Flexible Windows Design Preferred by Homeowners: a Survey of Universiti Teknologi Malaysia Staff Members

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ABSTRACT

User-oriented home construction necessitates participation on the part of the user in the initial design stage of gathering feedback regarding performance. The gap between designers and users, and time considerations means that developing flexible windows is a coping strategy for encouraging user participation and ensuring quality products that are economical and fully sustainability. This study investigated flexible window design based on the principles of design for disassembly and the relationship between the expectations of prospective users and windows features by understanding user motivations, what features they expected and the need for flexible windows. To achieve these goals, a self-administered questionnaire was given to Universiti Teknologi Malaysia staff. The results indicated that the best configuration for flexible windows had few parts, were easy to operate, had a simple structure, and could be quickly installed, were important while selecting windows. Moreover, a variety of designs, ease of maintenance, reusability and lightness of construction materials were additional appreciated factors. Slider windows and windows made of wood were the most preferred in terms of structure and construction material. The features expected by the users served as the basic knowledge that could be used to adopt an appropriate development perspective for the intended users.

Keywords - *Flexibility; design for disassembly; flexible windows design; user expectation; survey; Malaysia*

1. INTRODUCTION

Windows are usually investigated within the context of the relationship between humans and their environment. Abundant studies have illustrated that more functions are provided by windows other than just supplying a source of light and air (Korkut, Dilik, Erdinler, Koc, & Kurtoglu, 2010; SiuYu Lau, Gou, & Li, 2010). Industrial improvements put everything in flux and have made impressive developments in the production and quality of windows. As a consequence, improved window design has led to the development of various architectural concepts as well as construction techniques, changing economic and socio-cultural values, ecological approaches, and window preference (Lau, et al., 2006). However, windows are sometimes designed without flexibility and that do not offer easy customization. As a consequence of this shortcoming, not only does the process of replacing windows result in a large amount of demolition waste and damaged windows components but it also reduces the life cycle cost of the building (Deller, King County, Price, & Kahley, n.d.; Fawcett, Hughes, Krieg, Albrecht, & Vennström, 2012; Hurley, 2003).

Although extensive academic research has highlighted the need to develop flexible windows that can be easily replaced (Jusan, 2007, 2010; Omar, Endut, & Saruwono, 2012a; Omar, Endut, & Saruwono, 2012b; Rahim & Hashim, 2012a; Saji, 2012) and examined the failure to achieve this flexibility for recent window designs (Hurley, 2003; Jusan, 2010; Katsaros & Hardman, 2007), little research has examined how to develop flexible windows based upon user expectations.

The inability to determine the expectations of designers and homeowners, and the criticism that windows cannot be easily disassembled or unmounted, the wider goal of this study was to create an inventory of the knowledge used to develop flexible windows that optimized the sustainable use of building components. The immediate goal of this study focused on the identification of user expectations regarding features for flexible windows based on Design for Disassembly (DfD) guidelines that provided an initial inventory of the knowledge related to flexible windows. In other words, this paper attempted to investigate windows designs that are compatible with flexibility.

2. THEORETICAL FRAMEWORK

2.1 Need for Windows Replacement

Necessity is the mother of invention. The necessity of developing flexible windows becomes more pressing when windows are replaced or modified due to physical and psychological issues (Deller, et al., n.d.; Hanser, 2003; Jusan, 2007; Omar, et al., 2012b; Rahim & Hashim, 2012b; Saji, 2012). For instance, in the fenestration industry, each year over 16 million windows are replaced (National Center for Healthy Housing, 2005).

Usually, identifying a problem within existing windows necessitates adopting a new system in order to prevent housing stress as well as discomfort to the residents. The forces that motivate this effort not only enhance appearance and functionality of the home, but they also have a large impact on the fulfillment of physiological and psychological needs of the inhabitants (Farley & Veitch, 2001; National Center for Healthy Housing, 2005).

2.2 Inherent Windows Problems

The inherent problems of windows themselves are of paramount importance. The evolution of windows as they became integrated with the cover of the structure was a development that made the construction industry more industrialized and simultaneously generated significant challenges for the installation process. Creating windows as integrated units that included frame, sash, and hardware also created unique problems (Hardman & Katsaros, 2005; Katsaros & Hardman, 2007). A serious weakness with integrated units arose from the removal and replacement process that affected the area between the window frame and the integrated area. This method not only resulted in increased demolition waste, damaged windows components, a decline in reusability, and increased cost, but it also decreased the life cycle cost of the current method of windows replacement. For instance, when windows are replaced, a noticeable amount of windows components such as glass, timber and PVC framing end up in the landfill (Hurley, 2003). In spite of needs for renovation and modification, there is an inability to change and adapt in the current building system (Deller, et al., n.d.; Hanser, 2003; Jusan, 2007; Richard, 2006; Sadafi, Zain, & Jamil, 2011) as well as with windows (Hurley, 2003; Jusan, 2010; Katsaros & Hardman, 2007).

2.3 Design for Disassembly

It is becoming increasingly difficult to ignore the critical role played by DfD within the manufacturing industry. Despite efforts on the part of designers to prepare suitable living environments, designing and constructing according to rigid architectural concepts and components results in difficult reconfigurations. As a result, a convenient and feasible way of disposing of building components can be found by applying DfD (Deller, et al., n.d.). DfD has been defined as the way that buildings should be designed to make future changes using assembly and disassembly processes. Using DfD results in maximum economic efficiencies, minimum environmental impacts and slows the depletion of resources. DfD aims to make flexible, reusable, repairing, remanufacturing and recycling processes feasible (Deller, et al., n.d.; Hanser, 2003; Richard, 2006; Sadafi, et al., 2011).

2.4 User Involvement

The built environment is the subject of much research. Consequently, the intention of any theories regarding the built environment must be oriented to the process of designing, creating, supplying, and determining how the built environment functions once it has been created. Human behavior is influenced by features of the space they inhabit on both large and small scale (Vischer, 2008). Such a phenomenon makes the user central to the building construction process. Constructing an appropriate living environment is possible by designing, building and equipping houses according to the needs and preferences of the homeowner instead of speculative design (Christiansson, Svidt, Sørensen, & Dybro, 2011; Jusan, 2010; Rapoport, 2000). In order to recognize this and translate it into reliable design, a systematic and coherent approach for the involvement of the inhabitants for the purpose of innovation is required (Christiansson, et al., 2011).

3. METHODOLOGY

This study investigated flexible window designs with particular focus on the designs principles that reflected disassembly guidelines and understanding user reasons and expectations, which influenced their actions, behavior, and enthusiasm to participate in the process of windows replacement. The aim of investigating user involvement was to obtain knowledge about their behavior, as well as the factors, values and driving forces that would influence window flexibility in higher user-controlled living environments. User experience and relationships with a building can be used to guide designers to create windows that would accommodate both practical and theoretical concerns. A better understanding of how users are affected by different window types pivots on the notion of development. This knowledge can be used as a starting-point for producing flexible windows and new services in the future.

Christiansson et al. (2008) and Christiansson et al. (2011) remind us that before end-users end up with buildings created to meet necessary specifications, identifying end needs as well as a weighing and consolidation process must take place. Disregarding these processes may result in a conflict between wishes and expectations regarding building performance. Therefore, unveiling unrecognized needs, desires, expectations and longings that motivate people to act as they do are important. Christiansson et al. (2011) believed that there are several methods to capture user needs and creative ideas such as interviews and questionnaires.

3.1 Subjects

One hundred and eighty two academic and non-academic UTM staff members (85 male and 97 female) participated in this research.

3.2 Material

A questionnaire survey was designed to identify proper window structures and materials based on the relationship between user expectations and windows as well as material features expected by users for flexible windows and user involvement. Identifying the best flexible windows would be more reliable if the reasons it was preferred could be investigated. Therefore, 11 black and white windows photographs and the words describing the reasons why an image was preferred were distributed among the respondents. In addition to the design principles that allow for disassembly, recognition of the factors that were the most preferred for windows that would experience a higher level of user involvement resulted in a better understanding of the decisive factors for a flexible window.

The questionnaire was divided into studying (a) respondent characteristics (b) window types preferred for user involvement by declaring the reasons, and (c) window materials preferred for user involvement by declaring the reasons. The survey results were transferred to the Statistical Package for the Social Sciences (SPSS) environment and evaluated using frequency and cross-tabulation.

3.3 Procedure

The initial questionnaire was pre-tested using a sample of approximately 25 UTM staff members. Some items were reworded to improve validity and clarity. Data for the main study was collected by applying a self-administered questionnaire survey as a data collection technique.

Each subject was asked what type of windows they would be interested in installing and they were also asked to express the reasons for their preferences, which had been prepared on the back of the page. Users chose only one type of window to make it possible to better identify features and evaluate characteristics. The same method was used for investigating material but without using pictures.

Table 1 shows the gender composition of respondents with females representing 53.3% and males 46.7% of the total distribution. The proportion of married individuals to singles was found to be 48.6% to 51.4%. The age distribution shows that 20-30 years, 31-40 years, 41-50 years and 51-60 years had corresponding scores of 51.1%, 22.0%, 21.4%, and 5.5%, respectively. Those 60 and above were conspicuously absent from the respondents. Classification of the respondents into Academic and Non-academic staff members revealed that academic staff members were in the majority with a total 62.6% of the respondents compared to 37.4% for Non-academic staff.

Table 1: Summarized demographic/housing characteristic frequencies

Demographic Items	Frequency	Percentage (%)
Gender		
Male	85	46.7
Female	97	53.3
Total	182	100
Marital status		
Married	88	48.6
Single	93	51.4
Total	182	100
Age		
20-30	93	51.1
31-40	40	22.0
41-50	39	21.4
51-60	10	5.5
Over 60	-	-
Total	182	100
Type of employment		
Academic staff	114	62.6
Non-academic staff	68	37.4
Total	182	100

4. RESULT AND DISCUSSION

4.1 Identifying Influential Area for User Participation

It should be noted that 69.5% of users had no interest in being involved in the process of window replacement. The probability of user involvement in the process may increase if the area of user involvement is recognized and improved.

Flexibility was used as a design feature that allowed for disassembly. Motevallian, Abhary, Luong, & Marian (2007) maintained there are six requirements that need to be considered while designing a product for ease of disassembly. These requirements are product structure and lay-out, parts, materials, joints, accessibility of the components, and ease of disassembly. An investigation of the ability of the effects of the above factors for stimulating users to be involved in the process of window replacement using a Likert scale is represented in Table 2. In this table, the highest mean revealed that a large number of respondents allocated the highest level of significance to the accessibility of the components. This was followed by the type of material, weight of the components, windows structure, type and then number of fasteners. These results reveal the priorities for product improvement if the involvement of more users in the process of windows replacement is to be encouraged.

Table 2: Level of importance for user influence in the process of windows replacement

Areas	1	2	3	4	5	Mean
Accessibility of the components	2.8%	3.4%	11.8%	36.5%	45.5%	4.1854
Material	2.2%	2.2%	17.4%	38.2%	39.9%	4.1124
Weight of parts	3.4%	7.9%	18.5%	48.3%	21.9%	3.7753
Type of Structure	5.1%	3.4%	26.4%	41.6%	23.6%	3.7528
Type of fasteners	2.2%	10.1%	34.3%	50.0%	3.4%	3.4213
Number of parts	2.8%	12.4%	36.5%	44.4%	3.9%	3.3427

4.2 The Eligible Flexible Windows Characteristic

4.2.1 Identify the Most Preferred Windows

Among the 11 window photos, users showed a remarkable interest in just 3. The results of the investigation are summarized in Table 3. It was determined that 29.1% of the users expressed their interest in pick up glider /slider windows, while 19.4% preferred casement windows and 14.3% chose jalousies windows (Table 3). These 3 different types of window provide designers useful insight into appropriate flexible window features according to user preferences. The level of user preferences for the other options was not remarkable.

Table 3: Preferred windows users interested in installing

Type of windows	Frequency (N)	Percentage (%)
Awning	3	1.7
Bay and bow	10	5.7
Casement	34	19.4
Double-hung	8	4.6
Glider /Slider	51	29.1
Hopper	1	0.6
Jalousies	25	14.3
Palladian	14	8.0
Picture windows	11	6.3
Center pivot windows	6	3.4
Single- hung windows	12	6.9

4.2.2 Identify the Relative Importance of Design Factors

The descriptive statistics for the influential features in the order of significance are shown in Table 4. The relative importance of features in influencing users can be understood by acknowledging their significance. In regards to the significance of the features preferred for flexible windows, excluding the DfD requirements, the results showed that the respondents look upon the number of parts (40.1%), followed by ease of operation (39.6%), simplicity of the structure (36.8%), fast process (35.2%), ease of maintenance (33.5%), lightness (30.8%), and guaranteeing health and safety for user (15.9%), as significant reasons for becoming involved in the process of windows replacement.

Table 4: Reasons of preferences for the preferred windows

Reason of preferences	Frequency (N)	Percentage (%)
Few parts	73	40.1
Ease of operation	72	39.6
Simple structure	67	36.8
Fast process	64	35.2
Ease of maintenance	61	33.5
Lightness	56	30.8
Health safety for user involvement	29	15.9
Compatibility with various home style	26	14.3
Installable at any height	17	9.3
Free of dimensional constraints	13	7.1

4.2.3 Identify the Relationship between Design Factors and Windows Structure

Fig. 1 portrays the relative weight for each factor by looking at the frequency of each preferred product according to its specific design features based on user opinion. This weight gives designers insight into each specific window characteristic as well as information regarding features based on user opinions and perceptions so that a better product can be developed. This data indicated that among those three most preferred windows (slider, casement and jalousies) the slider window was the most preferred style. This style of window had the most frequently selected features as well as meeting flexibility needs and DfD (See Fig. 1). Only the slider windows featured fewer parts, a simple structure, fast process, ease of maintenance, and protected the health and safety of users as demonstrated by cross-tabulation used to illustrate statistically significant results. Cross-tabulating the two other window styles with the reasons for their preferences revealed that ease of use and compatibility were the two most significant reasons for preferring casement windows while jalousies was the lightest window style.

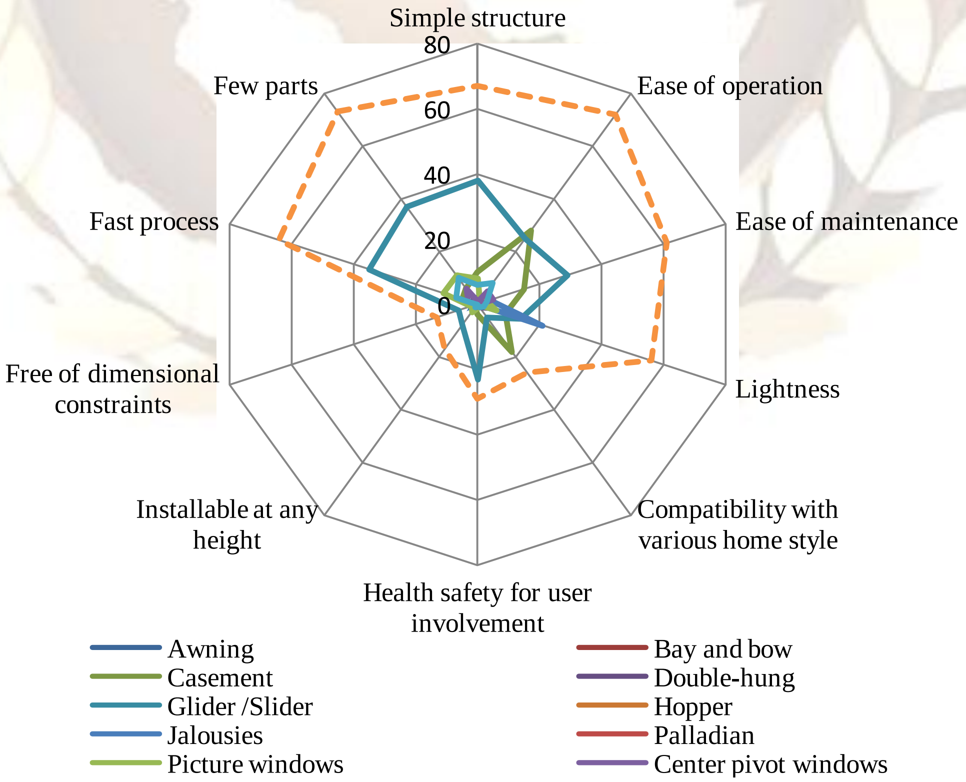

Figure 1: Preferred windows and their characteristic

4.2.4 Identify the Most Preferred Material

Material plays a key role in windows replacement and it can affect user psychological factors. Crilly, Moultrie, & Clarkson (2004) (as cited in Sacharin, Gonzalez, & Andersen, 2011) pointed out that despite the fact that emotions occur in response to perceptions about a product, they also influence judgments. Therefore, materials are the components that engage tactile and visual sensations. Wood had the most significant influence on user involvement (34.7%). Aluminum and PVC were next with 30.1% and 22.5%, respectively (See Table 5).

Each of the three most preferred materials has pros and cons that affected user preference. According to the literature and the results of this study, the increase in user preferences for wooden windows is more common in Malaysia compared to the rest of the world. Using wood as a material for flexible windows reflects earlier material preferences for windows, which demonstrated that the recent preference for PVC and aluminum has slowed (Korkut, et al., 2010). The contraction of demand for plastic material is a consequence of environmental awareness and the ecological approaches established in developed countries. The importing of these considerations to developing countries can be seen as an explanation for this trend.

Table 5: Preferred windows material users interested in installing

Type of Material	Frequency (N)	Percentage (%)
Wood	60	34.7
Aluminium	52	30.1
PVC	39	22.5
Wood with plastic cladding	10	5.8
Fiber glass	9	5.2
PVC-wood composite	3	1.7

Material selection was based on characteristics that covered design requirements, durability, upgradability and ease of maintenance and preservation. The frequency of the responses relating to the importance of specific features for flexible windows material indicated that people would like material offer in a variety of designs, colours, and styles (52.2%), that are easy to maintain and preserve (45.6%), are reusable and can be recycled (41.8%), lightweight (41.2%), durable (41.2%), easy to clean (33.0%), ensure the health and safety of the users during operation (31.9%) and have mechanical and resistance characteristics (30.8%) as illustrated in Table 6.

Table 6: Reasons of preferences for the preferred material

Reason of preferences	Frequency	Percentage (%)
Variety in design, colour and style	95	52.2
Easy to maintenance and preservation	83	45.6
Reusable and recyclable	76	41.8
Lightweight	75	41.2
Durable	75	41.2
Easy to clean	60	33.0
Ensure health safety during the process	58	31.9
Mechanical and resistance characteristics	56	30.8
Compatible with most home style	51	28.0
Adaptable	39	21.4
Repairable	38	20.9

4.2.5 Identifying the Relationship between Design Factors and Windows Material

Fig. 2 describes the preferred window materials according to their specific features compared to the most frequently expected features. Reusability and recyclability, compatibility with various home styles, reparability, variety in design, colour and style, safe processes and adaptability were cross-tabulated to produce a statistically remarkable result in favor of wooden flexible windows. In fact, wooden windows, because they are handmade, have the capability of being compatible with different types of dwellings. In addition, this increases reparability as well as its adaptability and the ability to provide a new look. What makes these findings interesting is that wood was considered to be the safest material. Sacharin et al. (2011) in a study called *Object and user levels of analyses in design: The Impact of Emotion on Implicit and Explicit Preference for 'Green' Products* reported that 'green' products focus on how a product expresses ideas related to being natural and safe. In fact, it was found that those products that are perceived as natural convince users by sending the message that they are also safe. In fact Saccharin's report gave an explanation for why wood is perceived as being safe.

Aluminium was chosen several times because of its ease of maintenance, mechanical and resistance characteristics and durability. Finally, PVC, the other popular material, was preferred firstly, for its lightness followed by ease of maintenance and preservation and variety and versatility in design, colour and style.

The reliability of the reasons for the preferences for each material was explained by findings about problems encountered by users of PVC, aluminium and wooden windows. Korkut et al. (2010) reported problems encountered by users with PVC windows that included difficulty cleaning, installation defects, lack of mechanical resistance, colours that were quick to stain or fade without the possibility of adaptation. Moreover, aluminium windows were found to be difficult to clean, heavy and changed colour over time. Wooden windows had their own share of problems as they had joints that lacked mechanical resistance and deformed quickly, were difficult to maintain and lost durability over time. In Figure 2, surprisingly, the length of the axis for each material indicating these characteristics is insignificant. This indicates that these problems and shortcomings are universal concerns. In general, there was a noticeable gap between the most frequently demanded features and each of the preferred material features, which represented the imperfection of recent materials for flexible windows.

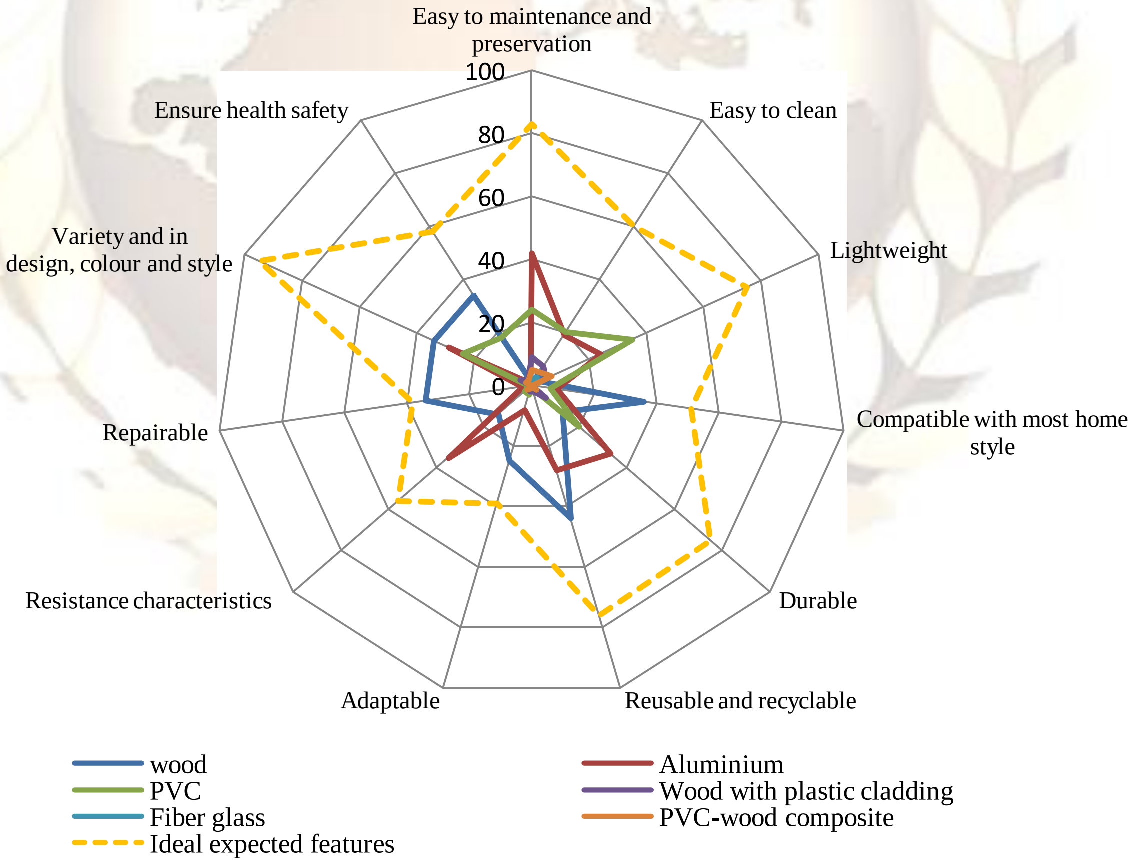

Figure 2: Preferred material and their characteristic

4.3 Developing Flexible Windows Design Models

The overall importance of the specific preferred features used to identify design requirements was illustrated. When these features and design principles are used for disassembly, more appropriate flexible window designs are developed. Generally, a flexible window should be designed to fulfil the following criteria; durability, versatility, access to services, redundancy, simplicity, upgradability, and independence. Investigating an appropriate flexible window design would be accomplished by looking at different factors namely, product structure and lay-out, parts, materials, joints, accessibility of the components, and ease of disassembly.

4.3.1 Product Structure

Generally, the cost and quality of the disassembly processes are influenced by the structure of the product. Minimizing complexity when assembling a product has been recognized as a way to enhance product quality, helping to reduce defect rates and assembly costs (Van Wie, Greer, Campbell, Stone, & Wood, 2001). Therefore, flexible windows structures must be simplified in order to offer significant opportunities for decreasing the level of complexity, costs, fewer disassembly operational steps and enhancing the level of maintenance for the components and materials.

Within this study, the structure of slider windows was identified by a large number of respondents as its most favorable feature. The root of such a substantial level of agreement could be explained by how the simple structure of this type of window minimizing handling efforts by decreasing the need to adjust the openings. Previously, Motevallian et al. (2007) and Boothroyd (1999) (as cited in Booker, Swift, & Brown, 2005) maintained that one of the design strategies for assembly strives to eliminate the need for constant alignment and adjustments. In fact, a self-locating method of opening integration within slider windows is the reason for this advantage (See Fig. 3). As a result of employing self-locating techniques, a number of disassembly efforts, the number of fasteners, parts, hardware, tools, required time, and energy, and possible threats due to using the needed tools, will be decreased.

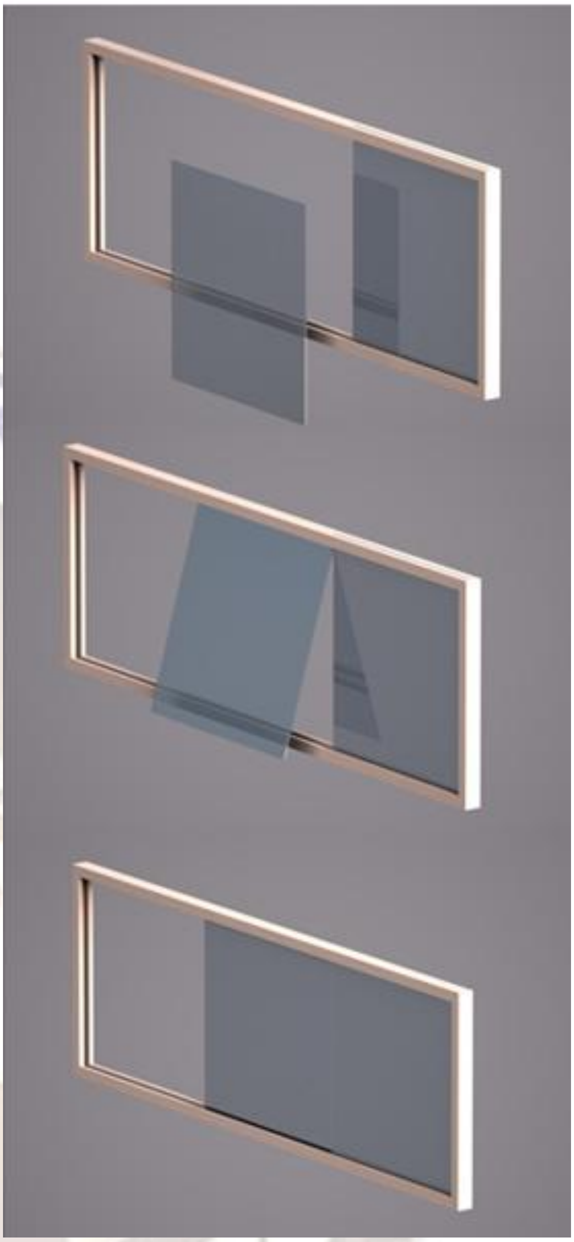

Figure 3: Sash installation as well as reinstallation by means of self-locating in slider windows

4.3.2 Ease of Disassembly Efforts

There are various strategies for promoting easy disassembly efforts. First, flexible windows components should be demountable. Although this feature exits in more recent window designs, frames that act as the foundation of the structure do not follow these requirements. As a result, permanently fixing window frame for the purpose of eliminating the deconstruction process should be avoided.

Self-locating techniques are the proposed strategy for opening integration. However, this strategy should be designed in a way that installing the components in an incorrect position would not be possible. This will result in decreasing the level of complexity. The insert window frame installation method is one of the two common methods of windows installation. Here the insert windows installation method should be employed instead of the full frame method. Comparing the pros and cons of each method reveals the usefulness of the insert frame installation method. Developing versatile frame for the purpose of increasing the capability of accepting various types of windows is also required.

4.3.2.1 Insert Versus Full Frame Window Installation

Each method has its own advantages and disadvantages. The full frame process necessitates tearing the frame out completely by destroying the area between the frame and the walls. Consequently, this process creates construction waste, affects the old frame and decreases the possibility of reusing the frame. However, in the insert procedure, the insert frame is put on the original frame. Table 7 and Table 8 cover the pros and cons of both methods.

Table 7: Advantages and disadvantages of full frame windows replacement

Full frame window installation	
Advantages	**Disadvantages**
▪ Light loss is not as much of a concern ▪ Increase total glass area for the same opening ▪ More of a custom finish ▪ Confirmation that the original installation did not have any leaks ▪ Lots of custom finish options and upgrades	▪ Usually involves destruction to exterior surface ▪ Usually 2X the cost of retrofit windows ▪ Time-consuming installation ▪ Destruction to interior finish because of increased frame size ▪ New paint typically needed to fix exterior finish

Table 8: Advantages and disadvantages of insert windows replacement

Insert window installation	
Advantages	**Disadvantages**
▪ Decreasing costs ▪ Much quicker installation process ▪ Typically no damage to exterior finish	▪ Wider frame means some light loss will be experienced ▪ Sometimes considered a cheaper option for resale purposes ▪ Cannot confirm the integrity of the original window instillation ▪ Fewer options and upgrades

The disadvantages of insert windows replacement are undeniable. However, it does have the advantage of a design for disassembly, which may outweigh the disadvantages. Insert windows are more useful because they are cheaper, faster, easier to install and less destructive.

4.3.3 Parts

It has been suggested that a product for disassembly should be designed by minimizing the number of components on the grounds that the number of parts has a direct correlation with economic efficiency factors in terms of time and cost. In addition, an inverse correlation exists between the number of mechanical components and further usability (Booker, et al., 2005; Branan, 1991; Guy, Shell, & Esherick, 2006; Motevallian, et al., 2007). Surprisingly this study produced result that showed users allocate the same levels of importance to design principles that allow for disassembly as they did to the number of parts. This is understandable since fewer parts was an expected flexible windows feature. Although, the number of flexible windows components should be as few as possible, an acceptable level of functionality should not be overlooked. Furthermore, designing heavy items, sticky parts and parts with sharp-edges should be eliminated to prevent slower processes, threats and a lack of user involvement.

4.3.4 Materials

Material has a great influence on the process of windows replacement and DfD. This surveyed identified materials as the second most important factor for user involvement in the process of windows replacement. Since flexible windows design should be in accordance with DfD guidelines, material selection should employ recyclable materials, and consider lack of variations in the materials. Using toxic, composite material and metal reinforcement in plastic parts should be avoided. This not only results in decreasing disassembly operational time but it also decreases the costs of separating and sorting materials for the purpose of recyclability (Booker, et al., 2005; Deller, et al., n.d.; Guy, et al., 2006; Motevallian, et al., 2007). In addition, designers should be aware that according to the findings of this survey, people appreciate materials that provide them variety of designs, colors, style, are light, and are easy to maintain and clean.

Improving the relationship between humans and their environment and supporting user comforts and personal well-being would not be possible unless physical, functional and psychological comforts are improved. Therefore, the functional aspects of the windows material are important. These sorts of features are ease of maintenance, reparability and durability. The present findings are supported by Korkut et al. (2010) who found that easy cleaning, maintaining, repairing as well as the ability to easily change the windows were the problems encountered, the reasons for discomfort and lead to recommendations for window improvements in Turkey.

Wanting a variety of designs, styles and colors is explained by the impact of color on humans. Jalil, Yunus, & Said (2012) believed that in the physical environment, color has an important role in influencing physically, psychologically, physiologically and sociologically aspects.

Wood was the most favored material among the users in spite of some of its shortcomings. For instance, in spite of offering variety of designs, styles and colors, wooden windows are difficult to maintain and preserve (Korkut, et al., 2010). Although wood is a renewable resource, creating wooden windows requires less energy and generates less pollution compared to the other materials, it still has some negative environmental effects.

Aluminum is not without its shortcomings. Although the level of user preferences for aluminum was lower that it was for wood, this type of windows material offers a variety of designs is easy to maintain and preserve, and it is adaptable and recyclable. However, producing this kind of window material is energy intensive and requires a large amount of electricity which causes economic and environmental issues (Korkut, et al., 2010; National Center for Healthy Housing, 2005).

Pure vinyl frames do not need preservation. Comparing the process of producing vinyl and wooden windows frame shows that the process of vinyl production requires less manufacturing time. Although it is durable, the health and environmental effects from producing, using, and dealing with related waste products require precautions.

Overall, the literature and findings from this study suggest that there is a need for further research to develop an appropriate windows material for flexible windows.

4.3.5 Accessibility

The accessibility of the components is crucial factor for disassembly operations and it has a direct relationship with time and cost (Motevallian, et al., 2007). A high level of accessibility in the configuration of flexible windows results in decreasing time and cost needed for the process of windows replacement. The position of structural components should allow for disassembly. Also, component should be designed so that there is a clear path for removal (Deller, et al., n.d.; Guy, et al., 2006; Motevallian, et al., 2007). This survey showed that accessibility of the components was the most effective factor for encouraging users to be involved in the process of windows replacement. However, windows frame installation does not support a high level of accessibility.

4.3.6 Fasteners and Joints

Fasteners and joints were the fifth most important parameter for user encouragement in this study. Fasteners have a vital impact on recovery and the process of disassembly. How fasteners should be considered in flexible windows design starts with the number of joints and fasteners. Since there is a direct relationship between the number of the fasteners, time and cost of operation, the number of fasteners should be reduced without impacting functionality. Joints must also be simplified and be easy to undo to prevent difficulties, complexities and decrease inherent risks as well as probable damages. Permanent integration connection techniques should be prevented. Moreover, decreasing the number of tools required would not be possible unless by the standardization of windows connector design is enforced. In fact, employing the same size of joints within the same system decreases the variety of tools needed.

5. CONCLUSION

This paper represents initial knowledge for developing flexible windows based on the principles of DfD and understanding user expectations. This study set out to introduce the idea of developing flexible windows that could be disassembled to eliminate the problems by carrying out investigations related to the meeting the requirements, user expectations and enhance environmentally friendliness without causing any health risks. The results of this study and a review of the relevant literatures suggest that in order to create flexible windows, designers should come up with a simple structure in order to decrease the level of complexity, disassembly operation steps, number of parts, cost and time required. The relationship between the accessibility of components to time required and cost, and the discovery that this factor was one of the most important factors for influencing users in the process of windows replacement indicated that the structure of a product should support a high level of accessibility. The permanent integration of the frame and other components must be avoided. Materials were the second most important factor when it came to user involvement and any materials chosen should be environmentally friendly. Any materials employed in the process of window construction should facilitate a wide product range and selection, ease of maintenance, and be lightweight. The intention of flexible window systems is to improve user physiological and psychological housing requirements. Facilitating reusability, reparability, remanufacturing and recycling will result in needed resources for future markets. Encouraging these factors will also improve job opportunities. In addition to providing opportunities within the waste management sector, new job opportunities in the installation industry are plausible, as not every respondent will be interested in installing their own windows. The results of this study add substantially to the requirements of inventing a flexible window. The fenestration of today must be continuously developed into the fenestration of tomorrow.

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