The iBuilder Wheel: A Decision Making Tool to Aid in the Selection of Innovative Residential Construction Strategies

Chinmay A. Nandgaonkar, Thomas H. Mills, and Andrew P. McCoy
Virginia Tech
Blacksburg, VA

Homebuilders are continuously scanning their environment to find the latest product and process improvements in residential construction. Notwithstanding the Internet, information is still decentralized among many sources without meaningful differentiation, hierarchy, or summarization. The authors believe that if this information is graphically designed on a tactile, user-centric, and freely associative tool it can influence the decision maker to explore residential technologies and housing solutions in an entirely different manner. By exposing a user to a particular product, process, or technology it will help in promoting the process toward its successful adoption altering how housing solutions are derived. This paper proposes a prototype decision making tool, termed the 'iBuilder Wheel', for just such a use. The iBuilder Wheel is a user-centric, tactile device aimed at improving communication and exploration of housing solutions as a function of product, processes, and systems innovations. This prototype tool addresses the kinesthetic learning tendencies of the homebuilder, a key decision maker, and relies on several sources of information about emerging products, processes, and technologies for its effectiveness. This paper describes the process of tool design, development, information content, structure and its future potential.

Key Words: Innovation, Homebuilder, Communication, Decision Making, Kinesthetic Learners.

Introduction

Residential construction is one of the largest market segments of the Construction Industry in the United States with 2007 residential construction spending exceeding 40 percent of the $1.15 trillion spent on the total construction put in place (U.S. Census Bureau, 2009). The residential construction industry is often described as 'laggard' in adopting new products, processes, technologies (Koebel, et.al. 2004). There are several barriers both organizational as well as technological, to the successful adoption of innovative products, processes, and technologies in the residential construction industry. The complex and fragmented structure, competitive and risky nature of the industry, education/communication between participants, individual preferences, and cultural values are some of the barriers to the successful adoption of innovations in the home building industry (Building Technology Inc., 2005). A product in its process of adoption has to go through various steps from the manufacturer's research through to consumer acceptance and its final application. The difficulty faced by homebuilders in this process is in accessing and sharing information about emerging technologies in an organization and between participants down the supply chain.

The challenge here is to analyze ways to accelerate or streamline the innovation adoption process in the home building industry and help decision makers identify and select innovative construction technologies. This study approaches innovative technology adoption by focusing on improving communication between innovators/manufacturers and decision makers through the medium of a tactile decision making tool. The proposed tactile decision making tool is a simple user manipulated tool that allows the user to self-direct their interests and objectives in discovering innovative holistic home building solutions, including individual products, processes, and systems, therefore we have dubbed the tool as a innovative builder's wheel and shortened to what is hereafter referred to as the 'iBuilder Wheel' (see figure 1).

Figure 1: The prototype iBuilder Wheel

The Home Building Industry

The US homebuilder is a unique product producer, according to a HUD produced report by Building Technology Inc. (2005) they can be characterized as:

- an assembler of parts. e.g., windows, doors plumbing fixtures, etc., which are provided by a diversified network of large manufacturing companies.
- a high value product producer (hundreds of thousands of dollars involved).
- as a financially conservative producer with relatively low capitalization

Housing in the United States comes in varied forms depending on land, climate, and available resources. Further there are variations in the end product with respect to size, layouts, materials etc. There are several interacting parts and subsystems involved in the construction of a home. This makes the process complicated and requires a high level of knowledge flow and interaction between large numbers of supply chain participants. Over the past years, the home building industry has witnessed changes in the design, use of materials, building techniques, financing, and planning strategies. This has changed what homes are made of, how they are built, and who can afford them (Hassell, et. al., 2003). These changes can be characterized as 'innovations'. These innovations have enabled homebuilders to construct homes at lower costs and thereby making homes more affordable, durable, energy efficient, greener, and less susceptible to natural disasters.

Innovation in housing commonly occurs when a new technology replaces another conventional product, process, and technology to improve the performance of the final product. NAHB (2001) mentions that new technologies are successful substitutes for conventional building products if they offer value to the homebuyer by providing:

- Functionality – improving energy efficiency, sustainability, etc.
- Productivity **-** reducing the costs of labor, materials, equipment.
- Systemic Efficiency **-** reducing the cycle time of construction.

Within the residential industry volume homebuilders commonly refer to new housing stock as 'product' (Mills and Beliveau, 2008). This term has been adopted throughout this paper to identify residential housing. The reader must be conscious during the reading of this article, of the interchange and the context when references to 'product' as housing and 'product' as manufactured goods are mentioned. As in most industries, the propensity to adopt new technologies is ingrained in the culture of an organization (Koebel and Cavell, 2006). There are clusters of innovative builders in every segment of the residential construction industry. Some small single-family production builders who are driven by consumer demand may adopt and build using more proven technologies, e.g., residential stick framing. However, irrespective of their size, homebuilders are constantly scanning the environment to improve their product's performance. Some large homebuilders have dedicated resources focused on finding or creating innovations to improve their product or for a competitive advantage. These homebuilders are open to new ideas, however they might not have sufficient time to learn and therefore be informed about current innovations (Koebel and Cavell, 2006).

Tool Development

Homebuilders often rely on suppliers, salesmen, and subcontractors for information about new products and how to choose among them. There are several Internet sources of such information, e.g., ToolBase (2009), BuildingGreen.com (2009), and Architectural Record (2009), etc. However, this information happens to be scattered over the Internet and various manufacturer's product catalogues. Large databases of product related technical information without meaningful differentiation or summarization may not be particularly helpful to decision makers interested in holistic product solutions and product specific innovations. Homebuilders generally do not have the time to scan all these sources and arrive at a decision. Though the Internet serves as a useful medium for technology scanning; acceptance of an innovation, closing of a sale, and training still depend largely on face-to-face contact. Regardless of innovative product discover, selection, and acquisition there is no holistic recombining of these individual products into a total conceptual housing solution. Many builders are "kinesthetic" learners who like to see and touch what they are buying (Building Technology Inc., 2005). The authors believe that a tactile tool can help users discover innovative solutions.

Review of prior literature on innovation in the construction industry, specifically residential construction emphasized on the need of a decision making tool that could aid in the decision making process of technology adoption in the homebuilding industry. Figure 2 illustrates the three generation process for developing the iBuilder Wheel based on the decomposition of housing components, then a re-composition of these components, and their subsequent assigned positions on the wheel with the intent to create a holistic residential systems construction strategy. The development of the tool involved prior research on the concepts of de-composition and re-composition of housing components and the concepts of information design and tool design as shown (see figure 2). The generational sequence of tool development is further explained below.

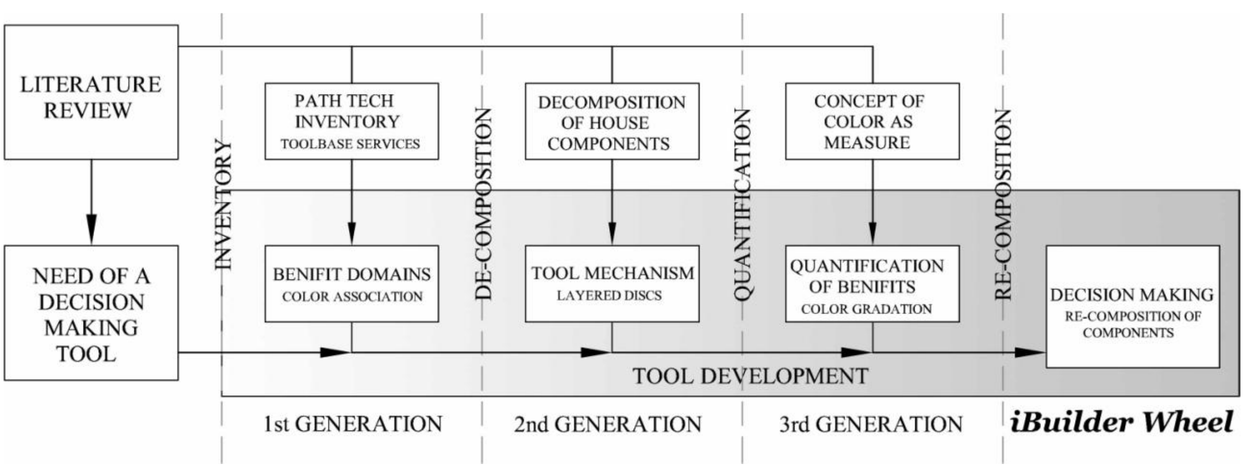

Figure 2: Research and Development Steps

Concept Development

Content for the first generation iBuilder Wheel was based on a content extraction from ToolBase (2009), a PATH Technology Inventory, which provides information of about 170 emerging or new technologies. Each of these demonstrate benefits to the housing industry by improving quality, durability, energy efficiency, environmental performance, affordability, disaster resistance, and safety in homes. Using an extraction from ToolBase, four domains of achievable benefits in the construction of new homes were prefaced as parts of the iBuilder Wheel, these being energy efficiency, affordability, sustainability, and quality/durability. These benefit domains are illustrated as quadrants shown on a circular disc (see figure 3a), and described below.

Affordability - The supply and availability of housing that is within the financial reach of families and matches their needs (PATH, 2008). New or emerging technologies can be classified as affordable if their use and/or application produce significant cost savings. These cost savings may be labor savings, material and equipment savings, and savings due to reduction in construction time.

Quality and Durability **-** Quality begins with the careful selection of materials, long lasting products at available and competitive prices to similar products in the market, with correct installation (PATH, 2008). Use of durable products saves on maintenance and repair costs over the life cycle of a home. Products, processes, and technologies possessing the attributes of safety and disaster mitigation are also included in this domain.

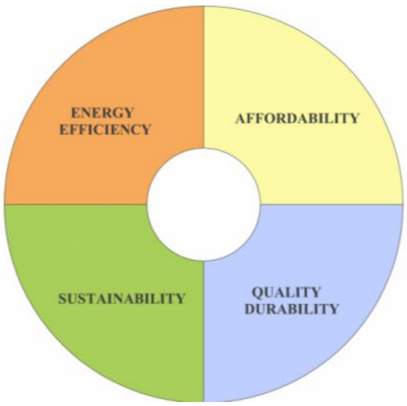

Figure 3a: Benefit Domains

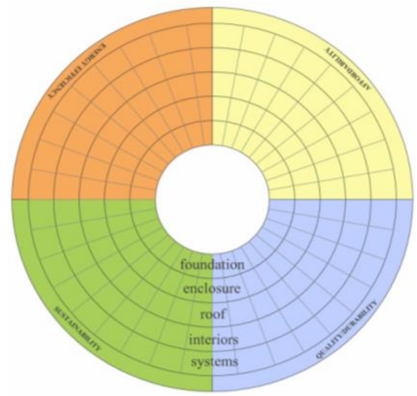

Figure 3b: Domains with five layered discs and visible cells

Energy efficiency **-** Use of energy efficient technologies and products can reduce the resources consumed during the house construction and also energy usage during the home's life cycle thus, reducing the homeowner's energy bills (PATH, 2008).

Sustainability **-** Sustainable products are those products providing environmental, social and economic benefits during their life-cycle (Sustainable Products Corp., 2001). These products reduce the amount of natural resources consumed and waste generated during construction and lessen the environmental impact of the built home. Sustainable products, materials, can be manufactured from re-cycled raw materials and can be re-used and/or re-cycled.

The benefits of strategically adopting innovative technologies, as defined by PATH, are included in the four domains described above. The domains are color coded such that the user can visually differentiate among them. As Tufte (1990) notes the human eyes are exquisitely sensitive to color variations. The users can consciously associate their thinking towards a particular benefit linked to a specific color. For example, the iBuilder Wheel's Affordability domain has a 'golden' color, which can be associated with financial savings. Similarly, the Sustainability, Energy Efficiency, and the Quality/Durability domains are associated with the colors green, orange, and blue respectively.

De-composition of housing components

Development of the second generation iBuilder Wheel focused on a decomposition strategy of reducing residential construction into five basic construction categories or systems based on the Mass Customization (MC) concept proposed by Mills and Beliveau (2008). These systems/components are as follows:

- Foundation Systems
- Enclosure – Framing, Sheathing, Masonry, Siding.
- Roofs – Roofing, Sheathing, Ventilation.
- Interiors – Partitions, Doors/Windows, Finishes.
- Systems – HVAC, Electrical, Plumbing.

These five basic categories of a house are designed as five rotating discs layered on the iBuilder Wheel decision tool (Figure 3b). The overlap of these five discs and the four domains form cells on the iBuilder Wheel. Each cell on the decision tool contains a product, process, or technology involved in the construction of a particular component of the house and maps to a color coded domain on the decision tool.

The third generation refinement of the iBuilder Wheel was based on using color gradation as a 'measure' of affordability, energy efficiency, quality, durability, and sustainability of a particular product, process, or technology. Color is a natural quantifier, with a perceptually continuous span (in value and saturation) of incredible fineness and distinction, at a precision comparable to most measurement (Tufte, 1990). Each cell on the decision tool is shown by a color value scale progressing from a light to dark intensity of the contained domain color depending on its individual performance within the particular domain. For example, a product/technology might be more affordable as compared to its peers in a particular domain and can be differentiated with a darker shade of the golden Affordability color. Each product/technology cell also has color coded bars indicating other attributes possessed by that particular product/technology. For example, a product, process, or technology in the sustainability domain can simultaneously have the benefits of being affordable, and/or durable. This is indicated with the help of green and blue colored bars in the respective product/technology cell. Depending on its position on the iBuilder Wheel and other attributes, each product/technology cell can map to a specific domain and a specific component of a house.

Re-composition of housing components

To further enhance the iBuilder Wheel, a guide bar (shown in black on figure 5), represents a re-composition of housing components into a construction strategy. The stationary outer disc is labeled with the four benefit domains which surround the inner innovative product, process, technology, and/or system (PPT&S) cells contained in the respective domains. These PPT&S cells are stratified using the concept of decomposed housing systems. The guide identifies and reinforces these areas of product innovation and allows the user to self-explore building system(s) and to strategize on their selection of PPT&S's integrating these within specific organizational or project objectives. In other words, the user re-composes the housing components to form a construction strategy which they may use to select innovative PPT&S to pursue further. For example, if the objective of the decision maker is to construct a green and affordable home, technologies would be selected from the 'Sustainability' and the 'Affordability' domains. The user can spin the five discs on the iBuilder Wheel to try different alternatives by running several permutations to yield a holistic construction strategy focused on specific innovations. The visual aspect of the individual cells helps in the easy selection of a particular product/technology for a particular construction element of a house. The objective of the decision tool is to help the user form a preliminary construction strategy which can then be furthered by a technical review of the individually selected products or technologies. The decision maker gets immersed in a mental activity of trying alternatives on the iBuilder Wheel and finally to derive a preliminary construction strategy by selecting the PPT&S's matching the organizational and/or project objectives.

This process of re-composing the housing components to form a holistic construction strategy can be thought as a part of the 'Decision' stage in the innovation-decision process as described by Rogers where the individual or decision maker engages in activities that lead to adoption or rejection of the innovation, (Rogers, 2003). The next stages in the decision making process described by Rogers (2003), are the Implementation stage, where the decision maker puts the innovation into actual use and finally the Confirmation stage, where the decision maker seeks reinforcement for the decision made. Further technical review of the PPT&S's selected as part of the construction strategy would help in these stages of the decision making process. One example, using all quadrants of the wheel for a re-composed strategy that defines the major systems of a holistic housing strategy and derived from spinning and selecting cells on the iBuilder Wheel may be an affordable precast concrete foundation system (golden), an energy efficiency structural insulated panel (SIPS) wall enclosure system, (orange), a sustainable green roof system (green), a quality and durable gypsum board on metal stud interior walls (blue), and a sustainable combined heat and power system (green).

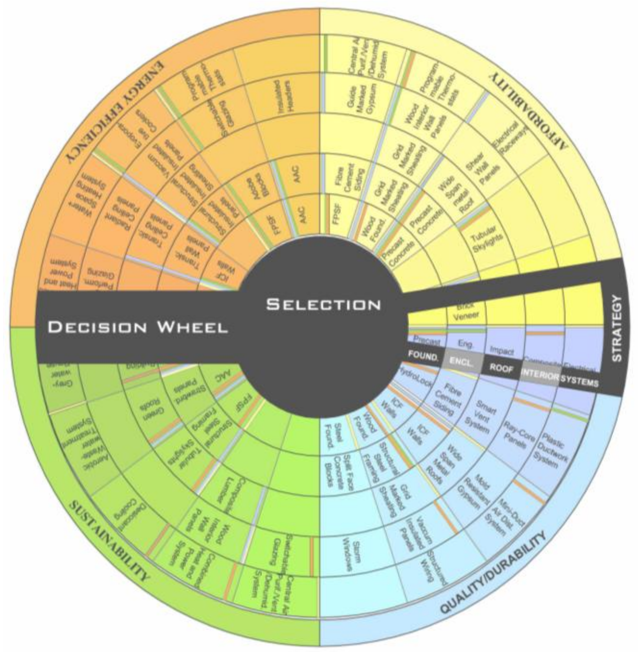

Figure 5: iBuilder Wheel with guide bar

Future Thoughts

The intention of the iBuilder Wheel is to guide the user to visually think of holistically different construction strategies while engaged in a tactile re-composition of the basic components of a home. The present prototype is intended for use by homebuilders. In addition to homebuilders, the authors believe that the iBuilder Wheel can also be made available to a broad spectrum of the home building community including individuals and practitioners involved in building design, new construction, renovations, and home improvements. These can be builders, architects, home designers, renovation contractors, current and future home owners, DIY individuals, and even home improvement stores, such as Lowe's and Home Depot, etc. A particular product, process, technology selected for a component of the home, might not be compatible with a product, process, technology considered for selection for another component. The user should be able to make educated decisions with respect to the compatibility and inter-relationship between the primary components of the home. Future research and development of the tool should address the needs of other stakeholders in the residential construction industry and also, other segments of the building design and construction industry. Field evaluations of the tool and a Homebuilders' Practices Survey (BPS) should be conducted to guide the further development of the tool and combine it with usage statistics. The primary components of the house can further be decomposed into their micro-components. For example, the primary component 'Enclosure' consists of framing, insulation, sheathing, paneling, finishing, etc. The concept of the iBuilder Wheel could be used to re-compose these micro-components of a home

During development of the iBuilder Wheel prototypes, the authors discovered innovative ways of using the tool. One such idea was to use the flip side of the iBuilder Wheel to provide Internet URL's linking to manufacturers' websites, project case studies, technical specifications, etc. of the PPT&S's in consideration. Once the user has finalized on a construction strategy, and the PPT&S's to pursue, the next step would be to further review the PPT&S's with the help of the links provided on the flip side of the iBuilder Wheel. The two dimensional (2D) nature of the tool has its limitations. The concept of the iBuilder Wheel could also be developed as a web iPhone (Apple Inc., 2009) application with a three dimensional (3D) interface or even as an electronic interactive gadget.

The present decision tool is based on an extraction of emerging products, processes, technologies from the ToolBase website. PPT&S's from other such websites, catalogues, and other resources can be reviewed and included on the iBuilder Wheel. A PPT&S Rating Matrix for each product (see Appendix A) was compiled and used to aid in quantitatively evaluating the relative position of such products, processes and technologies on the iBuilder Wheel.

The authors recognize two methods for content updating. A research entity such as HUD, NAHB, or USGBC could evaluate emerging products, processes, technologies, and/or systems to be included and updated on the iBuilder Wheel with assistance and support from the author's academic unit. The iBuilder Wheel could be updated annually where emerging products, processes, technologies, and/or systems replace successfully diffused innovations on the succeeding versions of the iBuilder Wheel. An alternative updating strategy would be that an Innovation Research Center could be formed which could evaluate products, processes, technologies and annually update the iBuilder Wheel. These annual versions of the iBuilder Wheel can then be marketed through big box home improvement stores such as Lowe's Home Improvement or Home Depot, etc.

Author Note

A patent application for the iBuilder Wheel is being implemented. For more information regarding the iBuilder Wheel, please contact the Commercialization Manager, Virginia Tech Intellectual Properties at www.vtip.org.

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Appendix A

THE PRODUCTS, PROCESSES, TECHNOLOGIES, & SYSTEMS (PPT&S) RATING MATRIX

	PPTS Considered	**Structural Insulated Panels**						
	Rating Index	**1**	**2**	**3**	**4**	**5**	**CONSIDERATIONS**	**SCORE**
AFFORDABILITY	Cost Effectiveness (labor, material, etc. cost savings)							**5**
	Initial Cost savings							
	Savings in construction time					1	quick to assemble	
	Savings in operations and Maintenance							
	Affordability Score	0	0	0	0	5		
DURABILITY	Life of the product/material							**8**
	Improvement in construction quality					1	factory manufactured, accurate	
	ease of installation							
	ease of maintenance			1			minimal maintenance	
	Durability Score	0	0	3	0	5		
SUSTAINABILITY	Reduction in resource and energy use							**10**
	Use of renewable materials					1	compressed straw / mineral wool	
	Recycled and Recyclable							
	Improved indoor environment					1	higher R values	
	Sustainability Score	0	0	0	0	10		
ENERGY EFFICIENCY	Reduction in energy consumption							**14**
	Savings in heating, cooling costs					1	excellent energy performance	
	Energy Efficiency Score	0	0	0	0	14		
RESULT	**Position of the PPTS in domain(s)**	**DOMAIN**		**COLOR**	**DISC**			
		Affordability		NA	**PPTS location on Discs**		Enclosure	
		Durability		Lightest				
		Sustainability		Lighter				
		Energy Efficiency		Color				
INSTRUCTIONS	**Rating Index:** Rate the PPTS with its individual attributes on a scale of 1 to 5 (1 rated as POOR to 5 rated as EXCELLENT). There are five levels of color gradation in every domain. The PPTS with the lighter gradient having the lowest score in the particular domain. The color becomes darker with higher scores of the individual PPTS's.							
	Color Grading Index							
	18 to 20	DARKEST						
	15 to 17	DARKER						
	12 to 14	COLOR						
	9 to 11	LIGHTER						
	6 to 8	LIGHTEST						
	Bellow 6 - CANNOT BE CONSIDERED IN THE DOMAIN							