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Classification and Utilization of Design Supportive Tools in Architectural Design Process

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ABSTRACT
The architectural design process has used a variety of design supportive tools with the potential of emerged new technologies available to architects today. Unfortunately, there is no comprehensive classification of design supportive tools in practice. Today's architects are practicing various advanced technologies in design activity, but they have the insufficient ability and method for utilizing artifacts into the design process. The issue mentioned above is problematic because new tools and applications have been developed without knowledge of clients. To achieve a reliable tool assessment, subjective factors such as client feedback must be considered as criteria of selection tools. Foremost, it requires comprehensive investigation of the current situation of architectural design practice. This study aimed to introduce a descriptive and holistic framework of the factors affecting the adoption and utilization of design supportive tools in architectural design practice. The significance of this study is that architect and client need to employ the design supportive tools based on the character and nature of each stage of the design process to achieve the design objectives. Thus, appropriate tools will help them to present the solution in a way which is understandable and tangible to both parties. Tools have a prominent role in this approach and because of vast development in design and communication tools in the digital era, by adapting the technological and behavioral changes into a design process an innovative approach will be generated.

Key words: Design supportive tools, architectural design process, utilization, communication, visualization

INTRODUCTION

The advent of digital information and communication technologies has forever changed the practices of architecture. The greatest changes can be seen in the tools and methods used by today's architects. In the architectural design process, the architect has traditionally viewed in the role of design specialist, which has managed or coordinated the whole design process. Design can be identified as a social construct and this means that the traditional role of the architect included navigating through a complex maze of clients and process to complete a design project. Now, architects must add mastering digital tools to their skill set. Any discrepancy between what the architect must accomplish and the available tools creates difficulties. New tools and technologies are continuously being developed but they are often used with no understanding of how they could affect architectural design process (Moum, 2008). It is becoming increasingly more important to examine the impact of digital media on the design process (Oxman, 2008).

Design tools and technologies aimed to allow the architect to design more intelligently and effectively. The one way for assessing the influence of digital technologies on a design process or design activity is to examine how much they empower the architect and the client (Kirkman *et al*., 2004). New computing technologies has improved the efficiency, control and intelligence of the design process and they have become essential for the architectural practices (Kalay, 2006). However, the practice of architecture is an ancient one and the incorporation of new technologies has resulted in an uneasy relationship. On the one hand, new tools are often poorly used or used for the wrong design task. On the other hand, this ancient discipline lacks the language to describe these phenomena. Failing to develop an appropriate vocabulary indicates that the power of developing technologies is under appreciated (Chastain *et al*., 2002).

Therefore, every Design Supportive Tool (DST) should be recognized precisely and classified based on the nature and the function of each design stages. Eventually, all barriers and opportunities, which affect the utilization of DST in the Architectural Design Process (ADP), should be investigated to determine the effective factors on the utilization of DST in the design process.

DESIGN SUPPORTIVE TOOLS: CLASSIFICATION OF TOOLS IN THE ADP

The architectural design process is becoming more complex and fragmented. This move may be due to harsher regulations, the advancement of technologies and growing of specialization (Norouzi *et al*., 2015a). Regardless of the reasons behind the complexity and fragmentation, the range and the availability of DSTs have been increased. The DST encompasses a various range of tools from basic checklists to the complicated software, which could support different design processes (Weytjens *et al*., 2009). However, very few studies have been focused on how DST frequently used and widespread (Lam *et al*., 1999; Mahdavi *et al*., 2003). This lack of information contributed to the problems for developing of tools without full understanding of the architect and clients' need (Weytjens *et al*., 2009).

The Fig. 1 over viewed the DSTs in the architectural design process. The design process here was assumed a linear process that includes feedback loops between each stage of the design process. However, some researchers have described the design process as a dynamic circular process that includes continuous feedback loops. The DSTs can be classified as being knowledge based, communication, visualization or presentation, evaluating and analysis tools. It might be possible for a tool to belong to more than one category mentioned below (Weytjens *et al*., 2009).

In Fig. 1, the vertical arrows indicate knowledge-based or information processing tools. These tools provide architects all design information that can be immediately used in the design. At the top of Fig. 1, the horizontal line indicates DSTs used for evaluation and analysis of design activities. These tools allow the architects and clients to monitor the design continuously and ensure that it is performing as expected. When the architect needs to update a design or present the design to a client, visualization and presentation tools is employed. The dotted horizontal line denotes communication tools (Weytjens *et al*., 2009). As designs become increasingly complex and the need for effective communication grows, the demand for DST specifically for architects grow. Also to all the purposes discussed this far, computers offer the perfect solution (Sariyildiz and van der Veer, 1998) that can also be used to create better design and design processes.

COMMUNICATION TOOLS IN ARCHITECTURAL DESIGN PROCESS

Supporting design solutions and the evaluation of design decisions as well as keeping the client updated with design activities is the reason behind communication during all stages of the design process (Norouzi *et al*., 2014). How these items are represented provides a medium for communication (Shen, 2011). The development of design ideas relies on skills of architect to select the best medium that can enable him to utilize representational techniques into ADP. Important communication skills include selecting and using appropriate design applications, listening to clients and encouraging meaningful communication (Breu *et al*., 2008a). Advances in computer technologies have brought about the development of Information Communication Technology (ICT) and has changed how the performance of a building is represented and has subsequently improved client-architect communication (Shen, 2011). Demkin (2001) pointed out that, "Strong client-

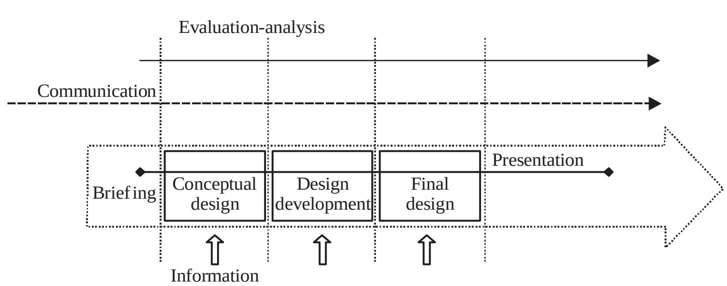

Fig. 1: Overview of design process and design supportive tools based on Weytjens *et al*. (2009)

architect relationships are rooted in understanding, commitment and effective communication and serve to reinforce client satisfaction." Clearly methods for enhancing communication about client requirements and design solutions will benefit the design process (Shen, 2011).

Communication tools are employed by a client to view rich design information and client-driven innovative ideas (Sanders, 2000; Sanders and Dandavate, 1999; Visser *et al*., 2005). Communication tools have become the preferred instruments for architect-client collaboration (Lee, 2008), which, they are particularly useful for generating ideas when the client is unsure of their needs. Muller (2002) stated that communication tools provide the following advantages:

- Contextualized communication between stakeholders is richer
- The architects and the clients worlds are more engaged
- Stakeholders collaborate better and develop a stronger collective voice
- Communication are used to enhance sensation, knowledge and expression
- The ability for emotional expression is provided
- The subject experience of a user is acknowledges

Employing communication tools in the design process has a beneficial effect on architect-client collaboration (Norouzi *et al*., 2015b). These tools provide a means through which architects and clients can discuss the design requirements and desires. Moreover, communication tools concentrate on widening the mutual understanding of the client's experiences including latent needs (Lee, 2008).

Information and communication technology in ADP: The importance of the tools and techniques used in the design process to gather design information cannot be over looked because they influence communication. One method of gathering design information is the Face-To-Face Interaction of architect-client. The FTF communication provides unspoken cues that can further improve communication and decrease misunderstandings. As mentioned earlier, the design process changes over time as a result, participants often rely on informal methods of communication such as FTF conversations and telephone calls to quickly resolve problems. The results of a study conducted by Breu *et al*. (2008a), revealed that real communication during a design project was typically the result of using informal communication techniques. Further studies showed that there are two parallel information paths. The first path is a formal channel (Fig. 2) and the second path is an informal channel where information is processed using informal communication techniques to resolve any ambiguities (Breu *et al*., 2008a). Communication has evolved from the early days of the telegraph to today's Computer-Mediated Communication (CMC). Computation plays an important role in design communication. Since the late 1960s, computers have been used as communication devices, at least experimentally (Licklider and Taylor, 1968). Ongoing technical advances have created a "network society" that reflects how persuasive CMC is in our everyday lives (Barney, 2004).

Communication and computation also positively influence the design process by creating a collaborative environment. As a consequence of sharing the information in this collaborative environment, more fitting solutions are found (Griffith, 2012). Design environment are becoming collaborative as they move away from depending on static linear processes to a setting where the focus is on dynamic and participatory processes where stakeholders can add information to the design process (Fig. 1). Employing the right tools and technologies that support the development of collaborative environments and correctly representing design information is essential, especially when stakeholders are separated by distance. A framework can be used to demonstrate the role played by

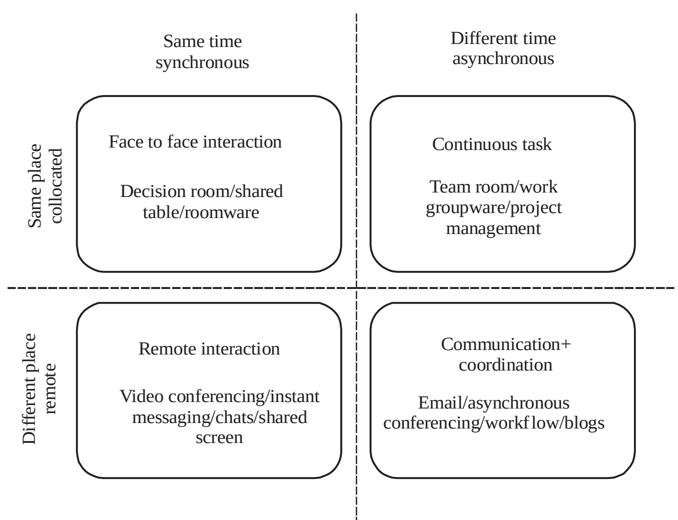

Fig. 2: Time/space classification of communication as a design supportive tool based on Johansen (1988)

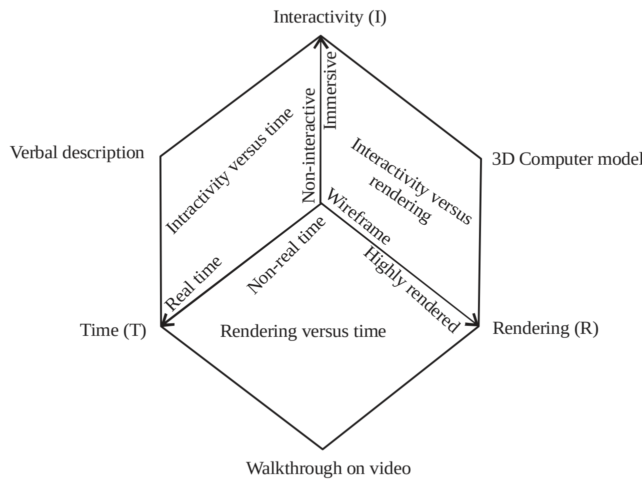

Fig. 3: Definition and scales of means of architectural communication

information in the design process, especially when the architect is far away from the client and context of the design. A framework can be a technical intervention that employs information and ICT so that architects and clients can remain part of the design process. Another example of a framework takes the form of developing the tacit and contextual knowledge of the architects while maintaining communication with clients and encouraging their participation in the collaborative design process (Griffith, 2012).

Several researchers have pointed out that the infrastructure required by ICT must be provided so that all participants can communicate (Pietroforte, 1997; Kamara *et al*., 2002; Breu *et al*., 2008b). This communication infrastructure includes the systems, equipment and software required to transmit information. Communication infrastructure supports the communication and collaborative processes required by successful designs (McGillan, 2009). Synchronous and asynchronous types of communication are used when participants communicate on a design project (Kumar, 2008). These design characteristics mean that technologies that allow for continuous, fast and flexible interactions between stakeholders are critical. The ICT permits interactions and coordination to occur (Pietroforte, 1997). Iterative media allows stakeholders to communicate about ambiguous situations that may occur during the design process (Daft and Lengel, 1986).

VISUALIZATION AND PRESENTATION TOOLS IN ADP

Paper-based technologies remain a popular way for architectural design to be presented and communicated. Despite their popularity, paper-based designs do not provide a full representation of the mental design model held in the mind of the architects. They also cannot be used to represent a changing perception of space, provide instant evaluations, or immediately adapt to changes. These critical aspects of a mental design model rely on design information processing. Digital visualization overcomes many of the drawbacks of paper-based technologies as it provides a way to present architectural designs in all four dimensions as well as embedding additional knowledge and proving analysis. Digital visualization bridges the gap between the actual design and its abstractions (Senyapili, 1997). The visualization defined as, “the act or process of interpreting in visual terms or of putting into visible form” and the, “formation of mental visual images.” Graell-Colas (2009) used this definition of visualization to define the term “visualization tools” as the instruments used to develop mental visual images or the mechanisms used to process visual information. The use of images in design imaging can be defined as, “a vivid or graphic representation or description.”

Nowadays, Virtual Reality (VR) is the most advanced virtualization technology. The future is bright for using VR in the field of architecture. On the one hand, VR technology provides a powerful media for displaying a design. In addition, VR allows the original design to be easily changed or modified long before any building occurs. Visualizing a design by VR impacts not only architecture but also design communication (Senyapili, 1997). In contrast to traditional design presentation tools, VR allow participates overcome the common challenge of interpreting two-dimensional representations of the three-dimensional object thus decreasing misunderstanding between the client and the architect (Kim, 2005).

Design information presentation and level of visualization: Figure 3 illustrates the scales used to describe the degree of information processing or visualization in an architectural design. The interactivity scale indicates the difficulty of defining and completing tasks. The time scale represents the time the display was available compared to the time consumed to create the representation. The third scale is the rendering scale and it ranges from the inconsequential and poorly executed renderings to high quality renderings that can be used for performance analysis as shown in Fig. 2 (Senyapili, 1997).

Thus, the level of design presentation and visualization could be determined by this classification. Moreover, it depends on subjective factors such as the purpose of visualization, the level of the architects and client's experience and the target of design. These factors enable the architect and the client to determine automatically the level of visualization. The classification could be used with any visualization software ranging from 2D drawing, 3D modeling and animation to simulation is addressed in different design context and different area provided with different infrastructure. Being able to define the level of visualization, the architects and the clients will have the flexibility to select different visualization techniques in architectural design and use it in virtual environments more efficient.

DEFINITION OF VIRTUALIZATION: LINKING COMMUNICATION AND VISUALIZATION

The term "virtual" refers to the blurring of the line between perception and reality or an original and its copy. A Virtual Reality (VR) can be created using digitally generated spaces that include objects. Geometry, attributes and behaviors are characteristics used to identify these objects. The VR environments become practical when users can interact with the objects (Moosavi, 2006). The growing popularity of virtual realities has positively impacted architectural design. To adopt a virtual reality technique and related tools in architectural design effectively, a classification system must be developed so that the most appropriate method can be determined (Schnabel *et al*., 2007).

Design visualization, presences in virtual space: Typically, VR is defined in terms of the hardware used to create it. It is less discussed in terms of the nature of the experiences it can provide. Unfortunately, a technological rather than experiential focus does not explain the processes or benefits of using VR. Defining VR according to the experience it provides instead of concentrating on technology is known as presence (Steuer, 1992). More concisely, presence is the feeling of being immersed in an environment. Several perceptual factors are responsible for creating a sense of presence. In addition to the sensory stimulus, mindfulness of the environment, perceptions and the mental process of interpreting stimulus improve the feeling of presence (Steuer, 1992). According to Heeter (1992), the distinct presences that create an overall sense of "being there" are the personal, social and subjective presence. Personal presence relates to how immersed the architect and the client are in the virtual environment. Social presence is the

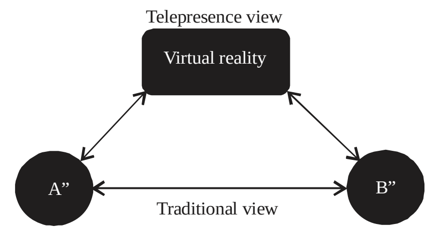

Fig. 4: Virtual reality and media: model of mediated communication

concern with the other entities encountered in the virtual environment, real or computer generated. Subjective presence refers to the intensity of the virtual environment experienced by the architect and client (Rahimian *et al*., 2008).

Design communication, telepresence in virtual space: An additional form of presence is tele-presence, which occurs when an environment is created using a communication medium. Unlike the type of presence defined above (Fig. 4), telepresence is the mediated perception of the environment that communications technology can be used to mediate perception. However, when communications technology is used to this end, the receiver must simultaneously be present in the physical environment and the environment created using the communication technology (Steuer, 1992).

The physical interface between the user (architect/client) and the computer is composed of physical and sensory components as well as the user's (architect/client) "mental mode" and how well the computer knows the user (architect/client). In other words, the interface is a virtual space where an architect and client can meet and communicate. Telepresence depends on both technology and the perceptions of the architect and client (Steuer, 1992). Sensory stimuli, how the architect and client interact with the virtual environment and the individual personalities of the architect and client will all affect telepresence. Variables that affect telepresence can be classified as either technological or context based (Sheridan, 1992). Examples of technological variables include the amount of sensory information available, how sensors in the environment are controlled and the ability of the architect and client to change the physical environment. Factors related to information communication technologies that affect telepresence are vividness and interactivity and are discussed below:

Vividness: Vividness is an expression of the sensory richness of the virtual environment. Sensory breadth is related to the amount of sensory stimulus concurrently could be experienced by the architect or the client. It also refers to the ability of the communications technology to stimulate each of the five senses (Steuer, 1992). On the other hand, sensory depth is related to the clarity or resolution of the stimulus. The more redundancies present in the virtual environment, the more vivid it will be.

Interactivity: The degree to which architect and client can participate in or even change a virtual environment is a reflection of how interactive the virtual environment is. Stimulus plays an important role in interactivity and it is determined by the technology used to create the environment. Factors that influence interactivity include speed, or how quickly new information is integrated into the virtual environment, range of possible actions and mapping, or the system's capability to manage changes in a realistic fashion (Steuer, 1992).

Therefore, VR would able to produce virtual environments that design requirements and design solutions could be presented. Additionally, the architect and the client can interactively communicate about design, design modification and design decision in such a virtual environment.

ADOPTION OF DST IN ADP: BARRIERS AND OPPORTUNITIES

The ICT refers to the integration of technologies and applications that harness the benefits provided by computers for data processing, storage and presentation with the ability of telecommunication technologies to communicate over large distances (Child, 1987; Pietroforte, 1997). In the fields of architecture, engineering and construction, the impact of ICT has not been as significant as anticipated. One reason that its impact has been dampened is that design and engineering work remains time-consuming. Other factors contribute to the time it takes to finish a project, including differing frameworks and knowledge bases, how labor is divided and the solitary nature of several design tasks. In addition to the challenges resulting from ICT, there are internal and external obstacles in the building design industry (Alaghbandrad *et al*., 2011). These obstacles are listed below.

Infrastructure: A set of hardware and software that provide reliable electronic services to clients and architects are part of the infrastructure. Thus, success characteristics of virtual communication and design strategy are to implement a widespread and high-quality ICT infrastructure. That will support a clients' and architects' experience of easy and reliable electronic access to each other and design information as well. In some instances, videoconferencing use a communication tool is not effective without high-speed Internet. Moreover, regulations that hamper the development and use of ICT tools may be in place and may need to be revised (Ebrahim and Irani, 2005).

Financial considerations: Cost of installation, operation, maintenance and training of design and communication tools are as financial characteristics. In addition to high cost of ICT professionals and consultancies, ICT cost especially in developing countries is high. The development and training of ICT systems can be expensive and may be out of the reach of those practitioners who do not have a reliable source of income.

Technological characteristic: Technology can be defined as a tool an individual uses to complete a task. In information systems, these tools take the form of computers systems and support services. Software quality define as, the capability of the software product to enable specified users to achieve specified goals with productivity, safety, effectiveness and satisfaction in a specified context of use' (Al Sudairi, 2013; Deng, 1999). The characteristics that are used to evaluate software quality are functionality, reliability, efficiency, usability, maintainability and portability.

Individual attitude: A great deal of research has been conducted regarding the attitudes and behaviors of users that how specific characteristics of tools affect user attitudes about the tools. For example Goodhue and Thompson (1995) found that high-quality tools or charge back policies, respectively, affected what they thought about the tools. Other studies built on these ideas and discovered that social norms, as well as user attitudes, created the intention to use tools. Eventually, these intentions turned into actual use (Goodhue and Thompson, 1995). Architects trained to use paper-based methods and who have used those methods over a long period resist trusting and using new ICT tools. In this matter, the easier it is to use ICT technology, the more likely it is that all architects and clients will use it, including those architects and clients who may be reluctant to try new technologies.

UTILIZATION OF DST IN ADP: LINKING TECHNOLOGY AND INDIVIDUAL ATTITUDES

The terms used to explain the connection between attitudes, behaviors and a decision to use specific tools known utilization. The behavior exhibited by an architect and client in terms of using DST to finish a design is known as utilization. The design task is an action that turns client's needs and requirements into the design alternatives and final design. Depending on the nature and type of the design, an architect and client may use a tool such as a computer system to complete the design. Utilization has been measured using the frequency or variety of tools and applications used. The decision to use a tool is influenced by social norms and expected outcomes. If a technology did not meet their expectations, they are unlikely to continue to use it. However, if a technology performed, as it should or if it exceeded expectations then the architect and client will continue to use the DST in the future. Feedback, which is the result of what happened when an architect and client initially used a DST and experience may also create a situation where they learn to use the technology better and improve the appropriateness of the specific DST to the architect and client (Goodhue and Thompson, 1995).

CONCLUSION

In this study, DST has identified precisely and classified based on the nature and the function of each design stages. This study directed on communication and visualization tools as a part of DST due to the important role-played in the perception of design as well as generating same design language to the architect and client in the design process. Then communication tools classified based on the time and space availability to the architect and client. This classification introduces a variety of tools enabling architects and clients to have synchronous and asynchronous design interaction in the entire design process. Visualization tools classified based on the interactivity, rendering and time, which introduce a wide variety of design presentation tools with the high resolution of artificially designed spaces to the architects and clients. Moreover, VR recognized a way to produce virtual environments that the architect and the client can interactively communicate about design, design modification and design decision.

All barriers and opportunities, such as infrastructure, financial, technological and individual characteristics investigated, which affect the adoption of DST in the architectural design process. Then practical factors such as client and architect’s attitude, behavior and feedback determined on the utilization of DST in the design process. Finally, architects and clients with consideration of tools classification, adoption and utilization criteria would be able to employ the right tools in the right design stages to enhance the quality and efficiency of the architectural design process.

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