was performed. The objectives of this literature review were to determine three criteria: a) Current degree of customization (parameters of customization viz. configuration permutation and variations in homes), b) Enablers, Drivers and Barriers of Mass Customization model in home building; c) Application of Mass customization for Production home building. The following table summarizes the findings of parameters of customization (Configuration C, Permutation P and Variation V) and associated enablers and barriers in the home building industry.
<table>
<thead>
<tr>
<th>Author-Year</th>
<th>Parameters (C,P, V) / Related Areas</th>
<th>Enablers</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Frutos et. al 2004)</td>
<td>Variations e.g. floor, wall covering, internal doors, metal fittings, equipments, electrical systems, water supply system etc.</td>
<td>Information Technology viz. F-CIS tool</td>
<td>Supply Chain</td>
</tr>
<tr>
<td>(Barlow 2003)</td>
<td>Configurations, Permutation and Variation</td>
<td>Supply Chain, prefabrication, Regulation (Japan)</td>
<td>Cost, Lead Time, Speculative Model (UK)</td>
</tr>
<tr>
<td>(Roy et al. 2003)</td>
<td>Configurations, Permutation and Variation</td>
<td>Build Process Reengineering</td>
<td></td>
</tr>
<tr>
<td>(Noguchi 2005)</td>
<td>Permutations</td>
<td>Quality, Cost, Communication</td>
<td></td>
</tr>
<tr>
<td>(Friedman et al. 1994) (Noguchi 2002)</td>
<td>Configurations, Permutation and Variation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Noguchi 2003)</td>
<td>Configurations, Permutation and Variation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Anumba et al. 2003)</td>
<td>Related Area- Inter-organizational communication tools</td>
<td>Distributed AI</td>
<td>Diverse and Heterogeneous IT systems</td>
</tr>
<tr>
<td>(Gibb et. al.2001)</td>
<td>Related Area- Standardization and Pre-assembly</td>
<td>Pre-assembly, Standardization</td>
<td>Cultural perceptions, Productivity, Quality Improvements</td>
</tr>
<tr>
<td>(Fox S.et. al. 2002)</td>
<td>Related Area- Design Imperatives of Homes and Consumer Goods- Authority (Producer to Customer Led continuum) and Application (Global market to specific location Continuum) Impact on production processes</td>
<td>General Purpose Systems and Processes for Customer led design and location specific, Supply Chain compatibility</td>
<td></td>
</tr>
<tr>
<td>(Lawrence 2003)</td>
<td>Variations e.g. floor, wall Infill</td>
<td>Chasis + Infill System Architecture, factory based modular components</td>
<td>Prototype Testing of Infill</td>
</tr>
<tr>
<td>( Manufactured Housing Research Alliance New York 2006)</td>
<td>Related Area- Research Manufactured Housing, Customization</td>
<td>Manufacturer-Retailer Communication</td>
<td>Time for Drawings and Design documents</td>
</tr>
<tr>
<td>Author-Year</td>
<td>Parameters (C,P, V) / Related Areas</td>
<td>Enablers</td>
<td>Barriers</td>
</tr>
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</tr>
<tr>
<td>(PATH Mullens Larson 2007)</td>
<td>Variation</td>
<td>Parametric Web Based Tools</td>
<td>-</td>
</tr>
<tr>
<td>(Larson House_n 2007, Larson 2004)</td>
<td>-</td>
<td>Preference Engine Customers; Design Engine Architects Grammar &amp; Production Systems Manufacturing Tools</td>
<td>-</td>
</tr>
<tr>
<td>(Beliveau 2004)</td>
<td>Configurations, Permutation and Variation</td>
<td>CAD based integration of design, manufacturing, construction and operation, processes. Design Engine</td>
<td>-</td>
</tr>
<tr>
<td>(Duarte 2001)</td>
<td>Configurations, Permutation and Variation</td>
<td>IT tool VirApps</td>
<td>-</td>
</tr>
<tr>
<td>(architect Jarmo Suominen 2007)</td>
<td>Modern House, FlatPack <a href="http://www.skanska.com">www.skanska.com</a></td>
<td>Modular, Prefabrication</td>
<td>-</td>
</tr>
<tr>
<td>(Schodek D., 2004)</td>
<td>Related Area : Component customization</td>
<td>Modular Design, Web based design Tool</td>
<td>-</td>
</tr>
<tr>
<td>(Khoshnevis, 2006)</td>
<td>Configuration, Permutation</td>
<td>Contour Crafting</td>
<td>-</td>
</tr>
<tr>
<td>(Cuperus Y., 2002)</td>
<td>Configuration, Permutation and Variation</td>
<td>Town Planning, Regulation Responsiveness</td>
<td>Lead Time</td>
</tr>
<tr>
<td>Author-Year</td>
<td>Parameters (C,P, V) / Related Areas</td>
<td>Enablers</td>
<td>Barriers</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------------------------------------</td>
<td>-------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>(O'Brien, 2002 ; Wakefield, 2001)</td>
<td>Related Areas – Production Home Building Industrialization, Customization</td>
<td>IT Tools</td>
<td>Information distribution bottlenecks</td>
</tr>
<tr>
<td>(Friedman, 1994)</td>
<td>Related Area – Row Housing</td>
<td>--</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 – Summary of Parameters, Enablers and Barriers of Mass Customization in Residential Construction Industry

<table>
<thead>
<tr>
<th>Configuration (C)</th>
<th>Permutation (P)</th>
<th>Variation (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Floor Plan Changes" /></td>
<td><img src="image2" alt="Elevation Changes" /></td>
<td><img src="image3" alt="Interior Equipment Changes" /></td>
</tr>
</tbody>
</table>

Figure 3 : E.g. of the three levels of Customization in Home Building : Configurations, Permutations and Variations
Discussion of Current Application of Mass Customization in Residential Industry:

a) Degrees of Customization for buyers in production home building beyond the interior variations? Based on the above literature search the customization parameters can be classified broadly as (1) Complete Geometry Customization which is a higher degree of customization allowing changes in floor plans, elevations and interior fit-ups (Configuration + Permutation + Variations custom options) (Schodek D. et al., 2004, Sekisui House, 2006) or (2) Partial Geometry Customization (Permutation + Variations custom options) (Frutos and Borenstein, 2003). The C+P+V model are more challenging as it demands efficiency in design and production process under a higher complexity for the builder. The Japanese Sekisui House model is probably the best example for this case (Barlow 2003). Since 1972 Japanese factory based builders have been offering home owners flexibility in designing shapes of homes and interiors features (Sekisui House, 2006, Ishawita 1990). The method of application largely is prefabricated (~80%) (wood or steel) frames following an open (non-volumetric) modular structure (Sekisui House, 2006). Another leading example of this high degree of customization is more focusing on a single building component like Architectural Skylights (Schodek D. et al., 2004). The Maine-based skylight company offers selection of market optimized options for design, geometric shapes, and material selection using a web-based tool with pricing information. There are several conceptual models that are being studied that could offer the high degree of customization like contour-crafting (Khoshnevis, 2006) and Chasis + Infill, House_n (post and beam non-volumetric) (Larson K., 2004). The Almere Housing in Netherlands (Cuperus Y., 2003) is an attempt made by Dutch city of Almere to test the impact of customer freedom in choices and options for homes on the production process. The major findings include the requirement for decisions from buyers on the long lead materials planning, timely and
dynamic support from town planners and regulators for information to the buyers about all the
changes made in the neighborhood community like building setbacks.

In dense urban apartment buildings, because of the structural enclosure, the interior
permutation and variations options is being implemented in various parts of the world to meet
diverse customer demands (Frutos 2004). Frutos (Frutos et al., 2004) developed a customer-
company interaction model using Object Oriented Programming language framework for this
kind of scenario for Brazilian apartments. The customization options included – wall coverings,
floor coverings, kitchen features, internal doors, metal fittings, equipments, electrical systems,
water supply system etc.

b) General Enterprise Level Enablers and Barriers for Production Home Builder:

The research and industry application of mass customization is a new area. The literature review
on the current enablers and barriers of mass customization strongly sheds light on the existing
complexities in home building industry. The following table summarizes the enablers and
drivers in home building industry.

<table>
<thead>
<tr>
<th>Enablers</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Tools</td>
<td>Economics</td>
</tr>
<tr>
<td>Supply Chain Integration</td>
<td>Lead Time for Decisions from Buyer</td>
</tr>
<tr>
<td>Industrialization</td>
<td>Supply Chain Responsiveness</td>
</tr>
<tr>
<td>Government Initiative and Regulation</td>
<td>Heterogeneous IT Systems</td>
</tr>
<tr>
<td>Innovation in Building Processes</td>
<td>AEC Cultural</td>
</tr>
<tr>
<td>Product Innovation</td>
<td>Quality Improvements</td>
</tr>
</tbody>
</table>
Conclusion

Production home builders are using web-based IT tools and NC machines to offer increasingly more options pertaining to changes in floor plans, elevation and interior fit-ups for single family home buyers. However, the changes in the home design impose a decision making challenge at the enterprise level of the builder. Some of the general enterprise level barriers for an ideal mass customization scenario include – economics, lead time from buyers, supply chain responsiveness, heterogeneous IT systems, AEC cultural issues, etc. The major enablers of a high degree of mass customization include – IT tools, Supply chain integration, Government initiatives and regulations, Innovation in new processes and products.

Consumers buying experience is enhanced through creative additions and deletions on a web based tools in home building. (Frutos and Borenstein 2003). There is not one single way of applying mass customization (Pine and Gilmore 2000). The two major routes in home building include – a) New production processes like contour crafting, or b) Industrializing through panelized construction like Pulte Home Sciences, Sekisui Home model. Also conceptual models like Chassis+Infill systems are being studied for industry applications. Mass production with customization is becoming a reality in home building like other industries (Barlow 1999) (PHS 2006). Mass customization applications methods outside US may have to be suitably modified. Some of these specific areas that have to be studied before any generalization on applicability can be made includes production process, climatic conditions, market needs, regulatory approvals, codes; demographics, trade skills and availability in US have. Large production home builders have started to offer home buyers more custom options. However the degree and level of customization is still a management decision making issue and hence are limited to standard additions or deletions to the plans and elevations (PHS 2007). More Research and Development
is required for developing successful strategies for implementing a high degree of mass customization in home-building industry primarily in the directions of digital tools, production process industrialization, supply chain integration and enterprise level management of AEC cultural barriers.
Reference:


http://www.sekisuiheim.com/english/unit/two_u.html/
