

**THE APPLICATION OF VISUALISATION
TOOLS TO ENABLE ARCHITECTS TO
EXPLORE THE DYNAMIC CHARACTERISTICS
OF SMART MATERIALS IN A
CONTEMPORARY SHANASHIL BUILDING
DESIGN ELEMENT FOR HOT ARID CLIMATES**

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School of the Built Environment
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DEDICATION

To my parents

ABBREVIATIONS

(ARCs)	Anti-reflective Glass Coatings
(BIPV)	Building Integrated Photovoltaics
(EC)	Electrochromic
(PVs)	Photovoltaics
(SHGC)	Solar Heat Gain Coefficient
(T _{sol})	Solar Transmittance
(T _{vis})	Visible Transmittance
(U-Value)	Thermal Transmittance

ABSTRACT

Contemporary architecture has changed the features of building façades and this affects the design identity, forms and aesthetics, yet despite the advantages of modern technology, architectural elements have difficulties in fulfilling the idea of beauty that once traditional elements provided. This problem calls for an interdisciplinary design approach to deliver sustainable development solutions to protect and control against the surrounding environment, especially in hot arid climates. This research seeks to select a smart material which mimics the dynamic characteristics observed in nature, inspired from biomimetics, taking into consideration the role of sustainable development. Such qualities are found in the characteristics of smart dynamic glazing material particularly in the switchable, reversible properties of transparency and colouration efficiency.

With this in mind, can a traditional window/wall/balcony design element be revived through the integration of new smart materials?

This study adopts a design science methodology incorporating methods of biomimetics, analogy, and 21 semi structured interviews with a thematic analysis as the main data analysis technique. The emergent findings are then evaluated by conducting further interviews with 6 architects, where the material characteristics are attached to a digital prototype to visualise the difference between dynamic and static properties. Lumion 3D, Smart glazing VR, and Revit plugin visualization tools were used to develop a 3D digital prototype that expressed the difference between a traditional window/wall/balcony element and smart dynamic glazing element. These tools were needed not just to engage the interviewees to be part of the design process, but also to provide a clear illustration of the dynamic material characteristics and its impact on the architectural façade to improve design quality. Whilst they favoured the smart material in improving environmental control it was not favoured in its aesthetic aspects due to the transparency role and the abstraction of screen pattern details. Accordingly, the fixed image of traditional shanashil still imposes difficulties in understanding the dynamic characteristics, both aesthetically and functionally.

This research concludes that the dynamic characteristics of smart glazing material are effective in delivering a multifunctional design quality. However, they still lack the

potential to illustrate aesthetic aspects regarding colour, texture, order and proportion. Future research is needed to improve dynamic material characteristics in order to collectively blend in harmony with the surroundings.

Chapter One

1 Introduction and Background

1.1 ARCHITECTURE AND TRADITIONAL ELEMENTS

Architecture is embedded in human community and culture providing shelter from changes of the surrounding environment, with the house considered a basic social element (Al-Thahab, Mushatat, & Abdelmonem, 2014). The rapid changes that came with modern planning systems have affected architectural and planning standards favouring the international style and its association with industrial and technological developments (Al Silq, 2011; Al-Ahbab & Neama, 2011). One of the main criticism of modernism in architecture is its contempt and disregard for the inherited social, cultural, environmental aspects (Bianca, 2000). This is exemplified through the rejection of the organic pattern of the traditional in favour of the benefits of the gridiron layout in modern urban planning. Further, the crucial point is that contemporary design elements have been imported without having been questioned as to their suitability, aesthetic satisfaction, and ability for the design to blend in harmony with surroundings (Eben Saleh, 1997).

As a result new design preconceptions have ignored cultural values and affected the overall design quality that was provided by traditional architecture, at the expense of form and environmental aspects. Raouf (1985) and Eben Saleh (1997) explain that since the early twentieth century, and precisely following the oil-economy boom in the 1970s, the new approach favoured different features that are disconnected from social values. For instance, in Iraq, economic and social changes have affected design in social and cultural inherited aspects (Heynen, 2000; Nouri, 2014; Salama, 2011), and consequently, the design pattern of the buildings' façades has changed. A good example is seen in the traditional architecture of Baghdadi housing that has lost the distinctive features of the *shanashil*. These elements are a closed wooden balcony extending from first floor of the façade. They were a multifunctional device which worked as a window/wall /balcony element, as shown in Figure 1.1.

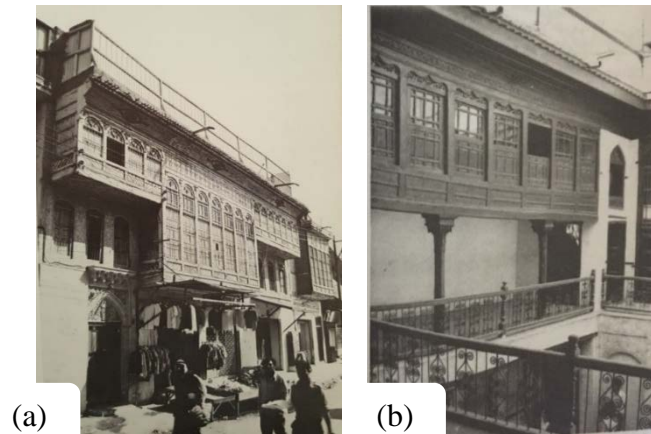


Figure 1.1 (a) illustrates external shanashil (Warren & Fethi, 1982) whilst (b) a small shanashil reflects Kabishkan on the internal facade (Al-Haidary, 2008).

This type of change affects the social and cultural norms of Iraqi people since the contemporary design of villa houses distorts and makes unclear social and cultural values, such that the family social space as the main multifunctional activity space is diminished (Abu-Gazzeh, 1993). Nevertheless, Heynen (2000) argue that modernity is important for its ability to free a person from the limitations and impact imposed by their family, community and local habits. Whilst Gruber (2011a) argues that architects need to develop other ways of design that can restore part of the lost value, and at the same time adapt to future problems such as global warming, the exploitation of raw materials, extensive use of energy, and the production of waste. All these issues add to the pressures that the designers of the built environment have to face (Doughty & Hammond, 2004; Gruber, 2011a; Mazria, 2003).

Modern planning has limited the impact of privacy and opening of social spaces to the outside, giving unlimited visual access to indoor social contexts and creating many restrictions with regard to privacy and communal social integration. Modern architects and planners tend to neglect the centrality of privacy in the housing design process because they see the old traditional design patterns as a limitation to their freedom of design. Moreover, a new type of aesthetic appreciation is linked to new technological methods and are considered more important than preserving inherited social and cultural values (Eben Saleh, 1997).

This research therefore agrees with Al-Thahab, Mushatat, and Abdelmonem (2014) and Al-Homoud (2009) that traditional values expressed the flexibility of design for private and public needs and acquires various interpretations in different contexts.

As a result whilst change is inevitable, and the use of modern material frees the design from the limitations associated with traditional pattern, local habits and community as a whole, however, this affects the consistency of design identity and cultural values by ignoring the nature of place and the uniqueness of its elements. Therefore the use of advanced technology and modern materials needs to be in harmony with the surroundings whilst focusing on environmental control, thermal comfort, privacy, and less energy use, and providing visual access between indoor and outdoor environments to be part of new building elements in a way that mimics what the traditional elements used to provide.

1.2 ISSUES AND CHALLENGES

This study proposes three overlapping phases for the changing relationship between building material and architecture:

The first is vernacular architecture that uses local materials and building technologies, that are by default responsive to social, cultural, and environmental constraints. The result is form, function and aesthetics that develop together to create the characteristic distinctiveness of traditional architecture in a particular location.

The second can be traced to Modernism in architecture and by the 1950s and 1960s the International Style came to be adopted everywhere (cold climates and hot, hilly terrain and flat) imposing specific materials and style (concrete, large windows and geometric forms). Form became a priority, function and aesthetics followed both of which were far removed from the specific environment and cultural sensibilities.

The third is announced by two key events: a global concern with sustainable development and energy-efficient building design; and innovations in building materials and technologies.

The changes of modernism, industrial, and technological advancement affected the unity of part-to-whole design relationship. For instance, changing the old organic pattern into a gridiron pattern to accommodate the modern way of life, and means of transportation, as shown in Figure 1.2.

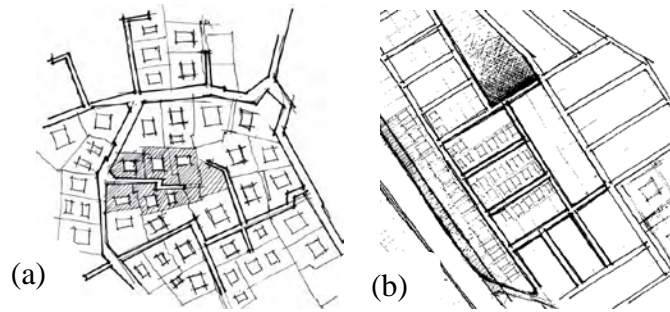


Figure 1.2 (a) illustrates a typical residential neighbourhood with organic pattern in Al-Kadhimiya, while (b) demonstrates the modern gridiron pattern (Al-Thahab, Mushatat, & Abdelmonem, 2014).

Moreover, there is also the loss of the distinctive features of traditional architectural façade elements in favour of the International Style that has no local identity. Accordingly, the traditional elements even if added now to modern architectural façade are considered useless as they are not able to deliver the design qualities that they used to provide. These changes have not just affected the aesthetic appreciation, which such elements used to provide in terms of material, but also the functional aspects such as environmental control (Bianca, 2000; Eben Saleh, 1997; Fethi, 1977; Warren & Fethi, 1982).

As a result, the old responsive and flexible design strategies are useless now, and there is a need to look for new adaptable ones that match the changes of the surrounding environment. The research problem to be addressed is in the lack of knowledge about the application of modern smart materials in achieving the continuity of environmental and social control, which was previously provided by traditional design elements.

This research takes the design element of *shanashil* as part of traditional Baghdadi buildings to demonstrate this three-phase change, where what was once a multi-functional space is now in danger of becoming a museum piece.

From the above issues the following four questions became apparent to the researcher as initial lines of enquiry:

- **What are the design aspects that impact the choice of material?**
- **How important is the choice of material in producing flexible design characteristics?**
- **For which types of buildings may such material be most suited?**
- **Is it possible to develop an aesthetically acceptable modern shanashil window?**

The thesis addresses the above questions by developing a 3D digital prototype that illustrates the added value of dynamic material characteristics to design elements in comparison to traditional elements.

Wiscombe (2012), and Knippers and Speck (2012b) argue that over the last decades architectural elements have been developed separately in terms of skin and structure, which in turn affect the quality of design both aesthetically and functionally. These elements, even when supported by technology, are not a fully integrated part of the whole sustainable design process. Moreover, Mazzoleni (2013) notes that architecture in comparison with other disciplines has a different perspective that looks into its elements in isolation. Accordingly, this issue has a negative impact on the design relationships of form, function, and aesthetics.

Thus, the research subject expands architecture through modern technology with a focus on the continuity of environmental and social control that was once provided by traditional elements. This continuity can be achieved through a bioinspired design approach that mimics the characteristics of these traditional elements. This is attained by using a smart dynamic material inspired from biomimetics strategies that delivers a multifunctional design quality in hot arid climate.

1.3 AIM AND OBJECTIVES

The aim of this thesis is to explore the dynamic characteristics of smart material that mimic the characteristics of the traditional element (*shanashil*) in Baghdadi buildings

in hot, arid climate through the use of visualisation tools. This aim is achieved through the following objectives:

- To identify the main characteristics of the traditional design element shanashil and search for new adaptable strategies to improve the flexibility of a new window/wall/balcony design element.
- To determine which smart dynamic material characteristics can deliver a multifunctional design quality taking into consideration the role of sustainability aspects of an architectural facade.
- To develop and visualise the characteristics of a smart dynamic material that can contribute to the implementation of a new window/wall/balcony design element.
- To assess the relative importance of window/wall/balcony element characteristics in both the traditional form and a contemporary design.
- To further refine the set of visualisation tools for the window/wall/balcony element to provide designer interactivity.
- To provide recommendations for architects in the implementation of a contemporary smart dynamic material window/wall/balcony design element with consideration of future sustainable development.

The research sets out to investigate the main characteristics of the traditional element to restore the design continuity by reviving the environmental aspects. The research focuses on identifying the potential use of a bioinspired design material using a biomimetic approach that can improve the flexibility of design elements by delivering a multifunctional quality. Therefore, the research in this thesis uses a smart material, due to its dynamic characteristics, in order to deliver aesthetic satisfaction within sustainability of social and cultural aspects.

1.4 RESEARCH METHODOLOGY

This section discusses the research philosophies, reviews the available research strategies, and explains the chosen design science research methodology. The detail

of undertaking a design science approach is given, outlining the design tools to be used in the research.

1.4.1 What Is Research Methodology

Research methodology explains the procedural framework by which the research is conducted (Amaratunga, Baldry, Sarshar, & Newton, 2002). It connects the different research parts as a whole in a coherent manner. These parts are the research questions, the conceptual approach to the topic, and methods to be adopted in achieving the research aim and their rationale. Ding (2008) explains that the methodology is a combination of various techniques used to investigate about a specific situation. Many factors define the appropriate research methodology for a particular research, such as the topic to be researched and the specific research questions (Amaratunga et al., 2002). A robust methodology is essential to achieve the research aim and objectives. Therefore, Table 1.1 shows existing choices of methodology components and justifies the selection made by the researcher.

Table 1.1 The methodological approach regarding design decisions and justification.

Design decision	types	selection	justification
Ontology	Objectivism Subjectivism	Subjectivism	Smart dynamic glazing material is still considered new to design elements and process. To reveal the views regarding the impact of dynamic characteristics on design quality, it was appropriate to select subjectivism reasoning (Saunders, 2012).
Epistemology	Positivism Interpretivism	Interpretivism	The researcher was looking at possible ways of obtaining knowledge about smart material applied in a modern context. This was done by understanding the views and experiences of traditional elements. Therefore, the study adopted interpretivism stance (Amaratunga et al., 2002; Saunders, 2012).

Design decision	types	selection	justification
Research Approach	Inductive Abductive Deductive	Abductive	<p>Modern technology and smart glazing are new topics in general and particularly in architectural design elements.</p> <p>Therefore, the abductive approach provided deep insights into them and allowed for generating new knowledge (Bryman, 2015; Kenneth, 2000).</p> <p>It was also appropriate during the evaluation process where the knowledge was already generated and needed to be identified and refined by experts on the role of screen design pattern.</p>
Research Methodology	Surveys Case Studies Experiments Design Science	Design science	<p>It is main approach is to improve the flexibility of the design element, environmentally, socially and culturally. This is through the development of a digital prototype that demonstrates the dynamic characteristics of a smart window/wall/balcony element.</p> <p>The developmental approach and flexibility of design science allows it to be mixed with other research strategies or methods (Vaishnavi & Kuechler, 2007). This is achieved in three stages: Pre-development, Development, and Post-development stage.</p>
Research Method	Qualitative Quantitative Mixed methods	Qualitative	<p>To cover the subject of smart elements, transparency, and screen design pattern comprehensively, it was essential to select qualitative method because it produced a wealth of detailed data on a small sample.</p> <p>In addition, the study was exploratory in nature and little was known about the subject under investigation.</p>
Sampling	Probability Non-probability	Purposive Followed by Snowball	The researcher had a clear idea of which interviews are needed with their knowledge of the characteristics of traditional shanashil.

Design decision	types	selection	justification
			The researcher then asked the interviewees who met the criteria to name others who would also be eligible and willing to participate in this study to increase numbers.
Data Collection	Interviews Questionnaire Documents (literature review) Observation	Interviews Documents (Literature review)	This technique is suitable to discover views, perceptions, and opinions of architects about smart dynamic glazing material. It also allows for conversation between the researcher and the participants to establish common understanding.
Data analysis	Grounded theory Content/ thematic Statistical	Thematic	The researcher aimed at extracting meaning from the interviews by looking for themes that were relevant to certain categories designed in advance, as mentioned by (Bryman, 2015; Taylor-Powell & Renner, 2003). The opinions of the interviewees were analysed and interpreted into themes, and sub themes (Braun & Clarke, 2006).

According to Aken (2005) the design science research approach intends to develop a design solution which is able to solve a real-world problems. This issue is in contrast to explanatory science research such as physics, biology, economics and sociology, where the main objective is to describe phenomena of the natural or social world. The methodology is also driven by ontological and epistemological assumptions (Easterby-Smith, Thorpe, and Jackson, 2012; Saunders, Lewis, and Thornhill, 2012), as depicted in Figure 1.3, which presents the different components of this research. Data collection techniques are the most obvious and visible components and features of any research project, however, Easterby-Smith, Thorpe, and Jackson (2012) argue that data collection techniques are highly dependent on decisions and assumptions that are progressively less visible, such as philosophical stance.

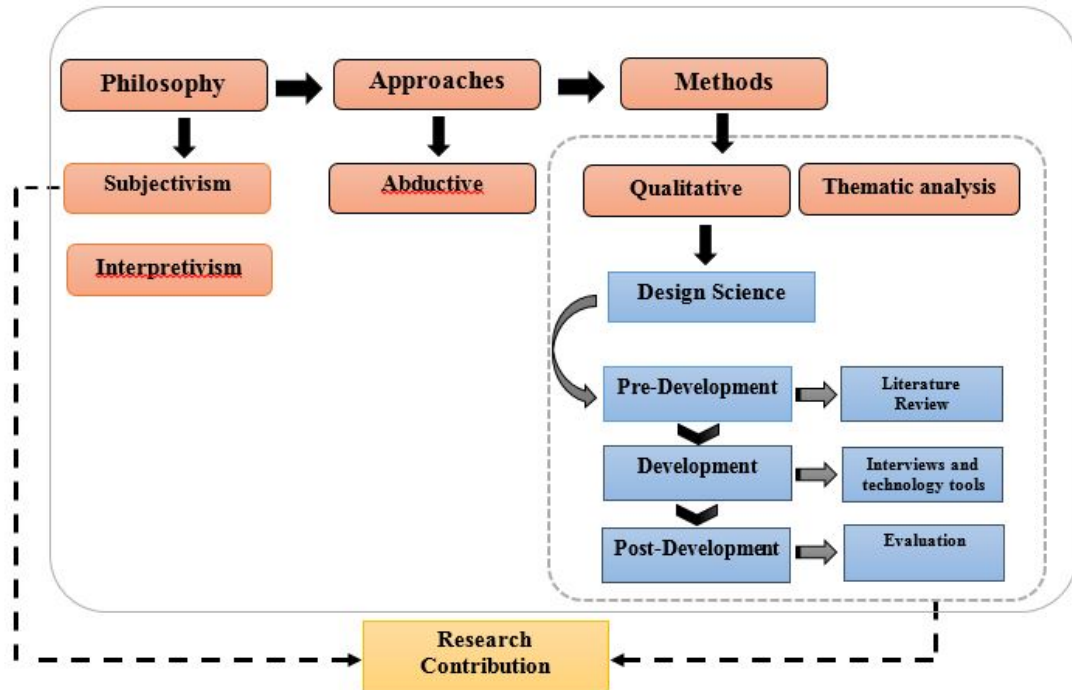


Figure 1.3 Methodology framework of this study.

1.4.2 Design Science Methodology

Design science, a term first used by Buckminster Fuller, and introduced at the 1965 conference on 'The Design Method' (Gregory, 1966). According to Hubka and Eder (1987) design science is a logical approach for design information and design process that aims to recognise the problems associated with the phenomena of design and practice, and interpret it as an applied method suitable for the design needs.

Hence, in order to identify the logical approach it is important to understand that there is an integrated relationship between design and science. According to Grant (1979) design is defined as an act that collectively combines both the scientific and non-scientific information process. According to Cross (2001) design science is an explicit, logical design process with a systematic approach that scientifically combines knowledge and practice in a way that is challenging to designers and also design theorists. According to Cross (1984, 2001) there is still ambiguity surrounding the idea of design science and that of a science of design.

Nevertheless, it is important to realise that scientists attempt to determine the pattern of the existing structure while designers attempt to invent new structures and at the

same time shape the pattern of these structures (Alexander, 1971). Accordingly, science instigates analytical behaviour through its problem-solving approach, whilst the pattern of the design method is set out to create artifacts (Gregory, 1966). The integrated relationship between design and science cannot be ignored, because of its important role in identifying the problems and suggesting the solutions, and this cannot be achieved without truly understanding the approach of the design pattern.

Design science has an innovative problem-solving pattern with an aim to create and improve an object and then evaluate it. In addition, design science is based on combining knowledge and practice by identifying an interesting phenomenon and recognising the problems associated with it, then it depends on an explicit interpretation process to develop a solution.

The process begins with identifying problems that have research potential through theoretical literature reviews and substantiated with empirical examples. Moreover, this research approach emphasizes a two-way combination of both theoretical and empirical evidence and as such is inherently narrowing the gap between practice and research (Lukka, 2003). The core of the method is the use of a Problem–Suggestions–Development–Evaluation–Conclusion cycle (Vaishnavi & Kuechler, 2007).

The Design Science approach starts with Awareness of a Problem and is sometimes called “improvement research” emphasizing the problem-solving, or performance-improving nature of the activity. Accordingly, suggestions for a problem solution are drawn from the existing knowledge or theory base of the problem area (Pierce, 1964; Vaishnavi & Kuechler, 2004). This thesis follows the general design cycle, as shown in Figure 1.4.

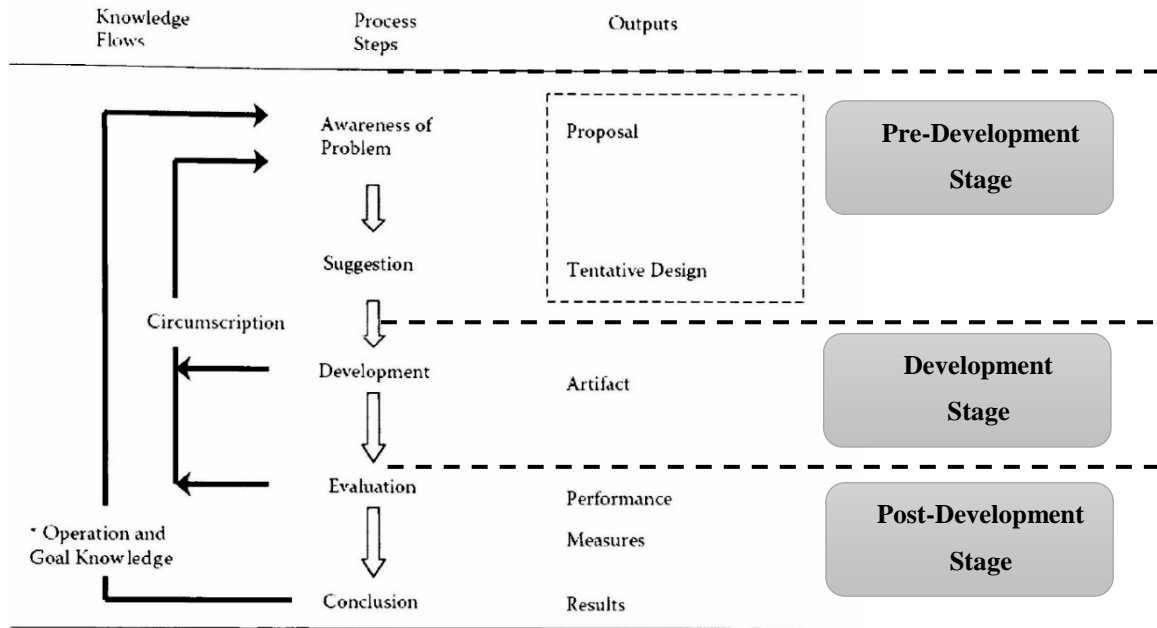


Figure 1.4 General Design Cycle adopted from (Takeda, Veerkamp, & Yoshikawa, 1990).

Pre-Development is the first stage, in the Figure 1.4, and involves developing an (awareness of problem and proposing the suggestion of a potential solution). The next stage is shown as Development stage and in this research involves the development of a digital prototype. This prototype is then evaluated in the Post-Development stage (Hayes-Roth, Pflieger, Lalanda, Morignot, & Balabanovic, 1995; Vaishnavi, 2008).

Design science is always based on the importance of awareness of a Problem as a fundamental first step in the process. However, McCarthy (1987) argues that the design science researcher learns, or discovers, when things do not work as planned, or according to theory. The reason is not due to a misunderstanding of the theory, but due to the incomplete nature of the knowledge base. When abstracting concepts it is important to be in control while deriving a solution by observing general design principles in multiple examples. The problem solving pattern is an innovative approach to suggest solutions. Furthermore, the design pattern may prove richer than anticipated because it could be flexible enough to be used in applications beyond its original intent (Vaishnavi, 2008). Further, design science contributes valuable knowledge in order to understand the ‘always-incomplete-theories’ that abductively motivated the original design.

1.4.3 Methodological Approach

The process steps in the Design Science methodology have outputs at each step. In the first step of the process, a suggestion will be an output of the problem awareness. The output in this research addresses the problem of losing the distinctive features of a design element, which in return affects the design quality both aesthetically and functionally, through the use of modern dynamic materials. The suggestion is to develop a contemporary window/wall/balcony element using a 3D digital prototype that illustrates the dynamic material characteristics associated with switchable transparency and colour of a smart glazing material. Figure 1.5 illustrates the design science approach applied to this research.

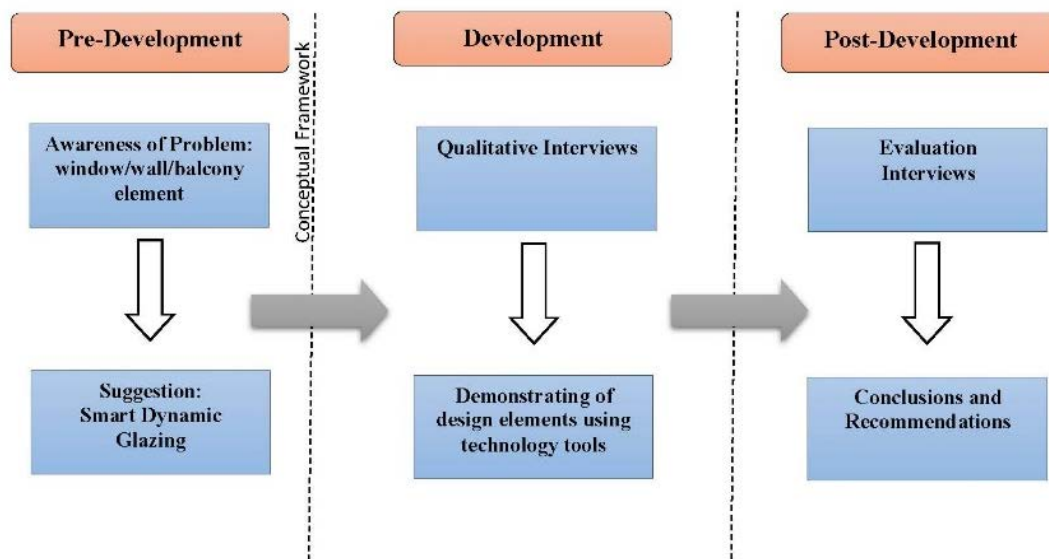


Figure 1.5 Methodological approach based on Figure of the General Design Cycle (Takeda et al., 1990).

1.4.3.1 Pre-Development Stage

The Pre-Development stage undertaken through a literature review produces an awareness of the problem of the inconsistency and disappearance of traditional design elements, and the role of change creating a loss of design identity affecting the design sustainability. This creates suggestions of alternatives in the use of smart dynamic glazing material, which is implemented as a window/wall/balcony design element that restores the environmental control that the traditional element used to provide.

The literature review facilitates comprehension of existing theories that convey the ideas of elegance, flexibility, and functional beauty; to form a coherent argument for further research and to demonstrate a fundamental understanding of biomimetics strategies, sustainability, and the role of active embedded technology in design. To examine the research question of how to revive the design continuity of environmental and social control, it is important to gain an understanding of the characteristics of traditional elements and the role of transparency that once were successful in providing aesthetic satisfaction, with sustainability of social and cultural aspects. After identifying the problem, the research derives suggestions to clarify the research problem and provide tentative solutions associated with the role of smart dynamic glazing material in design.

1.4.3.2 Development Stage

This Development Stage can be divided into two sections:

- a. The visualization of a smart window/wall/balcony design element using technology tools with solid demonstration, Revit tools, and smart glazing virtual reality prototype.
- b. In-depth qualitative semi-structured interviews with architects.

Vaishnavi et al. (1997) notes that in developing a smart object there is a need to decompose the problem into sub-parts. In this sense, the concept of a smart object combines elements with multiple patterns to create others that encourage interdisciplinary approaches by adapting functionality of these patterns (Garlan & Perry, 1995; Hayes-Roth et al., 1995; Vaishnavi, 2008; Vaishnavi, Buchanan, & Kuechler, 1997). Accordingly, the smart object pattern framework is described and then, the logical and architectural aspects reviewed. Similarly, the problem of defining the conceptual characteristics and functional aspects are further decomposed into sub-problems. The complexity of the problem is both defined and appropriately handled by this approach (Vaishnavi et al., 1997).

The Development Stage is where most of the actual design takes place with creative effort required in reorganizing and visualising the dynamic material characteristics when compared to static ones in a contemporary window/wall/balcony design element. The results of design science research may adapt and simplify from nature,

such as in the form of design pattern, models, or methods (March and Smith, 1995), and this research develops a 3D digital prototype that demonstrates the dynamic characteristics of a smart window/wall/balcony element.

The Development Stage is fully explained in chapter 4, however methodologically this required development using several technology tools. The first technology tool tackles the demonstration of a smart window/wall/balcony design element using Revit tools created in Lumion 3D application to demonstrate the difference between two 3D models. It is important to realise that the use of the technology tool (Lumion 3D application) allows the designer to provide the realistic visual quality of the lighting in the 3D environment. The first model on the right in Figure 1.6 is the typical Baghdadi house using traditional materials such as wood in the window/wall/balcony elements. The second model on the left demonstrates the contemporary window-wall elements using modern material (smart dynamic glazing). [The Lumion3D video demonstrations are contained in the DVD in appendix E].



Figure 1.6 Smart dynamic glazing on the left, traditional one on the right, rendered in Lumion 3D.

However, since there is no possibility to change the properties within Lumion 3D and provide the needed experience for the user to be able to change properties another tool is needed for more control of switchable properties of glazing material, before and after design process.

The second technology tool used is based on the concept of smart serious game and is a Smart glazing VR prototype that illustrates better interactivity by engaging the user to be part of the design process. The images captured from this prototype are illustrated to discuss three issues.

First is the difference between the modern material and old materials in a window-wall design element regarding role of material manipulation of transparency while maintaining private needs, order, proportion, and colours, as show in Figure 1.7. [The smart glazing VR prototype demonstration software is contained in the attached DVD in appendix E].

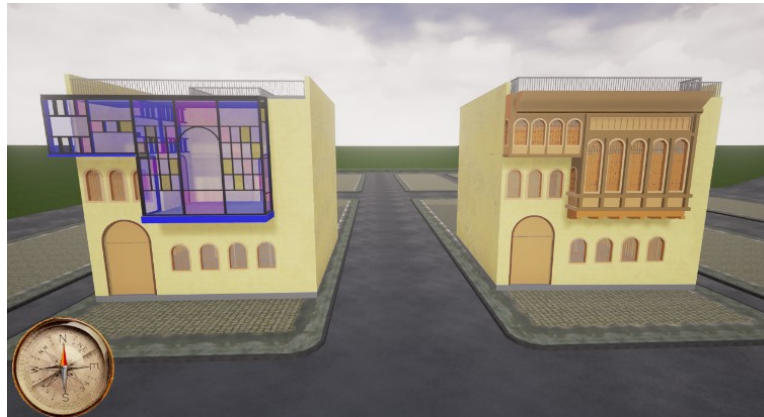


Figure 1.7. On the right is the typical Baghdadi house and its traditional elements, whilst on the left the use of smart dynamic glazing in the window/wall/balcony element.

The third tool used is BIM Tools (Revit Plugin). This tool is used to provide the opportunity to design predefined parameters such as family of properties associated with smart dynamic design element, as shown in Figure 1.8.

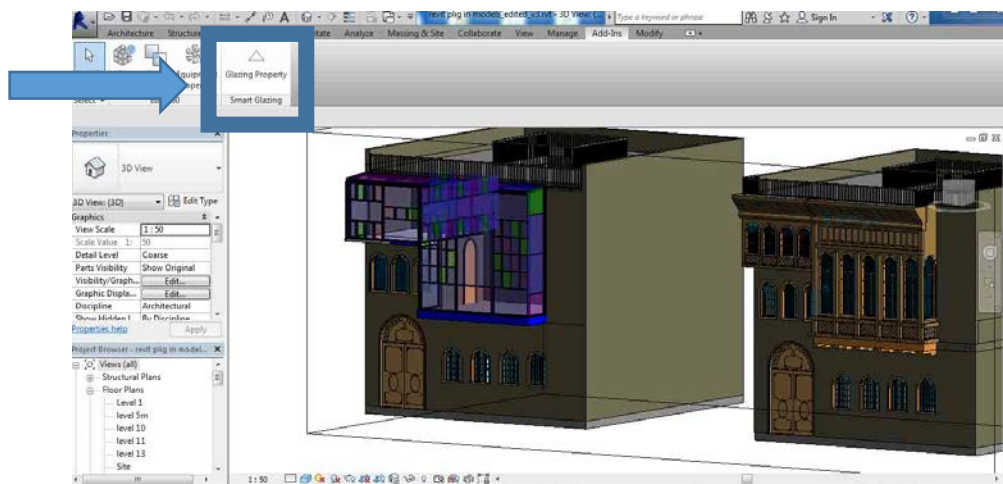


Figure 1.8 BIM Revit tools and Plugin reflecting the difference between traditional and contemporary design approach for the window/wall/balcony element.

However, although the BIM Revit Plugin tool has the ability of delivering predefined parameters, single entities, families or instances, it is not flexible enough to

demonstrate layers associated with realistic daylight condition and its integrated relationship with shadow, lighting intensity and light shaft for the flexibility of design layers to be improved. The Revit Plugin tool (3D prototype) is used and is contained in the DVD in appendix E.

The detail of the development stage is discussed further along with the qualitative data analysis regarding the opinions of interviewees concerning design quality between the traditional element and the contemporary in Chapter 5.

1.4.3.3 Post-Development Stage

The last steps of the Design Research process are evaluation and conclusion of the added value of dynamic characteristics of the smart material. Evaluation is about collecting and organizing data regarding the adaptability of a design product used by a specific group of users for a particular activity within a specified pattern context (Preece et al., 1994). The flexibility and effectiveness of an object can be demonstrated through well selected evaluation methods. A design object is complete and effective when its characteristics satisfy the requirements of the problem it was meant to solve (Basili, 1996; Hevner, March, Park, & Ram, 2004; Kleindorfer, O'Neill, & Ganeshan, 1998). The results of design evaluation method can vary depending on the designed element, variables and constants.

The choice of design evaluation method can vary depending on the designed pattern and the selected evaluation methods. In this research the limitations as well as the advantages of using a smart window-wall glazing element attached to a 3D digital prototype in order to improve the flexibility and quality of design, both aesthetically and functionally are considered.

The Post-Development stage is discussed further with qualitative data analysis regarding the perception of interviewees concerning the flexibility of the contemporary elements to improve design quality in Chapter 6 including the research conclusions.

1.5 METHODOLOGICAL STEPS

The whole of the Design Science approach can be summarised as follows:

- a) Pre-Development Stage: a comprehensive literature review undertaken to:
- To assess and identify new adaptable strategies for reviving the environmental aspects of architectural design elements;
 - Identify the main characteristics of the old materials associated with the traditional element *shanashil* that once provided aesthetic satisfaction with sustainability of social and cultural aspects;
 - Gain an understanding of the complexity of architecture and the flexibility of design pattern associated with the idea of functional beauty, exuberance, and elegance;
 - Explore how nature`s adaptable strategies through the use of biomimetics strategies can inform the built environment design process;
 - Identify existing smart dynamic glazing material;
 - Produce a conceptual framework that illustrates the important role of active, embedded technology associated with transparent, multi-layered material of smart dynamic glazing;
- b) Development Stage:
- Development of 3 visualisation tools to produce 3D digital prototype of Baghdadi buildings to illustrate the impact of a smart window-wall design element in design;
 - Conducting 21 qualitative semi-structured interviews with architects;
 - A detailed thematic analysis of the semi-structured interviews to identify design concepts and sustainability needs for a multifunctional design quality.
- c) Post-Development Stage:
- To evaluate the efficiency and the value of the proposed prototype and technology tools to visualise dynamic characteristics in architectural design;
 - To draw a list of recommendations for architects and designers based on the findings of the research.

1.6 RESEARCH ROADMAP

The thesis consists of seven chapters. Figure 1.9 presents the framework of the research discussed in the thesis with the outline of the thesis. A brief summary of each chapter is presented below:

- Chapter 1 explains the research background, problem, identifies research questions, aim and objectives. It also defines Design Science methodology and stages for an interdisciplinary design approach between nature's adaptable strategies and traditional elements such as *shanashil* in Baghdadi buildings. The chapter identifies Design Science as the research methodology. The methodological approach includes stages from Pre-Development to Post-Development, and discusses the role of technological visualisation tools to illustrate the contemporary elements attached to a 3D digital prototype. Further, the method of semi structured interview and thematic analysis is adopted to enable the use of the research methodology and identify the features' awareness of dynamic characteristics in smart glazing elements.
- Chapter 2 is part of the Pre-Development stage that reviews the literature related to the history and issues affecting the design identity and values through the inconsistency of its distinctive element *shanashil*. It discusses the role of technology in the interpretation process between living and non-living patterns in order to revive the flexibility of traditional elements.
- Chapter 3 is part of the Pre-Development stage that reviews the literature on the role of design quality and sustainability aspects including location and type of climate. It explores the types of smart dynamic glazing and the importance of transparency and glass windows in design. It examines the benefits of dynamic characteristics in a smart window/wall/balcony design element when compared to static ones.
- Chapter 4 focuses on the Development Stage of the contemporary smart window/wall/balcony element and its dynamic characteristics attached to a 3D digital prototype. It provides methods of qualitative data thematic analysis of 21 semi-structured interviews. The findings are organised into 3 major themes. Each theme has sub-themes and sub-sub-themes which emerged from the data analysis.

- Chapter 5 describes the Post-Development stage and the evaluation of smart dynamic glazing elements attached to a 3D digital prototype in different types of buildings. It includes further qualitative data analysis of 6 interviewees' perspectives on the final version of the prototype.
- Chapter 6 is the research discussion as a summary of the major findings obtained and in respect to each research question and objective.
- Chapter 7 presents the research conclusions, contribution to knowledge, limitations, and recommendations for future research.

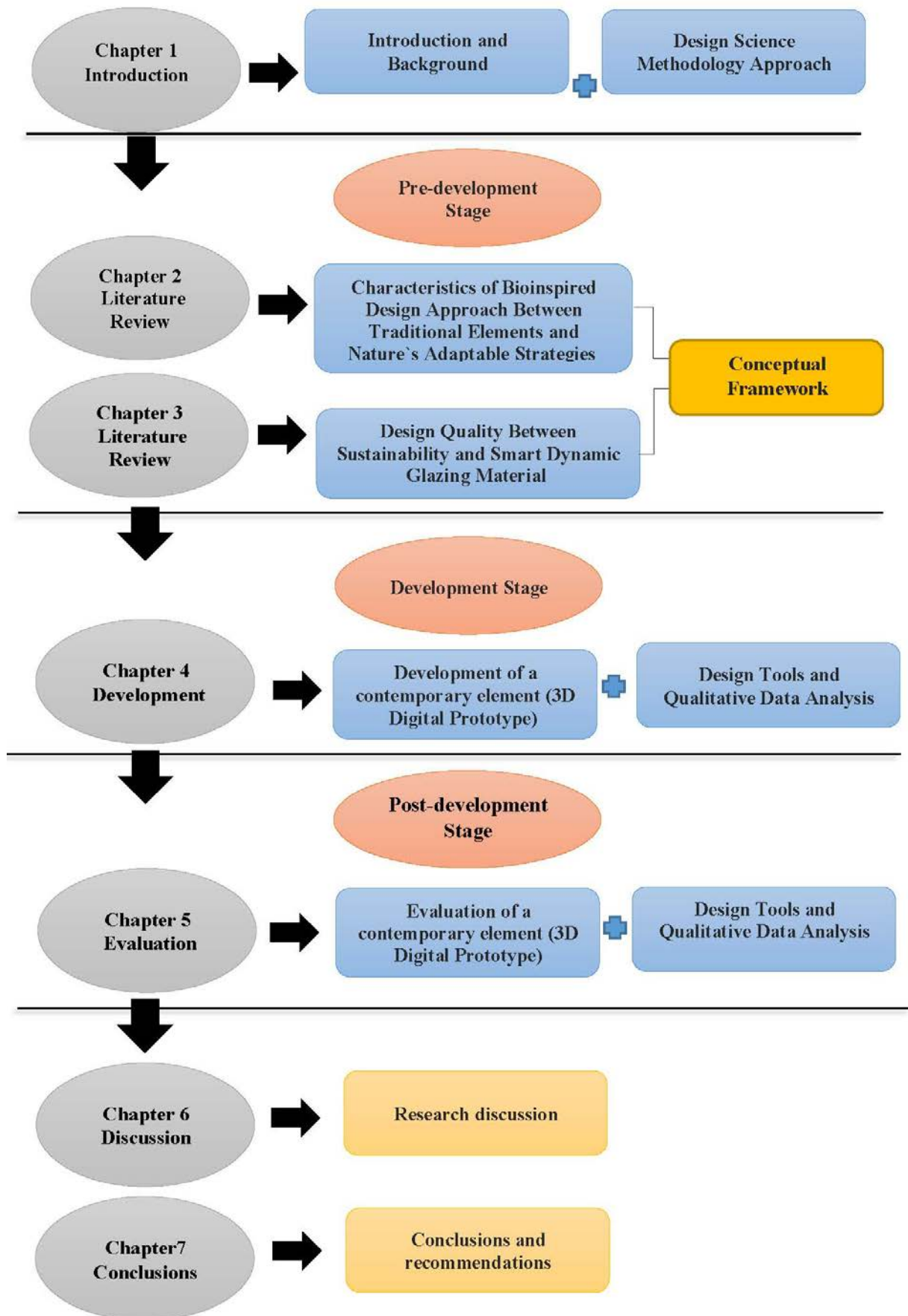


Figure 1.9 Thesis layout in relation to the Design Science stages.

1.7 SUMMARY AND CONCLUSIONS

This chapter introduces the research and explores the research issues and challenges. It also identifies and presents the aim, objectives, research questions, and methodological steps of the research. In addition, it argues that one of the approaches to establish a successful interdisciplinary architectural bio-inspiration is in having a clear insight of information transfer between natural examples and architecture's elements and that pattern is important in order to improve design flexibility, both in aesthetic and functional aspects. This flexibility is necessary to achieve and restore part of the design aspects in traditional elements in order to substitute the design gap in a more effective contemporary design approach.

This chapter also discusses Design Science methodology. This study lends itself towards the ontological subjectivism stance which resonates well with the epistemological interpretivism approach. In the research approach, this study follows an abductive approach as a combination of both inductive and deductive systems. The Design Science research is used for its flexibility and can be used with any method or strategy, to collect data. Moreover, the pattern of design science is a problem-solving pattern with an aim to create an object. In addition, qualitative method and design tools are explained for their potential in revealing and analysing the complexity of smart, dynamic design elements and pattern. Accordingly, qualitative techniques are adopted and details of research design are provided including data collection and analysis techniques, with semi-structured interviews being the primary instrument for data collection.

Chapter Two

2 Pre-Development Stage of a Smart Contemporary Design Element Using Technological Tools

2.1 INTRODUCTION

As stated in the previous chapter, the traditional window/wall/balcony design element represents one of the distinctive façade features relevant to the typical Baghdadi houses. Therefore, it is essential to highlight the multifunctional design quality which once provided by these elements. Such quality caters for aesthetic aspects including important issues related to sustainability in general with control of environmental sustainability in particular. This chapter aims to report these issues. It will also show the impact of change particularly modern planning and technological advancement on the integrated part/to whole design relationships between traditional elements and the organic pattern in sections 2.5, 2.6, and 2.7. Therefore, various trends are analysed and discussed based on the inspiration of traditional elements.

This chapter also imparts the findings of a literature review carried out to examine the overlapping pattern between nature and architectural patterns that contains many different layers and meanings in sections 2.8, 2.9, and 2.10. It also illustrates the inspiration of biological examples and *biomimetics* approach in sections 2.11, and 2.12. In addition, these sections refer to the relationship between the aesthetic and functional design aspects as an important part of the complexity of architecture in terms of functional beauty, exuberance, the idea of pattern, elegance, and the role of part/to whole relationships during the design process. This chapter then defines in depth the important role of technological advancement within the interpretation process of information transfer in architecture.

2.2 SHANASHIL: TRADITIONAL DESIGN ELEMENTS

In order to understand the main effective design characteristics which once were behind the success of traditional elements, it is important to identify the common characteristics between traditional and vernacular building, taking into consideration the role of material and its impact both aesthetically and functionally. Al-Bayati (2011), Al-Ahbab and Neama (2011), and Warren and Fethi (1982) variously discuss

that it is important to realise the indefinite threshold between vernacular building and conscious traditional architecture. On one hand the vernacular is the work of the people, the users, without the aid of designers, whilst on the other traditional architecture is the work of those who design as a deliberate art, often for their livings and usually for others. Between these two is the work of local builders, guided by experience and tradition and working directly to the wishes of their clients. For example, the traditional houses of Baghdad are considered an essential part of meaningful architecture including its elements (shanashil), as shown in Figure 2.1(a), and (b).

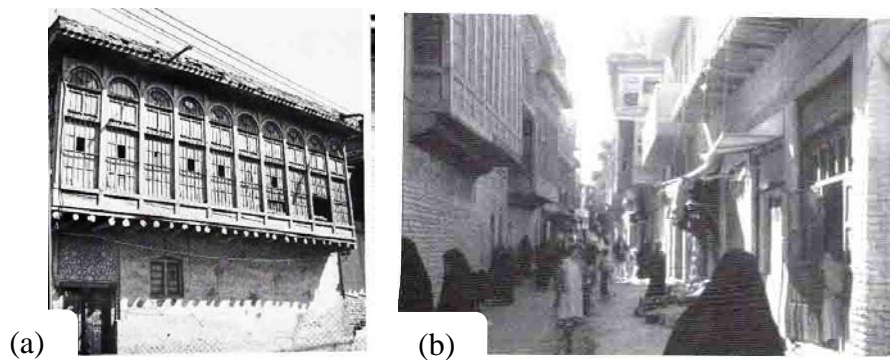


Figure 2.1 Traditional Baghdadi houses with their façade elements of shanashil (a) Al-Haidary, 2008 and (b) Warren & Fethi, 1982).

Senosiain (2003) argues that although vernacular building is not the end result of professionals` work, it becomes part of the traditional architect`s knowledge being passed down from home owners and the builders. As a result, part of traditional architecture is based on the vernacular. Further, vernacular building develops its individual characteristics by depending on nearby resources, as in materials, and then exploiting them to adapt to changes of the surrounding environment (Woolley, 2010).

However, Zhai and Previtali (2010) argue that in general professional architects have designed a very small percentage of building structures both now, and throughout history, whilst Oliver (2003) mentions that the Oxford Institute for Sustainable Development estimate that over 90% of all structures in existence today were designed by the people who use them, not architects. The Architect Tedeus Torucki noted that vernacular building is considered a complete foreigner to its environment when different materials are used that are not from the local environment (López, Cristofano, Higa, Johnson, & Timoshenko, 1970). Senosiain (2003) agrees with

Warren and Fethi (1982) that common characteristics of the design pattern are seen when boundaries between traditional and vernacular become blurred. Creativity in this situation is not done by imposing new ideas, it is more about adjusting and learning from the mistakes of the past whilst adding new knowledge as new needs arise. For instance, the successful impact made by traditional architecture was not always local materials, some of these materials were imported from distant foreign lands like teak (saj) wood in order to provide successful adaptation to the surroundings.

With this focus, Elaraby (1972, cited in Elaraby, 1996), and Warren and Fethi (1982) argue that wood has a qualitative and symbolic aspect which is responsible for elegant order with integrated relationships between colours, material, textures, forms, and patterns. More importantly in Iraq, timber of high quality was not available as part of local materials and was imported from India. Teak (saj) was particularly prized being the only timber resistant to termite attack (Fethi & Al-Madfai, 1984; Warren & Fethi, 1982). Also, Oliver (1997) points out that screen patterns were made of teak wood carved in the East Indies and were a product of the East Indian trade. Accordingly, although such a type of wood was not part of the surrounding environment in Iraq, yet builders and householders continued to use it as part of their adaptive strategies in design. The same type of wood also has other advantages, such as putting only a light weight on the relatively weak brick lower walls. Moreover, using wood in the upper floors saved on the amount of fired brick that was laborious and expensive to produce. A greater amount of wood would have been used in the kilns in order to provide a large enough amount of fired brick, as Fethi and Al-Madfai (1984) discuss the overall building facade was therefore more economical and energy efficient in the use of material. The design in its balance between the use of wood in the first floor and the use of brick in the ground floor was considered a swift and inexpensive method of construction at that time.

Equally relevant was that this way of design added to the sustainability in respect of the continuous availability of the materials and energy required within the surroundings to maintain and develop the level of economic activity. Buildings need to be considered responsive to changes of the surrounding environment such as the challenges of climate, and materials availability with the intention of optimizing the

energy performance of buildings. The same idea has been used widely over the last 25 years and concerns the ability of a design system to remain functioning over an extended period of time (Burger et al., 2012). As a result, buildings whether they are built by lay people, professional builders, or architects become part of the culture and values of the given space (Al-Ahbab, 2010; Al Silq, 2011; Nouri, 2014).

Therefore, this research agrees with Burger et al. (2012), Oliver (2003), Senosiain (2003), Warren and Fethi (1982), and Zhai and Previtali (2010) that considering the role of material it is important to understand how to blend it in harmony with the surrounding environment. This issue is important to realize when trying to design an innovative contemporary design approach that understands the problem in order to restore sustainability of environmental, social and cultural aspects.

The next section will discuss the history of the traditional buildings focusing on the typical example of the two storey Baghdadi house and its distinctive façade features called *shanashil*.

2.3 HISTORY OF TRADITIONAL BUILDINGS IN BAGHDAD

The same principles of design of the traditional middle class Iraqi courtyard house in the 1960s match the ones found in Larsa, the Sumerian city of Ur from 1800-1000 B.C. (Ur Excavations VII, 1976), as shown in Figure 2.2.

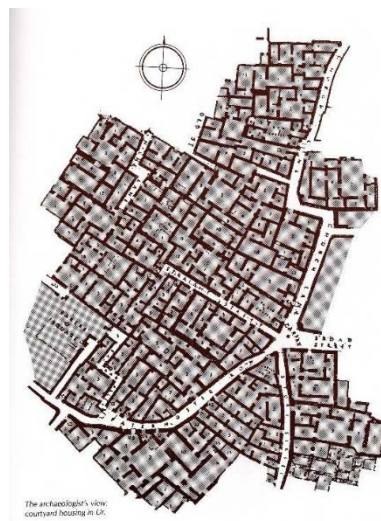


Figure 2.2 Courtyard houses in Ur (Warren & Fethi, 1982).

Al-musaed et al. (2007) explains that the first traditional houses created by Sumerians civilization in Ur city in the south part of Iraq displayed heavy facades and limited openings on the external elevations to provide protection from changes of the surrounding environment. However, the majority of the hot, tight, dusty mediaeval city has now disappeared. The overall city pattern has changed and expanded since 1902 with dual carriageways, flyovers, metropolitan railways, parks, gardens and suburbs, industrial estates, universities and sports cities. As a result, what remained of the old traditional pattern are fragments of the original which can never be more than tiny relics scattered in a modern metropolis, representing less than 1% of the area of the city now, and 0.5% of the city as planned (Al-Haidary, 2008; Al Silq, 2011; Fethi, 1977; Fethi & Al-Madfai, 1984; Nouri, 2014; Warren & Fethi, 1982).

Many of the important traditional houses are in two conserved areas. According to Fethi and Al-Madfai (1984) there are eighty-eight buildings that have been surveyed in detail. One of these areas is Al-Gaylani Shrine in Bab Al-Sheikh, as shown in Figure 2.43. The other area is Al-Kadhimain Shrine in Al-Kadhimiyeh area, as shown in Figure 2.44. In addition, only twenty-eight of these houses have been restored (Alfetal, 2001; Fethi & Al-Madfai, 1984; Nouri, 2014), as shown in Figures 2.3, and 2.4.

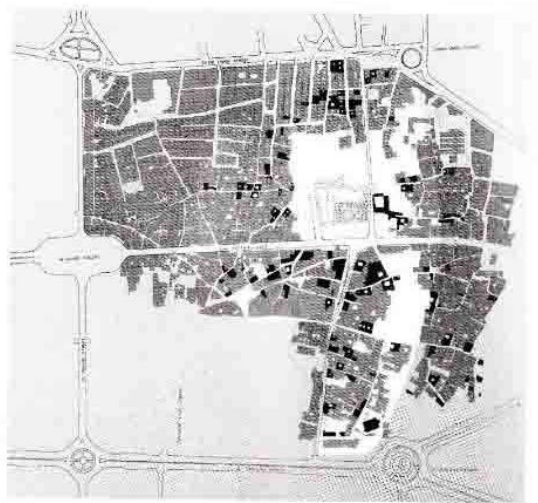


Figure 2.3 Area of AL-GAYLANI Shrine in BAB AL-SHEIKH, black areas illustrate buildings of historic importance (Warren & Fethi, 1982).

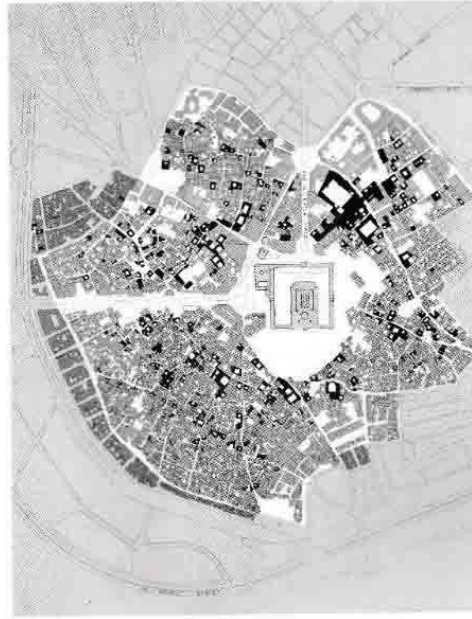


Figure 2.4 Al-Kadhimiyyah Shrine in which the traditional pattern is identified by its irregularity while open spaces are zones of demolition to accommodate the need of change regarding lifestyle and transportation means (Warren & Fethi, 1982).

Furthermore, the design of the traditional pattern is considered effective being part of the environment both socially and culturally, in its distinctive and elegant details regarding façade elements. Nevertheless, the development of the old pattern was not predetermined and developed organically, actively producing irregular shapes and sizes. The result are houses that are not an exact shape, size, or a given orientation, with every house tightly packed onto its site using the minimum of land to enable the defensive circle around the community to be as close as possible (Al-Ahbabi & Neama, 2011; Nouri, 2014; Reuther, 1910; Warren & Fethi, 1982). However, it is evident to acknowledge the role of change in winding lanes and intricately alleyways which are now cut through by major traffic arteries (Al-Ahbabi, 2010; Al-Bayati, 2011; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982).

Interestingly from a different perspective, a German traveller Niebuhr (1776) describes these houses as unimpressive from the outside but beautiful from the inside whilst keeping away the heat of summer. Adding to this Jackson (1799) describes the traditional Iraqi house design as a prison in which the house is a square with no light received from the street due to the absence of windows, as well as no communication between inhabitants and their neighbours. The author disagrees with both Jackson (1799) and Niebuhr (1776) in their Western viewpoints, since they had missed the significance of design element *shanahil* as a window/wall/balcony in the architectural facade element that allowed flexibility in inside, and outside relationships of design, as shown in Figure 2.5.

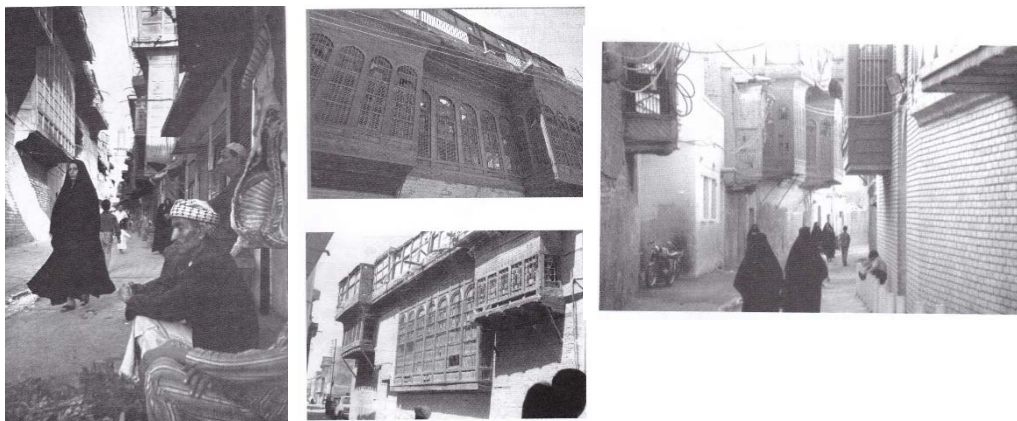


Figure 2.5 The relationship of the traditional elements of various shapes and sizes that overlook the narrow streets of the old organic pattern (Al-Haidary, 2008).

The author, however, agrees with Al-Ahbab (2010), Alfetal (2001), Nouri (2014), Reuther (1910), and Warren and Fethi (1982) that the original organic pattern evolved in a rapid complex way with specifically no exact shape.

2.4 SHANASHIL IN ARCHITECTURAL FAÇADES.

This section explains the use of window/wall/balcony design element in Baghdad called *shanashil*. Tristram Ellis (1881), and Alfetal (2001) describe the design pattern of Baghdadi buildings in the early 19th century as nearly universally built in the form of a quadrangle. The design idea of shanashil is of boxed screens extending from the first floor supported on brackets with a projecting, shading cornice. Although the houses are considered small the first floor has larger rooms and are well lit due to the use of shanashil, as shown in Figure 2.6 (a) and (b). Furthermore, Warren and Fethi (1982), and Al-Haidary (2008) explain that the shanashil are closed wooden balconies

extending out from the property boundaries on the road by 1 metre from the first floor. Due to the narrowness of the passageways, opposing shanashils became close to their opposite neighbours property, as seen in Figures 2.6, and 2.7.

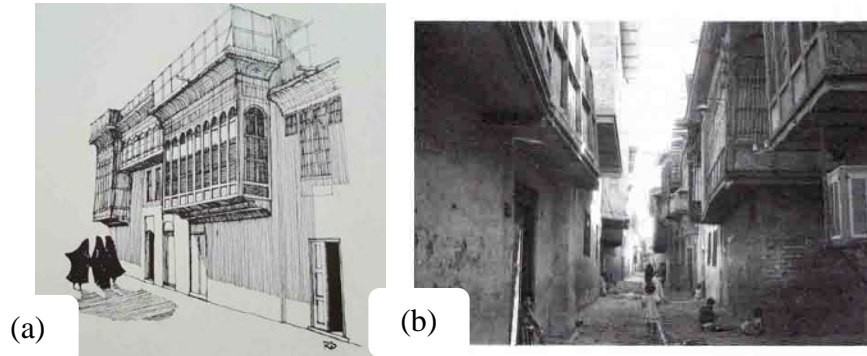


Figure 2.6 Traditional Baghdadi house elements called shanashil situated in the first floor as an extension that used to provide protection and shading ((a) Warren & Fethi, 1982; (b) Al-Haidary, 2008).



Figure 2.7 Closeness of shanashil elements projecting from the first floor (Al-Haidary, 2008).

The word *shanashil* is derived from the Persian, Shah Nashin, meaning "King" or the dominant seat among seats (Alfetal, 2001; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982). The same design pattern of the element can be seen in the traditional facade of many different countries not just in Iraq, but also in Egypt, Morocco, the Hejaz, in the cities of the Gulf, and others (Reuther, 1910; Vogt & Donnell, 2000). Fathy (1986) defined *mashrabiya* as another synonym for the traditional shanashil element, and also an important device that was used in Egypt. The device was a cantilevered space covered with a lattice opening, where water jars were placed to be

cooled by the evaporation effect as air moved through the decorative and intricate geometric screen pattern (Warren & Fethi, 1982), (El-Shorbagy, 2010), and (Oborn, 2012). The shanashil was useful as a shading strategy in providing a comfortable living situation not just for the occupants but also to the pedestrians on the street and narrow alleyways below. Although the design of traditional elements provided the same functions with aesthetic satisfaction to the occupants and community as a whole, there are still many details that differ from one particular window/wall/balcony element to another. For instance, the woodwork technique was more robust in Iraq and Turkey with the wooden screen made of two overlaid series of battens (Qeem) (Alfetal, 2001; Warren & Fethi, 1982). The turned wood technique was more familiar in the Egyptian mashrabiya and in Morocco. The screen pattern bars in the latter were simply notched and scalloped so that they formed attractive patterns when crossed on the diagonal and slatted together (Behrens-Abouseif, 1991; Mackay, 2012; Oliver, 1997). Another name for this design element is originally from the Arabic word *mashrafiya* derived from the verb *Asrafa* meaning to overlook or to observe the outside without being seen. The screen pattern with the woodwork delivers beauty to the design element especially with the effects of light and shadow patterns inside the room (Mackay, 2012). Such examples can be seen in medieval houses in Cairo, such as Zeinab Khatoun House, as shown in Figure 2.8.

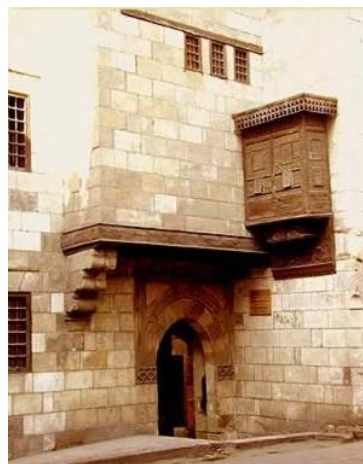


Figure 2.8 Masharabiya, Zeinab Khatoun House, Egypt (El-Shorbagy, 2010).

Also, the same design element is known in Yemen as *takhrima*, which means full of holes, whilst in Japan, the same device is used in the form of blinds of split bamboo (*sudare*). In Jeddah, Saudi Arabia, a mashrabiya is known in its simplest form, a framework without carving known as *rowshan*. The rowshan 2.4m (8ft) wide and

approximately 3m (10ft) in height, coinciding with Greenlaw`s (1967) description of rowshan at Suakin on the west bank of the Red Sea. They were favourite places to relax, lie down, sit, and chat (Oliver, 1997), as shown in Figure 2.9.



Figure 2.9 Rowshan supported by corbels embedded in the walls (Oliver, 1997).

Accordingly, there is more than one advantage for the use of shanashil and its derivations: a) it was a flexible element used for sitting or living in; b) it was used to provide privacy while keeping watch on the public outside; c) its sealed screen design known to being flexible to open on three sides to provide air ventilation, and a cooling effect; d) it provided shading to pedestrians on the streets and to lower walls of ground floor at the same time (Al-Khafaji, 2002; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982). Nevertheless, it is important to realise that shanashil was effective not only because of its individual qualities but for the combination of its features, as described by Almaiyah and Elkadi (2012), and Fathy (1986). Accordingly, the shanashil provided overall quality through focusing on the part-to-whole design relationship.

Shanashil was designed to be in harmony with the hot climatic conditions and the surroundings taking into consideration the choice of colour, technique, shade, and texture of material used. Therefore, the traditional element was flexible enough to maintain its overall design relationship.

The next section will discuss in depth the main characteristics behind the success of the traditional elements that once expressed aesthetic satisfaction and the sustainability of environmental, social and cultural aspects in the architectural façade.

2.5 THE CHARACTERISTICS OF TRADITIONAL DESIGN ELEMENTS

Contemporary architects can learn from the traditional architecture, elements and surroundings; the understanding of the success of their elements is through understanding the relationship between human beings and their physical environment. Agha (2015) discussed that traditional Baghdadi houses represent the typical example of Baghdadi buildings. However, the same features managed to develop in different ways and spread across different places with the same influence on existing location, construction, and climatic features due to their flexible design qualities (Sibley, 2006). This is because of the part-to-whole design relationship between traditional houses and their elements had an impact on the cultural, social and environmental aspects that in return facilitated sunlight, air flow, and visual as well as aural communication (Alkhalidi, 2013; Shokouhian, Soflaee, & Nikkhah, 2007; Warren & Fethi, 1982). An example can be seen in Al-Kadhimiya buildings in Baghdad, Iraq (Al-Akkam, 2013), as shown in Figure 2.10.



Figure 2.10 Components of the shanashil as a multipurpose design element in the Al-Kadhimiya historical area in Baghdad, Iraq (Agha, 2015).

Moreover, Almaiyah and Alkadi (2012) explain that the traditional elements in general work in harmony with surroundings due to their integrated relationship with façade's arrangements. For example, the tight busy streets and narrow winding alleyways are the most recognizable urban components that form the urban fabric and façade elements of old Cairo, as shown in Figure 2.11.

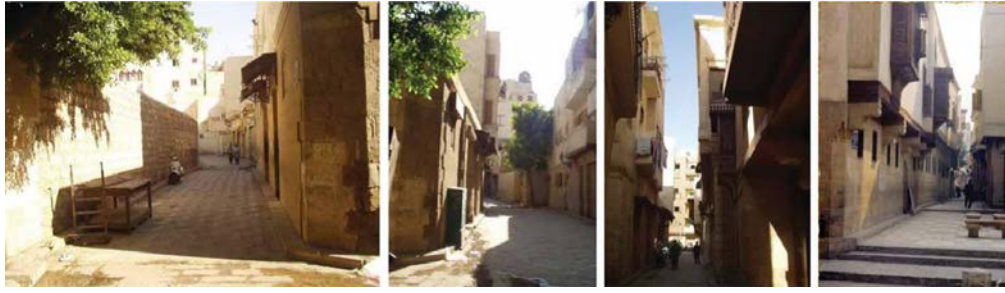


Figure 2.11 Traditional elements which overlook the narrow streets of old Cairo (Almaiyah & Elkadi, 2012).

Thus, integrated design relationships are needed to be understood in order to match the design needs such as controlling the changes of the surrounding environment without compromising the aesthetic quality of the space and the occupants' well-being. Accordingly, there are several integrated aspects, whether explicit or implicit, that demonstrate the aesthetic and functional design quality of traditional elements.

2.5.1 Regionalism

Regionalism suggests that architecture reflects its time, place and culture by linking to the past, the present and perhaps the future. Moreover, regionalism leads to the values and attitudes that determine architecture throughout its history. The ability of architecture and urban design to draw inspiration from, and contribute to, the particular special qualities of its context is a fundamental source of design meaning and richness. Regionalism also shows cultural differences (Hakim, 2013). For instance, the same traditional shanashil design element is found in Tunisia but in the colour blue that conveys the impact of location near the sea (Oborn, 2012), and at the same time reflects the flexibility of the window/wall/balcony design element, as shown in Figures 2.12, and 2.13.



Figure 2.12 Blue Mashrabiya, Sidi Bou Said, Tunisia (Oborn, 2012).



Figure 2.13 The use of blue colour in the expression of an architectural façade as seen in its traditional elements (TrekEarth, 2016).

The natural colours and shades of wood and local materials as fired brick are more familiar to design identity of traditional Baghdadi buildings in Iraq (Al-Bayati, 2011; Al Silq, 2011; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982), as shown in Figure 2.14.

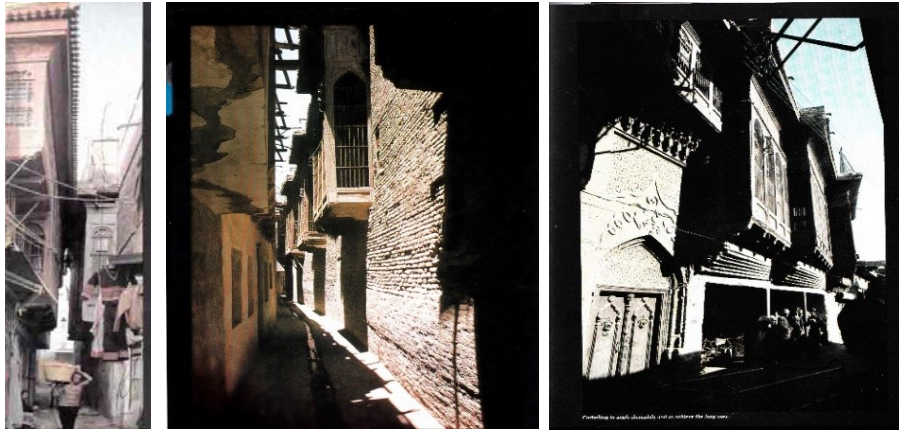


Figure 2.14 Neutral material colours in an order that blends in harmony with the surroundings (Fethi & Al-Madfai, 1984).

2.5.2 Transparency and the Idea of Elegance

The use of a window/wall/balcony element as an important, shading device has various interpretations such as clarity, transparency, delight, and intelligibility, as described by Kenzari and Elsheshtawy (2003). The shanashil as an external façade projects a flexible design in its various shapes, sizes and angled, as shown in Figure 2.15 (a) and (b).



Figure 2.15 (a) Different sizes of shanashil to prove it is flexible in a different elegant sense of form and function, (Al-Haidary, 2008). Figure (b) An angled shape to provide a longer view (Warren & Fethi, 1982).

Smaller shanashil are situated on corners or retreats at internal mezzanine level. The ceilings were sometimes as low as 1.7- 2 metres and their width ranged from 0.7 to 0.95 metres. These internal façades that overlook the interior courtyard is known as kabishkan (Al-Bayati, 2011; Alfetal, 2001; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982), as shown in Figure 2.16 (a) and (b).

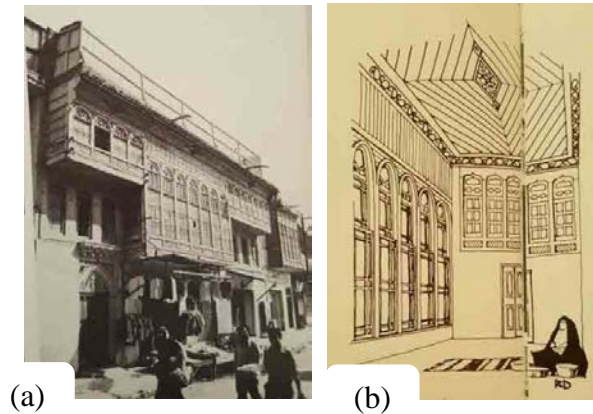


Figure 2.16 (a) Design elevation of traditional elements in various arrangements of shapes and sizes (b) interior connection between the mezzanine and the shanshal (Warren & Fethi, 1982).

However, Kenzari and Elsheshtawy (2003) point out that the screen design pattern on the surface is fixated by the idea of hiding, preserving privacy, and restricting the movement of women. However, it is important to realise that the same device pattern allowed women to partake in public life while preserving their privacy. With this same meaning, the veil as a layer in the design pattern has evoked remote participation and control. It allowed the women to keep their privacy while extending the family space into the streets beyond their home zone.

More importantly, the same social and cultural sustainability of traditional Baghdadi architecture is reflected as an analogy to the traditional women's practice of wearing the veil while walking in the streets. Kenzari & Elsheshtawy (2003) and Allen & Iano (2011) argue that the integration of a design pattern that allows transparency through weaving techniques is important to protect privacy that is sacred to cultural and social aspects of certain cultures, as shown in Figure 2.17. Thus, transparency provides a perception of different spatial locations, a viewpoint, from inside and outside.

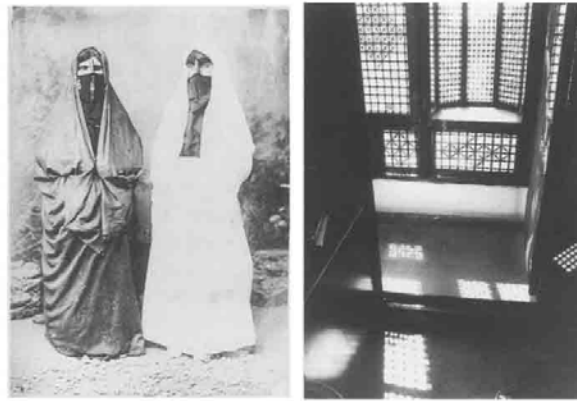


Figure 2.17 Analogy between the practice of women wearing the veil and the use of shanashil screen pattern as a device to deliver both public needs as well maintaining privacy at the same time (Kenzari & Elsheshtawy, 2003).

Transparency in architecture finds its meaning historically even before the use of glass through woven and braided wall strategy (Allen & Iano, 2011). In this sense, transparency expresses the idea of flexibility through the ability to reflect more than one meaning with control of clarity, and privacy between indoor and outdoor environment at the same time (Ascher-Barnstone, 2003).

Therefore, the concept of transparency in shanashil is about flexibility with control to maintain balance between private and public needs (Kenzari & Elsheshtawy, 2003; Mahfouz & Serageldin, 1990). Earlier shanashil had only the individual sash window units of wooden panels with little or no glazing. In later houses, circa 1880, iron grilles were extensively used for protection and coloured glazing was common (Al-Haidary, 2008; Warren & Fethi, 1982). Therefore transparency is not just an attribute of the clarity of the glass material itself. The concept of transparency is an attribute of certain needs such as observation (of the street) and privacy (of the individual). Accordingly, the design strategy is in the use of shanashil screen pattern as a flexible design element (Kenzari & Elsheshtawy, 2003).

The author agrees with Alfetal (2001), Kenzarri and Elsheshtawy (2003), and Lewis (2007) that transparency is a characteristic of material and not the material itself, allowing the screen design pattern to be flexible in providing a view for communication, light and shade needs, and healthy air ventilation while maintaining privacy. The design pattern delivered a multifunctional design quality. Thus, the next section will discuss the integrated relationships between transparency and order as

part of the screen design pattern that played an important role in the success of shanashil.

2.5.3 Order and Design Pattern

Alberti and Bartoli (1986) suggest that complexity of architecture is useful. It can be seen in a plain and simple design order. There is an order that guides the architecture principles in combining part-to-whole design. The same order is responsible for the complexity of architecture and for the design character reflected in putting things in their proper place (Vitruvius, 1960). In this sense, observing the design order is important to make proper adjustments to the forms of versatile expression related to a unity in the perspective, and elevation. Perspective is a sketch that illustrates symmetry, beauty of the adjustment details, and propriety needs regarding location to deliver the harmony that unifies the design pattern and context into one entity (Critchlow, 1999; Picon, 2013). Coulton and Rasmussen (1977) argue that the repetition of the components is important for the visualisation of form and function. Accordingly, order plays an important role in the identity of architecture through its role in the complexity of the design pattern and layers in terms of colours, textures, lines, curves, and arches. Traditional architecture reveals an understanding of the laws of composition, which create a conscious arrangement of elements of a building in a way that conveys functionality and visually satisfying the whole regarding architectural elements. Design tools such as scale, proportion, shape, size, contrast and balance are also used to enhance the design characteristics of traditional buildings. Nevertheless, harmony with the surroundings is an important part of the design element, for instance, the two storey house of Baghdad have been developed since the beginning of old cities and is integrated in harmony with the surroundings environmentally, socially and culturally (El-Shorbagy, 2010).

The order of the shanashil is an essential part of screen design pattern. Such window/wall/balcony elements were always extremely elaborate and richly ornamented with complex geometric patterns backed by coloured glass in later versions. In some rarely surviving cases the entire window/wall/balcony was made as one complete and complex panel of delicate interlacing geometric joinery whose beauty, scale, and intricacy rivalled other materials at that time (Al-Haidary, 2008; Alfetal, 2001; Warren & Fethi, 1982), as shown in Figure 2.18.

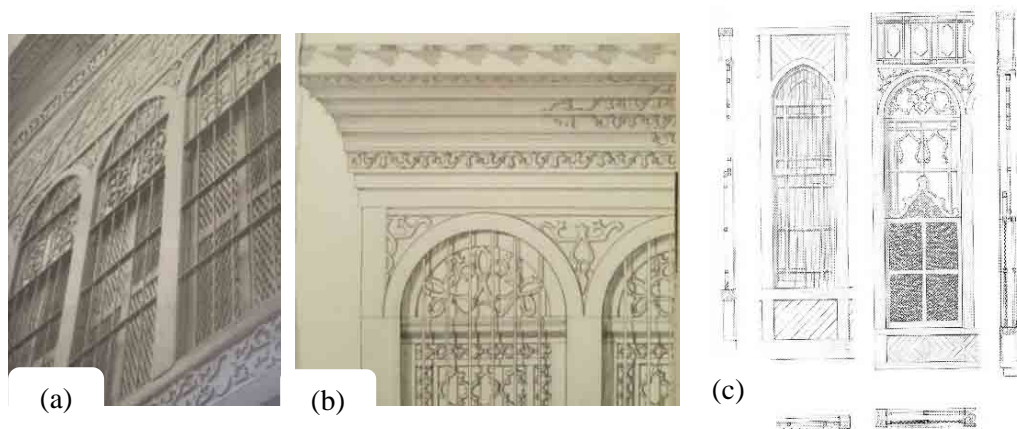


Figure 2.18 (a) (Al-Haidary, 2008), (b) and (c) (Warren & Fethi, 1982) The order that connects the window-wall element parts together can be seen in lines, curves, circles, arches, and ornament parts.

The visual impact of the homogeneous single colour emphasises the basic form of the building without the distraction of various colours. As a result, there is an order attached to every part of the design pattern which can be observed in the use of materials and textures. Thus, the next section will discuss in depth the integrated relationships of the design pattern between architecture and its elements regarding daylight and visual control, both aesthetically and functionally.

2.5.4 Visual Impact and Light Control

Every element of the building is usually designed to provide many effects whether social, environmental, visual or aesthetic. An aspect is the dynamic contrast of light and shade, which is one of the important features that can be observed in the architecture of shanashil. Light entering through a window or mashrabiyya evokes an expressive shadow, which highlights the shape of the interior (El-Shorbagy, 2010). In addition, Al-musaed et al. (2007) and Alkhalidi (2013) argues that the opposition of light and shade is dramatically expressed in the architecture of these screen patterns. The mix of diffuse light and shade is an essential aesthetic factor in these buildings. Light enters in a decorative pattern repeating the same decorative pattern of screen design. The design of screen pattern also controls the amount of light entering the building to protect from heat and therefore conserve the cool interior, as seen in Figure 2.19.



Figure 2.19 Traditional screen pattern from an interior point of view including light and shade role (Abdelsalam & Rihan, 2013; Fathy, 1986).

Due to the absence of glass in the original models of the design element, the traditional buildings used the wooden screens to control the light coming from the outside. The small openings designed through the screen pattern are deliberately made to allow a view from the inside and obstruct it from the outside. The screen design pattern allows sunlight to enter through limited spaces in order to reduce its uncomfortable effect on the occupants, the damage of furniture and raising the indoor temperature (Vine & Casey, 1992). More importantly, there is a quality of delight in the shanshil screen pattern that can be seen in the use of timber providing a rich pattern of soft and rich harmonies of light and shade (Al-Bayati, 2011; Al-Khafaji, 2002; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982).

2.5.5 Aesthetic Aspects in Traditional Elements

In the traditional buildings, the aesthetic aspects are often achieved through the use of the materials. Elaraby (1996) argues that part of the aesthetic values is harmony, compatibility in which function and aesthetic values are treated as one with balance and simplicity. Moreover, colour also play an important role in the visual and aesthetic effect of buildings. Consideration was given to providing harmony between the building elements, masses, and at the same time to the harmony between different buildings in one community (Alkhalidi, 2013). Decorative wooden patterns of shanshil add beauty to the interior and to the exterior of the building (Al-Bayati, 2011; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982).

According to Elaraby (1996), and Grube and Michell (1978) architectural design collectively caters for creativity and innovation even though every culture depends

on their own traditions. Nevertheless, culture itself is not a static condition since it is a way of life that constantly adapts to change. Part of the changing process is borrowing from the past while developing a distinctive object then passing it on to a new age.

The design of traditional architecture is about blending the life of individuals within the society and culture as a whole in a way that achieves maximum efficiency without losing the aesthetic satisfaction. For instance, decoration and ornaments are combined within a material to achieve elegant order (Elaraby, 1996). Moreover, one of the aesthetic qualities expressed in unity is the integrated relationship between colour and light as a whole. Further, colour cannot be expressed without identifying the importance of light; the same is with light since it unites all colours. Traditional architectural design is always aware of the impact of light, colour, and shade as an important part of the design pattern (Al-Bayati, 1983). This is based on understanding the sustainability of traditional architecture that caters collectively to aesthetic qualities in terms of light, transparency, shade, shape, size, colour, beauty, and texture (Ibrahim, 1986, cited in Elaraby, 1996; Serageldin & Herbert, 1981).

Accordingly, aesthetic qualities associated with the design pattern such as light, colour, shade, texture, shape and size are not isolated from the life of individuals. The next section will discuss in depth the role of sustainability and its impact on the overall design quality in terms of environmental, social and cultural aspects.

2.5.6 Sustainability of Social and Cultural Aspects

Sustainability as a concept is deeply rooted in the social and cultural aspects of the community as a whole. It might be difficult to separate social aspects from the design context that govern the design pattern's parts and layers (Grube & Michell, 1978). An example is seen in which traditional Baghdadi houses have an order of even height so no family would be spied upon from above. The same order is based on a religious order derived from the hadith (the saying of the prophet): "La dharar wa la dharar" "do as you would be done by" as part of a rigid social pattern. This issue was needed to sustain privacy and public needs stating that no damage should be done by the person(s) or to the person(s) (Al-Khafaji & Al-Qaisi, 2012; Fethi & Al-Madfai,

1984; Al-Ahbabi & Neama, 2011; Warren & Fethi, 1982), as seen in Figure 2.20 (a), and (b).

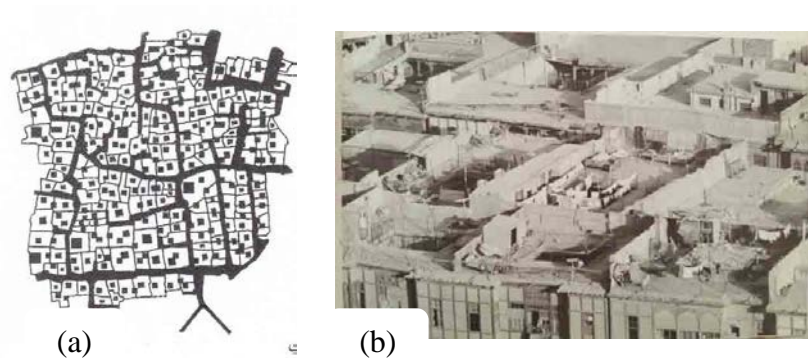


Figure 2.20 (a) Top view of the common traditional houses (Al-Haidary, 2008). (b) The even height of such houses, shared walls, and being adjacent to one another with its narrow streets and lanes (Warren & Fethi, 1982).

The same order governed the privacy and public state of the day to day life due to its effect on the building regulations, with traditional houses sharing party walls with the minimum street elevation. The elevation in general had small windows on the ground floor while the upper floor projected *shanashil* wooden balconies. The rooms generally face the north and east in order to be constantly in shadow (Al-Ahbabi, 2010; Al-Haidary, 2008; Warren & Fethi, 1982).

Moreover, the windows of *shanashil* projecting from the first floor level out over the street were within easy reach of other equivalent windows. This provided for public relations to thrive in which each house kept its own privacy while enabling easy communication among neighbours through their screened windows of the *shanashil* design pattern (Al-Haidary, 2008; Alfetal, 2001; Fethi & Al-Madfai, 1984; Warren & Fethi, 1982).

Reuther (1910), Al-Khafaji & Al-Qaisi (2012) argue that the unusual design quality at that time in comparison to modern life and in the West added to the freedom and flexibility of design. The design purpose of each room in the Western culture is defined by a fixed order regarding its position in the ground floor and by the furniture. Whilst from an oriental design perspective, there is always flexibility within the private and public state. For instance, the same separation of such a design approach takes into consideration the function of the rooms whether for living in, dining, or differing use during the summer, winter, morning, noon, or night. Therefore, there are

no fixed standards for the size of the rooms, as shown in Figures 2.21, and 2.22 (Warren & Fethi, 1982).



Figure 2.21 Different shapes and sizes of shanashil (Warren & Fethi, 1982).

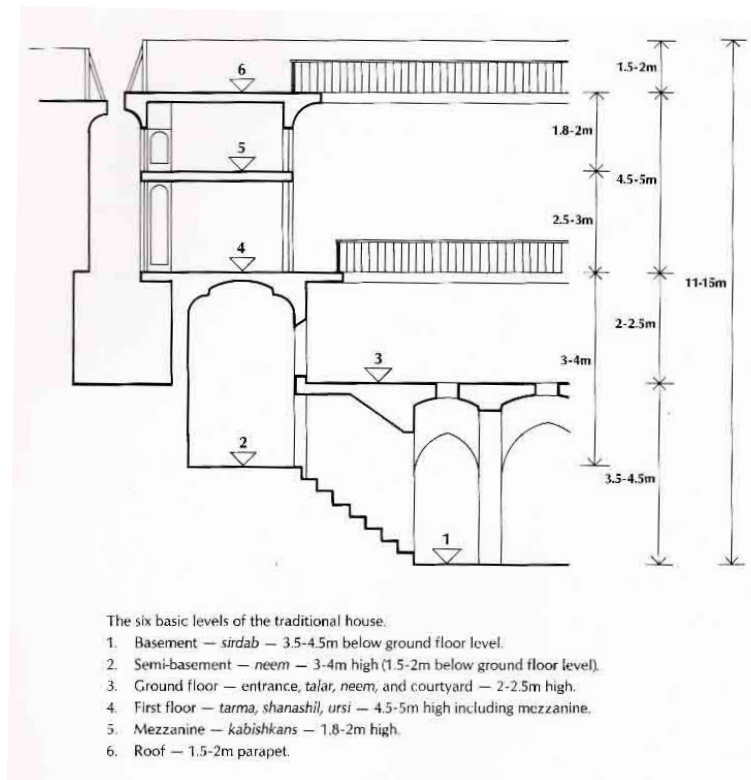


Figure 2.22 The flexible distribution of levels and rooms (Warren & Fethi, 1982).

Accordingly design flexibility is more limited in the modern approach when it is compared to that of the traditional approach. Culture, order, and change play a main role in influencing our design aspects and social interactions with others, whereas architecture is a physical expression of that influence.

The notion of privacy acquires various interpretations in different contexts to accommodate changes of social and cultural aspects. Privacy is defined as the mechanism of developing and maintaining the process of mutual relationship among individuals, within a small social group, or in society at large (Al-Thahab et al., 2014). Altman (1975) discusses that privacy boundaries are similar to those of a cell membrane boundaries when compared to individuals' privacy. Further, patterns reflect an individual's identity and their private needs (Al-Homoud, 2009). Alan Westin (1967) argued that privacy works as the withdrawal of an individual from society. In this sense, privacy is never absolute as it is a changeable interaction of social and cultural aspects (Ramezani & Hamidi, 2010).

Nevertheless, privacy is expressed through a dynamic ability of pushing towards an essential degree of openness-closeness, or accessibility-inaccessibility (Altman, 1975). For Rapoport (2013), and Ramezani & Hamidi (2010), privacy is the power and ability of managing cultural interactions between different social groups to achieve the desired level of interaction. The privacy mechanism provides personal privacy but allows visual, and aural means of communication among neighbours and friends (Rahim & Hassan, 2011). Salama (2011) argue that attaining the design pattern, order and context demand should not aim at merely providing affordable shelters, but also provide design solutions that are sensitive to the changes in environmental, social and cultural aspects in relation to privacy, and public needs.

Thus, the degree of social and cultural consistency between the public/private, and outside/inside notions determine the design elements of the architectural façade within the pattern context as a whole. The next section will discuss the effect of the environmental aspect on the design flexibility to improve its quality, aesthetically and functionally.

2.5.7 Environmental Aspects

The environmental aspects should be the main consideration given throughout the design strategy including adaptability to the surrounding environment. Design elements should have their environmental aspects deeply integrated considering the needs of thermal comfort, energy efficiency and type of material used. In this sense, our ancestors in the Middle East erected sophisticated buildings and their main concerns were the thermal, social and efficient performance of their designs.

Generally speaking, traditional buildings were closely integrated into their physical environment and their designs and construction were based much more on the performance rather than decorative use of materials (Heschong, 1979). For example, the traditional elements of Baghdadi Houses had successful air movement through the use of passive systems of wooden balconies which provided the flexibility and improved the overall design quality. This passive design reflected the efficient use of natural resources with the opportunity to adapt to the harsh environment and changes in the climate conditions by providing natural ventilation, natural lighting, and natural heating linked to thermal comfort through balance in heat gain and loss. Similarly, the passive system not only responded and respected the environment, it also provided inner comfort for the occupiers and encouraged energy conservation (Agha, 2015).

Passive design of traditional buildings and elements in the old compact cities were naturally adapted to create a comfortable indoor and outdoor environment (Capeluto, Yezioro, & Shaviv, 2004; Heschong, 1979). However, the same passive system does not work in a modern city pattern because environmental comfort is now lacking in the traditional shanashil due to wider streets suitable for vehicles and parking lots. As a result, the traditional shanashil lost their functional qualities because they were no longer able to provide the shading needed to overcome the harsh environment. Thus, there is a need to add new ways to improve the level of environmental comfort (Vale, 2012; Warren & Fethi, 1982).

The author agrees with Agha (2015) that there is a need to first understand the essence of passive design behind the success of the traditional design element in order to explore how active systems can enhance the performance of a contemporary design element and restore part of its environmental aspects. Accordingly, the sustainability of the design aspects can be improved through enhancing the environmental quality in terms of material and energy use (Biggs et al., 2012; Kamara, 2013; Kua & Lee, 2002).

Biggs et al. (2012) argue that in order to have a flexible design that enhances the design quality, there is a need to be in control of the environmental aspects through active systems in residential, office, or commercial buildings. Nevertheless, in order to achieve that, the researcher shares the same views with Wong et al. (2008), Alwaer and Croome (2010), and Holden (2008) that there is a need for active designs that

mimic the natural qualities of traditional design elements, such as shanshil. Holden (2008) confirms that active systems can achieve full control of the environment, having a positive impact on sustainability of design aspects. Notwithstanding, Mitchell (2015) explains that there is still a struggle in balancing active design in contemporary projects and delivering responsiveness to a pattern context and appropriateness of expression to features of traditional design elements. Although some architects have responded to context-related concerns by referencing to 'traditional' building elements and/or drawing inspiration from historical settlement patterns, there is still the constant change and complexity in identifying a flexible contemporary design approach that poses challenges that are sensitive to pattern order, context, and climate type.

Accordingly, there is a need to maintain a flexible, elegant design that is able to match the changes of the surroundings regarding all aspects environmentally, socially and culturally, as in the type of material used. Hence, the next section will discuss role of change regarding design context including people`s needs and lifestyle. There is also a need to understand the effect of change on the complex pattern and its impact on flexibility of design both, aesthetically and functionally.

2.6 MODERNITY AND SUSTAINABILITY OF DESIGN

Several changes have taken place regarding the design features of Baghdadi buildings as the result of architectural evolution and pressure over the centuries due to modern planning, means of transportation changes, industrial and technological advancement, as described by Al-Bayati (2011), Al Silq (2011), Nouri (2014), and Warren and Fethi (1982). Elaraby (1996) argues that traditional architecture`s values do not remain static and that sustainability aspects used to be integrated in the traditional design element and expressed in unity with surroundings.

Accordingly, the impact of modern planning has changed people`s lifestyle, needs, and services. It also affected the architectural design identity (Abdelsalam & Rihan, 2013; Albrow, 1997; Waterson, 2013; Wise, 1998). Warren and Fethi (1982), Al-Khafaji (2002), and Stark (1992) argue that the narrow streets of Baghdad`s organic pattern which allowed for two pack animals to pass enabled the traditional elements

to be used as successful shading device both, aesthetically and functionally, as shown in Figure 2.23.

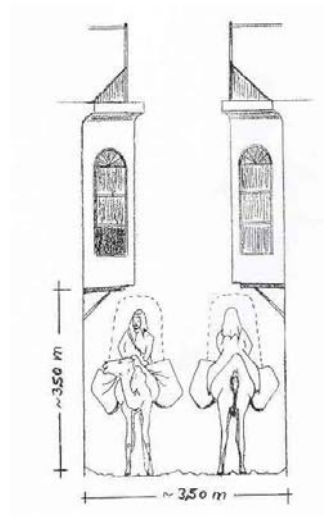


Figure 2.23 The narrow streets of the organic pattern allowed the accessibility of two pack animals to pass (Al-Haidary, 2008).

Nevertheless, the same screen design pattern and order could not survive the incoming effects of change in the nineteenth century when wider streets were established to accommodate the use of cars and parking facilities (Al-Haidary, 2008; Krier, 1979). Such change leaves the remaining traditional houses in a modern pattern left not shaded anymore by narrow streets which affects their sustainability of environmental aspects, as shown in Figure 2.24.



Figure 2.24 Empty area to accommodate the change of transportation means and car parking at al-Kazimayn shrine (Al-Haidary, 2009).

Furthermore, the new design pattern caters for larger houses that spread horizontally on one level in contrast to the old traditional design that was placed on a minimal site area with extraordinary diversity of spaces and accommodation, with high energy

efficiency (Al-Ahbab & Neama, 2011; Nouri, 2014). Figure 2.25 shows the difference between the small introverted traditional house (a) with efficiency of 100% and the large modern extroverted villa house design (b) that is six times less efficient than a traditional house (Warren & Fethi, 1982).

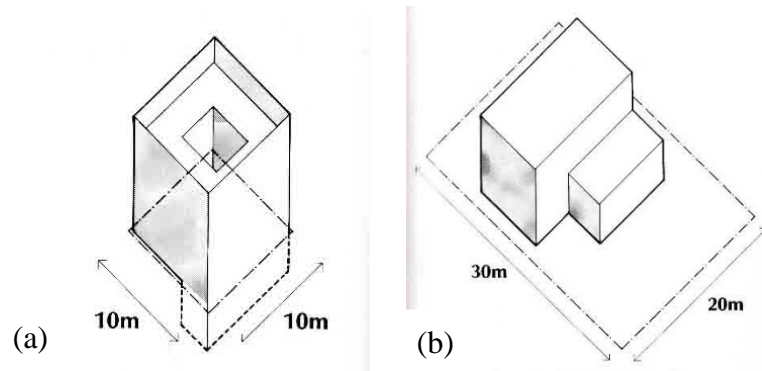


Figure 2.25 (a) traditional introverted Baghdadi house with plot area of 100sq.m completely covered by the building (100%), 350sq.m of usable floor space with floor to area ratio of 3.5 (b) modern extroverted Baghdadi detached house of floor area ratio of 0.6 and plot coverage of 50% (Warren & Fethi, 1982).

This issue has led to the historical and cultural detachment that traditional cities suffered, losing the identity and efficiency of their architecture (Abdelsalam & Rihan, 2013). In terms of material, it is essential to realise that the window/wall/balcony design element which was valued throughout centuries, now appears ineffective, and it started to disappear and lose its value (Lewis, 2007).

In addition, Fathy (1973) argue that it is important to maintain continuity of form and function through the harmony between aesthetic values and sustainability, both socially and culturally. This issue is important because architecture cannot exist without a living tradition. Senosiain (2003) argues that the house is essential for the formation of people`s lives therefore it should be convenient to both lifestyle and essential activities. Further, simplicity in design as in the use of material is important to provide an honest design expression. Similarly, there is a need to revive the essence of traditional values of a successful architectural design element. However, it is not about copying the past, or even to bow to the meaningless use of a new material, as described by Asfour (1998) and Kultermann (1999). Abdelsalam and Rihan (2013) explain that any imported idea and theories should be revised before employing them in the new context. It is about surpassing the old design by mimicking the qualities

for a better adaptive design within a contemporary design approach. Hence, manipulation of form and function provides potential for imagination and creativity. The use of modern materials should be to produce a new sense of harmony by identifying the important characteristics of design to maintain the design flexibility and deliver an overall quality, both aesthetically and functionally (Elaraby, 1996).

Although the traditional old material provided aesthetic satisfaction with sustainability of both social and cultural aspects, the use of natural material resources such as fired brick was always associated with impermanence issues. Fethi and Warren (1982), Fethi (1977), Fethi and Madfai (1984), Al-Bayati, (2011), and Alfetal (2001) discuss that even the old material like wood, which used to be the best choice to match the surrounding environment, had lost its value because the life span of the material itself had been reached in many cases, for instance, even timber which is integral to the structure had succumbed to termites. As a result, none of the traditional houses are of real antiquity because the majority have been rebuilt in the nineteenth century. In this sense, only less than 9% are of historic worth and they were built prior to 1869. In addition 63% of the listed buildings are in poor, or very poor, physical condition and have been degraded socially and have fallen into decay.

Nevertheless, all of this has changed due to the impact of modern planning and availability of modern materials in the lives of present generations (Al-Ahbabi, 2010; Al-Bayati, 2011; Al Silq, 2011; Nouri, 2014). Thus, replacement is necessary and there is always a temptation to improve. Moreover, the old structure must be improved to meet the needs of modern society. Al-Haidary (2008), Fethi (1977) and Warren and Fethi (1982) claim that the traditional design elements are in danger and the destruction of the majority of these elements seems assured, whilst at the same time, new featureless facades are built, ignoring the nature of the place. This way of design is affecting the identity and value of the place (Al-Thahab et al., 2014), Figure 2.26.



Figure 2.26 Contemporary residential units in Iraq (Al-Thahab et al., 2014).

It is important to mention narrow streets can no longer provide practicality regarding community lifestyles such as delivery and installation of kitchen appliances, not just in the city of Baghdad but others such as Al-Hilla (Al-Thahab et al., 2014), as shown in Figure 2.27.



Figure 2.27 Traditional elements in the external Baghdadi façade and the narrow alleys in Baghdad. Image courtesy of Ali Hassan Nouri.

Almusaed and Almssad (2015) explain that the choice of materials takes a high priority in the design process. Other significant changes have affected the environmental aspects regarding the traumatic escalation in energy prices, along with concerns over pollution, resource depletion, and climate change, as described by Strong and Ingemann (2003, cited in Abdelsalam & Rihan, 2013). Accordingly, change is necessary to develop the features of design. Therefore, the characteristics of traditional elements must be assessed because lifestyle cannot be frozen. Abdelsalam and Rihan (2013) identify that there is a need for a different material that can overcome such problems. This can be achieved through a different contemporary design approach that illustrates material characteristics in a different perspective. This

cannot be achieved without evaluating the design qualities of what the old material used to provide. Hence, the next section will discuss the design trends that architects produced based on the inspiration of traditional elements in architectural facade. It will also focus on which aspects in these trends were able to be expressed in design.

2.7 NEW TRENDS OF TRADITIONAL DESIGN ELEMENTS

There are examples that have focused on the role of screen pattern where it concerns the inspiration of traditional elements and its impact on the aesthetic aspects of the design. Such examples convey the flexibility of the traditional design element to be adapted and built using different materials using concrete, brick, or other materials instead of wood.

One of the examples that was inspired by the traditional element is seen in the design of Nassif house in Jeddah, Figure 2.28. The house represents an attempt by architect Hasan Fathy to reinterpret the traditional architecture of Saudi Arabia. The house facade features the essential Iraqi traditional architectural vocabulary, specifically in the aesthetics of screen pattern, as described by Alkateeb (1979, cited in El-Shorbagy, 2010).



Figure 2.28 Screen design pattern in the façade of Nassif house by architect Hasan Fathy in Jeddah (Archnet, 2002).

The prominent Iraqi architect Rifat Chadirji (1926) was aware of the traditional vocabulary of the Iraqi traditional architecture and employed it to serve contemporary needs. For instance, the architectural façade of Chadirji's Tobacco Building (1966) in Baghdad is clear evidence of a contemporary architecture. It exhibits a synthesis of abstract forms derived from his own traditions. For example, Chadirji employed a simple projecting shanashil image made of brick and concrete instead of the expensive wooden ones. Chadirji's architecture excluded simplistic imitations of

traditional features and primitive technologies to illustrate aesthetic design quality, as seen in Figures 2.29, and 2.30 (Chadirji, 1986).



Figure 2.29 Façade elements of Tobacco Building by architect Rifat Al-Chadirji , Baghdad, 1966 (Community, 2016).



Figure 2.30 Union of Industries building in Baghdad design by architect Rifat Al-Chadirji in 1970 (Sherzad, 2002).

Other examples can be seen in Baghdad in which the design elements were an inspiration from the traditional shanashil image and integrated in the façade of multi-storey buildings as in office buildings designed by a number of architects such as Hisham Munir, (Figure 2.31) and Said Ali Madhlume, (Figure 2.32).



Figure 2.31 Ministry of Commerce in Baghdad designed by Hisham Munir in 1965 (Sherzad, 2002).



Figure 2.32 illustrates the Art Institute in Baghdad designed by Said Ali Madhlume in 1974 (Sherzad, 2002).

Another example using brick expressing the facade element as an extension in the first floor instead of traditional material is seen in Al-Bataween, Baghdad, Figure 2.33, and depicts the type of transitional houses that were built in the middle of twentieth century, as described by (S. Al-Bayati, 2011; Al-Haidary, 2008; Nouri, 2014).



Figure 2.33 Transitional shanashil in Al-Bataween area in Baghdad, Iraq. Image courtesy of Iraqi architect Ali Hassan Nouri.

Moreover, there are several contemporary examples not just in houses, but also in residential and commercial buildings that capture the inspiration of the traditional element based on the aesthetic aspect as in the choice of material, colour and texture of the screen pattern, Figures 2.34, 2.35, 2.36, 2.37, and 2.38.

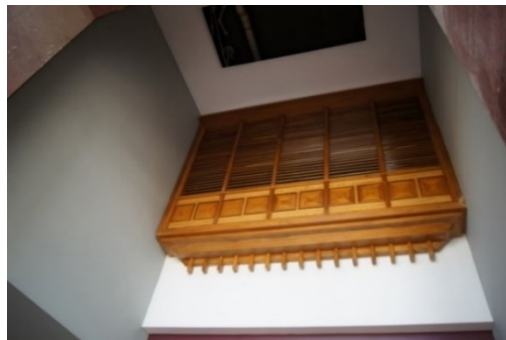


Figure 2.34 Inspiration of shanashil idea in one of the rooms in AL-Qasar Arasat Hotel in Baghdad 2013. Image courtesy of Prof. Ghada Alsilq.



Figure 2.35 Inspiration of the shanashil idea in a multi-storey office building built in Sulaimania, Iraq. Image courtesy of Prof. Ghada Alsilq taken in 2013.



Figure 2.36 Commercial building in which the inspiration of the shanashil is in the use of concrete designed in early seventies by Iraqi architect Hisham Munir in Baghdad, Iraq. Image courtesy of Prof. Ghada Alsilq taken in 2014.



Figure 2.37 Inspiration of the shanashil idea in Arbil, Iraq. Image courtesy of Prof. Ghada Alsilq taken in 2013.



Figure 2.38 Inspiration of the shanashil only in its aesthetic aspects in a multi-storey office building in Sulaimania, Iraq. Image courtesy of Prof. Ghada Alsilq taken in 2013.

Another example illustrates the active role of technology in the interpretation of the screen pattern design concept between transparency, light, shade, and privacy. The responsive façade building of Institute du Monde Arab in Paris has an intricate geometrical design made up of panels that are reactive light screens to control the amount of light and glare that open and close dependent on light levels, and so the overall design alters depending on light, which reflect a high-tech approach (Thiel-Siling & Bachmann, 1998), as shown in Figure 2.39.

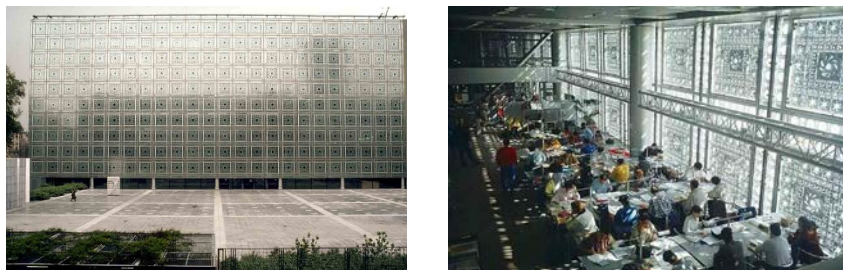


Figure 2.39 The façade design of Institute Du Monde Arab, Paris. (Winstanely, 2011).

Other trends can be seen in the use of the curtain-wall glazing due to the role of technological advancement to provide better design options in a hot climate in the Gulf Region (Karanouh, Miranda, & Lyle, 2011; Willis, 2015). Such options have led to the need for more dark-tinted glazing and closed blinds, with occupants relying on artificial lighting throughout the day (Derix, Kimpian, Karanouh, & Mason, 2011). However, Levine and Hughes (2008) argued that it is imperative that architects in the Arab world start designing climate adaptive, energy efficient buildings.

Therefore, whilst there is the need of transparency in design due to the need for more clarity and communication with the surrounding environment. However, Boake (2015) pointed out that there has been an increasing recognition for sustainability measures to be implemented and associated with energy issues in facade design that respond to the region's severely hot climate. The successful solutions have focused on solar avoidance, either through double facade techniques that employ modernised versions of the traditional mashrabiya-like screens, or through the incorporation of shading systems.

An example of such design can be seen in the façade of the Al Bahr Towers in Abu Dhabi (2012). Oborn (2012) argues that this integrated design is pushing the boundaries of modern design and technology in an innovative contemporary design. Such design takes into consideration the three issues of sustainability, bio-inspiration, and beauty principles. Furthermore, Percec and Rosen (2010) explain that bio-inspiration design provides novelty in solutions. Moreover, Chakrabarti and Shu (2010) discuss that inspired design enlivens the architectural form, creating an environmentally responsive facade material through dynamic added elements and conventional glass curtain wall, as seen in Figure 2.40.

The facade for the Abu Dhabi Investment Council Headquarters was developed and inspired by traditional elements to minimise the impact of the hot climate. Such transparent facade illustrates an exterior mechanised shading of 1,000 individual shading devices that form a layer on the east, west and south facades of the towers (Boake, 2015). The architectural facade employs an adaptive shading screen as a dynamic mashrabiya controlled by the building management system to reduce glare and solar gain, lower cooling loads, allow views to the outdoors and natural light.

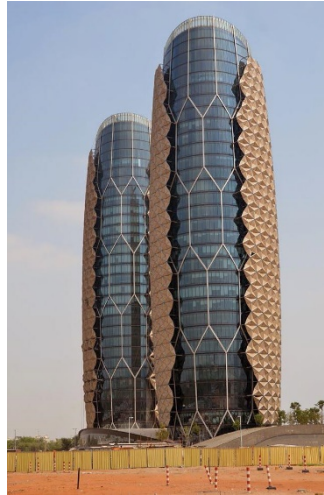


Figure 2.40 The use of transparency in Al Bahr Towers covered by exterior shading devices from all sides except the north façade (Boake, 2015).

This way of design will make the use of artificial lighting, energy consumption, and carbon emissions to be significantly reduced (Derix et al., 2011).

However, a major challenge is managing energy performance and user comfort through the design process. In addition, the design is an ambitious new one for the Abu Dhabi regulations which builds on a rigorous blend of the US LEED (Leadership in Energy and Environmental Design) silver standard, and the UK BREEAM (Building Research Establishment Environmental Assessment Method) standards for sustainable building indicating a significant reduction in cooling loads (Audrey Ellison, 2005; Derix et al., 2011; Oborn, 2012).

However, although this design approach depends on bioinspiration within the biomimetics approach, nevertheless, it is using smart material that is added to the design element in the curtain wall glazing and the added exterior shading device technology.

Furthermore, it is important to mention that other types of glazing materials were suggested like photovoltaics as a smart dynamic glazing at the concept stage of Al Bahr towers. The design idea was that the inspired mashrabiya devices would integrate photovoltaic panels on the roof of each tower. However, during the design development stage, the projected cost of installation coupled with the very low electricity consumption of the mashrabiya's mechanised system, which is negligible

when compared with the overall power consumption of the building, proved prohibitive and a decision was taken to omit the photovoltaic panels (Oborn, 2012).

Another example can be seen in the integration of Photovoltaics (PVs) at the Energy-Conscious Office Building in Ankara, Turkey designed by C. Elmas, USA. This example is one of the competition ideas focusing on encouraging architects to incorporate "Photovoltaics in Buildings" to tackle the technical and aesthetic challenges in design. In order to make this technology acceptable, this project uses the PV modules as sunshades that are reminiscent of traditional mashrabiya's wood lattice screens. PV modules used are fixed in location and transparency state in order to respond to the sun (solar radiation) Figure 2.41. Nevertheless, it is important to realise that one of the biggest weaknesses of the solar cells is the high installation cost (Sick & Erge, 1996).

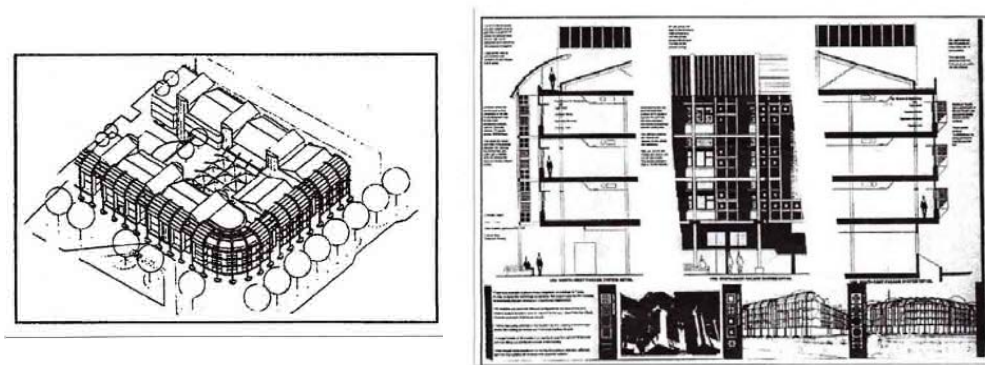


Figure 2.41 Distribution of Photovoltaics as part of the façade design in Turkey for IEA competition entry by C. Elmas, USA (Sick & Erge, 1996).

The amount of electricity generated by these solar cells is still not high when compared to the initial cost of setting up the solar plant (Writer Community, 2014). Kaan and Reijenga (2004) explain that the problem of architecturally integrating photovoltaic technology requires an interdisciplinary design approach. There are still many architects that have never thought about using PV as means of architectural expression and have therefore never produced good solutions for architectural integration of PV. Another issue with such inexperience and lack of PV knowledge by clients and designers is the cost and maximizing revenues. Moreover, the architect often has no convincing argument for combining the architectural and aesthetic qualities with the possibilities offered by PV systems (Kaan & Reijenga, 2004). The balance between the issues of PV building design and construction will vary greatly

according to the circumstances of each project (climate, budget, client priorities including aesthetics qualities such as colours (Sick & Erge, 1996).

Buildings of the future must be environmentally responsive in a way that delivers a balance between aesthetic and functional aspects. Therefore, the challenge in architectural design lies in the adoption and adaptation of new design material taking into consideration social and cultural sustainability, including location, climatic condition, and other aspects like light and shade. This can be achieved in terms of a smart material with better adaptive strategies that can improve the flexibility of design without destroying, or neglecting, the design values of traditional elements regarding aesthetic aspects.

Accordingly, the research acknowledges that all the previous examples discussed express only one aspect of the design element, mostly in the aesthetics aspect. Other examples depend on the role of active design in a way that is added to design with issues regarding cost and maintenance. Thus, they are still not delivering aesthetic satisfaction with environmental control that add to idea of functional beauty in design. This can be achieved through active design in terms of a smart material that is collectively embedded in the design element.

Therefore, the next section will discuss the need to focus on a smart dynamic transparency that is flexible and efficient in a way that differs from what traditional design elements used to provide and will discuss the idea of functional beauty in design aspects.

2.8 FUNCTIONAL BEAUTY IN ARCHITECTURE

The essence of architecture is found in whatever buildings exist. In this respect, almost every building has a trace of a design flare that does not entirely belong to the functional aspects (Andersen, 1977; Denyer & McClure, 1978; Forde, 2013; Oliver, 1976; Rapoport, 1975; Rudofsky, 1972). Beauty of any architectural composition depends to some extent on culture, surrounding environment and personal experience as it is associated with order and balance. As a result, the design object appears beautiful, elegant, and timeless. Thus, the essence of architecture is understood when the design is successfully connected to the surrounding environment and culture (Lehman, 2011). There is a problem when trying to define architecture as an addition

to a building, as architecture has an elaborate perspective that collectively covers the building process, bringing all aspects of the building together (Hillier, 2007). Although change is inevitable, Aristotle (1972; 1971) stated that any change that does not add to the essence of the object will be useless for the purpose it is made for. As for the relationship of form and function, there is a debate on which one dictates the other. Sullivan (1896, cited in Gómez, 1967) states that shape itself comes after function, whilst Le Corbusier argues that any process in nature starts from inside to out in which the interior dictates the exterior (Venturi, 1977).

The theory of organic form is not about the apparent shape but it is all about the function of that form (Bruckner, 2011b), whilst Steadman (1979) argues that the term 'organic architecture' is more about the aesthetic appreciation, in other words organic architecture combines the work of art and the phenomena of nature. A good example of organic architecture is La Sagrada Familia, Barcelona, by Gaudi. In this case, the decoration and sculptures are an imitation of nature and function following patterns of the structure within a part-to-whole design relationship (Steadman, 1979), as shown in Figure 2.42.



Figure 2.42 Decorative shell of La Sagrada Familia, Barcelona by Gaudi. The disposition of the parts is closely connected to the function within the whole (Steadman, 1979).

Similarly, aesthetic properties could appear from a background of non-aesthetic ones (Cohen, 1973; Sibley, 1959; Tatarkiewicz, 2006). Whilst, non-aesthetic categories could be perceived as beautiful for their functional needs (Davies, 2006; Parsons, 2008; Sauchelli, 2013; Shiner, 2011). Accordingly, Senosiain (2003) argues that there is no form without function; function is not separated from the form. Furthermore, form and function are not separated as they are closely connected to one another, for example, the leg is designed to support and move the body. In addition, everything

that is related to the leg in terms of shape, colour and texture is designed to support its living process as a whole, yet the leg as a part separated from the whole is unstable. This concept can be explored through biomimetics, as described in section 1.2, because biomimetics caters for the study of both function and form analogy to those of living models. Furthermore, the biomimetics approach is applicable to the designs of different branches of science.

However, the relationship between aesthetic and function has not been fully explored as a single entity within the principles of the architectural design process. This can be achieved within the quality of design elements in terms of shapes, colours, and lines (Sauchelli, 2012).

2.9 ORGANIC APPROACH IN ARCHITECTURE

This section will discuss in depth the approach of organic architecture and its integrated relationship with nature taking into consideration the impact of the surroundings.

The idea of organic architecture is flexible and does not just include traditional material like straw, wood but also new materials that provide better opportunities for structural innovation (Pearson, 2001; Sergeant, 1976). Organic architecture in its inspiration of nature's models helps manmade designs be built more cleverly, subtly, and ecologically, such as using less material and less energy (Pearson, 2001; Sergeant, 1976). Organic architecture is about delivering an organic space that is suitable for developing physical, social, and cultural needs to create comfortable, living spaces (Senosiain, 2003). Some architects of the twentieth century like Frank Lloyd Wright and Le Corbusier had implicitly reinvented the aspect of functionality by unwrapping the layers surrounding the desired form, Figure 2.43.

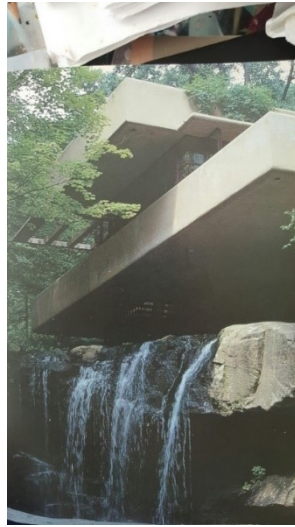


Figure 2.43 Falling water Bear Run, Pennsylvania by architect Frank Lloyd Wright (Pearson, 2001).

Further, organic architecture is based on a flexible, living tradition that can be constantly integrated with new directions for its diverse nature. More importantly, organic architecture is rooted in the reflection of natural forms through the interest of beauty and harmony of biological forms and processes (Cook, 1996; Pearson, 2001). However, Pearson (2001) argues that organic architecture is not able to free up design and the designer's creative processes. Thus, the need for technological advancement is to ease the modelling process from the traditional use of straight lines, right angles, and cubes to modern shapes and forms.

Accordingly, Senosian (2003) notes that change is inevitable, for instance, during the sixteenth century essential changes were necessary due to several changes in lifestyle, then changes were made regarding modern planning, privacy and the need to use vehicles. For instance, the organic introverted pattern of old city of Baghdad that is different in its street plans and housing density than the modern extroverted western city in the USA, as shown in Figure 2.44 (a), and (b).

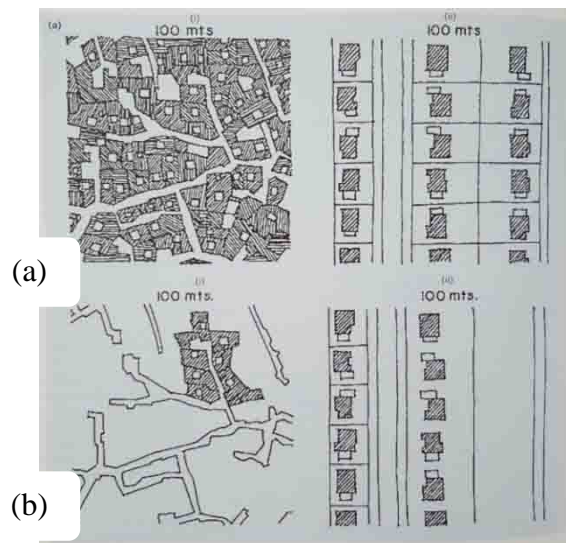


Figure 2.44 Comparison of the street plan and housing density between organic, introverted pattern (a) a city of the Middle East in Baghdad and modern, extroverted one (b) a Western city in suburbs of USA (Senosiain, 2003).

The complexity of the design lies beneath the layers that are part of the essence of the design process. Some architects such as Peter Eisenman and Greg Lynn took the approach of building elaborately over that essence while others chose to unveil it. The design process should implicitly add to its essential elements (Bruckner, 2011c). As regards imitating nature, there is a simple analogy by Le Corbusier that takes into consideration the design elements, where the modern free standing type of columnar structure of concrete or steel equals the external skeleton of an animal. The screen walls would then be equivalent to skin (Steadman, 1979).

The Spanish architect Santiago Calatrava (1993, cited in Hagan, 2001) presents design elements with a deep understanding and careful mathematical implementation. The design takes into account the unity between the function of the structure and an aesthetic quality added by the imitation of animal skeletons, as shown in Figure 2.45.



Figure 2.45 City of Arts and Sciences, Valencia, Santiago Calatrava: skeletal structure (Caltrava, 1993, cited in Hagan, 2001).

Gould and Lewontin (1979) discussed that technological development also affects the explicit aesthetic approach to nature in architectural design, form and function.

When architectural design does not support functional needs, it is considered a failure and loses any other aesthetic values attached to it (Conway & Roenisch, 2013; Roth, 1994; Scruton, 1979). For instance, Xenophon's Socrates explains that a golden shield that is too heavy to be carried in a battle is considered unworthy and loses its other values (Tatarkiewicz, 2006).

Therefore, the next section will discuss in depth the role of exuberance in design in a way that defines the importance of flexibility in design and the embedded details between form and function relationship. Such relationship was expressed in one of the distinctive features of shanashil.

2.10 EXUBERANCE IN ARCHITECTURE

According to Venturi (1977), as time goes by, architecture keeps facing new challenges; architecture in its ongoing struggle for vitality and validity faces new problems related to today's needs to overcome conflicts whether in program, structure, or other issues in relation to aesthetic expression. Architecture has embraced contradiction as well as complexity whilst addressing the Vitruvian elements of commodity, firmness, and delight. Accordingly, flexibility in design is

needed to provide the balance that enhances design quality, aesthetically and functionally.

Similarly, Colletti (Colletti, 2010a) argues that exuberance in architecture begins where common sense ends. A good example is in facing issues related to global warming by reconsidering the aesthetic aspects and thinking consciously to lower energy consumption and push the sustainability idea in design. In this sense, exuberance in design is in its potential to deliver sufficient qualities to fulfil the needed design requirements of beauty. Architecture is always capable of going beyond the simple, the obvious, and the rational through its ability to reinvent itself during the design process. Further, Reisner (2010) notes that the idea of exuberance is flexible for it goes beyond the shallow external features of any design as it lies deep within the complexity of the design process. It creates a direct response through the overall quality of the characteristic design approach towards beauty and delight. Nevertheless, although the focus is on the complexity of the design process, what is really important is the quality of the outcome which is expressed on the surface, and the three-dimensional exuberant depth. This includes what lies beyond the surface of 3D manipulations in form and material, as shown in Figures 2.46 and 2.47 (Reisner, 2010). The Figures illustrate the interactive relationships between the design elements on one hand and the ambience on the other.



Figure 2.46 The daytime phase, when the design shows an interactive installation of materials, textures, colours, light and shade (Reisner, 2010).



Figure 2.47 The nighttime illuminated phase, when the same design experience expresses a change in its 3D installation through gradient and shadows (Reisner, 2010).

The exuberance of architecture is in its complexity and can be developed to provide commodity, firmness, and delight whilst facing the challenge of global warming and the need to develop a design that is more sustainable with low energy efficiency.

Venturi (1977) argues that the complexity of architecture has an effect on the relationship of its design elements on various levels, both structural and ornamental. Nevertheless, the unity of the whole is hard to achieve; in the Gestalt theory the degree of wholeness can vary according to the characteristics of its individual parts. Moreover, according to Graham (2000), the form of architecture is independent, and equally important, to its function as the three basics for an adequate building design are structure, function, and aesthetic appeal.

Again, according to Graham (2000), there are three possibilities. One is for form and function to be treated separately, second is that form follows function, third is that form itself creates a function. An example is the extension of the House of Parliament in London. Along with the basic design structure erected by Charles Barry, the British government wanted architectural features influenced by the expressions of Englishness associated with Elizabethan and Jacobean styles. In this example, the complexity of function determined the form embellishment.

Further, Colletti (2010b) argues that the role of flexibility in architectural design is expressed within a two-fold conceptual tendency, the ornaMental and the pOrnamental. The first depends on abstraction to create pure form while the latter depends on sensation to reach the state of purely figural. Through the digital illustration and depiction of architectural design, simulation can produce pure

originality beyond the figurative rendering. OrnaMental is elegant within its value that expresses aesthetics and application whether it is in the symbolic structure, or digital strategy where abstraction equals ornament. For example, in Islamic patterns the figuration is skipped and instead classification of patterns and ornament is constructed. Its ornament is flat, and is more an intellectual and mental experience than mere decoration. Moreover, Almusaed (2011) argues that every architectural creation can be described by a building form (2D), but not every building figure can be described by architectural creation (3D).

POrnamentation, on the other hand, is not intellectual. Its value lies between aesthetics and performance where performance is understood as a task. The task is for the ornament to become the body where there is no intellectual strategy or structure. POrnamentation is exuberant through the complexity of ornament and architecture. Such complexity is seen in the temples of Mayas, Incas and Aztecs, and in India as in Jain, and Hindu temples. The downside is that pOrnamentation may take an extreme approach where the task's performance does not match the reality. In addition, for both ornaMental and pOrnamental design, ornament is not the only part of architecture (Colletti, 2010b).

In this section, studies like Colletti (2010a) and Reisner (2010) refer to architecture's ability to create through the meaning of flexibility encompassed by the both parts of the two fold conceptual framework, in which abstraction and sensation is important for understanding the relationship of form and function whether in a 2D or 3D design manipulation. However, it is important to realise that the Unity of the whole is hard to achieve.

Therefore, flexibility is in the complexity of design that caters for the integrated relationships of form and function as in 2D and 3D design parts. Accordingly, any illustration for an overlapped design approach between architecture and any other disciplines should be accompanied by a clear insight of the design pattern.

2.11 ELEGANCE IN ARCHITECTURE

This section explores the complexity of architecture as regards elegance principles that improve the design quality by combining both aesthetic and non-aesthetic aspects of design elements.

Architecture's main goal lies in having an integrated design approach that it is planned and changed to achieve the satisfaction and the comfort expected of designed spaces (Pallasmaa, 2012). Architecture as a phenomenon considers elegance the most influential objective aspect of design. For example, the Palais-Royal intends to elegantly deliver a respectful composition of design elements, Figure 2.48 (Lincourt, 1999).

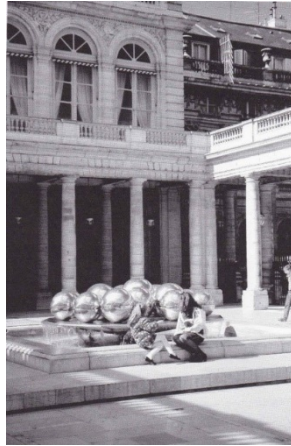


Figure 2.48 The Palais Royal and the children's play area showing respect for design elements (Lincourt, 1999).

Although some sort of ambiguity may always be present in architectural design, elegance expresses creativity in terms of tools, ornaments, or man-made objects in a work that presents continuity through simplicity that is drawn out of the complexity of the original context (Heidegger & Préau, 1962).

In addition, Lincourt (1999) argues that elegance in architecture is a double measure of quality satisfaction and beauty appreciation. In this sense, architecture is the phenomenon of a present object designed with a purpose that defines an elegant timeless space through the quality of design elements as a whole in terms of appropriateness, harmony, rhythm, order, contrast, colour, texture, light and shade. Levinson (2003) explains that an elegant design satisfies the requirements of efficiency and economy. In engineering, for instance, a solution may be considered elegant if it uses methods that are effective and simple to solve multiple problems.

According to Rahim and Jamelle (2007), multilayered design complexity can be expressed with refinement, precision, and maturity that is integrated with an aesthetic sense in terms of features, surface, and material practice through the concept of

elegance. The concept of elegance takes into account the part-to-whole design relationship. The composition of an elegantly designed building is an elaborated mix of both lightness and quality of design elements. An example for this is the New Urban lobby addition to Centrepont, London, 2006 by Melike Altinisik, Samer Chamoun and Daniel Widrig, and Patrik Schumacher/Yusuke Obuchi Studio (Architectural Association DRL). The tower here demonstrates elegance within the features of transformation from the surface background. The illustration of elegance in architecture is achieved through the pocketed spaces squeezed out of the vertical structure with the aid of technology, Figure 2.49.

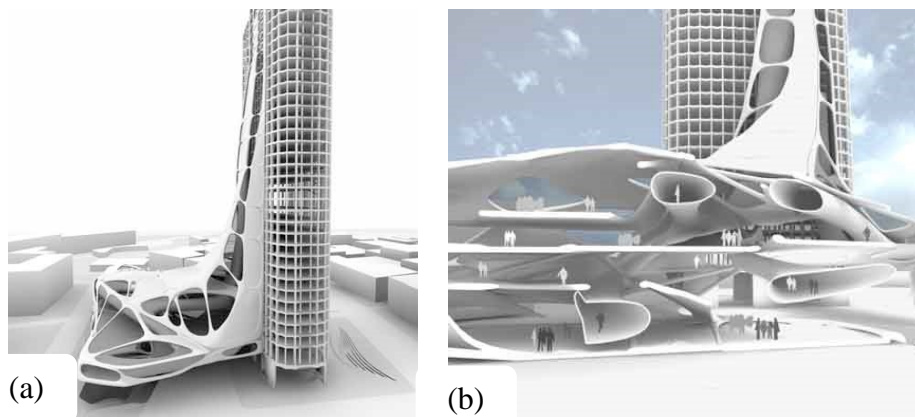


Figure 2.49 (a) illustrates the vertical tower and the distribution of features out of it, while (b) illustrates a number of pocketed spaces squeezed out of the vertical structure (Rahim & Jamelle, 2007).

Also, Lincourt (1999) argues that there are values underneath every layer of architectural design that should be collectively observed. One of these is the balance of public and private relationships. Another one is the performance of functionality that expresses fluidity, clarity, visibility of a three-dimensional design approach, and continuity through the integrated relationship between the natural setting and manmade surroundings which will deliver usefulness, efficacy, and a sense of order to the design quality.

There are different perspectives as regards the idea of architecture within elegance measures. According to Hawking (1995), the essence of architecture has a general theoretical perception where its phenomenon depends on a scientific theory. Furthermore, according to Delanda (2007), elegance has an objective aspect that is related to the practical experience of material where the form's outcome depends on the use of elegance. For example, if the material used within the design process is

meant to be efficient in terms of energy reduction, then this presents an elegant solution. Equally as importantly, there is elegance achieved through complexity in structure, form, and material, as in the case of biological processes. In biology, for example, there are three interrelated levels. First level concerns the interactive relationship between cells. The second level concerns the interactive relationship between the organs as parts of the whole. The third level is the interactive relationship of the organism as a whole. According to Lincort (1999), the concept of elegance could belong to a quality or the characteristics of an object.

Nevertheless, Goldblatt (2007) discusses that although the word elegance has been missing in both architecture and philosophy over the last century, the maturing of digital techniques has paved the way for the emergence of a different aspect in elegance perception. In this respect, aesthetic quality is defined within the idea of lightness and fluidity. Non aesthetic quality is concerned with the functional aspect of the architectural design and digital techniques.

According to Schumacher (2007), the refinement process takes place when the construction process and the structure both share an affective adaptable relationship and become one part of the design process as a whole. Elegance contributes to architecture and design complexity through innovative tools that affect the design system explicitly through mutation, selection, and recombination. Schumacher (2009) suggests the development of any pattern leads to the development of the design function in terms of material, texture, colour, reflectivity, or translucency which in return affects the capacity of the built environment. Furthermore, according to Pottman (2009), when designing surface patterns there can be a gap between design and construction as the architectural complexity could be limited in terms of material and manufacturing constraints.

In this section, studies such as those of Lincourt (1999) and Rahim and Jamelle (2007) argue that the concept of elegance expresses the multi-layered design complexity within refinement, precision, and maturity. This can be identified in an integrated private and public relationship with aesthetic aspects in terms of features, surface, and material practice as well as with functional aspects in terms of fluidity, continuity, clarity, and visibility of a three-dimensional design approach. Whilst studies like those of Schumacher (2009) and Pottman (2009) note that there is still a limitation

due to material and manufacturing constraints. Accordingly, the realisation of patterns needs to be deeper and must include both aesthetic and functional design aspects. Thus, the next section will discuss the idea of pattern in architecture and its role in illustrating design aspects.

2.12 THE PRESENCE OF PATTERN IN DESIGN

This section introduces the importance of understanding the idea of a pattern and its value to the integrated relationships of design, aesthetically and functionally.

According to Thompson (1942), the pattern is the identity of any object, whether in nature or architecture. Identifiable within its layers are all the details needed to comprehend its transitions and changes from inside out. Bruckner (2011c) notes that civilizations through all the history of mankind have interpreted the essence of beauty determined by an aesthetic appreciation for nature either through the idea of an object or through its overall shape. Moreover, according to Wurman (2009, cited by Garcia, 2009a) for an architect and designer the world is a mixed series of visual patterns, and there is no chance for the emergence of any creative process without fully understanding the parts of these patterns.

Furthermore, in Western civilisation, Plato's *Timaeus* describes the universe as a mix of fully integrated patterns, where each model of these patterns is a combination of order and beauty (Zeyl, 2013). The pattern itself is not an isolated entity as it is deeply rooted in the nature of things including human nature and actions. It is connected to other patterns, for instance, a neighbourhood part of a working community is incomplete without green spaces such as outdoor space, tree places, and gardens. Accordingly, the pattern is the sum of the important characteristics that define a particular kind of object, building, or design element. For example, the demonstration of the small Public Square pattern includes a photograph of people playing, chatting, and strolling around a small plaza, shaded by trees (Alexander, 1977).

As a result, these patterns are seen within a detailed decorated ornament or an embellished structure. Even the theories beyond these patterns included a wide range of concepts like order, beauty, complexity, unity, abstraction, function, and imagination (Garcia, 2009b). Moreover, architecture is in the middle between nature and the manmade world (Pallasmaa, 2012). Patterns are like living entities in which

each pattern describes and evolves to solve a problem that exists in our environment as a practical guide in a repetitive way. Understanding the problem describes the essence of the solution in a way to apply it each time (Alexander, 1977; Price, 1999). According to Ball (2009), an influential science writer, this does not mean a deficit of science capacity; on the contrary, it enables the artistic ability of scientists to concentrate on what to include or exclude in a model. Many distinctive patterns are man-made and formed by human intelligence and functional needs. In this respect, scientific phenomena are models that express parts of reality.

Venturi (1977) discusses that there are no fixed rules in architecture but there is an order that controls the contradictions of design elements within the complexity of architectural reality. Through such contradictions, consistent order should accommodate the circumstances either by breaking it or bending it in a way that represents the inconsistent relationship within the design elements as a whole. For example, the contradiction of design elements can be seen in the Palazzo Tarugi, where the application of arches and pilasters stand against the whimsical windows and asymmetrical voids, Figure 2.50.

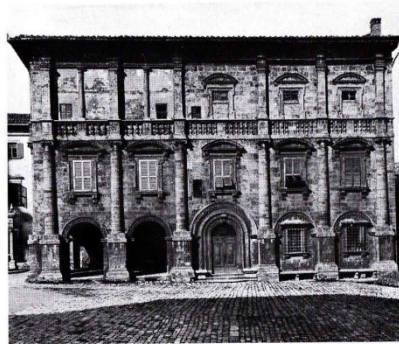


Figure 2.50 The historical design details of Palazzo Tarugi, Montepulciano (Venturi, 1977).

The pattern making allows the building structure to play an aesthetic and functional part as a façade surface. Further, an interdisciplinary architectural design approach is continuously developing new materials in which the building skins can either be surface skin or structural (Muir, 2011). The design pattern of traditional Baghdadi houses is a mixed one between local materials such as brick, and imported wood material to be used in their shanashil (Al-Ahbabi, 2010; Alfetal, 2001), Figure 2.51.

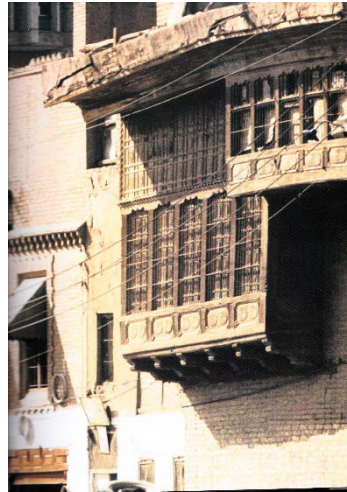


Figure 2.51 The design pattern of shanashil as part of Baghdadi houses` façade in Bab al Shaikh District, Rusafa, in Baghdad 1978 (Fethi, 2010).

Consequently, for an architect, Venturi (1977) argues that the selection tool in a part-to-whole design relationship is as important as the creation process of the whole. Gestalt psychology holds that any change in the parts creates new meaning to the context, and, conversely, context provides new meaning to the parts. Equally, juxtaposition is another tool that is used not just with the contradictions of design elements, but also for creating a resonance between the contrasting parts within the whole. This tool can permit a multiple meaning in the whole through the opposites within it. In addition, breaking the order can enhance the meaning as in the case of contrast between design elements.

Studies from Thompson (1942), Alexander (1977), and Pallasmaa (2012) state that any creative process is incomplete without truly understanding the details within the layers of each pattern for an interdisciplinary design process to be complete. Moreover, studies like those of Thompson (1942), Wurman (2009, cited by Garcia, 2009a), Ball (2009), and Bruckner (2011c) discuss the need to understand the idea of pattern and its parts, whether in nature or in architecture, as a step towards understanding the essence of architecture in its integrated part-to-whole design relationship. Such relationships combine both aesthetic and functional aspects of design, seen in a combination of order, beauty, complexity, unity, function and imagination.

One of the natural pattern phenomena is camouflage which is seen in several species such as in the skin pattern of chameleon lizards. Owen (1980) explains that one of the natural phenomenon that illustrates biomimetics strategies is camouflage. This phenomenon can be seen in natural biological examples through a various combination of colour and shape. The need for such ability is for survival as part of protective strategies to avoid predators. However, whether in nature or a manmade world each has its own rules and patterns and the ability to imitate is different. As a result a number of biological phenomena in nature have been able to be adopted in architectural principles through the aid of technology and biomimetics approach. For instance, Singh et al. (2012) discusses that camouflage is accomplished because the skin of some of these organisms like chameleon has highly elaborate and distinctive patterns. Such patterns depend on two aspects. The first is the illumination intensity of the surrounding environment in terms of high or low incidental light. The second is the constitution of that pattern combining thin transparent layers and different specialised cells filled with pigments (Bloomfield, 1993). These pigments reflect the colour of the surrounding environment by adjusting to its luminous intensity. Scientists have tried to mimic this natural phenomenon by creating specially adjusted visible colour fabric through the use of cholesteric liquid crystals (CLCs) for thermal and visual camouflage, Figure 2.52.



Figure 2.52 Camouflage phenomenon both in nature and an artificial manmade environment (Singh et al., 2012).

According to Wiscombe (2010; 2012), there is a growing desire to have a sustainable built environment, where the efficient use of energy has developed an innovative design process that lies within the complexity of architecture. The design surface is not just abstract, but also a mix between technology and design elements. This could be achieved through an overlap between biological and architectural patterns in an integrated relationship between visible and embedded technological elements, within function and form. For instance, in nature, the Australian Agamid lizard is known for its interwoven skin features. In addition to its skin displaying colour variation, the grooves on the skin play an important part in the survival of this species through the conduction of water from the lizard's back into its mouth. Similarly, in architectural design, a project for the EMERGENT lizard panel facade, (Wiscombe, 2009) is a prototype inspired by biomimetics strategy of the transparent architectural facade with embedded interwoven systems such as captive grey water and the algae photo-bioreactor system, in a way that produces structural as well as ornamental effects, as shown in Figure 2.53.



Figure 2.53 Embedded strategies as part of biomimetic strategies in EMERGENT prototype for lizard panel facade, 2009 (Wiscombe, 2010).

According to Gruber and Jeronimidis (2012), Tom Wiscombe's visionary design tackles two important issues. One is about different strategies applied to the surface such as blending, embedding, fusing, and winding in order to convey the design elements. The other is about the functional requirements of bioinspired material principles. This design, if applicable, could create assets for future built environments. More importantly, Wiscombe (2012) argues that an overlap between architecture and other disciplines will help change functional and aesthetic aspects. The aim is to come up with an approach that would go beyond 2D into a multifunctional embedded technology within the architectural surfaces to maintain a constant information transfer between structure and envelope. This could be achieved through composite design patterns with a transformation from 2 dimensional into 3 dimensional surfaces

where systems are fused, blended, and embedded to provide possible solutions to the changes in the surrounding environment.

Another example where the role of technology is an adaptable design that delivers an environmentally responsive building façade, can be seen in the Institute du Monde Arab in Paris by Jean Nouvel. The integrated design relationships made the conventional understanding of the window and wall indistinguishable and interchangeable (Mazzoleni, 2013). For instance, in the layers of the Arab World Institute in Paris each part of the external facade screen pattern has eye-like irises which can be opened and closed to control the amount of light entering the building and the whole internal temperature. The composition of design elements are influenced by the Moresque and each element can change from a wall to a transparent window, Figure 2.54.

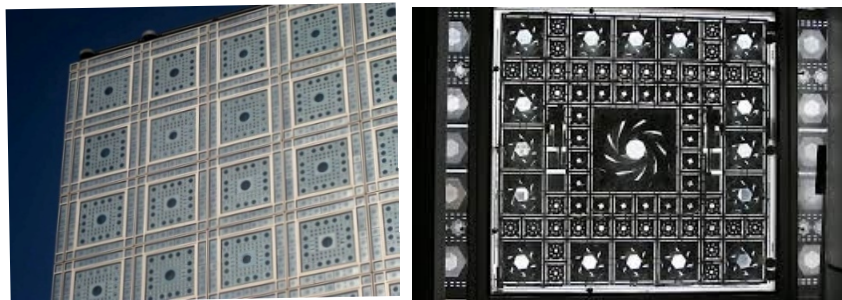


Figure 2.54 Institut du Monde Arab, Paris Iris movement window/wall element. (Mazzoleni, 2013).

Such a pattern delivers different qualities at one time as a whole wall, and another time as a whole window. In this design building, the role of engineering and architecture is unified and takes into consideration all the parts and layers of architectural design pattern from the early beginnings of design. The advancement of technology was responsible at that time in producing a complex design pattern. Such pattern is known for its changing ability between a wall to a transparent window in a way that reflects a dynamic and beautiful façade at the same time. However, technology must keep an ongoing developed state with long-term ease of maintenance and durability in mind (Mazzoleni, 2013).

In this section, studies such as Singh et al. (2012), Bloomfield (1993), Jeronimidis (2012), Mazzoleni (2013), and Wiscombe (2010) discussed examples of natural biological pattern that inspire a multifunctional design quality by combining both

aesthetics and functional aspects. The aesthetics aspects are illustrated in terms of colour changing while functional aspects are through the use of minimal resources to achieve maximum performance with less energy consumptions.

Moreover, the inspiration of natural skin or surface is demonstrated in man-made design to provide flexibility in building façades to deliver multiple options for architects and designers. However, this cannot be achieved without the role of technology.

2.13 SUMMARY AND CONCLUSIONS

This Chapter has presented a review of the complexity of architecture in the ability of pattern and layers to interact in harmony with the surroundings. It expressed that the origins of mimicking nature are seen in the integrated relationship between traditional organic pattern and elements such as traditional Baghdadi buildings and their distinguished façade elements called shanashil. It discussed in depth the role of such elements that used to provide for a multifunctional design quality, aesthetically and functionally, and illustrated the use of such elements as an important device as a window/wall/balcony element in the façade. However, such relationship that used to be part of successful adaptable strategies is now inadequate. The consistency in the presence of such elements has disappeared from the architectural scenery. Therefore, this chapter examined the role of change particularly in modern planning, transportation means, and technological advancement in design. The same change affected the consistency of these elements in a way that affected the identity and values of design. This chapter also presented several trends inspired by the same element.

The role of natural materials in design has been examined by observing its interesting phenomenon using biomimetic approach in design such as camouflage. The inspiration of natural biological models still lacks the strategies to be defined as a clear approach in design. The chapter explains an approach that combines the bio-inspiration and biomimetic for demonstrating new adaptable strategies in design. Such strategies are based on dynamic characteristics of natural models in terms of material.

In addition, it highlighted the inevitable role of technology, which is vital in the interpretation process of information transfer between living patterns in nature and non-living patterns in architecture. It also discussed the essence of architecture and its integrated relationship between aesthetics and non-aesthetic aspects. It showed several examples in which the inspiration of nature`s strategies had an impact on design aspects, particularly in the illustration of elegance, flexibility, and functional beauty ideas.

We can find natural biological models that have complicated patterns and layers that can be transparent with their surroundings; man-made products are able to mimic these models in a material that is smart, multilayered, transparent, and dynamic in its design characteristics.

Therefore, the next chapter discusses the design quality of man-made materials which can mimic the characteristics of traditional window/wall/balcony design elements in the integrated relationships with sustainability and transparency as a means towards creating and capturing the essence of an elegant, flexible design element in architectural facade.

Chapter Three

3 Pre-Development Stage

3.1 INTRODUCTION

The previous Chapter reviewed the disadvantages of traditional window/wall/balcony shanashil elements associated with the loss of design identity and values, particularly, in the consistency of environmental, social and cultural sustainability. However, although it demonstrated the important role of transparency while maintaining privacy needs, the link between the two is complex in order to obtain an elegant and flexible design pattern, both aesthetic and functional. Simultaneously, man-made designs may find it difficult to convert abstract natural phenomena strategies into viable design concepts. Therefore, this study proposes to use a biomimetics design approach to overcome these problems.

This Chapter presents an overview of the integrated relationship between biomimetics approach and the idea of sustainability in design. It starts with an introduction to sustainability, clarifying the relationship between design quality and biomimetics strategy in Sections 3.2, 3.3, and 3.4 defining the advanced role of technology, and reporting the integrated part-to-whole relationship between design pattern and the changes of the surrounding environment in Sections 3.5 and 3.6. In addition, this Chapter explores how design pattern, details, and layers deal with mimicking natural examples into man-made products by identifying the benefits of transparency in design (Section 3.3). Sections 3.12, and 3.13 justify the adoption of smart material, particularly, smart dynamic glazing in this study. Section 3.14 conceptualises the dynamic characteristics of a smart window/wall/balcony element to be applied in the empirical stage before summarising the Chapter in Section 3.15.

3.2 BIOMIMETICS AND SUSTAINABILITY

This section will discuss the idea of sustainability and its integrated relationship with biomimetics strategy. The field of biomimetics and bio-inspired design has become an important source of innovative ideas. The idea of the inspiration process itself is about bringing solutions to designers to solve a particular problem by making use of similarities such as between nature's adaptable strategies and man-made design (Bar-

Cohen, 2005; Vincent, Bogatyreva, Bogatyrev, Bowyer, & Pahl, 2006). Biomimetics, in particular, uses technological tools (non-living systems) to interpret biological examples (living systems) in nature. Nevertheless, the word bio-inspiration has been used more often, though it is still used in a more general sense, without the connotations of specific strategies and methods necessary for the design process. Moreover, Bruckner (2011a) argues that although a certain flare of *biomimetic* in architecture cannot be defined, nature`s footprints have been present through the architectural history of humanity from natural shelters such as caves to the use of natural materials to build houses.

Bruckner (2011b) shows that biomimetics is a concept based on practical observation of examples in nature. This observation looks for every detail related to biomimetic strategies, analogies, processes, and mechanisms in a way that collectively examines the relationship of form and function. In addition, biomimetics as a multilayered complex system is thought to improve and cater to technological innovation by applying scientific principles (Bruckner, 2011a). According to Jorna (2006), sustainable innovation is thought to be part of the multilayered scientific system of biomimetics. These multiple systems can interact and provide complex patterns.

Natural biological examples develop mechanisms and strategies embedded in their pattern`s layers and parts that use minimal resources to achieve maximum performance. This way presents a balanced relationship between nature`s strategies and the surrounding environment (Beukers & Van Hinte, 1999; Vincent et al., 2006). According to Bar-Cohen (2005), biomimetics is an approach based on the observation of design patterns in nature using the tools of abstraction to mimic the good strategies that natural examples use to adapt to the changes of the surrounding environment, as shown in Figure 3.1 (Kapsali & Dunamore, 2008).

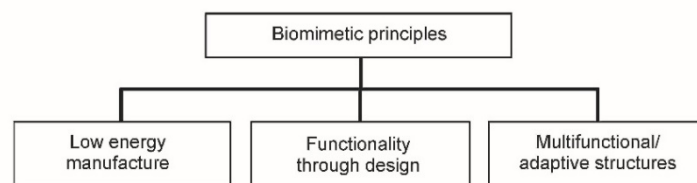


Figure 3.1 Biomimetics of natural material as a rich source for sustainability and design (Kapsali & Dunamore, 2008).

Jorna (2006), and Bruckner (2011a) outline a vision of sustainability that is part of the multilayered scientific approach in design when inspired from biomimetics strategies. Hence, this vision is adopted to discuss the integrated aspects of environmental, energy use, functional, and adaptability to the changes of the surroundings.

However, there are limitations in both natural examples and architectural design. According to Kinppers and Speck (2012b), biological systems are bonded to the same structural elements through their entire life and that in turn limits their lifelong performance. Gold and Lewontin (1979) noted that the same issue occurs in architecture through the limitations arising from functional expectations that limit the flexibility of the design and construction processes.

Beukers and Van Hinte (1999) suggest that the optimal use of minimal resources is a conceptual link to energy use in nature, design, and engineering. Equally relevantly, Benyus (1997) argues that the phrase ‘energy equals money’ simultaneously embraces the relationship between environmental cost and the consumption of natural resources during the construction process of man-made products.

Accordingly, Kapsali and Dunamre (2008), Shelby (2005), Hollington (2007), and Boden and Bagnall (2008) note that each example of mimicking nature’s strategies is different in nature. This issue is seen particularly in the way of adapting to the surrounding environment.

In addition, Knippers and Speck (2012) argue that form is another important element added to the relationship of structure and material. Natural forms and their structures are closely connected through material and both subjected to several changing processes like mutation, recombination and selection. In natural systems, forms are created out of functional adaptation to the surrounding environment. While in architecture, the aesthetic aspect of form does not always represent the building structure. According to Hollington (2007), biomimetic developments focus on the functional aspects inspired by biological structures and mechanisms through the interpretation of information transfer into man-made designs where there is no direct influence on the aesthetic aspects. Nevertheless, Kapsali and Dunamre (2008) argue that the field of biology is always a rich source for aesthetic inspirations for every culture. This aesthetic influence can be seen in the design of textiles as in flowers,

insects and various animals' skin patterns. However, there are fewer applications of biological mechanisms mimicked in industrial applications. For example, the invention of Velcro in 1950 is a development inspired by plant parts that use burrs to attach themselves to animal fur. Whilst Shelby (2005) demonstrated by coating glass with an antireflective surface layer that has the ability to transmit light in the visible region of the spectrum (300–800 nm) because of its amorphous structure it provides better clarity. Guo and Liu (2007) note that technological advancement, as in the use of electronic microscopy, has made it possible to observe the details of such patterns.

As a result, the interdisciplinary design approach between biomimetics strategies and the idea of sustainability provides a complex pattern that is functional and adaptable to changes of the surroundings. Such pattern reflects an innovative system through its parts and layers in which function is deeply connected to the form, and form is dictated by the function needed to adapt to the surroundings.

It is important to realise that there are differences between the production of biological material and the production of man-made material. The system of biological materials requires less energy and materials to deliver their functional properties, while conventional engineering of man-made designs needs too much energy and materials to deliver the required functional properties such as stiffness, strength or flexibility to material structures (Benyus, 1997; Vincent et al., 2006). On one hand, biological materials depend on their basic material design and distribution to deliver their functional properties (Benyus, 1997; Beukers & Van Hinte, 1999) and on the other hand, man-made materials obtain a multifunctional design pattern but often through the application of added technology made of several layers that are not embedded as in natural patterns (Hollington, 2007).

Accordingly, Kapsali and Dunamore (2008) argue that there are speculations among scientists, designers, and biologists about the biomimetics researchers' ability to identify biomimetics innovation possibilities; the biologists play the initial role of identifying the biological examples that provide useful applications in the industry. This is due to the specialist market's lack of biological knowledge in order to develop technology that meets consumer needs. Thus, there is a need for designers, manufacturers and biomimetic teams to collaborate in order to identify the right pattern for a successful design project. Gruber (2011a) argues that the role of

advanced technology is necessary to enable clear understanding of overlapped patterns to be mimicked and then implemented in merged discipline and architectural projects. However, so far there is no defined theory for using biomimetics examples and methods as an approach in design and in the future development of architecture.

Notwithstanding that such an approach is still in its infancy and is not developed enough to have a strong presence in industry, by applying biomimetics approach in design, this improves the design flexibility and quality by mimicking the strategies embedded within the pattern's layers. The role of advanced technology tools is to observe the details of nature's patterns and incorporate them into products (Kapsali & Dunamre, 2008). This can be seen in improving the glass material to match the requirements in terms of transparency, and to be better integrated in window/wall/balcony elements.

A good example is seen in the eye of a moth. This eye in particular has a distinctive surface layer with a nanoscale pattern of conical protrusions that provide an effective antireflective quality where light reflection is reduced to zero, thus optimising the use of the small amount of light available at night (Cannavale et al., 2010), Figure 3.2.

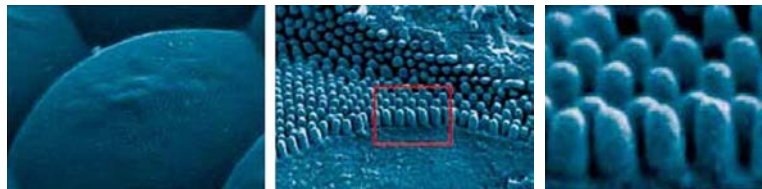


Figure 3.2 The moth-eye surface layer made of a nano scale conical protrusion that provides an effective antireflective quality (Cannavale et al., 2010).

One potential solution is that a modern facade can be made of a surface that is transparent and adopts multi-layer technologies in order to meet changing requirements. A number of researchers (Hiller, Mendelsohn, & Rubner, 2002; Prevo, Hon, & Velez, 2007) note that an example for this is the application of antireflective glass coating in building engineering and the construction industry. In addition, according to Duyar and Durusoy (2004), antireflective glass coating (ARCs) has a multipurpose application in architectural and automotive glasses, medicine, military products, mirrors, and all kinds of displays. Pettit and Brinker (1986) argue that antireflective glass coating is also used in smart material such as dynamic glazing and

in photovoltaic cells in which the transparency of glass in particular has an important role in the efficiency of the cell itself.

The quality of ARCs relies on the transparency and the layers of material and there are two types of ARC. One is the single layered ARC which is widely used, however, there are problems that weaken its use due to the high tensile growth stress and the poor mechanical properties, combined with the fact that materials needed for such type are rare (Kennemore & Gibson, 1984; Schulz, 2006). Another type is the multilayered ARC, which is an expensive type of material used to reduce reflection. Such coatings are incompatible with plastics due to the solution and temperature requirements for depositing these coatings (de Oliveira, Becker-Willinger, & Jilavi, 2010; Pilipavicius et al., 2008; Prado, Beobide, Marcaide, Goikoetxea, & Aranzabe, 2010; Tadanaga et al., 2008). As a result, although transparency is important for the characteristics of window's design to be useful and efficient, also the flexibility of transparent material improves the design quality and is crucial to consider such as glass coatings.

In order to utilise the sustainability aspects and to reduce the ambiguity around the biomimetics approach in design, it is necessary to clarify the relationship between design quality and sustainability.

3.3 DESIGN QUALITY AND SUSTAINABILITY

According to Pulselli, Simoncini, Pulselli, and Bastianoni (2007), quality of design is one of the crucial requirements in both the design process and the construction of buildings. It has a relationship with environmental impact through the extensive use of non-renewable energy, the overexploitation of materials, the exhaustion of resources and the wastage of energy, while ensuring energy conservation, convenience and comfort (Boeri & Longo, 2013).

The idea of sustainability is based on a multi-dimensional concept that includes all the different developmental elements such as economic growth, well-being of the population and environmental quality (Brundtland & World Commission on Environment and Development, 1987). Costanza and Patten (1995) explain that sustainability is an ongoing process of survival or persistence. However, Costanza (1992), Pearce and Atkinson (1993), and Pezzey (1990) argue that it is difficult to

adequately define the concept of sustainability. For instance, in biological fields, sustainability is the process of surviving and reproducing while avoiding extinction. From an economic point of view, sustainability means a situation that prevents instabilities and discontinuities and avoids major disruptions and collapses. At its base, sustainability takes into account longevity in particular and temporality in general. Therefore, most definitions of sustainability are predictions of today's actions intertwined with the hope of achieving a state of sustainability.

Quality of design is about providing comfort while maintaining the balance between the use of energy and daylight needs. Accordingly, quality is essentially integrated within environmental aspects and energy consumption issues as lighting energy, and air conditioning. Achieving the sustainable state in design is essential in providing a balanced relationship with the surrounding environment. Such design will allow a better flexibility, for example, windows that add to less energy use.

The old adaptable strategies are now considered outdated such as the use of traditional elements, small windows, or even conventional glazing types that require appropriate shading devices to avoid sunlight and solar gain. These design strategies have become obsolete in many countries such as United Arab Emirates UAE. However, traditional elements that once were functional are now merely used as a decorative feature for cultural association such as shanashil. Nevertheless, due to global warming issues and the rapid shift in building construction over the past 40 years, there are many concerns regarding the distinctive features of architectural design. Accordingly, it is important to acknowledge that traditional architecture of this region, based on high thermal mass and natural ventilation, has been outdated with the advent modern skyscrapers, such as Burj Khalifa in 2010 that follow the concept of daylight architecture to try to maximize penetration of natural light. Nevertheless, these large glazed areas lead to inefficient energy consumption and high operating costs, particularly in the use of air-conditioning (Askar, Probert, & Batty, 2001). These changes regarding the design of architectural elements from traditional to large glazed areas are affecting design quality by losing its flexibility and being sustainable in the surrounding environment.

Therefore, the next section will discuss the integrated relationship of sustainability aspects and the role of energy in design.

3.4 THE INTEGRATED RELATIONSHIP BETWEEN SUSTAINABILITY ASPECTS IN DESIGN

Sustainable development takes into account the quality of design by improving the standards of health as well as social, environmental and economic aspects for present needs without compromising those of future generations (Brundtland, 1987). Sachs and Warner (1995) define sustainable development as the great challenge of the 21st century. The challenge is in delivering an overall design quality that maintains a healthy and active indoor environment.

Kohler (1999) argues that sustainable development is about delivering a sustainable built environment which has three dimensions: 1) Ecological Sustainability, 2) Economic Sustainability, and 3) Social and Cultural Sustainability, Figure 3.3.

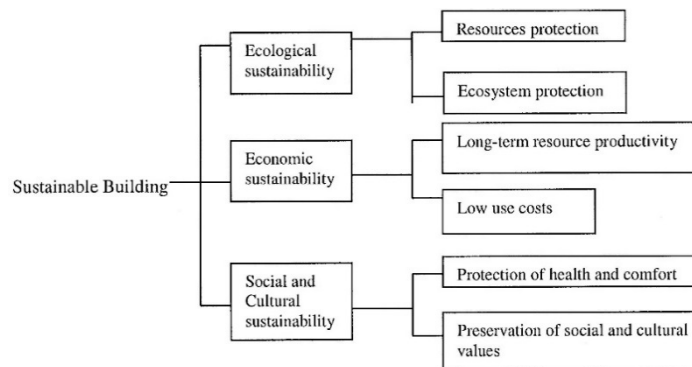


Figure 3.3 The three dimensions of sustainable building (Kohler, 1999).

Firstly, the ecological dimension and the preservation of resources are based upon physical, biological, and ecological systems (Edgar & Lahham, 2008). Secondly, the economic dimension based on the principle of increasing the long term welfare of society through the optimum utilization of natural and human resources. Thirdly, the social dimension, which refers to the social and cultural values of human beings and their health. Almusaed (2011) discusses that one of the design principles in a sustainable contemporary approach is to improve the material efficiency of residential buildings by reducing the amount of materials used in construction, which in return reduces the waste generated in the construction process. These design principles focus on the following factors: energy efficiency, daylight strategy, and building materials and techniques, as described by Edgar (2007, cited in Abdelsalam & Rihan, 2013).

Abdelsalam and Rihan (2013) suggest that the appropriate way to react to the western technology is to examine its advances, filter it, and then take what is applicable in terms of its appropriateness for the Middle Eastern social and cultural context. It is about understanding the essence of design sustainability and avoiding blindly copying modern technology from one context to another in order to deliver a multifunctional design quality that blends in harmony with sustainability aspects both environmentally, socially and culturally.

Therefore, the next section will discuss the important role of technology in understanding the added value of the biomimetics approach in design whether in identifying an integrated relationship of design pattern, or in the interpretation process of information transfer between nature's examples and architecture.

3.5 TECHNOLOGY AND INTERPRETATION OF BIOINSPIRED DESIGN PRINCIPLES

This section clarifies the role of technology in the interpretation of the information transfer from biomimetics to architectural principles for clear and enhanced material design specifications to be implemented in a part-to-whole relationship in the design process.

According to Weber (1989), technology is an ongoing process of change. Further, there is an ambiguity in the meaning of the process of technology. The changing process allows technological aspects to break and combine again into an ambiguous representation (Heidegger, 1977). In addition, Heidegger (1977) and Benjamin (1969) argue that the reproducibility in technology allows art to become functional in a way that enhances the aesthetic aspect. The reproduction process uses the tools of abstraction, selection, reduction, and mutation. However, the abstraction and reduction of the technological reproducibility process may involve the separation of form and function (Barnhart, Steinmetz, & Barnhart, 1990). According to Stiegler (1998) technological aspects are developed to be an essential part of design pattern, parts and order.

There is little published scholarship in the area of biomimetics as a source of inspiration in design, and reported research, books, conferences, and other resources show that there is still a great deal further investigation necessary into this field of

study. There are a number of studies that define biomimetics through its integrated relationship with technology, Kashani (2012) notes that although the technology role in design has been inevitable in the interpretation process between natural biological examples and architecture in order to transfer ideas from nature, still the application remains a crucial goal for man-made design. Whilst Vincent (2005) states that about 70% of engineering problems can be solved by focusing on energy demands and issues rather than focusing on the details of the design pattern, layers and order: Therefore for any interpretation process to be successful, the focus should be on observing the design pattern, details, layers, and order in a way that allows for less use of energy to deliver an effective multifunctional design quality.

Bruckner (2011b) in Gruber (2011b) argues that the type of information needed can be found in interesting natural phenomena in relation to surfaces, materials and/or structures, functions, construction, mechanisms, Figure 3.4.

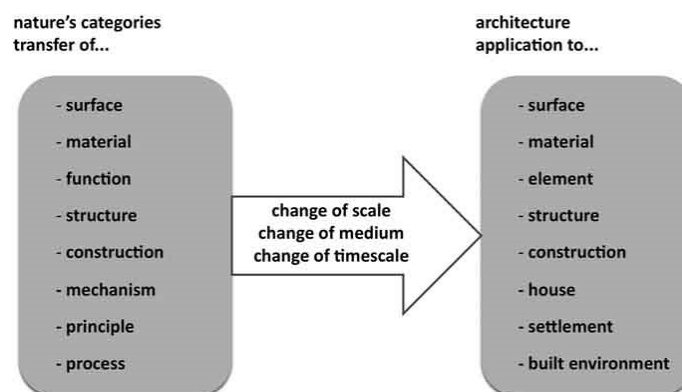


Figure 3.4 Information transfer from nature to architecture (Gruber, 2011b).

Natural systems are multi-layered, each with different functions, but the techniques to implement this in the architectural design process have not been fully explored (John, Clements-Croome, & Jeronimidis, 2005). Milwich, Speck, Speck, Stegmaier, and Planck (2006) explain two biomimetics approaches that deal with the information transfer in order to deliver an architectural model for the built environment:

- 1- Biomimetics by induction: This approach depends on observing an interesting natural phenomenon and then analysing it as a starting point.
- 2- Biomimetics by analogy: This approach is based on identifying the technological problem as a starting point (Milwich et al., 2006).

Furthermore, Bruckner (2011b) argues that an abstract phase is inevitable to ensure a successful transfer from a ‘nature’s category’ to an architectural design process. A reduction of the complexity of the process is advised in order to maintain an easy transfer of information, Figure 3.5.

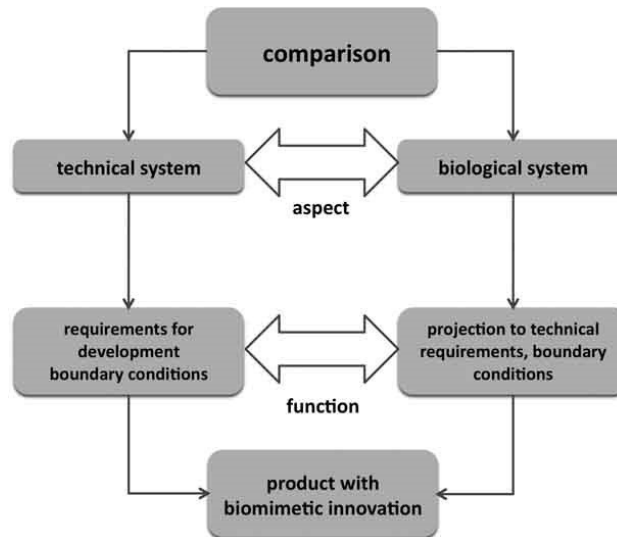


Figure 3.5 Comparative approach to biomimetic information transfer taking into consideration the role of technology (Bruckner, 2011b).

Lepora, Verschure, and Prescott (2013) argue that in order not to fall into the trap of merely coping without truly understanding biological patterns and strategies, the emphasis must be on the information transfer between biomimetics and other disciplines. This would only be achieved by careful observation to gather enough details about the natural pattern and sustainable strategies embedded within its layers, thereby providing the background for successful implementation of design principles. Bruckner (2011b) states that this ability of transferring information is useful because it can combine many levels and strategies such as the ones found in biomimetic innovations. However, it is impossible for all levels to be included, particularly in a biomimetic developmental process. For example, the technical aspects can be integrated into the building technology as a whole process, or they can be integrated in a way that is limited to one part such as a biomimetic surface characteristic like the "Lotus" paint that has self-cleaning properties. This type of paint is a substance based on the "Lotus-effect" patent of Prof. Wilhelm Barthlott, developed in 1999 (Bruckner, 2011b).

Consequently, according to Gruber and Imhof (2007), engineers, designers and architects depend on biomimetics as a scientific way to observe various interactions between elements and systems that deal systematically with biological principles. Werner Nachitgall (2003), a zoologist and biologist, has classified and organized the field of biomimetics from a wide perspective that integrates the aspects of design and building. Architects such as Frei Otto and his group used the same approach calling it natural design, where biomimetics is used as a tool (Otto, 1985). Furthermore, Knippers and Speck (2012) argue that natural forms and their structures are closely connected through material, and both are subjected to several changing processes like mutation, recombination and selection. While in architecture, the aesthetic aspect of form does not always represent the building structure, in natural systems, forms are created out of functional adaptation to the surrounding environment. In architectural design, forms and structures do not always meet to serve the functional needs of the built environment. As a result, there are a number of biological phenomena in nature whose principles architectural designs have been able to adopt through the aid of technology.

Within the context of the research reported in this thesis, the interpretation process using the biomimetics approach by analogy is considered the most suitable, since it starts with identifying the problem and issues by the designer and then suggests the qualities needed as a solution to be transferred from biological examples into man-made world. In addition, design tools such as abstraction are also considered in order to overcome the copy and paste issues during the design process.

3.6 THE DEVELOPMENT OF DESIGN PATTERN

This section discusses the necessity of understanding the pattern and its layers as part of the creative design process between nature, architecture, and technology.

According to Garcia (2009b), advancements in the field of technology have played a part in the change of pattern perception. Consequently, there has been a shift of interest from traditional patterns to other invisible kinds of pattern in a way that would reshape the future perception of the patterns in design. Moreover, such an approach in the application of integrated patterns paved the way for a different insight of patterns recognition, mixing, and interaction.

An example for this is the Urban Reef prototype details presented by shampoo designers Pavlos Fereos, Konstantinos Grigoriadis, Alexander Robles Palacio, and Irene Shamma, at Design Research Lab with their tutor Theodore Spyropoulos of the Architectural Association, London in 2009. The idea combines a fibre based structure system and coral growth principles to create a hybrid mix of digital and analogue computation, as shown in Figure 3.6 (Spyropoulos, 2009). Figure 3.6 depicts an approach that is biomimetics by induction - observing the design pattern of interesting phenomena in nature to apply it in man-made design but in a way that focuses more on the form and shape than function.

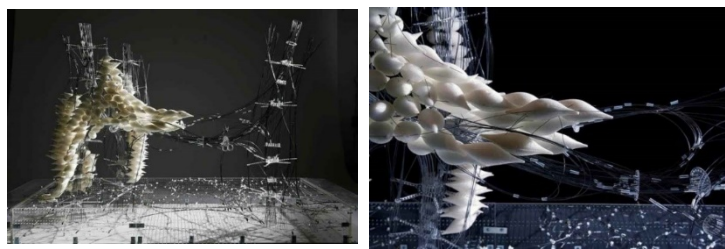


Figure 3.6 Prototype of a hybrid idea between the principles of coral growth and a fiber based structure (Spyropoulos, 2009).

Accordingly, the design focus should combine both the form and the function in order to serve the idea of functional beauty as discussed in section 2.8. This way of design starts by identifying the problem, and then suggests an approach that tackles part-to-whole design relationships of form and function with the surroundings.

Hensel and Menges (2009) argue that the performance of the built environment is related to the state of patterns recognition in the design approach and in terms of material characteristics and environmental influences. Architects tend to explore the state of patterns in architecture using two distinctive approaches. The first focuses on the ornament within the man-made design, and is similar to biomimetics by induction, which starts by observing an interesting phenomenon and then integrates it into a man-made design pattern. The second looks for a clear insight on the relationship of pattern with the surrounding natural environment (Garcia, 2006, 2009a) and relates more to biomimetics by analogy, which starts by identifying the problem in man-made world, and then looks for inspiration from interesting phenomena to provide solutions that adapts to changes of the surrounding environment.

Zaera-Polo (2009) states that there is no consistency embedded within the overall design process because new technologies with modern materials are not able to demonstrate the complexity of the design pattern, layers and details. There are concerns about losing the identity of the architectural design through the process of merging the whole with the parts. As a result, the envelope patterns would be rootless. Hence, contemporary architectural design focuses on the functional aspects that are connected to the building envelope as architectural elements in relation to patterns, as shown in Figures 3.7 and 3.8. The main idea is in observing part-to-whole design relationships that can be seen in every design pattern, particularly, through the details attached to its layers.



Figure 3.7 OMA project, China Central Television Building, Beijing, China, 2009 (Zaera-Polo, 2009).



Figure 3.8 Foreign Office Architects (FOA), project, John Lewis Building, High Cross retail and cinema complex in Leicester, 2008 (Zaera-Polo, 2009).

Vincent (2009) argues that an in-depth insight of bioinspired patterns would add value to the information transfer between biomimetics and architecture. The simplified design details that go beyond the layers of each pattern would lead to a

better design process by finding solutions that lie within the layers of biological patterns. However, the flexibility of design may be at the same time crucial to the engineering aspect in terms of low energy usage, easy recycling, durability and versatility derived from a few available materials that might be suitable for a sustainable design process. According to Hagan (2001), although there have been attempts by architects such as Frank Gehry and Peter Eisenman, where the designs present complexity of form, there are still missing parts which are needed to deliver the essence of elaborate natural patterns for the completeness of the design process.

Altogether, this last section identifies the importance of understanding the pattern layers and details and its relationship with the surroundings, as an essential part of design identity, moreover, the functional aspects are important as part of the contemporary design approach due to its integrated relationship with the building envelope, material, and environment.

3.7 ORDER IN MATERIAL AND DESIGN QUALITY

This section discusses the role of technology in the order and production of material characteristics. According to Beukers and Van Hinte (1999), material plays an active role along with concept and process as they have an equal importance from a functional point of view, as well as a surface one. Gruber (2011a) argues that the surface and the structure both have interactive relationships with the surrounding environment in a way that defines the characteristics of material in terms of strength, weight, and flexibility. According to Hagan (2001), materials have always been the means of achieving aesthetic and functional aspects whether they are natural or man-made products.

Leatherbarrow (1993), and Ballantyne (1995) discuss the need to maintain an efficient perspective that looks beyond the skin of buildings in use of material. More importantly, materials have both primary and secondary characteristics. The former is considered as an essential part of the object, the latter, even if it is detached, cannot affect the essence of the object. Furthermore, primary characteristics are related to the original material specifications before they are modified; they include the density, strength (in tension or compression), heat resistance, brittleness, flexibility and,

weight of the materials. The secondary properties are those that materials gain after intervention in terms of cutting, baking, polishing, etc. (Hagan, 2001).

Leatherbarrow and Mostafavi (1996) also noted that the way materials are organised or put together is what matters. The architect is focusing on not just the natural qualities, but also on the potentials and abilities as well. For instance, transparency and opacity have an important role not just in terms of material consistency but in terms of the overall design of the building as well. For example, the façade of Herzog and de Meuron's Goetz Gallery, Munich (1992), Figure 3.9, expresses an integrated relationship between traditional and modern material, stone and glass respectively. Heavy traditional stonework would crush the lightweight glass in this building had it not been for the use of lighter stone cladding, making it possible for the architect to use the glass differently to take such presence and space in the building façade.



Figure 3.9 Integrated relationship between stone cladding and lightweight glass in Goetz Gallery, Munich. Herzog & de Meuron Archetektin (Hagan, 2001).

Gruber (2011b) argues that in the life cycle of any building, energy and material will be in a constant process of change in order to adapt to the surrounding environment in terms of accessibility and openness through layering. As can be seen in the layering system in the Institute du Monde Arabe in Paris, designed by architect Jean Nouvel in 1987. The building envelope presents the complexity of architecture in which design elements are parts of a pattern with rules and order that hold them together that combines the concept of Arab culture and highly technological European architecture. The south façade emphasises the latticework ornamentation of the windows (Thiel-Siling & Bachmann, 1998).

However, Gruber (2011a) also notes that the innovative design process in architecture is not easy to maintain as well as technological implementation. For example, the

"Capsule Tower" by the architect Kisho Kurokawa was an impressive building in 1972, but it is now almost invisible among other high-rise buildings. However, new technological developments that can be seen in new materials and according to Vincent (2001) these new materials reflect the smartness of natural materials in their adaptability to the surrounding environment. For instance, transparency can be integrated with the implementation of the design process through the use of materials such as Electrochromic (EC) material in glass design, for the requirements of vision or light (Gruber, 2011a, 2011b).

In this section Beukers and Van Hinte (1999), Hagan (2001), and Gruber (2011a) argue that the essence of a material serves an important aesthetic characteristic as well as a functional one in terms of opacity, translucency and flexibility. More importantly, studies by Leatherbarrow (1993), Leatherbarrow and Mostafavi (1996), and Salter (1989) argue that it is important to bear in mind that each material has natural primary qualities which can be altered to have a secondary properties such as transparency and opacity for an adequate integrated relationship with architectural design elements as a whole. Thus, secondary material properties express the result of the human intervention on them. Consequently, flexibility in the characteristics of material is an important consideration as one of the main properties in design. This is in order to express a multifunctional design quality that adapts to the surrounding environment in terms of accessibility, openness, vision, and light through layering of design pattern.

Therefore, the next section will discuss the intertwined relationship between design quality and modern materials including its integrated relationship with technology in design.

3.8 MODERN MATERIALS AND THE ROLE OF TECHNOLOGY IN DESIGN

Contemporary design approach is focusing on developing alternative energy efficient models that are less dependent on non-renewable energy sources, such as fossil fuels, and more into renewable energy in a way that reduces the environmental impact of contemporary lifestyles.

Gebeshuber, Aumayr, Hekele, Sommer, Gösselsberger, Gruenberger, and Aumayr (2010) argue that there is no fine line between material, surface or structure in natural examples because they work as one entity within the surrounding environment in service of that example. Such behaviour is also found at different levels, specifically in the biomimetics approach of energy efficient façades, as discussed in section 3.2, and Figure 3.3 which focused on mimicking the design pattern and layers of the moth eye to be applied in glass windows in design. In this sense, Palmer (2011) argues that the contemporary approach needs to be flexible to respond to new technologies in modern materials that are invented to develop a better design quality. For instance, Masdar city established in 2006 is considered a sustainable design initiative; the residential façades include glass-reinforced concrete (GRC) mashrabiya-line screens designed by Jean-Marc Castera, Figure 3.10. The GRC panels that form *mashrabiya*-like screens provide shading by blocking direct solar radiation and allow air flow. Air enters into the ground floor and as it is heated rises and escapes through openings on the upper floor. The use of GRC material in its curved forms expresses an appropriate contemporary example inspired by traditional element of shanashil to enhance flexibility in design. The screen facade acts to minimise heat gain by providing self-shading from high sun, oblique views in narrow streets while maintaining privacy (Mitchell, 2015; Palmer, 2011), as shown in Figure 3.10.



Figure 3.10 The use of modern material GRC in the façade of screen pattern (Palmer, 2011).

A further example is seen in the role of technological development that is changing the fixed image of the heavy, cold and grey material concrete into a translucent material. The manufacture of translucent concrete is similar to regular concrete; however, optical fibres are embedded technology into the concrete, being spread throughout the aggregate and cement mix, and are then connected together (Mainini, Poli, Zinzi, & Cangiano, 2012). This develops a translucent concrete material, which

can allow 80% light through and only 30% of weight of standard concrete (Kashiyani, Rania, Pitroda, and Shah, 2013). The Italian Pavilion in Shanghai Expo 2010 demonstrated the use of this material, Figure 3.11. The main disadvantage is that such a material is very costly because of the embedded optical fibres.



Figure 3.11 The use of translucent concrete as a design element in buildings (Litracon, 2017).

However, the use of smart materials is becoming more common in the building industry because of the ability of such materials to react to the changes of the surrounding environment. For example, there are self-cleaning and easy-to-clean surfaces in the glass industry in addition to coatings with properties such as anti-reflectivity, switchable transparency, and darkening, others such as in antibacterial, and resistance to fingerprint smudging, fire, and scratching.

Different studies (Addington & Schodek, 2012; Bell & Rand, 2006; Lyons, 2002) on materials used in architectural design processes agree that modern technologies play an affective role, not only in the production of different types of materials, but also in their successful implementation within the construction process. One of the materials widely used in architectural design is glass. Glass panels such as smart glazing materials have been produced in various colours and shades with different surface treatments giving them the ability to change their own colours and transparency (Gavrilović & Stojić, 2011).

Windows are considered one of the less energy efficient building components with larger maintenance requirements. However, due to technological advancement in improving the quality of design, the standards of windows are constantly improving. For instance, smart windows can change properties in response to changing environmental conditions (Baetens, Jelle, & Gustavsen, 2010). One of these products,

specifically, is a smart glass with an ability to be either transparent or opaque through the use of electric current. This type of smart glass is able to fully regulate daylight penetration and influence the percentage of dimming in building interiors. Such glass can be used as a smart wall or a smart window in contemporary architecture (Gavrilović & Stojić, 2011; Lampert, 1999).

Therefore, the next section will discuss the role of transparency as one of the most important characteristics of the façade window and its impact on the overall design quality, both aesthetically and functionally.

3.9 THE ROLE OF GLASS WINDOWS IN DESIGN

Glass is not a new material. Natural glass was used as a raw material to produce works of art along with functional objects 5,000 years ago, and was first used in houses at least 2,000 years ago. Today it has a significant role in building construction and facades due to its light weight. In architecture, glass established itself as an element that provided cohesion between the inside and the outside, for its transparency, and it is one of the few building materials that combine tradition with technological innovation. The flexibility of the material harmonises colour, reflectance, transparency, texture and thickness and is the only material that is 100% recyclable (Gonçalves & Margarido, 2015). Windows in the façade are important to provide opportunity for natural ventilation; control odours; reduce indoor air pollution; moderate internal moisture levels due to occupant activities; minimise the risk of mould growth; distribution and control of ventilation to maintain safe carbon dioxide (CO₂) levels (Abu Dhabi Urban Planning Council, 2008; Roaf, 2003). In addition, windows in general determine the amount of admitted heat through solar gain. The role of windows accounts for a significant proportion of all energy used in buildings, covering both heating and cooling needs. Therefore, there is the constant demand to develop windows with advanced thermal properties, since the energy saving potential from improved windows is very large (Tsikaloudaki, Theodosiou, Laskos, & Bikas, 2012).

Recent life-cycle studies (Cetiner & Özkan, 2005; Hassounah, Alshboul, & Al-Salaymeh, 2010; Roaf, 2014; Sekhar & Lim Cher Toon, 1998; Yaşar & Kalfa, 2012) have shown that from cradle to grave, design decisions have a much bigger impact

during the use of the building taking into consideration location and type of climate. In this sense, windows at the beginning of design process represent not a large initial environmental impact (a priority in design decisions). From the design of the building to it actually being built, windows have less impact. However, windows have a large impact in the usable life of the building, when it is occupied and during the building lifetime of use. This is because if the windows are badly designed, they are wasting energy, or requiring more energy to provide thermal comfort. When it is demolished, there is again little impact because glass as a material can be recycled. The vast majority of glass products for buildings are recyclable at the end of their lives and this lessens the environmental impact of glass. When recycled into new glass products, glass waste helps to economise both raw materials in manufacturing new glass products. However, architects are often reluctant to specify recycled materials in their projects due to concerns related to design properties (Sassi, 2004).

Glass technology for buildings has undergone radical changes and extended the functions and applications of glazing in modern architecture over the last fifty years. Due to the development in the role of technology in design, windows are now multi-component and have a multi-functional quality. The improvements are based on reduced material usage, weight, and thermal conductivity. It also focuses on less energy consumption and hence, reduced environmental life cycle impacts (Allacker et al., 2013). For instance, the smart use of efficient glazing solutions is already helping to design and build aesthetically stylish and comfortable low energy buildings. Technological innovations such as the use of double and triple glazed units with inert gas filling and invisible low emissivity coatings have significantly improved the insulation properties of windows and facades (Hee et al., 2015; Selkowitz, 2011). Further, such glazing products allow maximum natural daylight into buildings and can limit solar heat gains, depending on the desired thermal objectives and energy balance (Dussault, Gosselin, & Galstian, 2012). Glass by nature is a good material that provides a wide variety of visible light transmittance (from less than 10% to 83%) while limiting energy transfer through the glass, and maximizing the natural light entering the building (Glass, 2016). The careful use of glass is considered a useful design strategy in hot, arid climates (Abu Dhabi Urban Planning Council, 2008). For hot climates, solar control coatings will reduce the amount of heat from outside to inside, whilst for buildings in climates where heating is necessary,

low-E coatings will reduce heat losses. It is important to take into consideration key issues such as: location; orientation; living space; and size of the windows so that is suitable for the design demands (Glass, 2016). However, the choice of material properties in terms of thickness, type of glass, colour, and texture is up to the architect (Gonçalves & Margarido, 2015). Sarja (2003) pointed out that architects influence reusability and recyclability of building materials through the choice of the structural system, component types, and through the choice of materials.

Hence, there is a need for the continuous improvement in window design, combined with new methods that encourage better energy use through less consumption in terms of lighting energy and cooling loads, including better thermal insulation performance (Abu Dhabi Urban Planning Council, 2008; Roaf, Brotas, & Nicol, 2015). Credit systems such as the Building Research Establishment's Environmental Assessment Method (BREEAM) are important in improving environmental, comfort or health benefits whilst achieving sustainable buildings (BREEAM, 2016; Pilkington, 2013). In terms of the number of buildings certified, BREEAM is the biggest certification scheme in the world, with 200,000 buildings certified and over one million registered (Guardian Industries, 2016; Saint-Gobain Glass, 2016). Also there is LEED standards (Leadership in Energy and Environmental Design) used as a green building tool that addresses the entire building lifecycle and offers a certification scheme for sustainable buildings (Abuzeinab, 2015; LEED, 2016).

However, design standards and requirements vary according to the country, type of building such as office building, retail and others. Regarding Iraqi regulations, the need for windows is mentioned for habitable rooms but in a very simplified way without going into detail, about location in the facades; floor-area ratio (FAR); areas of window; number of openings; and orientation (Roads and Buildings Regulations No. (44) For the year (1935)). Lately, a new study was carried out by the Ministry of Housing and Construction (MHC) (2013) with the Institute of Town and Regional Planning (University of Baghdad). The study reviewed and revised all the regulations concerning housing standards. They have reached the conclusion of preparing new standards due to the fact that previous standards are too old (1977), as described by (Ministry of Construction and Housing (MCH) (General Committee for Buildings (GCB)), 2013a, 2013b, 2013c, 2013d).

Thus, there are several requirements that need to be applied in the building façade regarding glass windows for the success of design process which are explained in the next sections.

3.10 THERMAL COMFORT

A requirement for a healthy indoor environment is thermal comfort, and the use of high-performance glazing can contribute to thermal comfort in both winter and summer, through efficient insulation and solar control (Glass, 2016; Pilkington, 2013; SageGlass, 2016a; Wang et al., 2014). In winter, the goal is to keep heat inside, but in summer the goal is to keep the heat outside to prevent heat from penetrating the inside space. In summer, the solar gains are reduced through solar control and shading systems, which reduce overheating and the need for air conditioning. Without this, an occupant working close to a window may feel a discomfort due to direct sunlight, or coldness coming through the window (Mahmoud, 2010; Roaf, 2005; Saleem, 2003). Smart dynamic glazing can eliminate this so-called “cold wall” phenomenon with a difference in temperature between room atmosphere and the inner surface of the glass remaining low and rarely exceeding 3°C difference. The high-performance insulation properties of Saint-Gobain’s glass claim a U_g coefficient down to 1.0 W/m².K for a double-glazed unit and to 0.5 W/m².K for a triple glazed unit this limits heat loss while the greater transparency to solar radiation (high solar factor up to 71%) increases solar energy gains (Glass, 2016). Similarly, there is a range of coated glass well-suited for the design needs for various building facades (Glass, 2016). To obtain and optimize thermal comfort, there is a need to pay attention to details including building shape, orientation and location of the facade, interior layout, and the effect of trees regarding location, type, size, and shape (Abu Dhabi Urban Planning Council, 2008; Mahmoud, 2010). Flexibility in design is important for the performance of thermal comfort needs to be achieved.

3.11 DAYLIGHT AND TRANSPARENCY

Daylight is an essential requirement for building users so that the window design needs to give sufficient access to daylight. Lighting quality is a complex issue which needs to consider various factors including visual comfort, health, safety and well-being. It is also related to economics and the environment in respect of the installation,

maintenance and operation of the lighting system (Abu Dhabi Urban Planning Council, 2008; U.S. Green Building Council, 2016). Another requirement is the view when looking out to offer occupants the possibility to refocus their eyes from close work and enjoy an external view, thus, reducing the risk of eyestrain and breaking the monotony of the indoor environment by offering a way to view the world outside. Whilst glare control is an important requirement to deliver a healthy, comfortable work environment, (Saint Gobain Glass, 2016), therefore, the next section will discuss in details the needs to reduce glare and provide shading to improve the flexibility and quality of design.

3.12 GLARE AND SHADING CONTROL

In traditional architecture, the use of plants and trees is used to shade houses particularly windows, and to reduce unwanted glare and heat gain (Al-Asad & Musa, 2004; Al-musaed et al., 2007), as shown in Figure 3.12. However, although the shading can reduce the temperature between 5-10°C, shading on the house structure or outer spaces is not enough for creating a cool situation in a house in a hot climate (Al-musaed et al., 2007; Mahmoud, 2010).

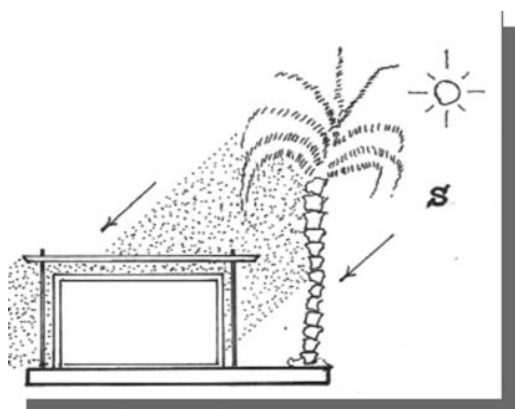


Figure 3.12 Traditional shading by the use of trees in Iraq (Al-musaed et al., 2007).

When the sun's rays hit the window at right angles the greater the transmittance, and the sun's rays are nearer right angles in winter than in summer in Iraq. Accordingly, the window should be shielded from most of the direct summer radiation (The Architects Collaborative, 1981). Thus, the building has to be equipped with an occupant-controlled shading system on windows, glazed doors and roof lights in all relevant building areas (Glass, 2016), or extra shading devices to block the

transmittance of sun's rays and radiation to control the harsh glare on work surfaces (Saleem, 2003; The Architects Collaborative, 1981), as shown in Figure 3.13.

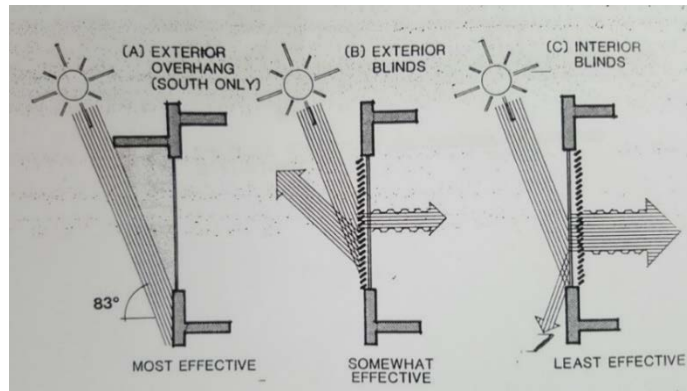


Figure 3.13 Different types of shading devices and possible locations for summer months (The Architects Collaborative, 1981).

Both exterior and interior shades have disadvantages for design quality both aesthetically and functionally. Improving the design quality is not about how many materials to add to windows and blinds, but instead to develop design strategies that use less material with more flexible glazing properties in order to control the glare, and heat inside the space to provide a comfortable work environment. To improve building energy performance and enhance the experience, a smart, dynamic, glazing with switchable, reversible properties can be used.

Saint-Gobain Glass offers a fully-integrated system including switchable properties that meets BREEAM standards and is an electronically tintable glass which improves building energy performance. It enhances the way people experience daylight in buildings by controlling glare and enables more sustainable design and construction by replacing mechanical shades (Glass, 2016), as shown in Figure 3.14.



Figure 3.14 Chabot College, San Francisco, USA, using SageGlass that fits BREEAM requirements (S.-G. Glass, 2016).

People spend over 80% of their lives inside buildings (Strong, 2012), so, the design of buildings and in particular daylight provision is critical to the quality of life. Accordingly, transparency in glazing enables daylight to penetrate the interiors of buildings and provides a view with a connection to the outside world.

A good example of Electrochromic (EC) smart dynamic glazing is a product by SageGlass company that allows architects to design environments that offer an unobstructed connection to the natural world and all the health and comfort benefits as it is easy to use within control of the indoor environment. It provides occupant comfort, outdoor connection, and energy savings due to flexibility within control of the design possibilities. Due to its switchable, reversible properties, especially transparency and colouration efficiency, dynamic glazing eliminates the need for blinds and shades (Gavrilović & Stojić, 2011; Rudolph, Dieckmann, & Brodrick, 2009; Spohn, 2016). Furthermore, it reduces energy consumption by up to 20% and often reduces the size of the HVAC system required for a building. In addition, it is a sustainable solution that contributes to LEED certification points (Malmqulst, 2016; Spohn, 2016). A further example that demonstrates the multipurpose applications of dynamic glazing is in the Morgan library at Colorado State University, Figure 3.15. Studies show that students learn material 20%-26% faster in a classroom with natural light and views of the outdoors (Edmonds, 2016).

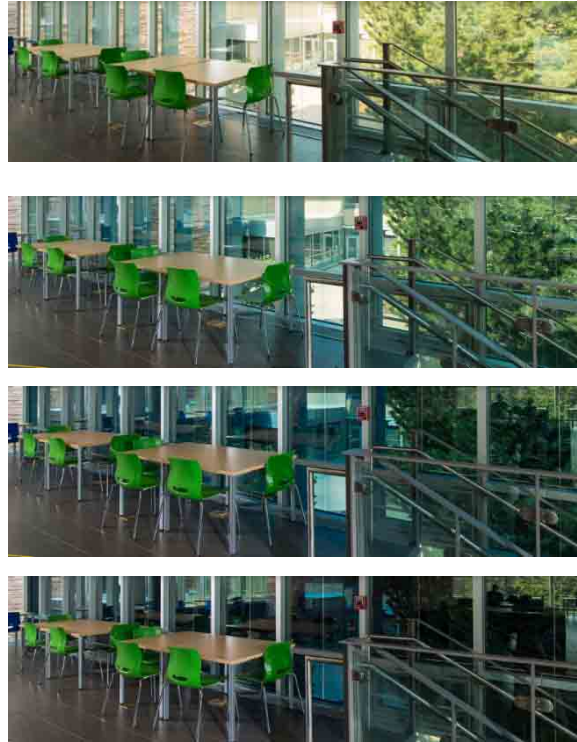


Figure 3.15 Smart dynamic properties of dynamic glazing used in Morgan Library (Edmonds, 2016).

As a result, smart dynamic glazing is better for its flexibility and the ability to be integrated in traditional or new buildings. One of requirements for the material in this research is to be flexible to accommodate the daily and seasonal variation of the sun's path.

3.13 SMART WINDOW DESIGN

This section discusses the added value of smart material in relation to design approach and strategy to deliver flexibility in window design.

The nature of a window is to allow the penetration of natural light, combine inside and outside view, and natural ventilation into buildings. The benefits of natural lighting and the exterior view has been confirmed by research to ensure healthy and comfortable working environment (Caudill, Peña, & Kennon, 1978; Chang & Chen, 2005; Cuttle, 1983; Sop Shin, 2007). There is a need to develop different fenestration designs with better adaptive strategies that fulfils its nature of providing natural lighting and an external view while keeping the balanced energy performance of a building (Hee et al., 2015). Lurie-Luke (2014) discusses that a smart material has the ability to change certain properties in response to a range of chemical, mechanical

and environmental conditions to provide differing opportunities such as the change of transparency with colouration efficiency.

The researcher agrees that the role of windows is crucial for the flexibility of design to be successful. Thus, the role of transparency should be improved in order to be adaptable to the changes of the surroundings. In this sense, the dynamic characteristics associated with the role of transparency and colour in smart glazing material are helpful to improve designs. This is therefore adopted to discuss the types of smart glazing starting from the photovoltaics (PVs) in the subsequent sections 3.13.1, and 3.13.2 to Chromogenics in section 3.13.3.

3.13.1 Aesthetic and Functional Aspects of Building Integrated Photovoltaics (BIPV) in Design

Photovoltaics (PVs) application can be taken as an example of smart dynamic glazing materials. The photovoltaic effect is a phenomenon commonly studied in physics, photochemistry and electrochemistry (Jelle et al., 2012; Oxford Photovoltaics, 2015; Roaf, 2014). Over the years the integration of PVs has developed from an ‘add-on’ design approach into more sophisticated integrations such as Building Integrated Photovoltaics (BIPV). The primary objective of BIPV is to generate electricity, but also it is to ensure that the module is a functionally integrated element of the building’s envelope. However, the costs associated with BIPV are generally higher than regular PVs systems (Van Berkel, Minderhoud, Piber, & Gijzen, 2014). BIPV applications allow the design element to be integrated into different parts of the building elements such as roofs, external building walls, semi-transparent façades, skylights, and shading systems. Moreover, BIPV is also used to give self-powering, possibly wireless features, and provide noise reduction (Benson, Crandall, Deb, & Stone, 1995; Sick & Erge, 1996). Kaan and Reijenga (2004) explain that a BIPV system is applied invisibly, and is therefore not architecturally ‘disturbing’, and can harmonize with the total project. Three examples are given using this material.

The Future Business Centre in Cambridge, Figure 3.16, demonstrates a mix between PVs opaque (100 Watts) and transparent (90 Watts) double glazed units. The PVs used are in a design Area of 57 m² offering U-values of 1.2 W/m²K and G-values of 42%. The objective in this material which is used as a curtain wall façade is to generate renewable energy whilst being weatherproof and giving aesthetic satisfaction to the design whilst taking into consideration building requirements to achieve BREEAM standards. It combines the benefits of a highly thermal efficient building cladding material with renewable energy technology in one. It is designed to keep the cold out and the heat in during the winter and vice versa in summer. Moreover, it provides reduction in energy consumption, giving less need for A/C, reduction in CO₂ emissions, and improving environmental credentials (Polysolar, 2014).



Figure 3.16 Future Business Center Cambridge with an integrated design pattern of opaque and transparent Photovoltaics (Polysolar, 2014).

The second example is seen in health facilities such as the Clinical Sciences Building, Wythenshawe NHS Hospital, Manchester, 2014, Figure 3.17.



Figure 3.17 Clinical Sciences Building, Wythenshawe NHS Hospital, Manchester, (Polysolar, 2014).

The objective of using such material is to reduce the substantial energy bills and CO₂ emissions at the major acute teaching hospital of the University Hospital of South

Manchester NHS Foundation Trust. The installation was designed to enhance the look of the building with edge to edge mounting of the panels, without penetration of the roof's waterproof membrane. The wiring and inverters were concealed within the restricted space of the roof structure. The solar installation is expected to save up to 30 tons of CO₂ a year and reduce the building's electricity costs by up to 10%, saving the NHS Trust over £10,000 a year (Polysolar, 2014).

The final example can be seen in the original Building Research Establishment, Integer House BRE Watford built in 1998. The same design was taken over and modernised and refurbished by British Gas in 2013 and subsequently renamed the 'Smart Home', with a new waterproof atrium designed to reduce thermal gain and supply the buildings electricity needs (Polysolar, 2014). This house is a demonstration of the use of integrated new modern technology through the installation of transparent BIPV (90 Watts) (Polysolar, 2014), Figure 3.18.

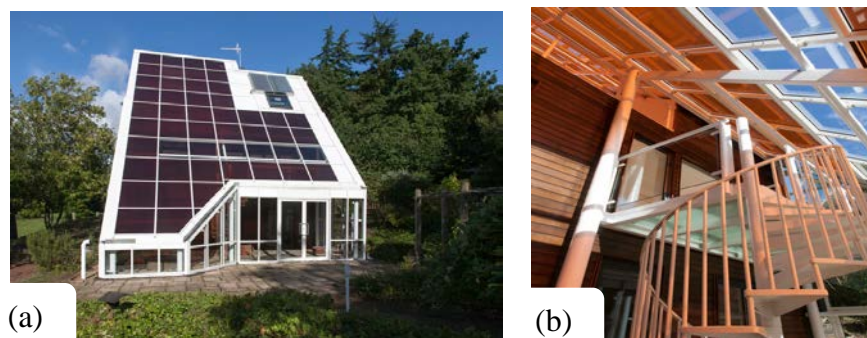


Figure 3.18 (a) Exterior façade and the use of transparent BIPV in the roof (b) Interior view for the transparent BIPV (Polysolar, 2014).

Accordingly, the use of BIPV is still restricted to certain design elements due to several issues regarding sunlight, shadings, and amount of solar radiation.

In relation to aesthetic design aspects, the use of BIPV as part of smart dynamic glazing materials can be an integral part of the building façade elements, nevertheless, the conventional PVs or the BIPV all provide a fixed state of transparent, semi-transparent, or opaque façade, Figure 3.19 (Van Berkel et al., 2014). Sick and Erge (1996) argued that for a building facade to be aesthetically and functionally satisfying

it must not only keep out water and regulate heat loss, it must also regulate the entry of light.



Figure 3.19 Semi-transparent BIPV façade Schott Iberica, Barcelona (SolarServer, 2015).

Due to improvement of the manufacturing process, the performance increased from 42 watt to 64 watt peak per square metre. However, the transparency is still considered crucial to the performance of the solar cells and its relationship with design building elements as a whole (Van Berkel et al., 2014).

Transparency of the glazing material may affect the performance of solar cells. Accordingly, the available visible transmittance (T_{vis}) which, particularly, decides the amount of natural lighting within the building (Hee et al., 2015), may be lower in BIPV glazing when compared to other glazing types. This is because higher T_{vis} will reduce the sun radiation for solar cells to produce electricity. Therefore, one of the challenges for solar cells window is the optimization of two features: day lighting and electricity generation (Chow, Li, & Lin, 2010; Jelle et al., 2012), as Lu and Law (2013) explain BIPV glazing with high T_{vis} is a good choice for day lighting, but not for electricity generation.

Similarly, other issues should be considered regarding the colouring of the glass back panel. Accordingly, designer tools intend to deliver new design interpretations such as in framing, cell placement, cell and module colours, patterns and material finishes in various combinations (Van Berkel et al., 2014). Architects from UN Studio provide bespoke design solutions in the field of PV architecture applying well-considered design interventions, adaptations and additions using the latest PV products, to enhance flexibility and quality of design. For instance, the use of colours can add vibrancy and decoration to the architectural façade, however, the colour range, shade and intensity choices are limited as colours and shades affect the efficiency of solar

cell performance. The colours at present to protect cell efficiency are red, blue, green, aubergine and anthracite; all of these colours are in the darker colour range, Figure 3.20.

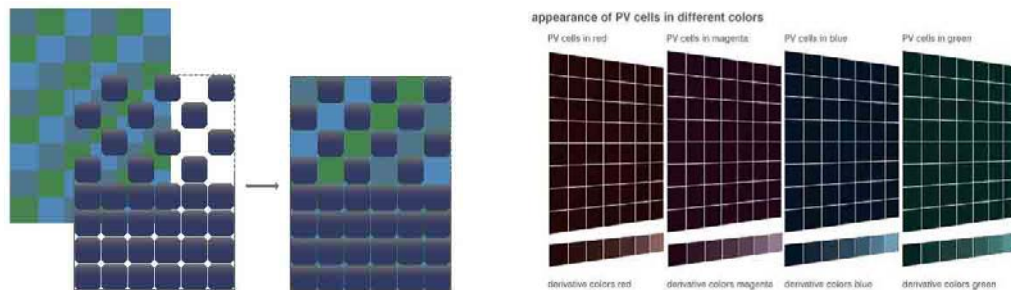


Figure 3.20 Layering enhancement in relation to cell colours (Van Berkel et al., 2014).

BIPV modules are almost maintenance-free and the energy-payback time of BIPV systems is between 1 and 3 years depending on cell type and location, and the average guarantee is 20-25 years. Nevertheless BIPV, in comparison to a standard glass façade, or a structural glazing façade, is an additional cost of about 350-500\$ per m² (approx. £284 - 405 per m²) which is roughly 4\$ per W (approx. £3.25 per W) (Bendel et al., 1999, cited in Benemann, Chehab, & Schaar-Gabriel, 2001). Moreover, the use of BIPV is still limited in improving the flexibility of design due to fixed properties regarding the state of transparency, and location in which the quality of the smart glazing material is determined by the amount of solar radiation (Deb et al., 2001; Sick & Erge, 1996).

Such issues add restrictions to the use of BIPV as an efficient and flexible window/wall/balcony design element in the architectural façade. Moreover, the production cost and process simplification are major issues in terms of clarity, transparency control, durability, and efficiency of solar cell performance. The same issues are observed in AL Bahr Towers in Abu Dhabi, as mentioned in section 2.6 in which the design decision required omitting the use of Photovoltaics panels even though the project was planned in an environment with an abundance of sun light.

Other smart glazing products such as Chromogenics are still favoured for many glazing applications, because of their switchable, reversible design properties associated with transparency, privacy, and colour specifically Electrochromic (EC) properties as they deliver better clarity. In addition, one of the EC glazing advantages

is that it only requires electricity to change its opacity but not to maintain a particular shade. It has a good durability and can be cycled from clear to opaque (Katanbafnasab & Abu-Hijleh, 2013; Lampert, 2003).

The fixed properties regarding transparency state affects the efficiency of design which closely relates to daylight needs, privacy, energy savings and consumption in terms of lighting energy and HVAC in addition to related cost issues. Hence, there is a need for a smart material with dynamic characteristics to be applied in façade elements to improve design flexibility and adapt to the surrounding environment, local influences and colours. The idea of a multifunctional design quality is about being in control of windows` properties such as transparency, colour, and privacy to deliver indoor comfort, aesthetically and functionally. Such materials have a strong aesthetic aspect since they represent the visual component of the building's envelope. Therefore, the next section will discuss the objectives and principles of BIPV as a multifunctional material quality in relation to the role of climate.

3.13.2 Photovoltaics Efficiency and The Role of Climate in Design

This section will discuss in depth the issues that affect the integrated relationship between PVs cells' quality and performance with the surroundings regarding location and type of climate.

The impact of greenhouse gases (GHG) on the environment and global warming is affecting the quality and comfort of people's lives. Hence, there is a need to improve design quality in a way that delivers an innovative approach to lowering cost and increasing system performance (Sarver, Al-Qaraghuli, & Kazmerski, 2013). Although the solar photovoltaics PV industry has been around since 1960 as a renewable source of energy (Tyagi, Rahim, Rahim, & Selvaraj, 2013), the fact that although sunlight is an abundant and essentially inexhaustible energy resource, nevertheless, it is not distributed evenly across the earth's surface is a problem (Insolation, 2008). For instance, deserts and arid zones offer an enormous potential for solar energy harvesting that significantly exceeds current market demand thus promoting the operation of large-scale PVs material, but such applications face substantial challenges.

One of the main challenges is the energy yield loss caused by dust accumulation on the optical surfaces of solar energy conversion systems such as PV modules. The so-called “soiling” effect, referring to particulate contamination of the optical surfaces, has been found to have a significant deteriorating impact on energy yield due to the absorption and scattering losses of the incident light (Sayyah, Horenstein, & Mazumder, 2014), as shown in Figure 3.21.

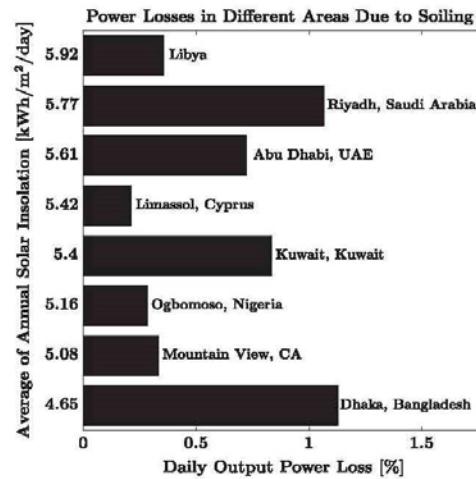


Figure 3.21 Daily output power losses in different parts of the world caused by dust accumulation on solar collector surfaces (Sayyah, Horenstein, & Mazumder, 2014).

Cleaning the panels by rain and wind is also dependent upon the tilt angle and orientation of surfaces with respect to wind direction, where a relatively high wind speed will be more effective at a high tilt angle. The primary reason for this low inefficiency of wind removal is that the adhesion force of the particles is higher than the removal force (Hinds, 1999; Hinds, 2012). Additionally, dust storms also cause fractures in the PV panel that reduce its lifespan (Kazem, Chaichan, & Kazem, 2014). Iraq faced 122 sand-dust storms in 2013 (UNPIO, 2013), and sources suggest that within the next ten years Iraq could witness 300 dusty days and dust storms per year. Whilst Baghdad has the highest tendencies for dust storms (Kazem, Chaichan, & Kazem, 2014; Sissakian, Al-Ansari, & Knutsson, 2013).

Although the regions illustrated in Figure 3.21 receive high solar irradiance (Insolation, 2008), dust accumulation has a detrimental effect on the performance of solar cells and collectors. El-Shobokshy and Hussein (1993) investigated experimentally the impact of red soil, ash and dust pollutants on the performance of

PV panels and found ash has the highest effect in comparison with other pollutants, Figure 3.22.

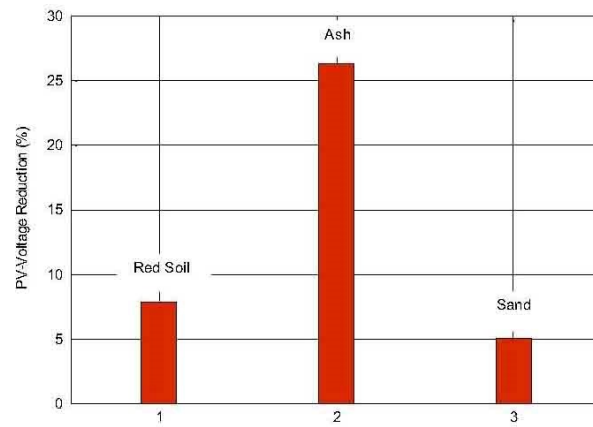


Figure 3.22 The damaging effect of pollutants on energy production of PV panels (El-Shobokshy and Hussein, 1993).

Whilst (Khatib et al., 2013) investigated the dust effect on PV performance of red soil, ash, sand, calcium carbonate, and silica. As a result, it was found that the PV voltage and power decreased due to pollution and deposit level, but ash was for the worst of all the pollutants, Figure 3.23.

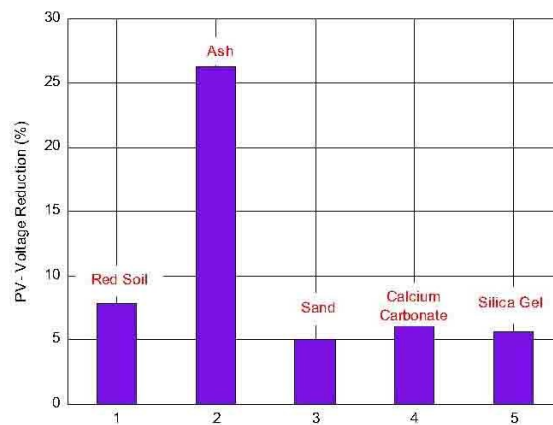


Fig. 9. Decrease in PV voltage due to different types of dust [17].

Figure 3.23 The damaging effect of ash on PV performance in comparison to other pollutants (Khatib et al., 2013).

Accordingly, dust storms cause major loss of the performance of PV installations, and whilst these storms are mostly unpredictable they occur more frequently in certain months of the year. Commercial PV panel's efficiency is between 15% and 20%, however, dust accumulation on a PV panel reduces their efficiency further and

increases cleaning needs. This condition reduces the PV market especially in countries with large oil and gas production and reserves such as Iraq (Kazem, Chaichan, & Kazem, 2014). As a result, electricity is still mainly generated by non-renewable energy sources (Darwish, Kazem, Sopian, Al-Goul, & Alawadhi, 2015).

3.13.3 Chromogenics in Design

Chromogenics can be used in various applications for large areas in glazing automobiles, planes, aircraft, and building elements as in windows, skylights and sunroofs, and for certain types of electronic display.

Kraft (2008) showed that the history of Chromogenics dates back to 1704, when Diesbach, a colour maker in Berlin discovered the chemical coloration of Prussian Blue which was the first purely synthetic pigment used as a blue colour in paintings. In the 1930s, electrochemical coloration was noted and twenty years later, Kraus observed electrochemical coloration in thin films. The first electrochromic devices were made by Deb in 1969 (Deb, 1969, 2008). In 1978, Neff published a short notice in which he described the electrochemical thin films of Prussian blue that can be switched reversibly by electrochemical means between different coloured states between transparent, semi-transparent, and opaque state in a process called Electrochromism. Electrochromic in particular was used as a smart device in the 1980s for switchable mirrors in cars, which continues as a viable product to this day. This device was developed for various glazing applications, for instance, several companies in 1990s began developing devices for glazing applications such as smart window-wall design elements.

However, Beatens, Jelle, Gustavsen (2010) explain that although the glass window is often regarded as a less energy efficient building component with a larger maintenance requirement, however, their technology has been developed over the last several years to overcome this deficiency with soft and hard coatings, Some coatings like low-emissivity (low-e) coatings can be categorised into both hard and soft coatings, whilst hard coatings are more durable than soft coatings and can be toughened. Nevertheless, soft coatings are usually flexible enough to be applied to individual glass panes after manufacturing. Soft coatings are more transparent than hard coatings but require extra protective layers due to their lack of durability (Chiba, Takahashi, Kageyama, & Oda, 2005; Del Re, Gouttebaron, Dauchot, & Hecq, 2004;

Hammarberg & Roos, 2003; Reidinger, Rydzek, Scherdel, Arduini-Schuster, & Manara, 2009). Furthermore, the advanced technology has improved the flexibility of smart dynamic glazing materials such as Electrochromic (EC), Figure 3.24.

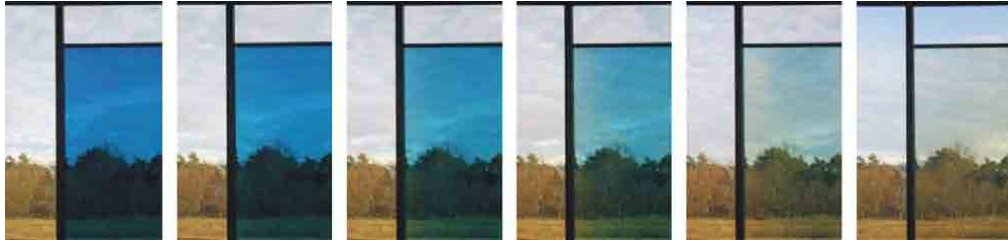


Figure 3.24 Switching sequence of an electrochromic laminated glass (Gesimat, 2015).

This type of smart window can change properties such as the solar factor and the transmission of radiation in the solar spectrum in response to an electric current, or to the changing environmental conditions themselves. The application of such windows may lead towards a drastic reduction of the energy consumption in highly glazed buildings by reducing cooling loads, heating loads and the demand for electric lighting.

Such smart windows are found to be able to reduce up to 26% of lighting energy compared with well-tuned day lighting control by blinds, and around 20% of the peak cooling loads in hot climates such as California (USA) (Baetens et al., 2010).

There are other types of the Chromogenic such as Photochromic and Thermochromic. However, Electrochromic is more suitable as a window/wall design element. Photochromic materials change their properties as a function of light intensity. (Ander, 2003). Two disadvantages of Photochromics are (1) the threshold for change is fixed once a unit has been installed; (2) there is no seasonal selectivity to allow for less solar gain in the winter. Notwithstanding, when Photochromics are activated, heat gain is still an issue that needs to be addressed. Thermochromic materials change optical properties as a function of temperature. However, a limitation of clarity affects the quality of such material, and the disadvantage of a fixed threshold for change (Ander, 2003; Selkowitz & Lampert, 1989). The coatings of both Thermochromic and Photochromic are not able to provide the full dynamic range of optical and thermal control required for windows (Selkowitz & Lampert, 1989).

Electrochromic materials (EC) change properties as a function of applied voltage. Properties can change from coloured to bleached, or anywhere in between. Although the systems of EC are more complex than other systems, they offer the best combination of switching properties for chromogenic window applications (Selkowitz & Lampert, 1989), as seen in Figure 3.25. Figure 3.25 shows that although the three types Electrochromic, Photochromic, and Thermochromic are part of the same material type which is Chromogenics, still Electrochromic provides better performance and flexibility through the balance between design needs in terms of lighting and cooling energy use.

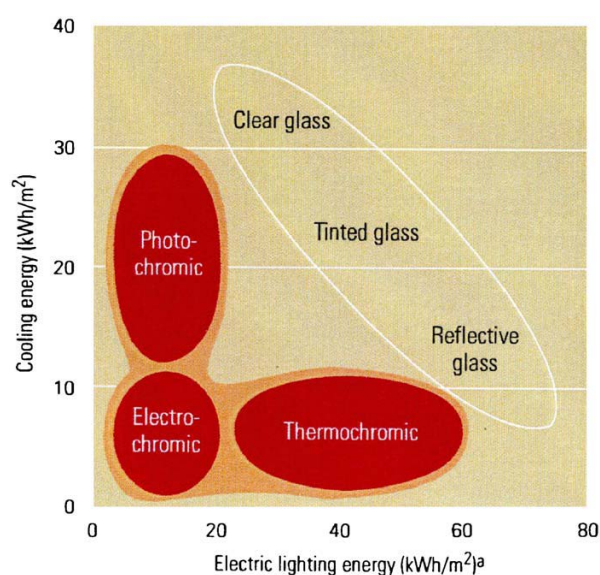


Figure 3.25 Comparison between conventional static glazing (clear, tinted, or reflective) and Chromogenics in delivering energy savings (Electric, 2009; Granqvist et al., 2010; Selkowitz & Lampert, 1989).

The threshold of EC for change can be altered in an existing unit, allowing for different occupants and seasonal adjustment; with visible light transmission that can be varied from 10% to 70%, and switching times that are relatively fast and use a low level of power. Electrochromic coatings can be combined with smart control systems to give constant light levels, and they can be applied to various layers of single or double-pane units or combined with other coated or uncoated glazings (Ander, 2003; Selkowitz & Lampert, 1989). Nevertheless, the transparent conductors are a significant cost of the switchable glazing, and necessary for all device types (Kaneko & Miyake, 1986).

Further, Lampert (1998) argue that Electrochromic windows are the most popular items of all switching technology. Over the last ten years about 200 US and international patents have been granted per year on electrochromics. The major advantages of electrochromic materials are: (1) they only require power during switching; (2) require a small voltage to switch (1—5 V); (3) are specular under all conditions; (4) have continuous dimming; (5) many designs have a long-term memory (12—48 h). Further, the use of EC as a smart window-wall design element improves thermal and visual comfort by reducing lighting energy, cooling energy and peak electric demand. It provides flexibility in glare control, daylight intensity control, and also control and reduction of heat loss and maintenance of solar heat gain potential. The EC performed well in solar control except in West orientation (Selkowitz & Lampert, 1989).

The coatings of Electrochromic smart window-wall glass material can be multi-layered with more complex such as 3-7 layers than the current generation of low-E coatings (1-3 layers), Figure 3.26.

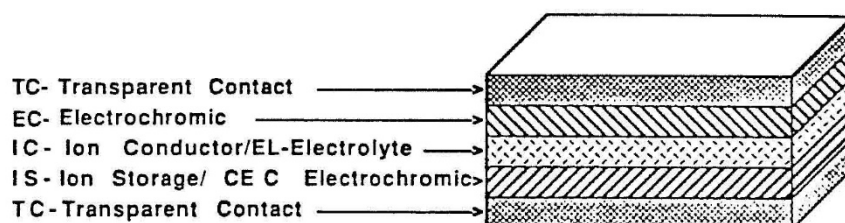


Figure 3.26 Five layers in a schematic cross-section of a solid electrochromic device (Selkowitz & Lampert, 1989).

When EC is compared to the suspended-particle (SP) device, the maximum transmittance as well as the modulation range in the visible spectrum is much higher for EC windows (Baetens et al., 2010). SP window of Cricursa Cristales Curvados (Spain) (Curvados, 2009), has been tested on the applicability as a smart window for building purposes (Vergaz, Sánchez-Pena, Barrios, Vázquez, & Contreras-Lallana, 2008). Whilst the response times have been found much shorter, i.e. between 2 and 3 times shorter compared with the longer switching times in EC windows, Curvados mentions two major concerns regarding possible wide-spread building applications:

1. The device can only be cycled for less than 1000 switches (switching times) before break down, due to stresses caused by abrupt changes in the applied voltage;
2. The optical direct transmittance in the clear state is poor below 25% (Baetens et al., 2010).

Fischer et al. (2004) argue that there are advantages for the application of Electrochromic glazing. For instance, Electrochromic glazing can be used in smart windows without any mechanical sun protection system which can gradually change the transmittance in response to the intensity of the solar radiation. Such windows prevent overheating rooms during intense sunshine and therefore it is suited for hot climates. Moreover, protection against glare and harmful radiation are additional advantages. Also, there is no case in which the maximum tensile stresses exceed the tensile strength of the glass material. The EC glazing system is expected to operate damage-free under the considered irradiation conditions (Fischer et al., 2004). Therefore this gives flexibility of the design element having switchable, reversible properties between colour, and privacy needs. There are other details that define the pattern of dynamic characteristics to be successful such as clarity of the transparent layers, stability of layers quality, multi-layered, flexibility of threshold units, and the use of minimum energy to achieve energy efficiency. These issues are important to deliver an efficient integrated design relationship between transparency/colour, and private/public states that bring aesthetic satisfaction with sustainability aspects.

3.13.4 Static and Dynamic Glazing in Design

Architects are interested in strategies of interesting phenomena, not only to find new ways of building, but also to find new sources of inspiration with better adaptability and aesthetic satisfaction. In many cases, the results are buildings that are highly efficient, more durable, and require less energy or fewer materials (Todorovic & Kim, 2011). One area of interest is between static and dynamic glazing. Selkowitz states that “*Delivering dynamic, responsive control of solar gain and glare, but permitting daylight use, is still the holy grail of technology*” (Selkowitz, Lee, & Aschehoug, 2003, p. 162). Smart windows can change the solar factor (SF) and transmittance properties to adjust to outside and indoor conditions, thus reducing energy costs

related to heating and cooling in addition to the ability to embrace multi-layers and various types of coatings (Baetens et al., 2010; Jelle et al., 2012).

Static glazing with its fixed properties does not provide the energy savings that are possible with dynamic glazing. Each static glazing offers the architect a single fixed light transmission with associated fixed energy transmission. At one extreme, the choice of high transparency allows daylight to enter the building at the cost of high solar heat gain and high cooling loads. Low transparency static glazing reduces solar heat gain but also restricts natural day lighting (Sbar, Podbelski, Yang, & Pease, 2012), Figures 3.27 and 3.28.

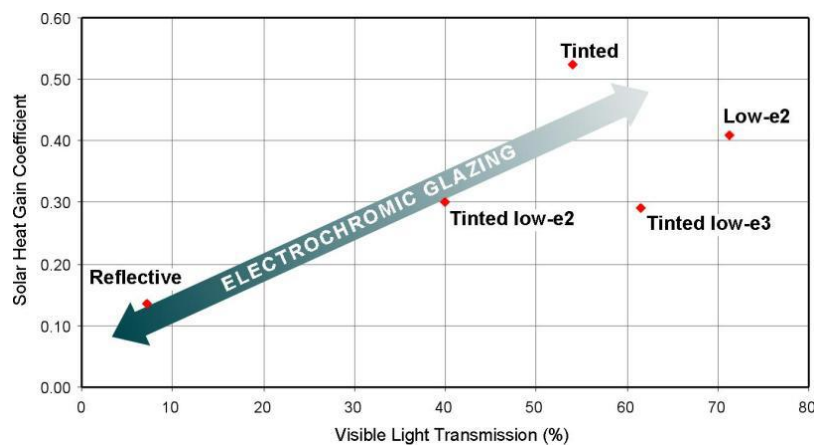


Figure 3.27 The dynamic range of an EC glazing in both visible light transmission (T_{vis}) and solar heat gain coefficient compared to generic static glass (Sanders & Andreau-Wiedenmaier, 2014; Sanders & Podbelski, 2009b).

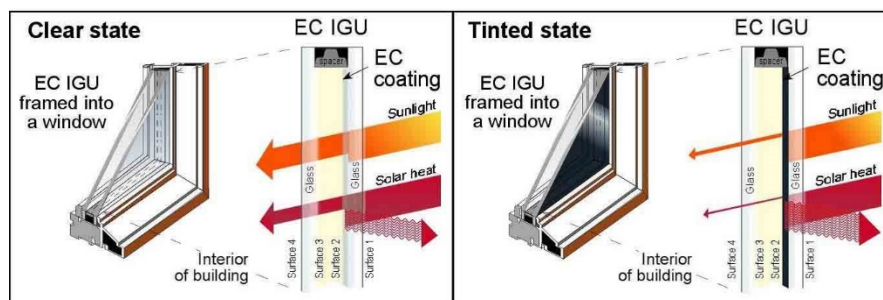


Figure 3.28 The switchable properties of dynamic glazing and its control heat and light modulation with change of transparency level (Fischer et al., 2004; Sanders & Podbelski, 2009a).

Electrochromic glazing can be comparable to and in some cases lower in expense than static glass because even with high-performance static low-e, additional methods of solar control (exterior sunshades, interior shading systems, or larger HVAC capacity) are

frequently required to complete the overall solar solution. As a result, this will add to the initial cost of the static glazing including higher ongoing energy expenses. Thus, the dynamic characteristics of smart glazing can improve flexibility of design by delivering all the benefits without the need of added systems (Sanders & Podbelski, 2009a).

The EC glazing is combined with a clear glass pane. Both panes are 6 mm thick and the 12 mm space between them is filled with argon. In the window configuration, the EC coatings are located on the inside surface of the exterior pane of glass (Sbar et al., 2012), as illustrated in Table 3.1.

Table 3.1 Switchable optical and thermal dynamic properties of SAGE EC glazing product (Sbar et al., 2012).

Key optical and thermal properties for SAGE EC IGUs.						
Product		Transmittance		U-Factor		SHGC
Level of tint	Inner Lite	Visible (%)	Solar (%)	Winter	Summer	
Clear	6 mm	62	38	0.29	0.28	0.47
Intermed. 1	Clear	21	9	0.29	0.28	0.17
Intermed. 2		6	2	0.29	0.28	0.11
Fully tinted		2	0.7	0.29	0.28	0.09

In addition, Sanders and Podbelski (2009) discuss that the U.S. Environment Protection Agency EPA estimates that up to 30% of commercial buildings' energy is used for lighting and as much as 80% of this lighting energy results in heat, which must be removed by air conditioning. HVAC systems account for more than 35% of energy use in commercial buildings. Further, Lawrence Berkeley National Laboratory (LBNL) conducted an assessment showing that using EC smart dynamic windows can save up to 60% of daily lighting energy. U.S. Department of Energy (DOE) predicts that commercial buildings relying on EC window systems could save up to 28% in energy costs when compared to buildings with static types. The U.S. DOE also reports that Electrochromic glass products can help save 10-20% operating cost savings; 15-24% peak demand reduction; up to 25% decrease in HVAC system size; and reducing maintenance. Unlike blinds, EC technology has no moving parts or added elements due to the embedded technology design approach.

3.13.5 Smart Dynamic Glazing and the Role of Technology

According to Baetens et al. (2010), the most desired properties of smart dynamic glazing are related to flexibility with control such as (i) integration with other coatings such as the development of highly insulating dynamic windows (ii) glare reduction, (iii) consistent-looking tint changes regardless of window size, (iv) light control between the dark and clear transparent state, (v) a high blockage of UV light, and (vi) fast switching speeds. Also, Deb et al. (2001) explain that the major advantages of EC materials are: (i) ability to change their optical properties in response to an electronic field and returned to their original state by a field reversal; (ii) they only require power during switching; (iii) they have a small switching voltage (1–5 V); (iv) many designs have long memory, up to 12–48 h, and various coloration ions can be used.

In terms of aesthetic aspects, this material has five specially deposited thin metal-oxide layers in a vacuum between two glass panels. This material product has a colouring range to choose from and this is achieved by the application of colour in the layer of lithium metal oxide (Rudolph et al., 2009). The parts are: 1) Conductive layer; 2) Positive ion storage layer of colourless lithium metal oxide; 3) Conductor/electrolyte layer; 4) Electro chromic layer-negative tungsten oxide; and 5) Conductive layer (Gavrilović & Stojić, 2011).

However, the colouration mechanism is still not fully understood, but it is related to the reversible character in a number of shades (Niklasson & Granqvist, 2007). The primary issue preventing widespread implementation of these materials is expense, but if the unit demand increases, then the cost of the technology will decrease (Graff et al., 2000; Lampert, 2003). In this respect, more work on such issues is necessary and integration with other material is still needed to be far enough advanced for the design element to be efficient and successful.

3.13.6 Flexibility of Smart Glazing Element

Smart window/wall glazing material improves the quality of design, aesthetically and functionally through the switchable facility from clear to tinted state. This property is considered an elegant design solution that provides clear unobstructed view from the building to the outside (Sanders & Andreau-Wiedenmaier, 2014). The multi-layered

glass material optimizes daylight penetration without admitting unwanted solar heat in summer whilst using passive solar gain in winter. All of this will improve the quality of the built environment by reducing CO₂ admissions and utilities costs (Loddo, Mandas, Pittaluga, Cossu, & Fenu, 2009; Sullivan, Lee, Papamichael, Rubin, & Selkowitz, 1994).

Such smart dynamic material appeals to building owners because it is an eco-friendly alternative to conventional skylights and solar controls such as shades and blinds, allowing natural light and creating a more energy efficient building. For architects, smart dynamic glazing costs the same or less than conventional systems when considering the overall total cost of the solution. With traditional sun controls, architects need to budget for shades/blinds (plus installation and maintenance), exterior sunshades (plus transport and installation), larger HVAC systems, increased energy usage, lighting, and peak demand electricity charges. Smart switchable glazing material eliminates these needs while preserving an aesthetically pleasing design (Sanders & Andreau-Wiedenmaier, 2014).

The use of dynamic glazing offers flexibility in solar and glare control as well as in shapes and the range of colours. Thus, architects and building owners have more freedom in optimizing daylight and reducing energy consumption in buildings by allowing them to incorporate dynamic glass instead of the conventional glass in several design elements such as windows, skylights, or any curtain wall scenario (WBDG, 2016). In addition, the development of highly insulating dynamic windows for application in both the commercial and residential sector could save about 4.5% of the annual energy used in the United States (Gillaspie, Tenent, & Dillon, 2010).

3.13.7 Climate and the Use of Electrochromics

Regarding the use of EC smart glazing in architectural facades, it is important to consider the role of temperature on the efficiency of the design element (Katanbafnasab & Abu-Hijleh, 2013). According to Jestico (2013), the use of Smart EC dynamic glazing provides 5-6% higher reduction of annual energy consumption when compared to static glazing types in cold climate zones. This is due to the need for more artificial lighting in static glazing during colder periods, which in return increases the annual lighting consumption. As a result, the internal heat gain of up to 12 W/m² effectively complements the heat demands. Hot climates such as Madrid an

EC application gives the lowest annual energy consumption in terms of cooling and lighting energy demands. Although the use of static glazing with external shadings may give between 8% to 18% higher energy consumption, nevertheless, the annual lighting energy consumption is 40% higher than with dynamic EC glazing (Jestico, 2013; Sanders & Andreau-Wiedenmaier, 2014).

Another example compares the energy performance of EC dynamic window glass with other conventional and high performance static glazing in the United States. Each window type was modelled in a standard eight-story office building using computer simulations based on the design and maintenance of indoor environments standards of American Society of Heating, Refrigerating, Air Conditioning Engineers (ASHRAE) 90.1. 2007 national energy code, as described by (Markit, 2016; Sbar et al., 2012). The Analysis was conducted for three different US climates; Minneapolis which represents a cold climate that is dominated by a heating load; Phoenix AZ known for hot and dry weather in which daylight is prevalent and a cooling load is dominant throughout the year; and Washington, D.C. which represents a composite climate that has both extreme heating and cooling seasons (Sbar et al., 2012), Table 3.2.

Table 3.2 The performance of static glazing per ASHRAE 90.1-2007 in different cities in the U.S in comparison to dynamic glazing (Sbar et al., 2012).

		SHGC	U-Value	VLT
Phoenix, AZ		0.25	0.75	40%
Washington, DC		0.4	0.55	40%
Minneapolis, MN		0.4	0.55	40%
SageGlass Double Pane (Argon)	Clear	0.47	0.29	62%
	Tinted	0.09	0.29	2.0%
SageGlass Triple Pane (Argon)	Clear	0.38	0.14	52%
	Tinted	0.05	0.14	1.9%

There are several glass characteristics that affect the design quality regarding aesthetic satisfaction within sustainability of the built environment, which are thermal transmittance or U-value, solar transmittance, visible transmittance T_{vis} , and g-value, also called solar heat gain coefficient (SHGC). The U-value represents the resistance offered by the glass to conduction of heat flow from the inside to the outside or vice

versa. U-value is the rate of heat transfer and how effective the building material in insulation, with the lower the U-value, the better the materials' ability to resist heat conduction. The SHGC ranges between 0 and 1, where 1 is low shading and zero is high shading. The lower the number, the less heat gain there is through the window system. Tvis is the visible transmittance of the window (Jaber & Ajib, 2011; Sbar et al., 2012; Sullivan, Rubin, & Selkowitz, 1997). As a result, the use of EC glazing delivers less energy consumption in comparison to other types of glazing.

3.13.8 Applications of Smart Glazing in Architectural Design

Smart dynamic glazing EC provides an innovative design approach that can be used in many building types as a sustainable approach to control heat gain and glare without blocking daylight. The government building of the U.S. General Services Administration (GSA) headquarters in Washington, D.C., underwent construction to connect two of the three main wings of the historic building. Part of a large open courtyard was transformed with a six-story south facing atrium with skylights. The atrium serves as a public gathering space and reception area, therefore, occupant comfort was a critical design objective. Accordingly, the GSA building needed effective control of both solar heat gain and glare to meet the requirements of energy efficiency, safety and worker comfort conditions (SageGlass, 2014), Figure 3.29.



Figure 3.29 Dynamic glazing in the clear and opaque state (SageGlass, 2016a).

Dynamic glass can also include automatic sensor controls for maintaining a comfortable level of sunlight throughout the day. Building owners can also use a remote control to manually adjust daylight to their liking. In addition to the practical benefits of optimizing daylight while controlling glare and solar heat gain (SageGlass, 2016a).

Another example of the benefits of using design flexibility of EC smart glazing to provide a healthy, comfortable working environment is seen in the government building of the Utrecht Region in Netherlands. Due to the glare caused by a conventional static skylight in the main conference room, people were not able to use the space for audio-visual presentations. Therefore, EC glazing was constructed and installed to solve the design problem by reducing glare while maintaining daylight and a view of the sky (SageGlass, 2016b), Figure 3.30.

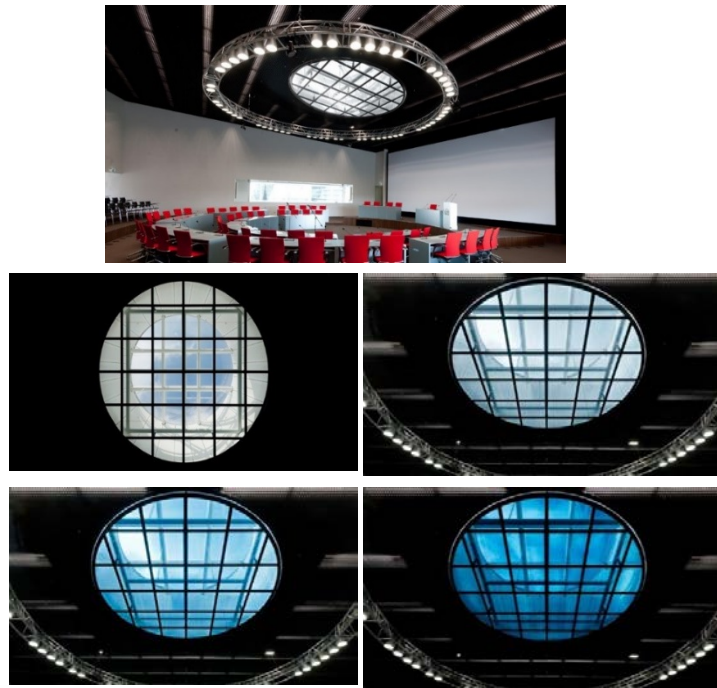


Figure 3.30 Infinite number of shades in the skylight of the Government Building in Utrecht, the Netherlands (SageGlass, 2016b).

A different example of switchable glazing applications is seen in 3 Large arched windows at Goldsmiths University (Qi Sealtite, 2016), Figure 3.31.



Figure 3.31 Arched windows installed with smart glass (Qi Sealtite, 2016).

An interesting example can be observed in commercial buildings of The East Winter Garden, England that opened in 2010 with smart glass exterior revolving doors of the building. Moreover, it is considered a futuristic element that complements the vision of an integrated role between modern material and technology (Smartglass, 2015), Figure 3.32.

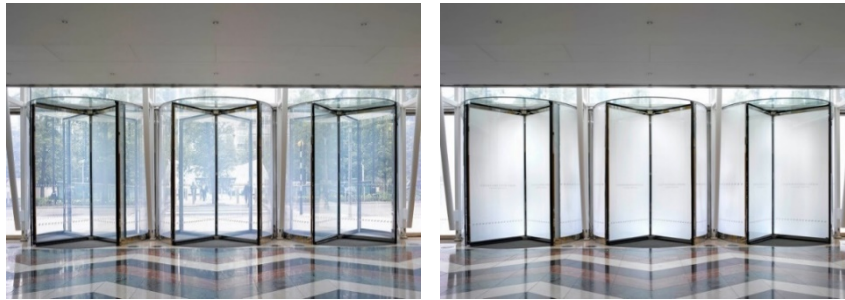


Figure 3.32 illustrates the use of smart glass in the exterior as revolving doors in the East Winter Garden, England, in London (smartglass, 2016).

In relation to cost issues, Fenlon (2010) explains that companies are working to improve the technology that can regulate the reflectivity and transparency of glass. For instance, Soladigm company has developed its own Electrochromic glass with costs around \$20 per square foot ($\$215/\text{m}^2$) (approx. $\pounds 176/\text{m}^2$) based on 2010 prices. However, advanced static low-emittance glass only costs about \$10 per square foot (approx. $\pounds 89/\text{m}^2$). However, EC with its smart glazing characteristics could save about 25% of annual HVAC costs in commercial buildings.

This research agrees with Fenlon (2010), Sanders and Podbeski (2009), and Lampert (1998) that more issues need to be addressed regarding the efficiency and performance of EC elements in real projects, particularly when integrated in different locations that reflect different types of weather in hot and cold climates. However, because of the complexity of these new materials the use of visualisation tools can help architects make sound decisions about the usability or integration of certain materials in design. Therefore, the next chapter will discuss the role of visualisation in design. It will also discuss technological development, concept and tools to facilitate the demonstration of material design characteristics associated with transparency and colouration efficiency.

3.14 SUMMARY AND CONCLUSIONS

This chapter examined design quality and its integrated relationship between sustainability aspects and the role of glass windows in design. It discusses smart dynamic glazing types and illustrated two types of smart dynamic glazing which are the Photovoltaics (PVs) and Chromogenic. It establishes that for the development of a smart window/wall/balcony design element, the dynamic characteristics of Chromogenic particularly in its Electrochromic (EC) type is found to be a most suitable in design, because it provides the design flexibility with control due to its switchable, reversible properties regarding transparency, and colouration. The chapter demonstrates its application in various building types.

In conclusion, the literature review undertaken suggests that the problem highlighted in Table 3.3 is in lack of consistency in the use of traditional elements in a way that affected the design sustainability environmentally, socially and culturally in architectural facade. This is due to the loss of the multifunctional quality that once traditional elements used to provide.

As a result, there is a need to revive part of the environmental control of traditional elements shanashil through the use of smart material taking into consideration the important role of transparency, privacy, and advanced technology in design. However, there are three challenges to achieve the flexibility and balance between the dynamic characteristics and design requirements both aesthetic and functional that are as follows:

- Revive environmental control with thermal comfort to deliver a healthy, active environment regarding role of material (transparency and colour), energy efficiency in terms of lighting energy and cooling loads.
- Harmony with surroundings associated with elegance, flexibility, and functional beauty.
- Sustainability of social and cultural aspects with aesthetic satisfaction taking into account daylight needs, cost and maintenance issues.

Table 3.3 illustrates the identified problems and suggestions of the research.

Identified Problems	Suggestions
1. Loss of design identity and values regarding distinctive features in modern architectural façade found in traditional design element <i>shanashil</i> .	Understanding the main characteristics of <i>shanashil</i> that used to provide a successful design element, aesthetically and functionally.
2. Old adaptable strategies associated with traditional elements are useless now due to: a) Modern planning from the irregular organic design pattern to gridiron layout. d) Industrial and technological advancement, change of transportation means, lifestyle and activities.	<ul style="list-style-type: none"> • There is a need for new adaptable strategies which can be found in biomimetics design approach capable of delivering a multifunctional quality both aesthetically and functionally. • The research subject is about expanding beyond architecture by bridging into modern technology with a focus on the continuity of environmental and social control once provided by traditional elements. • The continuity of design can be achieved from a bioinspired design approach that mimic the characteristics of traditional elements by using a smart dynamic material inspired from biomimetics strategies to deliver a multifunctional design quality in hot, arid climate.
3. Lack of knowledge about the application of modern smart materials in achieving the continuity of environmental and social control, which was previously provided by traditional design elements.	<ul style="list-style-type: none"> • Understanding the changes that affect the idea of transparency in design while maintaining privacy needs. • Understanding the dynamic characteristics of smart glazing and its added value to improve design flexibility by delivering aesthetic satisfaction with sustainability of environmental, social and cultural aspects. • Achieving energy efficiency through better balance between daylight needs, less consumption in lighting energy, and cooling loads.

Finally a conceptual framework is produced as a result of literature chapters 2 and 3, as shown in Figure 3.33.

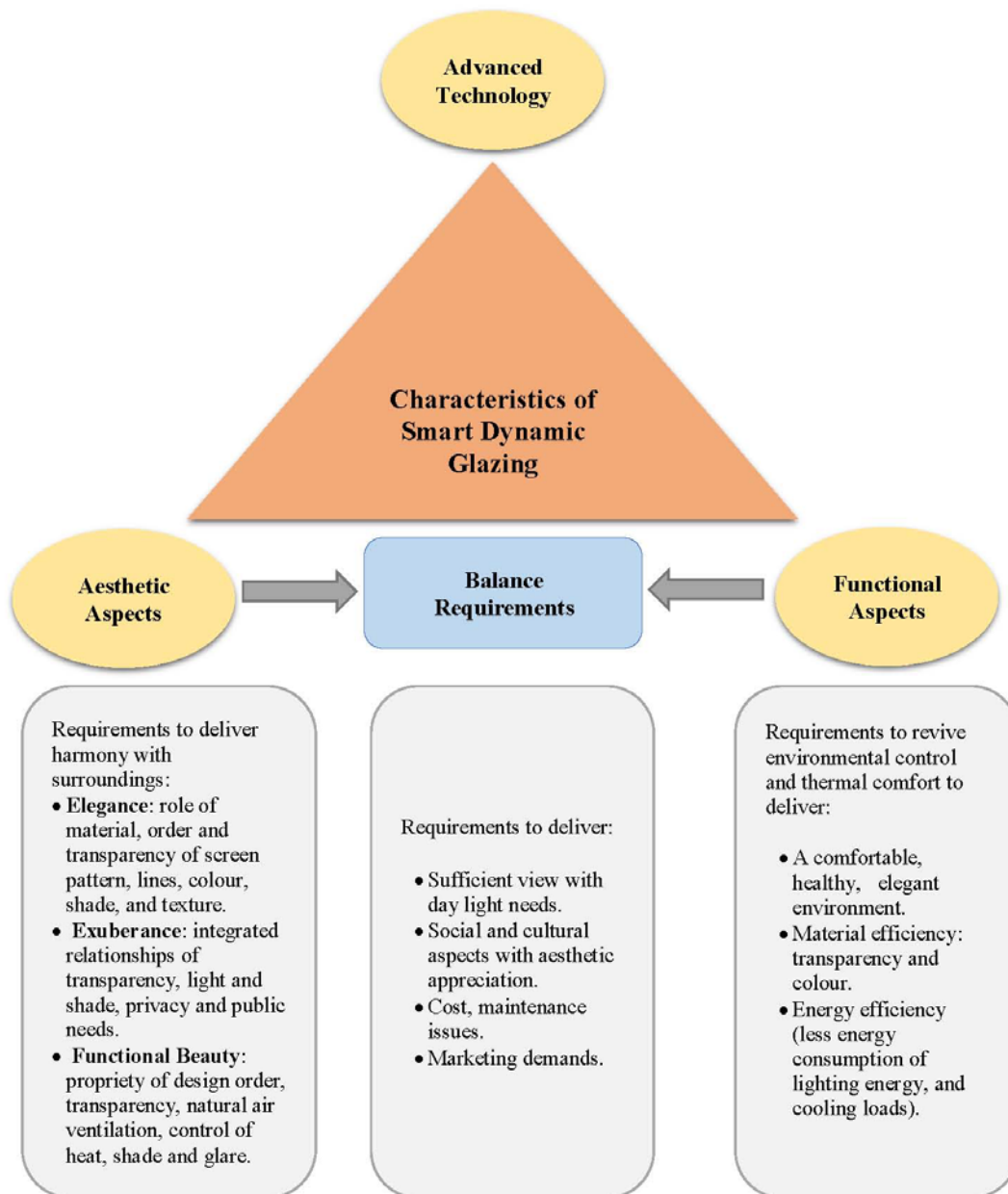


Figure 3.33 Conceptual framework of research study

The dynamic characteristics of a smart window/wall/balcony design element have switchable, reversible properties associated with transparency, privacy, and colour. It is important to illustrate the added integrated relationships with design aspects to enhance design quality in a way that delivers aesthetic satisfaction within sustainability of environmental, social and cultural aspects. This is achieved through understanding the ideas of elegance, flexibility, and functional beauty and its integrated relationship with sustainability aspects. Based on the conceptual framework, the challenges of developing a smart dynamic window/wall/balcony

element are strongly connected to its switchable and reversible properties, multi-layered, and the role of active embedded technology. Such challenges are associated with the dynamic characteristics of a material in terms of transparency, colour, privacy, and energy efficiency, as shown in Figure 3.34.

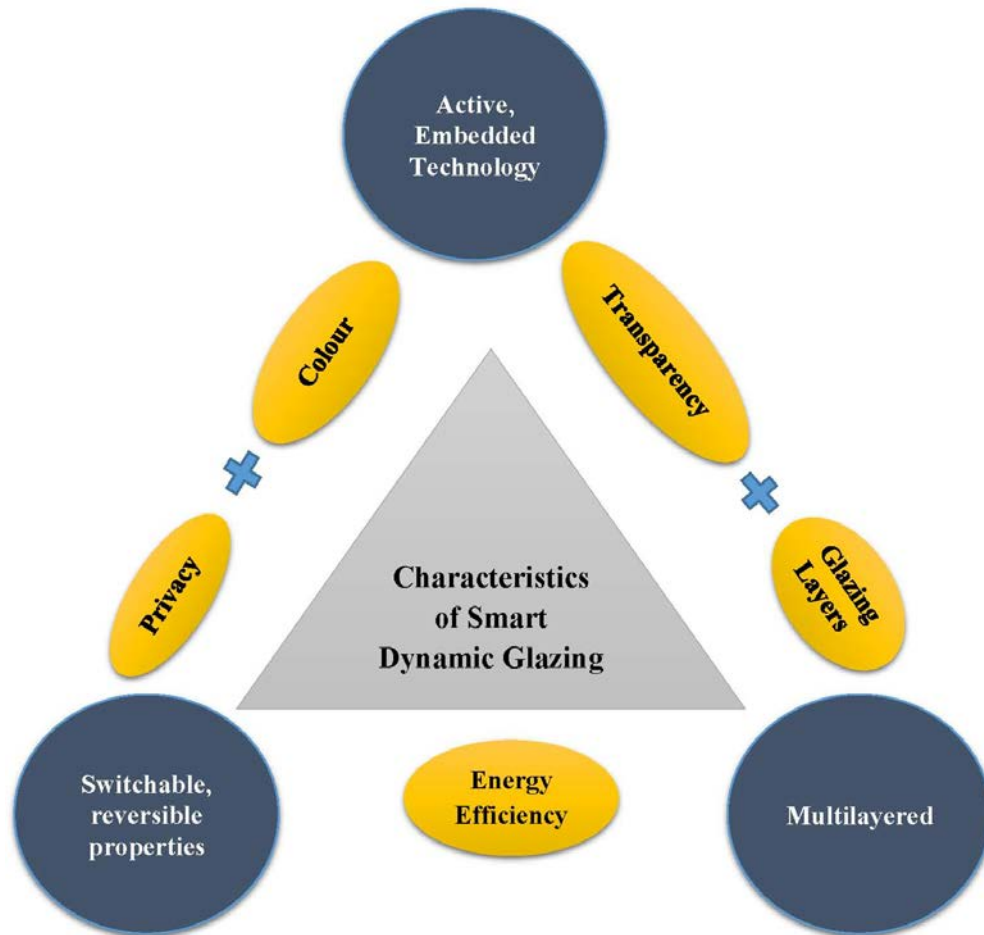


Figure 3.34 The dynamic characteristics of smart dynamic glazing implemented in a window/wall/balcony design element.

Hence, this research will develop as a solution a digital prototype that integrates the dynamic characteristics of a smart window/wall/balcony design element to help architects make conscious decisions about using switchable, reversible properties in design, both aesthetically and functionally. To meet these challenges the following Design Science Development Stage, Chapter 4, is followed to illustrate the added value of dynamic material characteristics implemented to be part of architectural elements.

To evaluate the innovative contemporary approach for the implementation of the dynamic characteristics in a smart window/wall/balcony design element in architectural façade, Chapter 1 outlined the Design Science approach. Based on this methodology Chapters 4, and 5 explore the aspects that contribute to the environmental, social and cultural sustainability and assess the role of transparency in design while maintaining privacy needs to deliver an elegant, healthy, and active environment in order to develop a design solution.

Chapter Four

4 Development Stage and Assessment of a Smart Contemporary Design Element Using Visualisation Tools

4.1 INTRODUCTION

Chapters 1, 2, and 3 form the foundation for the Development Stage and seek to highlight the important design aspects that improve the flexibility of design regarding the ideas of elegance, flexibility, and functional beauty, whilst focusing on the impact of sustainability aspects environmentally, socially and culturally on the design identity and values to blend in harmony with the surroundings and type of climate.

The next part of the Development Stage involves the use of technology tools in order to visualise the impact of dynamic characteristics of a smart window/wall/balcony element on design quality, both aesthetic and functional. Therefore, the next section will discuss the important role of technology as part of design tools in visualising and delivering 3D models that demonstrate the added value of dynamic material characteristics in design.

4.2 VISUALISATION OF TECHNOLOGY IN DESIGN

Due to the dynamic characteristics of modern materials and the impact of transparency in design, there is a need to use technological tools to ease visualisation and allow designers to engage with them as part of their design process. What architects need is a clear and comprehensive design tool to assist them in visualising the dynamic characteristics and its added value to design, both aesthetically and functionally. 3D models created with the aid of technology tools are needed to visualise different parts of the design (Irizarry, Meadati, Barham, & Akhnoukh, 2012). Technology tools allow designers to deliver a more elaborate contemporary approach and enhance the capabilities of designers and learning experience (Casey, 2008; Gulling, 2008; Ku & Taiebat, 2011).

The Development Stage requires the creation of a 3D visualisation process to illustrate design flexibility of a multifunctional window/wall/balcony design element. Accordingly, a 3D digital model is developed to represent the reality of the design.

An example of the window/wall/balcony is rendered in Revit tool in which each design element is associated with predefined parameters. Consequently, Autodesk's Revit tool classifies the 3D design elements that define within the model walls, windows, balconies by categories, families, types, and instances (Krygiel, 2011; Younis, 2010). However, some of these elements represent the whole real world components as a separated single entity and cannot serve to depict the actual construction process (Goedert & Meadati, 2008). In addition, the lack of an individual layer selection limits the flexibility of part-to-whole design relationships (Irizarry et al., 2012). Therefore, this research adopts Autodesk's Revit tool to develop a 3D digital prototype that demonstrates the impact of smart dynamic material characteristics in improving the flexibility of design, aesthetically and functionally.

However, there is a need for different technological tools to overcome the limitations of the design tools both in terms of interactivity and visualisation in order to illustrate such material characteristics (variables and constants) and their added value to design, aesthetically and functionally.

Hence, the next section will discuss further concepts and technological tools to provide a collective perspective able to illustrate the dynamic nature of material characteristics. The research will develop a 3D digital prototype that integrates the variables and constants properties of a smart window/wall/balcony design element to help architects make decisions about dynamic characteristics that deliver a multifunctional quality, both aesthetic and functional.

4.2.1 Comparison between the Revit Tools and the 3D Virtual Environment Technology

There are two approaches used to support the research findings. These are customised Revit BIM tool and a smart glazing VR prototype. Both approaches allow users to change the property of the glazing windows (colour and transparency). However, due to the limitation of Revit tools, only the 3D Virtual Environment solution provides the realistic lighting condition such as shadow, lighting intensity and light shaft (Ward, 1994). Palsbo and Harty (2013) argue that Revit has a limitation to provide the dynamic characteristics of the material. For example, the colour and transparency of the material cannot be changed individually. As a result, the solution is to use Smart Serious Game technology by incorporating the knowledge of the smart glazing

property to each window object and allow the user to interact with the 3D environment in real-time (Mittring, 2012).

Cardoso (2015) discusses that the Lumion 3D uses the Revit model and allows the designer to provide the realistic visual quality of the lighting in the 3D environment. However, it only produces video to the end users, which limits the user's ability to navigate and change the property of the smart glazing. Therefore, tools and methodologies have been developed to provide feedback loops from design to operation that invite creative input.

Nevertheless, it is important to mention that there is an interactive visualisation tool, Autodesk Live (Autodesk, 2016) for presenting the Revit model. Architects can upload their Revit models to the Autodesk cloud. The models are then converted and downloaded onto their local computers for the interactive visualisation. Once the interactive model is loaded then, they can navigate the building both internally and externally; present the lighting and rendering styles; and query the property of the building elements. The additional feature is that it can share the interactive model via the mobile app to support team collaboration. Compared to the visualisation tool adopted by this research, however, the Autodesk Live does not have knowledge of smart glazing. It does not allow users to change the window properties such as colour and transparency. More importantly, the environment cannot dynamically update the lighting condition through the characteristics of the smart glazing property.

In the aspect of the user interaction, the smart glazing VR prototype provides the presentation style which allows the user to use a gamepad to navigate the scene freely (Shiratuddin & Thabet, 2002); whilst the Revit is developed more towards to engineering CAD style and only uses the traditional navigation system, as discussed in (Bouchlaghem, Shang, Whyte, & Ganah, 2005), and broken down into separate viewing mode, for instance, rotate view, pan view and zoom view.

The user interface of the Revit environment relies on the default Revit user interface which uses Microsoft Windows styles menu and button. The 3D Virtual Environment allows the developer to provide a customized interface element such as 3D compass for supporting the scene navigation.

The next section will discuss in depth the concept of Smart Serious Game technology and tools of the dynamic material characteristics. Such characteristics are demonstrated in a 3D digital prototype to enhance interactivity and engage the end users such as architects, to be part of this design process.

4.2.2 The System Components of the Smart Glazing VR Prototype

The prototype adopts Smart Serious Game technology (Rüppel & Schatz, 2011) for the purpose of providing the real-world events and realistic environment for user engagement. This has been applied to various domains and industries such as scientific exploration, education, health care, emergency management, city planning, engineering and politics (GAIA, 2010). Accordingly, Smart Serious Game deliberately sacrifice fun and entertainment in order to achieve the desired progress and present potential solutions to the user.

The material specifications using smart serious game will be illustrated in two architectural façades that show the changing state of the façade appearance depending on the integrated variable and constant relationships between transparent, to semi-transparent, and then opaque facade material

This Development phase is where most of the actual design variables and constants take place, with creative effort required in synthesising existing knowledge and a well-defined problem definition into a digital prototype for solving the problem (March & Smith, 1995). The Development Stage includes changing the state of some of the variables identified at the Pre-Development Stage into constants such as colour, texture, shape, and type of material as part of design decisions. However, there are variables that will continue to be one as part of the process such as opacity, transparency, and translucency in order to demonstrate the flexibility of a multifunctional design quality in terms of material.

The Smart Glazing VR Prototype is developed using BIM software (Revit API) (Chang & Shih, 2013), and a game engine framework (Unreal Engine) tool (Hilfert & König, 2016). It comprises several modules in order to achieve the required functionality, as shown in Figure 4.1.

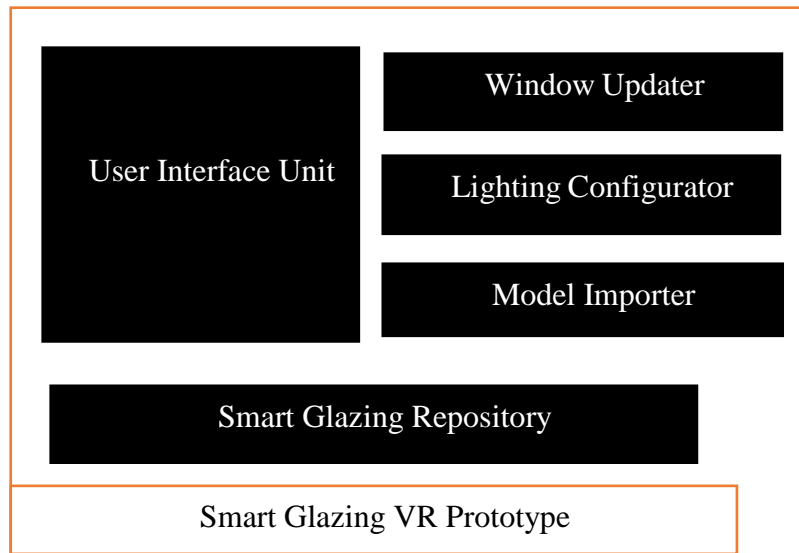


Figure 4.1 System architecture of the platform.

The 3D Revit building model is designed and exported from a custom Revit Plugin (Model Exporter). The plugin exports the building geometry and material into a format that the VR Prototype can interpret through the Model Importer. Once the 3D building is imported and positioned in a correct location in the 3D virtual world, users can interact with the building through the User Interface Unit. It contains common user interface widgets such as buttons, checkboxes, sliders and dropdown menus and a custom compass 3D object. The common user interface is to help users to change the windows properties (e.g. transparency and colours) while the custom 3D compass is to assist identifying the orientation in the virtual world.

The Smart Glazing Repository keeps knowledge of the glazing information such as the Visible Transmittance (T_{vis}), Solar Heat Gain (SHGU), and U-Value. This is the core module which can control other modules when presenting the visual information. For example, when the user selects the windows and sets its glazing type it then notifies the Window Updater to change the windows glazing properties (such as transparency and colour). Next, it also commands the Lighting Configurator to update the lighting condition such as lighting intensity and the environment shadow property.

In order to make the prototype flexible enough for adding/extending new or future glazing categories, the Smart Glazing Repository can be enhanced by connecting to an external database system for updating the glazing information.

4.3 DESIGN RESEARCH-DEVELOPMENT STAGE

As a result of the development research approach, this stage focuses on the need for the 3D digital prototype to demonstrate dynamic characteristics of material; and as a guide for the interviewees to visualise, interact, and assess their awareness and perception of the window/wall/balcony elements between the traditional and contemporary using smart dynamic glazing material. In order to undertake the Development Stage two distinct steps are taken:

- Identify requirements needed to solve the problem and demonstrate the concept of dynamic characteristics of smart glazing material
- Incorporate requirements into technology tools in order to enable the visualisation of the added value of dynamic characteristics in the design element. These tools are utilised:
 1. A demonstration of a smart window-wall design element using Lumion 3D application (Revit Plugin) as it uses the Revit model which allows the designer to provide the realistic visual quality of the lighting in the 3D environment, as shown in Figures` scenes of 4.2.

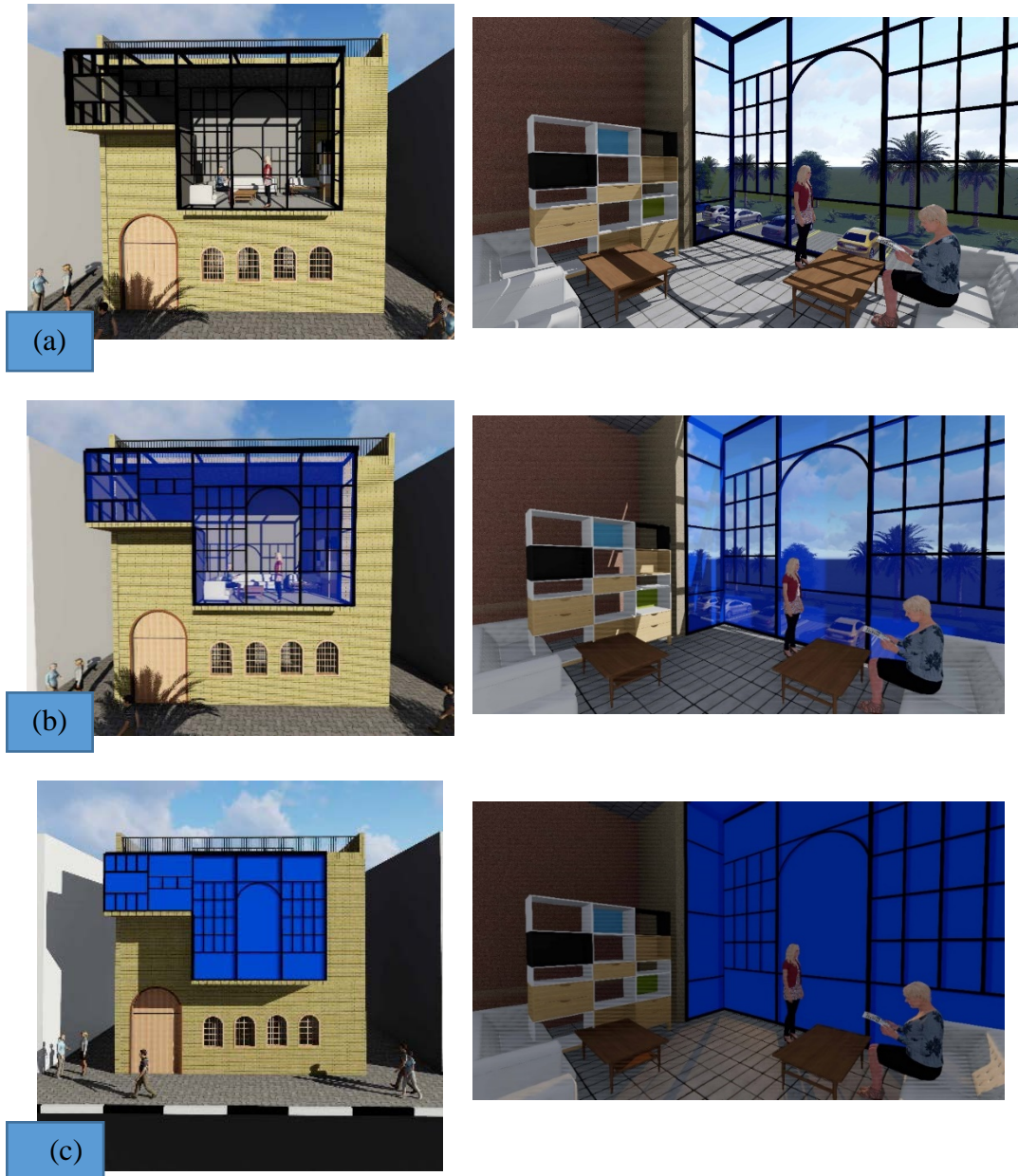


Figure 4.2 The use of dynamic material characteristics between (a) transparent state (b) semi- transparent state, (c) opaque state, and its impact on indoor environment.

However, this is a solid demonstration and therefore there is no possibility of changing the properties and providing the needed experience for the user. Realise the difference between static and dynamic characteristics is also not possible. Therefore, another tool is needed for more control of variables and constants, before and after design process.

2. Smart glazing VR prototype: the concept of Smart Serious Game is used as a means to deliver better interactivity by engaging the user to be part of the design

process. The images captured from this 3D smart glazing prototype are illustrated to discuss the role of the modern material (smart dynamic glazing) when compared to traditional materials (wood with static glazing) in a window/wall/balcony design element, as shown in Figures 4.3.

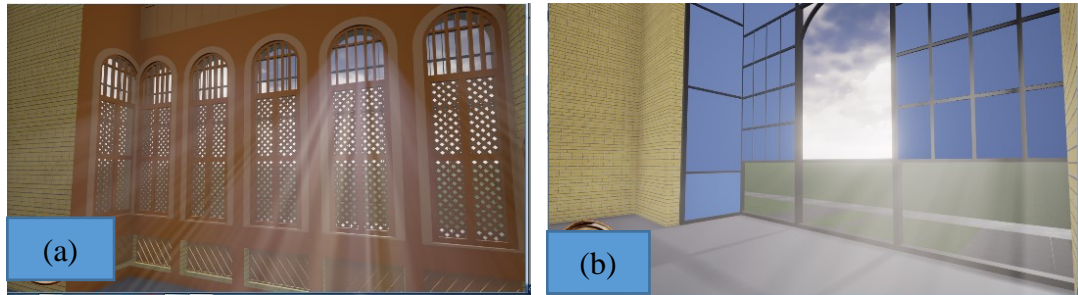


Figure 4.3 The difference in the manipulation of light and shade aspect between traditional materials in (a) whilst (b) shows modern material.

Figure 4.4 demonstrates the integrated relationships between daylight and several factors such as visible transmittance (T_{sol}), solar transmittance (T_{vis}), Solar Heat Gain Coefficient (SHGC), and U-Value in the modern material. This is particularly due to the switchable, reversible properties of smart dynamic glazing element. It also illustrates the changing properties and its impact on delivering a better environment. However, there is still a need for a tool that is more suitable with predefined parameters for an architectural design application.

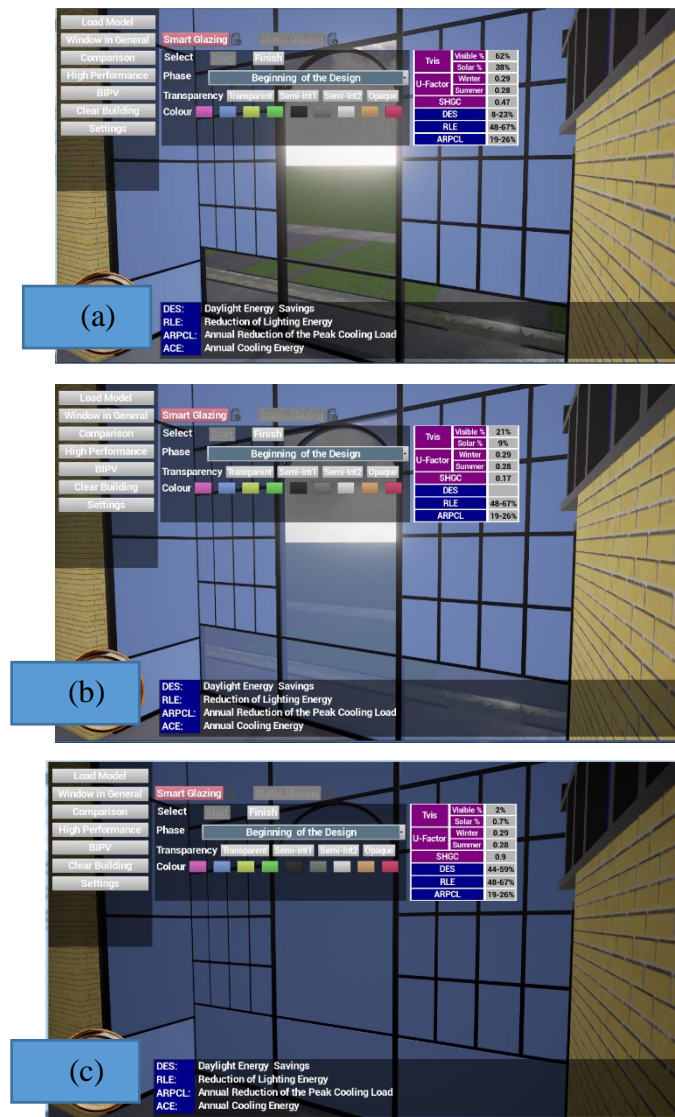


Figure 4.4 The design element which are seen in the state of transparency and the choice of colour.

3. BIM Tools (Revit Plugin): This tool provides the opportunity to design a family of predefined properties and families associated with the smart dynamic design element, as shown in Figure 4.5 (a, b, c). However, it is not flexible enough to demonstrate layers in terms of realistic daylight condition and its integrated relationship with, shade and lighting intensity.

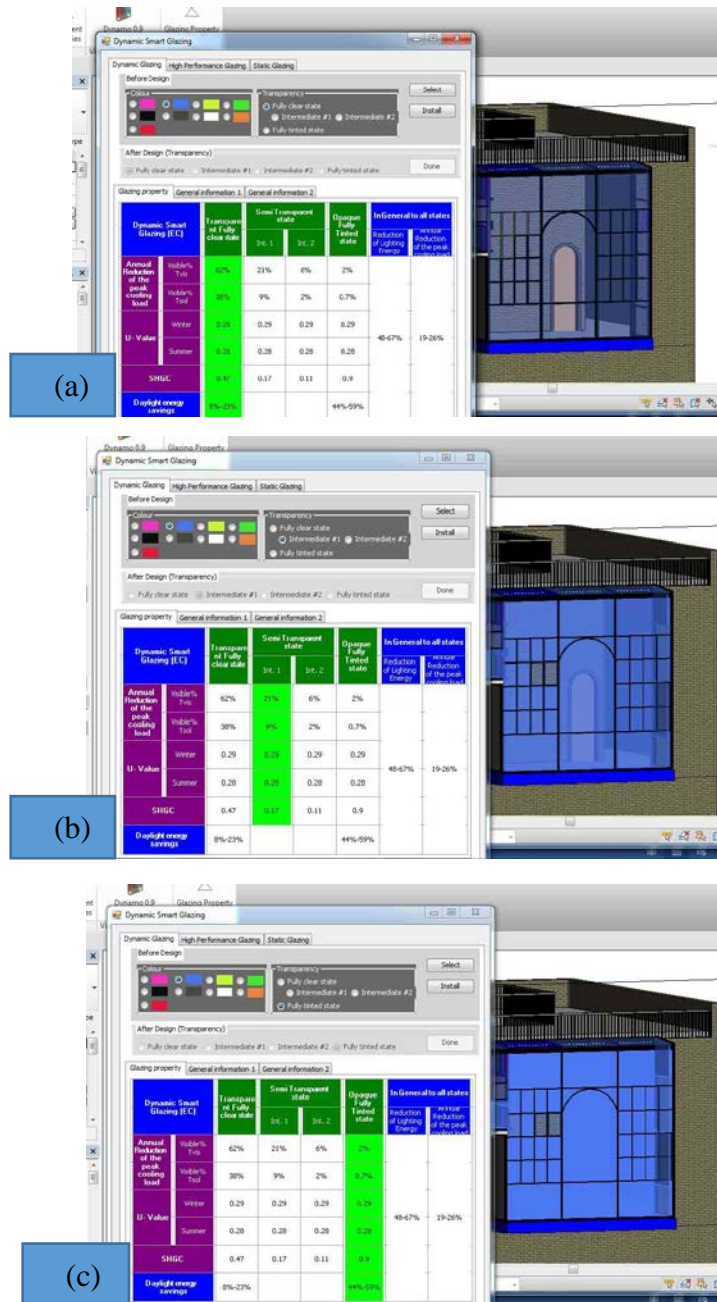


Figure 4.5 The use of Revit tools and plug in to express the impact of switchable, reversible properties from transparent state in (a), to semi-transparent in (b), to opaque in (c).

This is to improve design quality focusing on less energy consumption needs particularly lighting energy and cooling loads through better balance and distribution of daylight needs whilst providing thermal comfort.

The researcher found difficulty in expressing the impact of dynamic material characteristics to improve the design quality of a smart contemporary window/wall/balcony element, both aesthetically and functionally. Hence, the

intention before each interview was to use the visualisation tool Lumion 3D first and send it to the interviewees in order to gain their acceptance to be part of the research study. Although the Lumion 3D shows clearly the switchable, reversible properties of the external façade in comparison to the traditional one, still it does not allow the interviewees to engage and participate during the design process. Thus, another design tool is used during the interview which is the Smart Serious Game Smart glazing (VR). This tool allows for the interactivity between the researcher and the interviewees. It also allows for the interviewees to engage and be part of design process. This tool also shows the difference of indoor environment between traditional element and contemporary element. Nevertheless, a third tool Revit plug is also needed to illustrate the predefined parameters for the interviewees to understand the importance of the integrated design relationships between switchable transparency, colour, and privacy to improve the sustainability of environmental aspects associated with the needs of daylight, lighting energy, and cooling loads.

The Development Stage is discussed further with the opinions of interviewees concerning design quality between a traditional and contemporary design element in the next section.

4.4 QUALITATIVE DATA COLLECTION METHOD AND ANALYSIS

The literature shows that the main problem in improving the design flexibility is not only in what technology offers in terms of smart material, but also in the preconception of the main dynamic characteristics which in this case are transparency, privacy, light and shade manipulation, and thermal comfort. The main aim is to explore the dynamic characteristics which contribute to the effectiveness of part-to-whole integrated design relationships associated with a window/wall/balcony design element in order to restore part of the lost design identity and values.

Ospina (2004) argues that qualitative methods are needed when there are questions that cannot be answered by way of quantification. In addition, the design of such methods is focused on capturing the experience and perceptions of participants involved in the phenomena or process being investigated (Onwuegbuzie & Johnson, 2006). Whilst, Liamputtong and Ezzy (2005) note that this way of investigating is

better than quantitative surveys specifically in acquiring information about research issues where little is known.

During the arrangements for interviews, extra attention was paid to ensure that the interviewees;

- Were already engaged in the field of architectural design;
- Interviewees have deep knowledge and experience about the traditional design element shanashil. This is important to understand design identity and values including the choice of material and its effect on part-to-whole design relationships with the surroundings and type of climate.

However, there is no universally accepted set of conventions for qualitative data analysis compared to those associated with quantitative data. Accordingly, it is essential for qualitative researchers to choose and justify analysis techniques. Data analysis techniques refer to a range of ways in which data can be made sense of and attached to meanings. Easterby-Smith, Thorpe, and Jackson (2012) suggest that most analytical techniques can be used for a wide range of data. However, it is important that the researcher adheres to analysis techniques that are consistent with the philosophical and methodological choices of the study. Acknowledging the philosophical and methodological assumptions as explained above, this research adopts a semi-structured interview and thematic analysis technique which is covered in more detail in the next subsections.

4.4.1 The Sample

The sample of interviewees was selected according to their knowledge of architectural design profession, buildings, elements, and modern materials. Interviewees were also selected based on their knowledge about the city development of Baghdad, its traditional elements shanashil, and the role of change associated with modern planning and transportation means including industrial and technological advancement. According to Saunders (2015) the sample size is an important aspect when carrying out any research study. However, in relation to qualitative research Kumar (2011) states that the selected size of the sample in qualitative research is less important than in quantitative research. Creswell (1994; 2014) suggests that between 5-25 interviews are enough for an interpretive study whilst Rubin (2004) proposes the

range of 10-15 interviews. Also, Francis et al. (2010) suggests that the quality and number of the interviews depends on data saturation, so interviews are conducted until no new ideas emerge.

A purposeful sampling technique was initially used to identify those willing to participate in the study. Purposeful sampling is mainly associated with qualitative studies and can be defined as selecting individuals based on particular purpose to answer the research questions (Suresh, Charles, Akintola, & Jack, 2012). The profile of interviewees was based on a subset of Iraqi architects, either professors or consultants. In order to increase the overall sample size snowball sampling was then used in this research to identify further interviewees through mutual association (Marshall, 1996). Overall 21 interviewees took part in the research study. 16 interviewees are based on purposeful sample and 5 interviewees on snowball technique.

4.4.2 Interview Method

In this research study, it is important to have in-depth face to face discussions as there is a need to discuss architectural design details, for instance, the role of material and the screen design pattern as an essential part of architectural façade in terms of colours, texture, and design order. The research has adopted a semi-structured interview technique with the 21 interviewees. Qualitative interviews based on semi-structured conversations in which a researcher guides a conversational partner in an extended discussion. The researcher searches for depth and details about the research topic by following up on answers given by interviewee during the discussion (Douglas, 1985; Merton & Kendall, 1946). Rubin (2004) argues that this situation is the opposite of the quantitative survey research in which exactly the same questions are asked to each individual. Further, qualitative interviews are good in explaining how and why things change (Rubin, 2004). However, interviewees may often have difficulty explaining the object or picture because it is related to a culture they take for granted and hence it is invisible to them (Boje, 1995; Hummel, 1991; McCall, 1990). Therefore, visualisation tools are used to overcome such difficulty by developing a 3D digital prototype that demonstrates the impact of dynamic material characteristics in design. These tools enable the interactivity between the researcher and interviewees to engage and be part of design process. As a result, interviewees

were also able to observe the impact of switchable, reversible properties, particularly, the role of transparency and the choice of colours in improving the quality of design, both aesthetically and functionally.

The semi-structured interviews contain a mixture of open-ended and closed questions asked during the interviews and lasting approximately one hour (Appendix A). Lumion 3D was first used within the interview process to allow the interviewees to see and understand the switchable, reversible properties as part of the architectural facade, but it did not provide the engagement with the interviewees. Therefore, a smart glazing VR prototype was also used as a second visualisation tool to engage the interviewees to be part of design process. It enabled the interviewees to understand the flexibility of the smart dynamic material such as the choice of colours before design and understand the impact of the choice after design. Additionally, a Revit plugin tool was also used to understand the impact of the predefined parameters on the integrated design relationships, particularly, between daylight needs, lighting energy, and HVAC requirements (cooling loads). It also enhances the perception of dynamic characteristics of the smart material to illustrate impact on design quality.

Devaus (2002) argues that careful selection of people can provide valuable sources of ideas which can help add value to the research since high quality responses are possible. The decision to use the interview with professionals viewing the 3D digital prototype demonstration in this study was influenced by two main considerations:

- 1- The interview allowed for more depth and flexibility of response than other methods.
- 2- The use of an interview offered the opportunity to ask interviewees supplementary questions, which might improve the researcher's understanding of the issues and opinions raised by professionals.

Twenty one interviews were conducted with architects taken from academic and private practice. Interviewees had qualifications that varied between the highest academic level of professors, and senior consultants in architectural design. 10 out of the 21 interviewees had between 30 to 50 years of experience of working in the Middle East, mostly in Iraq. They were working in ministries, such as the Ministry of Regional Planning Commission, Ministry of Housing & Construction, Ministry of Higher Education, or Universities such as The University of Baghdad, University of

Technology, University of Basrah, and municipality of Baghdad, National Center for Engineering Consultancy, in Iraq.

4.4.3 Thematic Analysis

Denscombe (2014) states that there are different methods to analyse qualitative data including content analysis, grounded theory, discourse analysis, conversation analysis and narrative analysis. Yin (2014) adds that thematic analysis is another approach used to analyse qualitative data, whilst Borrell (2008) points out that thematic analysis is one of the most common methods of qualitative analysis. Braun and Clarke (2006), (Patton, 1990), and Holloway and Todres (2003) mention that thematic analysis allows researchers to identify, analyse and report themes within data by organizing and describing the significance of the patterns in rich detail and it presents experiences, meanings, and the reality of participants. Thematic analysis is useful in summarising the key features of large body of data and offers a 'thick description' of the research data (Braun & Clarke, 2006). It can also highlight similarities and differences in the themes, and can produce unanticipated insights with the possibilities for social, as well as psychological, interpretations of the data. It is accessible to researchers with little experience of qualitative research, and can be communicated without major complications, therefore is used in a wide range of disciplines (Bryman, 2015; Taylor-Powell & Renner, 2003).

Braun and Clarke (2006) identified six stages in a step-by-step guide for researchers when performing thematic analysis, Table 4.1.

Table 4.1 Phases of Thematic Analysis (Braun & Clarke, 2006).

Phases	Description of the process
1. Make yourself familiar with your data	Read and re-read the transcribed data
2. Start initial coding	Coding interesting features of the data in a systematic fashion across the entire data sets, collating data relevant to each code
3. Searching for possible sub-themes	Collating codes into potential sub-themes, gathering all data relevant to each potential theme
4. Reviewing sub-themes	Checking if the sub-themes work in relation to the coded extracts (level 1) and the entire data sets (level 2)
5. Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
6. Completing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples; final analysis of selected extracts; relating back the analysis to the research question and literature; producing a scholarly report of the analysis

In this research study, step 1 was achieved through the researcher transcribing the interviews (Appendix B), reading through the data several times, and listening again to the audio recorded materials. The researcher wrote down any impressions and initial ideas during the interview regarding the use of design tool to ease the visualisation of dynamic characteristics and to engage the interviewees to use this in the design process. The approach to step 2 focuses on the analysis of interviewees answers. This approach allows for comparisons between the traditional model and contemporary design elements using a modern material. Step 3 builds on the previous step where interview questions are considered under the themes as they emerged. The interview questions were developed through established existing empirical research (Al-Bayati, 2011; Kapsali & Dunamore, 2008; Kenzari & Elsheshtawy, 2003; Kohler,

1999) and this suggested predetermined themes based on the design characteristics of traditional window/wall/balcony elements. The main themes which guided this study were as follows:

- Traditional design element:
 - a) Identifying the characteristics that provided for the idea of elegance, flexibility, and functional beauty;
 - b) Identifying the sustainability aspects which such elements used to provide in terms of material;
 - c) Identifying the role of change regarding modern planning and use of cars and its effect on the consistency of design identity and values;
- Smart material:
 - a) Exploring the perception of the interviewees on aspects that are important for the smart material to improve quality of design whether aesthetic or functional;
 - b) Identifying the added value of dynamic characteristics of smart glazing material to be used in a contemporary window/wall/balcony element;
 - c) Issues and challenges of using a smart dynamic glazing material

The main themes were then organised and sub-themes emerge in step 4. For example, the characteristics of traditional design theme proved to contain five sub-themes: elegance, exuberance, functional beauty, and two sustainability aspects - environmental and social/cultural. The combination of predetermined and emergent themes demonstrates that this research was sensitive and accountable to the data analysis. In step 5, the researcher presents the findings with clear connections to the existing literature where connections are possible. The data analysis details and findings are further discussed in the next section.

The interview was divided into five sections:

4.4.3.1 SECTION I – PROFILE OF INTERVIEWEES

Information on the background of the interviewee's expertise and responsibilities.

4.4.3.2 SECTION II – THE CHARACTERISTICS OF TRADITIONAL ELEMENT SHANASHIL

This lists the characteristics attached to the traditional design element *shanashil*. These characteristics have an integrated relationship with design concepts of elegance, flexibility, functional beauty focusing on the role of material that once provided a multifunctional quality both aesthetically and functionally. This section assesses how flexible the traditional elements used to be in terms of type of material, colour, texture, screen pattern, manipulation of light and shade, transparency, privacy and public states. It also focuses on the sustainable aspects provided by traditional material using passive technology as part of rapid organic pattern to collectively cater for part-to-whole design relationships.

4.4.3.3 SECTION III – DEFINITION OF SMART MATERIAL

This section explores with interviewees the definition of smart material and the need for its use to improve design quality. It also explores the perception of the interviewees for the role of modern material associated with transparency, privacy, and active, embedded technology in improving the sustainability of design aspects environmentally, socially and culturally.

4.4.3.4 SECTION IV – THE DYNAMIC CHARACTERISTICS OF SMART CONTEMPORARY ELEMENTS

Questions on the perception of interviewees regarding the impact of dynamic characteristics of smart glazing in improving the design flexibility when compared to traditional materials are included in this section. It also investigates different types of smart dynamic glazing material to understand the important characteristics affecting the success of integrated part-to-whole design relationships in the external facade.

4.4.3.5 SECTION V – ISSUES AND CHALLENGES OF USING A SMART DYNAMIC GLAZING MATERIAL

Interviewees are asked to assess how future shanashil can be designed in a way that environmental control can be maintained to deliver aesthetic satisfaction. It tries to identify the advantages and disadvantages of replacing old materials such as wood and static glazing with a new dynamic glazing material and its impact on design quality, aesthetically and functionally.

4.5 RESULTS AND ANALYSIS

The aim of this section is to bring together data obtained from the semi-structured interview questions, undertaken in the Development Stage in (Appendix A). The 21 interviews are categorised under the five sections.

4.5.1 SECTION I – Profile of Interviewees

Information on the background of each expertise and their responsibilities of the interviewees in the architectural design field are given in Table 4.2.

Table 4.2 Summary of the interviewees` profile.

	Job Title	Type of Organisation	Responsibilities	Years of Experience	Type of Projects
A1	Architect, Design and BIM	University	Lecturer	30 years (Mixed Academic and private practice)	UK and Asia Housing projects, schools, office buildings, museums, airports.
A2	Architect, Architectural Design, and Technology	University	Lecturer	15 years (Mixed Academic and private practice)	Europe and UK worked in design solutions, design, construction mixed projects
A3	Architect, (Architecture and construction technology)	University	Lecturer	17 years (Mixed Academic and private practice)	UK (Mixed projects)
A4	Architect, Architecture Design, Urban Ecology	University	Professor, Dean of School of Built Environment	26 years (Mixed Academic and private practice)	Middle East, Africa, UK,
A5	Architect	University	Research Fellow	15 years (Mixed Academic and private practice)	UK and Middle East in Housing, reservation, refurbishment details

	Job Title	Type of Organisation	Responsibilities	Years of Experience	Type of Projects
A6	Architect Architectural design	University	Lecturer/ PhD candidate	17 years (Mixed Academic and private practice)	Middle East Projects such as Housing, Religious buildings, Urban and Master planning.
A7	Architect	University	Lecturer, PhD candidate	15years	UK and Asia, mostly in housing projects, and office buildings, and school
A8	Architect	University,	Associate Professor/7 years architect	20years (Mixed Academic and private practice)	Asia and Middle East (mixed projects, villages, hotels, and housing)
A9	Architect	Government/ private practice	consultant (Everything from design planning to construction)	21 years private practice	Asia and Middle East (mixed projects, villages, hotels, and housing)
A10	Architect/	University	Professor, consultant, Dean of College of Engineering.	34 years (Mixed Academic and private practice)	Middle East: Housing, airports, office buildings.

	Job Title	Type of Organisation	Responsibilities	Years of Experience	Type of Projects
A11	Architect, Theory of Architecture: Theory of Design and Conservation of Architecture	Head of Department	Professor, consultant	35 years (Mixed Academic and private practice)	Middle East Urban design consultant (comprehensive development Baghdad master plan 2030), redevelopment of Kadhimia plan, renewal Samara Plan, Renewal Old district Mousil, banks, housing projects, hotels, office buildings, campuses, hotels, studios for TV production. Housing, and office building, dormitories
A12	Architect, consultant , architectural design and urban planning	University, government, and private sector	Ex deputy head of regional planning commission, senior planning architect,	An architect since 1966, 50 years (Mixed Academic and private practice)	Middle East (Mixed Projects) hotels, housing projects, office buildings, religious tourism.
A13	Architect/	University	Professor, consultant	32 years (Mixed Academic and private practice)	Middle East Housing, and office building, dormitories
A14	Architect/ consultant	University	Professor in planning and urban design, consultant in architectural planning and urban design	30 (Mixed Academic and private practice)5 years	Middle East, Housing projects

	Job Title	Type of Organisation	Responsibilities	Years of Experience	Type of Projects
A15	Architect,	Public/Municipal: Design and construction sector, and related institutions	Senior level in counselling based on prior expertise in design, construction, project management, property development, teaching, R&D. (employment part) In charge of developing and leading the counselling and authority function in the county	38 years (Mixed Academic and private practice)	Middle East, and Europe: all types of construction, landscape and planning projects.
A16	Senior Architect	Government /municipality	Consultant in Planning and urban design	33 years (Mixed Academic and private practice)	Middle East housing and residential projects.
A17	Senior draftsman involved in architectural profession	National Center for Engineering Consultancy	Architectural Drawings/ Structural Drawings Coordinator: between the engineering departments to finish the working drawing , Presentation, Working & Drawings/ Details Maker, Site work control/ three dimensional models maker.	44 years (private practice)	Mixed Projects in Middle East and Europe projects; in housing, airports, office buildings, hospitals.
A18	Architect,	Ministry of housing & construction	senior chief engineer in design, construction, supervision, consultancies, researches & academic	39 years (Mixed Academic and private practice)	Mixed projects in Middle East like housing, health facilities, museums, office buildings,

	Job Title	Type of Organisation	Responsibilities	Years of Experience	Type of Projects
A19	Architect/	University	teaching assistant/ PhD candidate Architectural design, and Urban design	14 years Mixed experience	Mixed projects in Middle East like housing, urban design, interior design, exhibitions.
A20	Interior Designer Involved in architectural design profession	Sole practitioner	Interior Design of top end residential projects	20 years in private practice.	Housing Projects in UK, Middle East, and Europe.
A21	Architect	University, Professor, Consultant in Architecture, Urban Planner and Heritage Conservation	Ex Dean of several colleges in Middle East: such as Architecture and Art, Engineering and Design. Ex-Chairman of school of Architecture. Member of the supreme Committee of Culture Heritage of Iraq, Founder of the Architectural Heritage Section at the Baghdad Municipality from 1982-86.	More than 45 years, author of several books such as My Iraq, and Traditional Baghdadi Houses.	Worked with prestigious cultural entities across the Middle East, Europe and the United States. Consultant for the Iraqi Council of Culture, and the Getty Conservation Institute (GC) in Los Angeles since 2005, the World Monument Fund (WMF) in New York since 2005, Worked in the international Centre for the study of the Preservation and Restoration of Cultural Property (ICCROM) in Rome since 2007.

4.5.2 SECTION II – The characteristics of traditional Elements shanashil

i. Transparency in traditional design elements Shanashil

The objective of this section is to explore the main characteristics of traditional material that made it successful as a distinctive feature of facade identity. The interviewees were asked to define, *what are the distinctive feature(s) of the traditional design element shanashil in traditional Baghdadi Buildings?* This is given in the interview questions appendix A.

17 of the 21 interviewees agreed that *shanashil* are distinctive for their screen pattern which provides transparency, and privacy within its ornamentation parts, in lines, curves, circles, and colours. 4 interviewees of 21 interviewees were less able to comment due to not sharing the same background. However, only 3 interviewees, A11, A20 and A21 discussed that flexibility of overall design provided many options. They claim this is because the design element is more than just a vertical window but it is a window/wall/balcony element that used to provide environmental control associated with thermal comfort in terms of heat, glare, and natural air ventilation. In this sense, A21 discussed that, *"You cannot make a distinction of one feature of shanashil. This is because the design element is more than vertical sash windows. It's a veiled architecture with fitting wood techniques. The shanashil in their whole from the frieze, body, to base and corbels including the qeem screen pattern, are important to consider"*.

Accordingly, a distinction to a feature like vertical windows cannot be made because it is a veiled architecture that functioned collectively as a window/wall/balcony design element. Thus, there is a need to understand the integrated design relationships between the role of material used and meanings they provide to design quality with elegance as influential in design and associated with appropriateness, double sided measures, order and visibility. The interviewees were then asked about, *what aspects of elegance do you think the traditional model provides in its illustration of design element shanashil?*

All the interviewees were in consensus that the use of wood gives the favoured features and benefits not just in privacy alone but also in providing shades for pedestrians and occupants at the same time. Such combination of transparency while maintaining privacy needs establish an iconic element of this traditional architecture.

A18 stated that, *"the use of wood in its screen pattern, colours, and privacy control gives the favourite features of it"*. Moreover, A16 argued that, *"the use of such an element preserved the identity of the place. The extended design element made benefits inside and outside, not just in privacy and socializing but also in providing shade to pedestrians walking on the streets from the sun heat. They are considered pieces of arts for the richness in design details"*.

More importantly, A21 stated that, *"Due to irregular patterns, sometimes the shape of the house was not of regular shape. As a result, the builder creatively planned the square courtyard and the room distribution by designing angled shanashil as triangles to correct the irregular shape and provided special correction for architectural design façade and plan outlines"*. In A21's opinion, the part-to-whole design relationship added to the idea of elegance and functional beauty.

A15 focused on the design pattern and the extended element that played a role in the elegance of design. A15 argued that, *"the light weight of wood structure and its application in the façade order and modules/rhythm, proportions, materials and details including surface/depth differences gave the combination of privacy and being able to see the public space at the same time. This Iconic element of established traditional architecture is a very safe element to utilize, develop and market"*. It can be therefore concluded that wood which is implemented gives the most important aspect, or its success, for interviewee 15.

What exuberance do you think the traditional model provides in terms of form, function, and aesthetics?

The role of design pattern is fundamentally connected to the complexity of architecture in the integrated design relationships of form and function. This is seen in the flexibility of screen design patterns and order that ruled its material in 3D pure figure and in 2D pure form associated with ornamentation parts, lines, curves, colour, and texture of design material. For instance, A15 highlighted that the traditional

design element was flexible in order to combine the needs for a successful element. A15 stated that, *"The interior aspect is very important as it creates a variation of patterns of shade and shadow as well as cosiness and transition between the outside and the traditional courtyard (hoash) inside the house, as well as the climate aspect of shadow and ventilation"*. A13 added that, *"the integrated relationships of the design element as a whole, whether aesthetic or functional matched the surrounding and by that I mean the propriety aspect regarding location and type of climate"*. Similarly, A14 explained that, *"the flexibility in the use of material is in its manipulation of privacy and public needs, light and shade, and most importantly the control of transparency for social and cultural needs"*.

Regarding flexibility, 2 of the interviewees were less able to comment due to not sharing the same background. 19 of the 21 interviewees agreed that the flexibility in the use of material is in its manipulation of privacy and public need, light and shade, and more importantly the control of transparency from three sides. A21 agreed with A20 on the design of the closed balcony that, *"the flexibility of design provided Visual comfort for privacy protection while maintaining observation needs from three sides, social communication, ventilation and cooling, and Spatial correction. Also, the closed wooden balcony provided for the protection from changes of the surroundings as the heat of the sun, glare, wind, and rain"*. Further, A21 pointed that, *"Shanashil means also Shah-Nashin the one who is in control by watching people from inside without letting others to notice him"*.

The same relationships challenged the flexibility and control of design in its manipulation of transparency, privacy and public state, and light and shade.

The interviewees were then asked, ***what functional beauty do you think the traditional model provides through a combined aesthetic and functional design quality?***

This provided for the idea of functional beauty which is in the use of design elements that delivers a multifunctional quality, both aesthetically and functionally. A20 mentioned that, *"from my experience as an interior designer with shanashil also known as mashrafiya which is the turning technique of wood were all part of the flexibility as well as the beauty of such design elements. I have designed a sofa that*

is part of the mashrafiya as a multipurpose design element which engaged with the interiors elegantly as a unity. You wouldn't be able to tell the difference between the sofa and the façade exterior. All of this is because the flexibility of traditional material". A11 added, "The role of material was essential to deliver not just the beauty of screen design order, colours, and texture but also in the environmental control in terms of heat, light, glare, and natural air ventilation. You cannot see such qualities in many of the modern examples that are inspired from the idea of shanashil".

Table (4.3) below summarises the main design characteristics in the traditional element in terms of as the wood material described by the interviewees. As a result, Table 4.3 demonstrates the characteristics of the traditional design element that the old material (wood) used to provide according to the interviewees' perspective.

Table 4.3 demonstrates the main features that define the multifunctional quality in traditional design element shanashil based on the opinions of 21 interviewees.

Interviewee	Traditional Design		
	Elegance	Flexibility(Exuberance)	Functional Beauty
A1	Design pattern	Type of material enabled flexibility and control of privacy and public needs	Type of material, colour and texture Transparency within private and public state
A2	Design of screen pattern	all	All specifically in Transparency of design within control of privacy
A3	Design of screen pattern	all	all
A4	Transparency within privacy	all	all
A5	Design of screen pattern	all	All specifically in Transparency of design within control of privacy
A6	Visibility including choice of material	all	All specifically in Transparency of design within control of privacy

Interviewee	Traditional Design		
	Elegance	Flexibility(Exuberance)	Functional Beauty
A7	Design of screen pattern	all	All specifically in Transparency of design within control of privacy
A8	Design of screen pattern	all	All specifically in Transparency of design within control of privacy
A9	Design of screen pattern	all	Type of material, colour and texture Transparency within private and public state
A10	all	all	all
A11	All including the choice of material	all	all aspects to provide beauty, design propriety, and environmental control.
A12	All including harmony of screen pattern parts to whole design relationships.	all	all
A13	Design of screen pattern	all	all
A14	all	Manipulation of light and shade, privacy and transparency needs	all
A15	Design screen pattern and multilayered	All including control of privacy within three sides, Climate responsive and requirements for ventilation	All specific colours of material
A16	Design Screen pattern	all	All
	multilayered	All including choice of material	Type of material, wood

Interviewee	Traditional Design		
	Elegance	Flexibility(Exuberance)	Functional Beauty
A17			transparency Light and shade
A18	multilayered	All including choice of material in harmony with others as a whole	All including transparency
A19	Double sided measure as an external and internal facade	all	All including colours
A20	all	Manipulation between privacy and public needs	All including the colours and texture
A21	all	all	all

Table (4.3) shows that 19 out of 21 interviewees argued that traditional design element *shanashil* is a flexible, elegant design because it provided aesthetic satisfaction and the comfort expected of the design. This issue is closely connected to the type of material used, colour, and texture. The elegant design element is considered flexible because of the use of material that allowed ornamentation to be part of the designed screen pattern not only aesthetically, but also for the design element to work as a flexible window, wall design element. The old adaptable design strategy allowed users to control design needs like the manipulation of private and public state, light and shade as well as air ventilation to provide a comfortable, healthy, active environment. An example of this is given by one of the interviewees A15 stated that, *"Aesthetic features like proportions and place in facades, rich workmanship and wooden details as well as social features such as allowing privacy while being able to see in three directions"*. A12 and A15 agreed that wood was essential in almost every aspect of people`s lives. A12 explained that, *"wood was familiar and more likely to be the first choice in every house at that time due to its light weight and because houses were relatively small and surrounded by each other which meant less options in facades` numbers. So the extended closed balcony using the wood was an*

ultimate solution at that time. Other flexible properties as a natural organic material with the flexibility to produce certain shapes and sizes not just in exteriors but also in the interiors".

Another interviewee A13 further indicated that, *"in shanashil specifically, one of the most favourite features lies in the design of screen pattern associated within the order, type of material, colour and texture reflected in the use of wood"*. With the same meaning, interviewees A7, A8, A9 agreed that what defined *shanashil* over any other element is the exuberant design form in its 2D ornamentation. However, none of the interviewees suggested that the use of the traditional design element was only directed to one aspect of design. Within the same meaning, interviewee A12 stated that, *"shanashil is made of wood basically for its light weight in comparison to other materials like brick. This material in particular allowed for an extension of first floor and by that increased the house area which was relatively small and adjacent to other houses giving less options in facade numbers, the extension by wood was an ultimate solution at that time. Other flexible properties of wood as a natural organic material with the flexibility to produce certain shapes and sizes not just in exteriors but also in the interiors"*.

10 interviewees mentioned that all parts of *shanashil* joined together are considered the main reason for the success and the distinctiveness of the design screen pattern. A21 highlighted that, *"shanashil design value lies in its totality. There is no one distinctive feature of shanashil because it is a totality. All parts are important from frieze to base including body parts such as sash windows wood techniques as in the Qeem screen, and corbels or brackets for support"*.

19 of the interviewees agreed that it is the screen pattern that made the traditional elements distinctive, aesthetically and functional. Whilst 17 of the interviewees argued that the role of material is what provided the elegance of the design element, and 15 of the interviewees discussed the important role of transparency in which such design element provided.

However, 19 of the interviewees noted that it is the role of material in the screen design pattern which delivered a successful flexible design element. All interviewees argued that such relationships catered for a multifunctional design quality. The same quality is illustrated in the screen design pattern regarding the flexibility of design within an elegant order in terms of material used, transparency, order, privacy, and colour. 17 out of 21 interviewees argued that it was the role of the material that dominated the elegant design element and enhanced the overall quality of it. 15 out of 21 interviewees also specified the meaning of transparency which *shanashil* presented. 14 out of 21 interviewees noted that order and proportion was illustrated in the screen pattern while maintaining privacy which also made the design distinctive. 12 out of 21 interviewees also mentioned that colour is important in a way to provide for the harmony of design to blend within the surroundings as in the location, and type of climate, as shown in Figure 4.6.

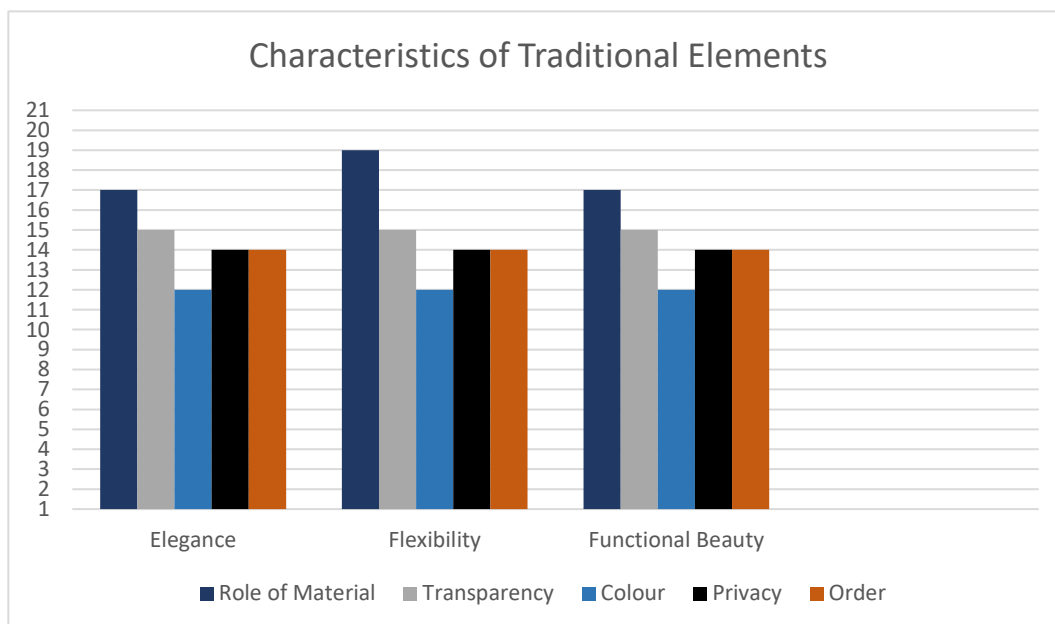


Figure 4.6 Opinions of the interviewees regarding elegance, flexibility and functional beauty.

It can be therefore concluded that the use of traditional design elements particularly in the use of material, expressed the idea of functional beauty that once delivered a multifunctional design quality. The same idea is fundamentally integrated with the meaning of elegant order, transparency and privacy that allowed the flexibility within control of traditional screen pattern as a whole.

ii. *Sustainability aspects in traditional design elements Shanashil*

Sustainability played a role in the success of the traditional design elements *shanashil*. With this in mind, the interviewees were asked, *what aspects of sustainability do you think the traditional model provides to design quality? In which aspect? Whether, social, cultural, environmental, all, or others.*

All of the interviewees agreed that sustainability aspects combined in unity is important in the success of the traditional design element, however, 6 interviewees A3, A6, A10, A13, A18, and A19 gave credit first to environmental and then social and cultural aspects.

Accordingly, sustainability aspects have integrated relationships in design. A6 stated that, *"speaking of sustainability, you cannot separate social aspects from cultural aspects. This issue is because both are closely connected as they directly affect one another. For instance, the social aspects associated with people's lifestyle and activity have informed the cultural aspects in a way that defines the identity of the place"*. Similarly, A21 explained that, *"visual aspect of design as well as audio communication as an essential part of privacy was very important and still considered a vital part of social and culture aspects which form the identity of the place"*.

The location and type of environment is important to consider together with economic aspect which govern the type of material used. Interviewee A12 discussed design sustainability in its integrated relationship between environmental and economic aspects. In this sense, A12 indicated that, *"As for environmental aspects, the location and type of climate is very important to consider in order to provide thermal comfort in terms of heat, light, glare, and natural air ventilation. Both of those affected the choice of material in a way that blended in harmony with the surroundings affecting the identity outlines associated with social and cultural aspects in terms of colour, texture, and type of material. The environmental aspect also affected the sustainability of economic aspects specifically in the type of material suited for the environment and type of craftsmanship that dealt with its production, cost, and maintenance"*. A10 had an experience regarding the sustainability of traditional design in terms of economic aspects, stating that, *"from my own experience as a researcher and a consultant in architectural design projects and construction, I have*

looked for any financial documentation that illustrates the cost including type of material and the requisite skill sets of traditional shanashil. However, the economic aspects are unknown because people such as carpenters with a certain craftsmanship, who were responsible for the production of shanashil details and design order do not exist anymore". Thus, shanashil in its traditional image are now considered pieces of art, or pieces in museums. Similarly, even craftsmanship that was involved in the making of such pieces has been lost.

Answers to the aforementioned question indicate that one of the main characteristics that played a fundamental role in the success of traditional design element is the sustainability of environmental as well as the sustainability of social and cultural aspects. However, the economic aspect is closely connected to the environmental aspect specifically in the type of materials suited to the changes of the surrounding environment as location and type of climate with considerations for cost and maintenance. Thus, the choice of material is important to consider for the success of the design element and characteristics to match the needs of the surrounding environment such as colour, texture, location and type of climate.

From an economic point of view, A6 mentioned that *shanshil* were not available to everyone, as for instance, poor people. However, A11 agreed with A12 that cost had little to do with the production of *shanashil* at that time. This refutes the idea that it was only for rich, sophisticated group of people due to the availability of craftsmanship supported by lifestyle at that time. The only difference was in the simplicity of 2D ornamentation, as described by (Al-Bayati, 2011; Al Silq, 2011; Fethi & Al-Madfai, 1984; Nouri, 2014; Warren & Fethi, 1982). A15 and A17 also supported A11 that the economic aspects did not affect the use of such material at that time. Accordingly, A17 mentioned that, *"families lived together in the small houses beautifully designed in levels as part of compact city designs within the irregular design pattern of Baghdad, and even rented some of their rooms to neighbours. As you can see, privacy had totally a different meaning which added indirectly to economic aspects"*. Hence, the issue of traditional, organic patterns was part of social and cultural aspects in which privacy had a different meaning at that time. However, all the interviewees admit that all these *shanashil* are considered as pieces of art by

today's standards, they cannot be reproduced within the same multifunctional quality, Table 4.4.

Table 4.4 Opinions of interviewees regarding sustainability of the traditional design element.

Interviewees	Traditional Design: Sustainability Aspects		
	Environmental	Economic	Social and cultural
A1	Integrated with others	Economic aspects	Social and cultural regarding location and type of climate
A2	All each aspect affects the other	All in (manipulation of transparency, light and shade, privacy and public needs).	All
A3	Environmental aspect as part of adaptable strategies		
A4	All regarding Transparency provided by type of material	all	all
A5	All	all	All regarding location and type of climate
A6	Environmental within economic aspects		Privacy control and type of material.
A7	Design of screen pattern	all	All specifically in Transparency of design within control of privacy
A8	all	all	All specifically in Transparency of design within control of privacy
A9	all	all	all
A10	Environmental aspects	all	all
A11	The choice of material added to environmental aspects to combine others	all	Social and cultural through the traditional rapid, irregular pattern.
A12	Environmental within economic aspects	Economic aspects integrated with the use of material	

Interviewees	Traditional Design: Sustainability Aspects		
	Environmental	Economic	Social and cultural
A13	Environmental: use of material		Material type suited the location and type of climate
A14	all	all	all
A15	all	all	all
A16	all	all	all
A17	all	All	All
A18	Environmentally informed other aspects		
A19	Environmentally which positively affected economic, social and cultural aspects.		
A20	Environmental impact in material type used	Economic aspects were practical to design needs.	Changed with the meaning of privacy
A21	all	all	All (changed with the meaning of privacy and illustrating of transparency)

15 out of 21 interviewees mentioned that traditional elements were successful to cater for the sustainability of environmental aspects which informed other aspects. More importantly, 11 out of 21 interviewees acknowledged that environmental aspects are not separated from economic aspects. However, 6 of these 11 interviewees argued that environmental aspects had priority that dictated the economic ones. While 6 out of 21 interviewees argued that social and cultural aspects determine the role of sustainability in design. However, 9 out of 21 interviewees acknowledged that the irregular pattern was behind the success of environmental sustainability which added to functional aspects in a way that enhanced flexibility of the design element to deliver aesthetic satisfaction in the community, the culture and society, as shown in Figure 4.7.

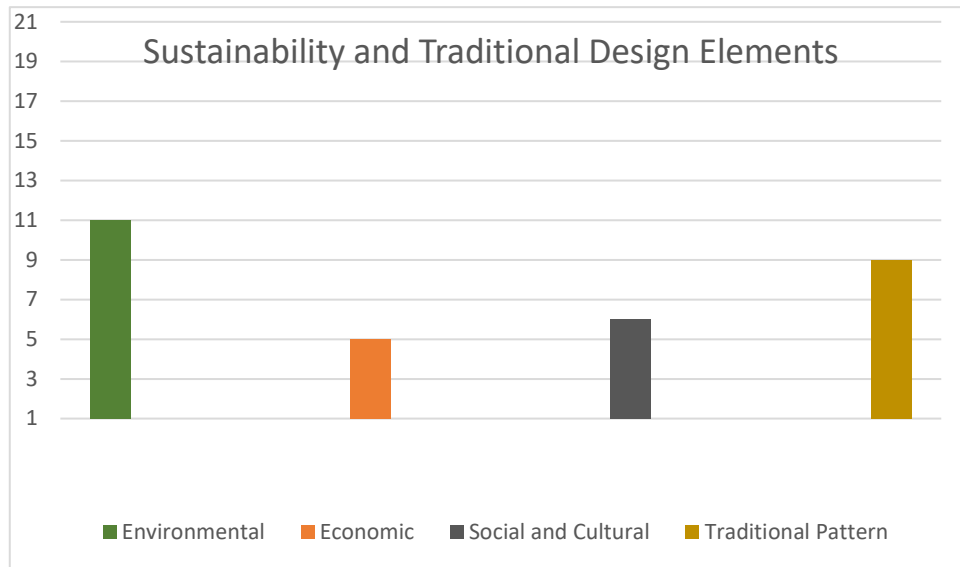


Figure 4.7 Opinions of the interviewees regarding sustainability aspects of traditional design elements.

iii. Changes of design values and discontinuity of identity

In this section, interviewees were asked, *why the value of such a traditional element is lost, from your perspective, what are the issues that could be the reason behind its absence?*

Most of the interviews emphasized that it is the change from old organic street patterns to the modern grid iron pattern due to modernity, industrial and technological advancement. More importantly, one of the interviewees A11 emphasized that the impact of change is as stated, *"modern planning is the reason behind the disappearance of such tradition in design. The same change followed by the changes in lifestyle and transportation means"*. Such changes led to the disappearance of the traditional element. For instance, the changes of transportation means that changed the design pattern from narrow streets to wider ones to match the use of vehicles and car parking. Other interviewees agreed to the explanation as did A6, A10, A12 and A15. This is further corroborated by A15 who said, *"There are urban and climate features related to the structure and dimensions of alleys in the old cities. The latter disappear in a modern villa area or similar. Both as well as loss of awareness/appreciation, economy and disappearing resources/skills. They simply disappeared from the map of architecture in the area since the 1950s"*.

This issue indicates that even the meaning of privacy had changed affecting the sustainability of social and cultural aspects from living in houses adjacent to one another that once suited the traditional life style, into living in villa style modern housing. Moreover, the narrow streets and alleys have changed as interviewee A13 commented, *"it is a dramatic change in which narrow streets and alleys were designed for pedestrians and at a maximum two pack animals which was part of design order at that time. Now, cars and parking lots are considered vital and an essential part of community lifestyle"*.

Whilst A18 stated that, *"although there were several changes that produced new design ideas like modern planning as well as change of transportation means, it is people's will to change that took the design pattern from organic to a modern grid iron pattern. People demanded a different type of privacy that the traditional adjacent courtyard house could not provide"*. Also A21 agreed with A8, A9, and A18 and stated that, *"now it is totally a different story. Even the meaning of privacy that used to rule a veiled architecture has changed. People now are more adapted to outdoor lifestyle more than indoor lifestyle"*. Although A17 agreed with A18, nevertheless, A17 pointed that, *"it is ignorance of the developmental role of technology potentials and how it can be applied properly to suit design needs, location, orientation, and type of climate. This is applicable to modern material, including smart material, with a different perspective"*.

All the interviewees mentioned that there is a need to deliver a better screen design alternative, with a material that would regain part of control on the indoor environment in terms of heat, daylight, and glare. Thus, there is a need for a contemporary approach that caters for the functional design quality in a way that completes the aesthetic part.

19 out of 21 interviewees argued that the flexibility of design is affected by the loss of design quality, both aesthetically and functionally. 3 of the interviewees did not comment because they did not share the same Iraqi background. Such loss has led to the disappearance of the design elements from the buildings` façade and the architectural scenery as a whole. This reason is due to several changes related to modern planning that affected design identity and values. Further, 15 out of 21 interviewees argued that the loss of functional aspects affected the aesthetic appreciation of design element and led in return to the loss of the idea of functional beauty that traditional elements used to provide. 3 of 21 interviewees mentioned that aesthetic aspects have changed due to change in the material used, loss of certain craftsmanship, and change of privacy needs, as shown in Figure 4.8.

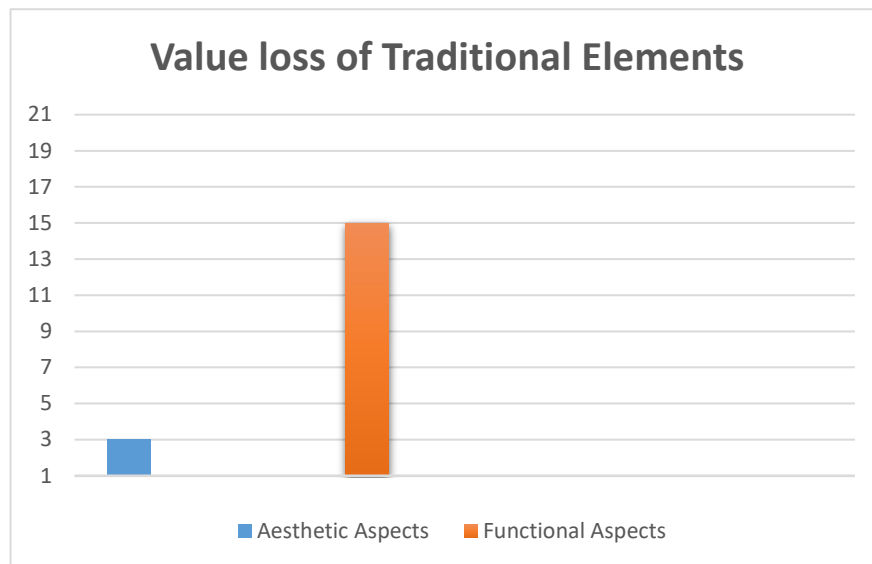


Figure 4.8 Opinions of the interviewees regarding the disappearance of traditional elements due to the loss of the functional aspects that collectively affect the design quality.

As a result, all the interviewees mentioned that there is a need to deliver a better screen design alternative, with a material that would regain part of control on the indoor environment in terms of heat, daylight, and glare. This is because the environmental aspect is lost. Thus, there is a need for a contemporary approach.

19 out of 21 interviewees agreed that the main reason for the disappearance of traditional elements is due to modern planning particularly in the change from organic, irregular pattern (narrow streets, small houses adjacent to one another and transportation means), to an gridiron one (wider streets, bigger houses, use of cars and

parking). Moreover, 14 out of 21 interviewees also mentioned that the advancement in technology is another reason all of this affected the design quality and led to the loss of shanashil value. However, 6 out of 21 interviewees mentioned that other reasons like change in peoples` needs which affected their lifestyle and the meanings of transparency, and privacy at the same time, as shown in Figure 4.9. They have also mentioned that it is ignorance of how to employ technology particularly in copying without truly understanding its potential and how it added value to design.

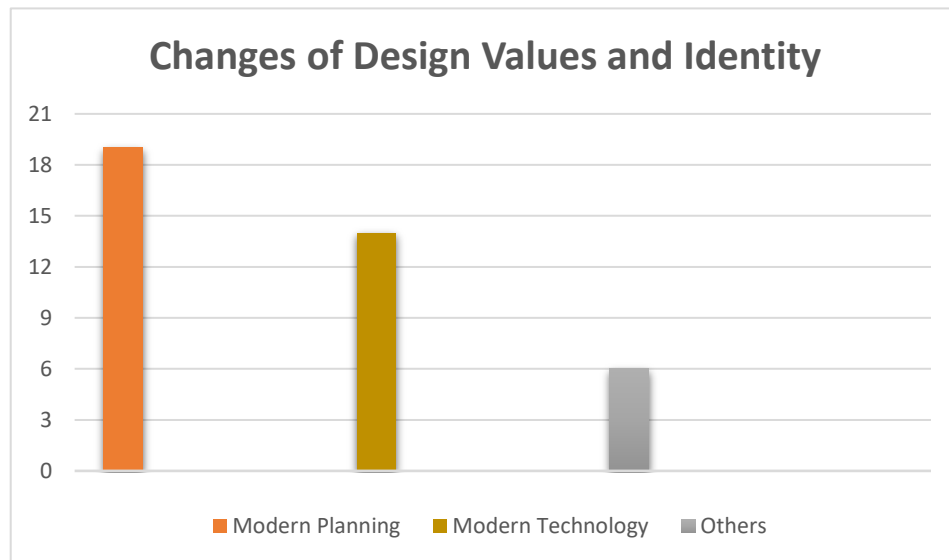


Figure 4.9 Opinions of the interviewees regarding the role of technology in design.

As a result, there is now a need to find an alternative that mimics the multifunctional material quality which used to be part of traditional design element *shanashil*. Although advanced technology provides an alternative in terms of smart material, still there is a need to understand the impact of such a role on aesthetic satisfaction in the sustainability of social and cultural aspects.

4.5.3 SECTION III – Definitions of Smart Material: Role of Transparency as Part of New Adaptable Strategies in Design

The objective of this section is to understand the general perception of smart material and why architects and designers would suggest the use of a smart material. It is about defining what aspects are important and how smart material can be used to improve design quality, both aesthetically and functionally.

The interviewees did not object to the use of smart material in design per se, however, some had different perspectives on how the material can add to improve quality of design aspects, within consideration of sustainability in the environmental, social and cultural aspects. The interviewees provided examples of what can be classified as a smart material including types of dynamic glazing. These examples are consistent with examples and strategies from the literature review.

The first question considered the interviewees perception of smart material and its role in design. The interviewees were asked, *what is the definition of smart material from your own perspective as an architect (designer)? And how do you think a smart material could be applied in an architectural façade?*

As a result, one of the important things is that a smart material should be adapted to meet the sustainability of environmental aspects, in a way that is not separated from the surrounding environment. 4 of the interviewees A3, A18, A20 and A21 explained that the surrounding environment is important to be in harmony with the design's concept and application. A20 defined smart material focusing on the integrated relationships between sustainability issues, flexibility and energy efficiency by explaining, *"It is a material that reacts with the environment which provides a more sustainable affect by less energy needs, less complications and more flexibility as in insulation, and air ventilation"*.

A3 defines smart material as *"a material that is adapted to the environment"*. A18 also focused on environmental issues and stated that, *"smart material is any material which can adapt to function with the environment"*. A21 defined smart material as, *"a material that is environmentally friendly, available and affordable with no waste as part of the designers' duty towards the environment"*.

A11 defined smart material as *"a material that separates the design space inside and out but at the same time affording privacy and protecting the building more environmentally. The same material should provide for both aesthetic and functional aspects"*. A11 focused on the importance of environmental aspects to provide a successful design. However, A11 emphasized at the same time on how important is privacy as a means to deliver both aesthetic and functional aspects.

Other definition discussed the role of material in relation to energy efficiency issues as A17 who defined smart material as *"a material that makes full use of energy without waste and at the same time achieves best performance with less possible cost by using minimum energy resources"*. A8 agreed with A9 and focused on the important role of adaptability and the role of technology within economic aspects and discussed that, *"smart material is a material that adapts to climate, consumes less energy, and is sustainable in the long term, but does not necessarily use high-end technology"*. Similarly, A12 defined smart material as *"smart material is a material that provides climate and social solutions without the excessive or direct need of human intervention such as controlling the amount of heat and daylight"*. A1 focused on the importance of having a material that is available with less cost, effort and easy to maintain in relation to environmental and economic aspects, *"smart material is measurable, achievable, attainable, and realistic"*. A1, A12, and A8 agreed that the role of technology is important to consider. However, A1 suggested that passive technology is a better example that provides for the sustainability of design while A8 and A12 support the use of active technology but not necessarily a complex or expensive one. In a related vein, another interviewee A16 focused on the importance of having a material that improves economic aspects of design specifically with less cost, effort and time needed. However, one of the interviewees defined smart material in a design pattern that takes into consideration both aesthetic and functional aspects. A15 defines smart material as *"a material that works and fits into a design combining both aesthetics and functional aspects"*. In this sense, flexibility of design is important to provide a multifunctional quality both aesthetically and functionally.

A2 agreed with A15 about the importance of flexibility by defining such material as, *"smart material is a material that could answer all your questions where you can combine spaces and shapes"*. Whilst A4 described that, *"smart material can sense data, analyse, and adapt and react"*. A4 argued that it is important that flexibility of material should be defined in a more detailed way such as in factors related to energy efficiency and environmental sustainability. Similarly, A14 focused on the importance of a material that adapts to its environment and type of climate. A14 defined smart material in design as *"smart material is a material that adapts to environment and climate needs, and provides at the same time offers an effective performance in relation to design and economical aspects"*. A14 identified that the

efficiency of a design will not be complete without considering the sustainability of environmental and economic aspects. A14 explained that, *"sometimes it is hard to separate environmental aspects from economic ones. This issue is the same when you talk about culture because it is deeply connected with people's lifestyle and social activities"*. A12 agreed with A14 by further adding, *"sustainability as an idea and practice has integrated relationships in which the environmental and economic aspect convey a unity in design. The same thing as when you describe social aspects. Such aspects are in unity with the cultural ones. The two provide the identity of the place which is closely related to location and type of climate"*.

The interviewees mentioned that it is important to acknowledge the role of technology. Notwithstanding, the interviewees had different opinions on the type of technology; passive or active. This is closely connected to energy efficiency and sustainability of design in relation to the environmental and economic aspects, including cost and maintenance issues. The interview then explored, ***would you consider using smart dynamic glazing as a smart window, wall design element instead of traditional materials in shanashil?***

The interviewees were not against the use of modern materials, however, they stressed the suitability depending on the type of projects and the surrounding environment such as location and type of climate. Some of the interviewees had the opportunity to use smart materials in their projects in a way that is guided by rules and requirements to mimic aspects of the traditional pattern context as a whole.

A further question explored the experience of the interviewees, ***have you used or criticized a smart material or something similar in relation to design issues? Could you give an example of that?***

A11 has worked in projects that used a smart material mimicking the traditional local materials with better qualities of insulation and aesthetic aspects in relation to colour and texture. A11 explained that, *"I have been part of a consultancy team in recommending and using smart materials that had common characteristics with traditional materials as local bricks. I admit that the new material is better due to the role of the modern technology. Nevertheless, we were careful in deciding the shape, the colour, and the texture. Because there is an order that the design should embrace*

and match the context as a whole not to drift away from the identity of design. Such identity is guided by location and type of climate". Therefore, A11 argued that the smart use of modern material should deliver the basics of traditional design such as environmental control and the screen pattern order in terms of lines, curves, arches, and colour in a way that blends in harmony with social and cultural aspects including privacy and transparency needs. A11 agreed with A13 that traditional design was also considered flexible with a multifunctional quality at that time not just in its passive design but also the screen pattern order and colour of the design element. The screen follows a traditional order that worked beautifully in a way providing an elegant design environmentally, economically, within the sustainability of social and cultural aspects. A13 mentioned that, *"there is some sort of propriety that needs to be part of design standards and requirements to indicate the design identity which you see clearly in traditional design, materials and element as a whole".*

A1 and A12 mentioned the smart material of Photovoltaics was a smart dynamic glazing. According to the interviewees` opinion, A1 claimed that, *"energy efficiency and environmental aspects are important to consider. I know from practical experience that location and type of climate is an important part of the complete design requirements. As for transparent efficient material, I can only think of photovoltaics".* In this sense, A1 and A12 mentioned the use of PVs as part of smart dynamic glazing material and source of renewable energy. A1 discussed that, *"PVs is highly recommended around the world for its part in producing energy from sunlight, a renewable resource "*. Both interviewees mentioned that it is important to depend on energy efficiency issues by making use of renewable energy on site.

Nevertheless, A12 with an experience of some types of smart dynamic glazing was against the use of PVs specifically as part of a window, wall design element. A12 noted that location and type of climate is very important to appreciate before choosing this type of technology. Moreover, A12 worked previously in projects in which the implementation of smart dynamic glazing was vital as part of renewable design requirements in Baghdad and The Emirates. A12 explained that, *"The use of modern technology like Photovoltaics on the roof of houses is preferred for better amount of solar radiation. It will definitely improve sustainability of environment using renewable energy instead of non-renewable energy such as fossil fuel. This way of*

design will reduce the pollution, noise, and the cost of energy bills. However, the quality and efficiency of solar cell is a critical aspect in design that may not be suited for any location and type of climate". However, A12 explained that even with the role of advanced technology the flexibility is still critical due to location and type of climate. A12 added, *"If you want to make a comparison between two countries Iraq and another one like Abu Dhabi, both in the Middle East, you will find that the hot, arid climate as in Baghdad, Iraq is known for the dust storms that affect the quality and performance of Photovoltaics solar cells. The dust storms that occur in the Baghdad climate also adds to the cost and maintenance In Abu Dhabi, the weather is also hot and, arid but known for its sand storms that have less effect on the performance of solar cells in comparison to the dust storms of Baghdad".* Thus, due to transparency issues integrated with energy efficiency, the Photovoltaics is still restricted in its flexibility to deliver a multifunctional design quality. Moreover, transparency is a constant with no ability to control the private and public needs. This has an impact also on energy and consumption issues.

From economic point of view, A2, A15, and A17 have seen the use of smart materials like Electrochromic, Photovoltaic and Photochromic in some of design projects in Europe. A2 explained that, *"In one of my projects I designed a smart glazing façade for a cafeteria based on the clients` needs. Although the material was suggested by the client, the use of smart glazing is considered successful in the switchable, reversible green tinted appearance that was beautiful and also practical. However, the material was considered expensive but it suited the needs of design".* Accordingly, A17 explained that *"although smart material is still considered expensive when compared to other types, however, in the long run it can be more economical as the impact in the reduction of the energy bills is impressive".*

The most important thing in this part was about focusing on energy issues by using less energy and making use of renewable energy on site. For instance some mentioned Photovoltaics (PVs) as one of the design options of smart glazing material as a better option for implementing transparency from both the aesthetic and functional aspects. However, many limitations are important to consider when implementing new materials in design even with the role of modern technology. Such limitations are closely related to location and type of climate, cost and maintenance issues.

Would you think of using smart materials such as smart dynamic glazing products with switchable properties like changing transparency, better environmental control in terms heat, light, glare and air ventilation, and can they replace traditional blinds?

The interviewees argued that smart dynamic glazing material is considered a better option to revive the functional design aspect specifically environmental aspects rather than aesthetic ones. The same environmental aspects provide a better environmental control with thermal comfort regarding heat, and glare. It also provides natural air ventilation to improve the quality of indoor environment. The same environmental aspects have an integrated relationship with the economic aspect in terms of material characteristics. Such characteristics also take into consideration part of the integrated relationships with social and cultural aspects to deliver transparency while maintaining privacy needs to design.

What would be your reservation regarding the choice of this material?

The interviewees argued that traditional material is still favoured even if it is closely connected to social and cultural aspects. The objective of this section is to understand the meaning of 'smart material' in architectural design and the characteristics that architects suggested add benefits to design quality. 18 of the 21 interviewees had criticised smart materials because they were sceptical of the role of their transparency in the use of smart glazing in the screen pattern. 19 out of 21 interviewees defined smart material based on its adaptability in design such as environmentally, being climate responsive, and availability. However, 8 out of 21 interviewees focus on its role regarding energy efficiency in less use of material and energy consumption. Moreover, 7 out of 21 interviewees defined it based on its potentials in providing privacy, social and cultural aspects. 3 out of 21 interviewees defined smart material based on aesthetic aspects as in colours, order. 13 out of 21 interviewees focused on

the role of active technology as part of the smart material definition, and 2 interviewees talked on the passive role of technology, as shown in Figure 4.10.

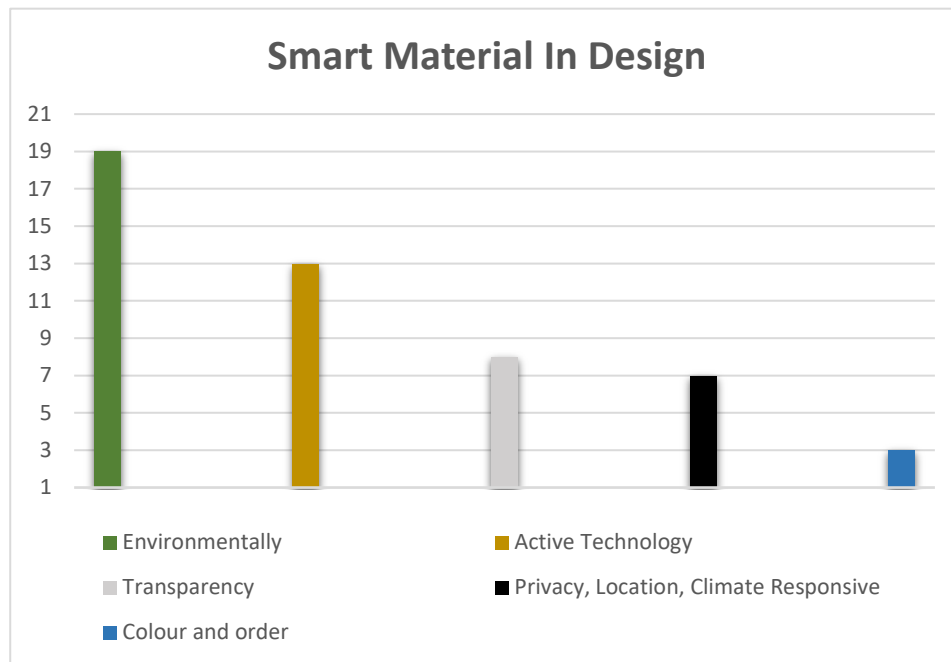


Figure 4.10 Opinions of the interviewees regarding the definition of smart material in design.

The interviewees agreed that reduction in cost is important to improve the sustainability of economic aspects. A11, A13, A14, A18, also A10 mentioned that, *"The use of less material as in less need of blinds in this way adding to having more active as well as a more healthy environment which suits not just health facilities like hospitals but also different types of buildings such as houses and office buildings. I believe that such smart material if applied carefully with true understanding of its potentials will upgrade design quality"*. The interviewees did not object to the use of new material and specifically to smart material in design. The importance of environmental sustainability aspects to be considered in order for successful use and obtain benefits from its material characteristics that improve the flexibility of design of material characteristics, A1, A11, A13, and A12 expressed that flexibility in a material is to be climate responsive in order to suit the changes of the surrounding environment.

Based on the aforementioned answers, the interviewees were concerned about energy role, cost savings, and maintenance issues including role of climate when comparing between traditional elements and the use of smart modern material. 19 of the

interviewees acknowledged that there is a need to provide a clear illustration regarding the characteristics of smart material both in appearance and function, and in order to deliver successful designs that can restore at least the environmental aspects of the traditional multipurpose design element.

5 of the interviewees were encouraging the use of smart material specifically the dynamic glazing, which can be attributed to the fact that they are forward thinking with active technology in a way that could improve the adaptability of design, taking into consideration location and type of climate. However, when it comes to the essence of traditional design that is deeply connected to social and cultural aspects, the most important issue was the design pattern order of the screen design that were shown to be sufficiently effective in a passive design. For instance, A10 explained that, *"a glass that provides transparency with advanced qualities is important specifically in a climate like Baghdad. This reason is because of the hot, arid climate known for its dusty storms"*. A10 added that, *"I remember from a practical experience when designing an airport in Baghdad. There were many requirements in using a specific type of glass. The glass needed was of highly advanced qualities such as clarity, glare reduction, including certain types of coatings most importantly being self-cleaning"*.

A15, A17, A20 and A21 also worked on projects that used smart dynamic material called photochromic. However, A17 mentioned that, *"I have worked with a type of smart glazing called photochromic. Although it was useful in relation to environmental aspects for its switchable, reversible transparency, the installation of such material is complicated due to the need of certain skills, training and knowledge regarding orientation as part of design requirements"*.

As a result, although the study was about smart dynamic characteristics and its impact on design process within the role of modern technology, this section demonstrated the separation in the architects and designers approach regarding design aspects between aesthetic and functional aspects. In this sense, interviewees were more focused on functional aspects that are deeply connected to the adaptability regarding environmental aspects with economic concerns (considering cost, energy issues, and privacy needs). They also considered the role of transparency in relation of social and cultural sustainability aspects. The use of photovoltaics in facade design is still

considered critical due to several issues regarding performance, transparency, and solar radiation amount to be successfully integrated in architectural façade elements. Thus, more flexible types of smart glazing material with switchable, reversible transparency need to be considered for more successful adaptable strategies to challenge design problems that deliver a multifunctional design quality.

From the above, smart material can be defined according to its characteristics that plays a role in improving the flexibility of design taking into consideration the sustainability of the indoor environment. The same characteristics need to be adaptable to the changes of the surrounding external environment. Therefore, the material characteristics need to cater for the following aspects:

- The interviewees focused on the importance of functional aspects, particularly, the adaptability of design to blend in harmony with the surroundings:
 - a) The interviewees gave priority to Environmental aspects. For example, the role of material characteristics is effective in improving design flexibility taking into consideration location, type of climate, energy efficiency, cost and maintenance.
 - b) There are other aspects that are deeply integrated as part-to-whole design relationships for instance social aspects are not separated from cultural aspects for both provide the identity of the place.
- The interviewees acknowledged that transparency while maintaining privacy needs is important to be part of external facades in order to maintain distribution and balance of daylight, to deliver a healthy, active, comfortable indoor environment. However, only 8 out of 21 interviewees encouraged the use of transparency, while the rest were critical about its role in delivering energy efficiency in design.
- 13 out of 21 interviewees focused on the role of active technology in improving the design flexibility to adapt in harmony with the surroundings. However, the type of embedded technology which provides switchable, reversible properties in a transparent, multi-layered material is still critical to understanding the design of screen pattern.

Accordingly, the importance of functional aspects were given priority over aesthetic aspects, in particular environmental sustainability with economic considerations and energy efficiency issues for a design approach to be successful. Sustainability of social and cultural aspects were recommended to reflect the identity of the place. Aesthetic aspects came second according to the interviewees' perception for the design element to blend in harmony with the surroundings regarding design pattern, order and colour.

As a result, the interviewees tended to favour adaptability in smart materials particularly to the surroundings, which accords with (Bruckner, 2011a; Gruber & Jeronimidis, 2012). The interviewees gave priority to the environmental aspects, and they emphasised the necessity that any design should not be isolated from changes of the surrounding environment.

This demonstrates the added value of using biomimetics approach focusing on its adaptable strategies that improve design sustainability by using minimum resources to achieve maximum performance. Figure 4.11 illustrates the opinions of the interviewees regarding smart material role in design. All the interviewees defined the smart material as a material that is adaptable to its surroundings focusing on environmental aspect in a way that takes into consideration the location, type of climate, cost and maintenance issues. Similarly, the interviewees focused on the functional aspects of the material giving a priority to that rather than its aesthetic aspects. However, adaptability of a material is not complete if it is not in harmony with surroundings. Further, Figure 4.11 illustrates the need to focus in depth on new adaptable strategies that take into consideration the role of advanced technology to improve flexibility of design by delivering a multifunctional quality, both aesthetically and functionally.

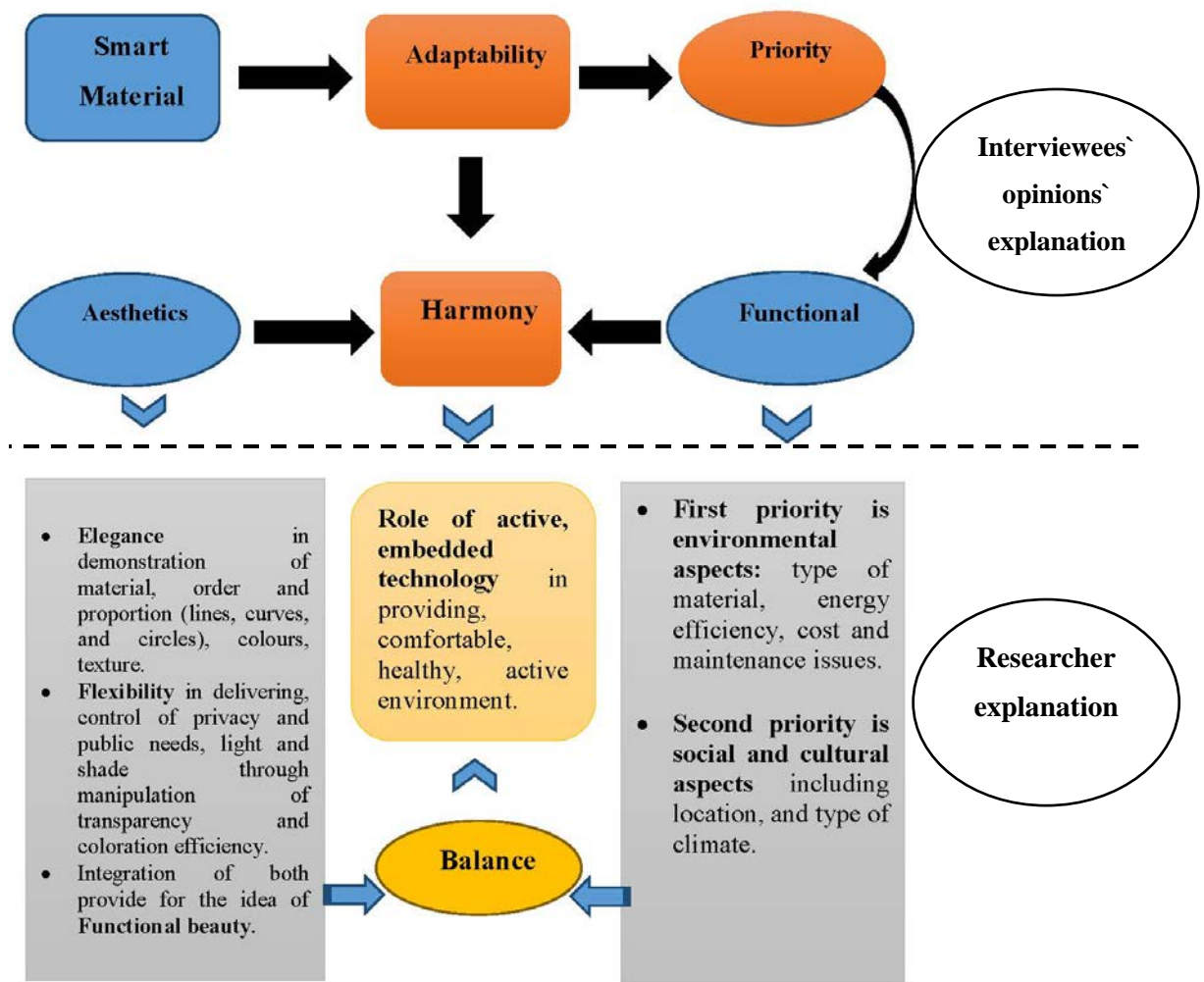


Figure 4.11 Opinions of interviewees on the importance of adaptability for design strategies, diagram based on Bruckner (2011a), and Gruber & Jeronimidis (2012)

Summary:

The opinions and arguments of the interviewees were based on their rich experience and high qualifications between academic and practice in architectural design. The interviewees focused more on functional aspects rather than the aesthetics aspects of design. Thus, architects and designers think separately when it comes to prioritising in design, including the use of material as a design element since the main focus is on the adaptability of environment, privacy, and energy efficiency with economic aspects. However, all the interviewees agreed that transparency is important to provide a healthy, active, and comfortable environment. It is important especially for occupants to keep in touch with the surroundings.

Some of the interviewees had concerns in using the smart glazing material due to reservations regarding transparency role in hot arid climate. This issue indicates that even with dynamic characteristics of smart material, there are many aspects that need to be considered in order to maintain a successful, effective design.

Therefore, the next section will discuss the aspects of design quality that dynamic characteristics of smart material can restore to improve flexibility of design.

4.5.4 SECTION IV – The Dynamic Characteristics of Smart Contemporary Elements

From the literature review it was possible to derive a list of the dynamic characteristics of smart materials to improve the flexibility of design. The objective of this section is to determine the dynamic characteristics and their integrated relationship with the transparency of smart glazing. This objective is achieved considering the variables of a multipurpose window wall design element regarding transparency and colouration efficiency in delivering a multifunctional design quality. The interview results are now discussed:

i. Transparency in smart contemporary elements

When the interviewees were asked, *what aspects of elegance do you think the contemporary model provides in its illustration of shanashil using smart dynamic glazing?* 18 of the interviewees objected to the use of smart dynamic glazing as an option specifically in representing the aesthetic aspects of *Shanashil*. This affected the idea of elegance when using modern material instead of traditional materials.

A14 argued that, *"the use of smart dynamic glazing in such an abstract pattern did not mimic the idea of shanashil. In other words, the details that are responsible for the beauty of the screen design pattern"*. Whilst A13 stated that, *"The excessiveness in using glass solely in such large dimensions makes the design looks strange from its own environment. This affects the meaning of design propriety to match the surrounding environment specifically in Baghdad that is harsh due to sun and heat and lots of dust. This issue consumes almost the inside of any building design not to mention the exteriors like windows"*. Equally, A15 expressed that, *"The presentation shows that the entire volume of the traditional shanashil is replaced by a clean*

expanse of glass with no connection to order, recesses and material. Perhaps another type of presentation is needed or revisit the solution to find a hybrid of both epochs".

This statement indicates that it is important to consider the design pattern and the order of any object to reflect its identity. For instance, the value of *shanashil* is lost aesthetically if the order, and details of ornamentation parts that used to beautifully define its windows are not expressed. In the same meaning A18 was not objecting to the use of new modern material but argued that, *"when using the dynamic glazing instead of traditional material, I am afraid of not giving the traditional essence and for that it is not shanashil any more"*.

Nevertheless, A17 explained that, *"modern examples in their use of transparency with the embedded technology adds to better sustainability aspects in the long run including environmental and economic sustainability"*. A2, A4 and A12 also agreed that transparency of smart dynamic material improves the sustainability of design through its impact on overall energy consumption. A12 also asked a question about the flexibility of the material, *"I have used many glazing types from early, as you may call, from single to advanced types of glazing. Is dynamic glazing in Electrochromic easy when opening the window or is it fixed? Because if it is fixed that would affect the air ventilation quality which is important to maintain fresh air for a healthy active environment"*. In this sense, the type of smart glazing can be used in revolving doors and as a multipurpose window wall design element. Moreover, protection against glare and harmful radiation are additional advantages. However, there is still a need for more effort to be made to improve durability and better transmittance ranges, as described by (Fischer et al., 2004), (Lampert, 1998), and (Beatens et al., 2010).

As a result, 18 of the 21 interviewees although understanding the need for change including the type of material, still criticised the aesthetic aspect, specifically the transparency of smart dynamic material. This is because the presentation of transparency did not mimic the traditional screen pattern order and details regarding lines, curves, arches, and colour. The issue is important so that the propriety and identity of design element can be preserved.

An issue concerns the colour and texture of the smart dynamic material used for the design element to blend in harmony with the surroundings regarding location and type

of climate. These issues regarding flexibility and elegance also affect the idea of functional beauty. Accordingly, 18 out of 21 interviewees did not favour the use of transparency solely in the screen design and its large dimensions. Also, they preferred certain colours instead of blue colour. They preferred that contemporary screen pattern mimics the traditional screen order in terms of lines, curves, and arches for the illustration of functional beauty idea to be in harmony with surroundings.

Out of 21 interviewees only 4 interviewees noted elegance in the transparency role, order, and colour. Moreover, 18 out of 21 interviewees favoured integration between transparency and other materials like wood. In addition, 4 interviewees acknowledged the switchable, reversible properties regarding transparency, and only 3 interviewees accepted the role of colours and order in design. Accordingly, other interviewees noted that the absence of elegant order and design harmony relating to location and type of climate did not provide for the aesthetic aspects which in return affected the idea of functional beauty.

Further, only 5 out of 21 interviewees acknowledged the added value of dynamic characteristics in its flexibility regarding heat, light, shade, glare, and air ventilation while maintaining privacy needs. 18 out of 21 interviewees did not find the harmony between the design element and the surroundings in design collectively using smart dynamic glazing material, as shown in Figure 4.12.

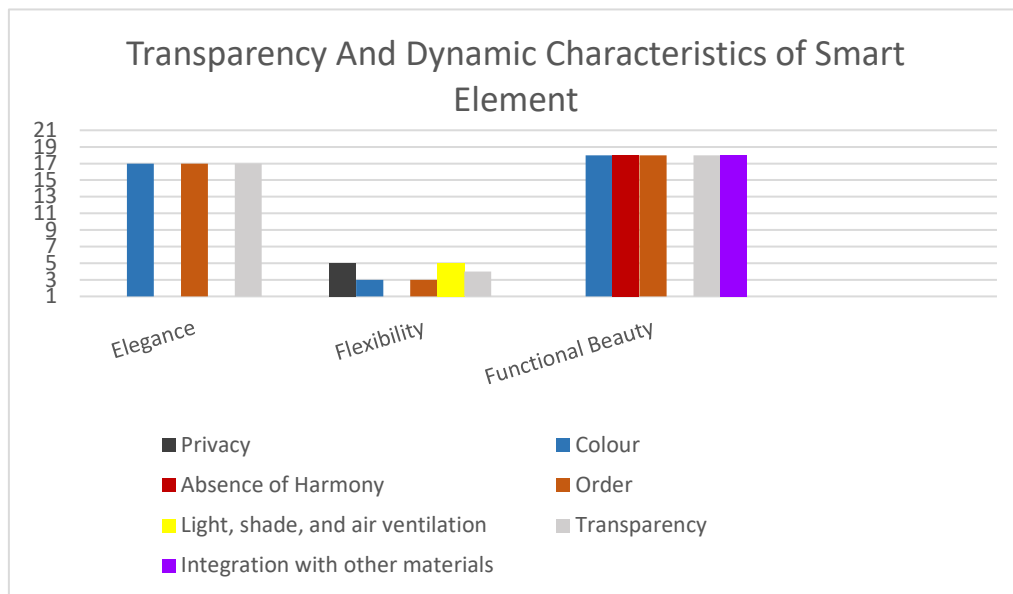


Figure 4.12 Opinions of the interviewees regarding the use of smart dynamic material and its impact to revive the traditional elements.

ii. Sustainability aspects in smart contemporary elements

Interviewees were asked, *what aspects of sustainability do you think the contemporary model provides to design quality?*

Although many interviewees objected to the use of transparent material aesthetically as an option instead of traditional materials, most interviewees 16 out of 21 interviewees agreed that the new modern material is better at providing sustainability aspects specifically environmental control and thermal comfort. Further, A8 explained that, *"Now the approach is more into transparency in design. Clients tend to choose a design that connects them to the surroundings more. In addition, the design approach in general is into a transparent healthy, active indoor environment. I imagine why people are more into the transparency that is not limited to one type of building. This is because the new material provides better sustainability in its environmental aspects. However, I still think that the modern material need more development and effort to represent the traditional details of screen pattern to deliver social and cultural aspects"*. Whilst A15 explained that, *"It is appealing in the sense of providing a contrast to the traditional shanashil by using a "transparent" material to provide "privacy", combined with the other aspects the smart glass offers such as control of light, heat, and glare"*. A15 argued that new material is better at delivering sustainability aspects including part of social and cultural aspects. A10 mentioned that the use of less material should be encouraged. In this sense, A10 stated that, *"natural material of shanashil specifically wood is now considered inefficient. This is because the contemporary design approach provides less pollution, less material throughput, and saving of natural resources, and therefore I encourage the use of transparent multi-layered material"*. A10 added that, *"I totally understand that using less material in design will definitely add to less cost, time, and maintenance not to mention less pollution related to energy waste, and material throughput. This issue also adds positively to the aspect of environmental sustainability. For instance, less use of natural material like wood will prevent the deterioration of natural resources. I was present in several conferences in Iraq and Middle East in which researchers mentioned the source of wood needed to build such detailed design elements"*.

16 interviewees agreed that the transparency of smart dynamic material improves the sustainability of environmental aspects when compared to traditional materials.

However, there were concerns regarding transparency use in addition to economic aspects in their integrated relationship with energy efficiency, cost and maintenance issues.

As for sustainability of social and cultural aspects, although only 3 out of 21 interviewees agreed that control of the transparency between private and public needs improves the design flexibility, and 18 out of 21 interviewees were critical about the added value of transparency of smart material in design regarding sustainability aspects including location and type of climate, with 12 of 18 interviewees sceptical about the economic aspects. However, 16 out of 21 interviewees identified the added value to design sustainability regarding environmental aspects when compared to traditional elements. Thus, 18 of the interviewees, except the 3 interviewees that do not share the same background, noted that there is a need to provide better illustrations for the contemporary screen pattern that mimic the traditional pattern order and proportion regarding colours, lines, curves, and harmony for the design to reflect the identity of place, social and cultural values, as shown in Figure 4.13.

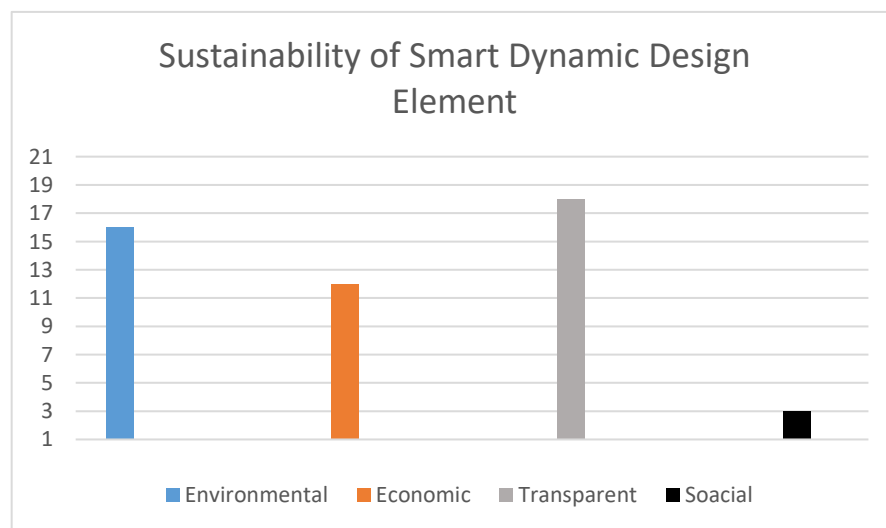


Figure 4.13 Opinions of the interviewees regarding the role of smart material and its impact on design sustainability.

iii. Active embedded technology in smart contemporary elements

The interviewees were asked several questions regarding their experience and perception of technology role in design. In respect of the question, **how would a smart material influence the traditional element in a contemporary design approach?**

A15 expressed that due to the role of active technology, the modern material shows better solutions in improving design quality and delivering better energy efficiency, and stated that, *"The modern material has a great potential to do so"*. A11 also stated that, *"traditional materials used to work efficiently by combining passive technology and the sustainability of environmental, economic, social and cultural aspects. Now the same material is unable to compete with the changes of modern planning and technological advancement which are changing every aspect of people's lives and needs. Thus, using other materials is necessary to improve design quality. However, both aspects should be considered whether aesthetic or functional"*. Similarly, A3 and A8 agreed that it is important to reflect the screen pattern even in the use of active technology to represent the idea of transparency. A3 stated that, *"One of the examples of traditional design trends in the Middle East is (Al-Bahr Towers) in which the transparency of the towers is shielded by exterior shading devices. Although the entire façade is transparent due to the advanced technological role, yet the massive exterior shading devices which covered the façade for protection from heat and sunlight which depicted the essence of traditional design in a 2D ornamentation. In addition, the flexibility of design of screen pattern was applied in which the details took several interpretations like bioinspiration of nature's shapes and lines as well as Islamic geometry"*.

Also A 12 expressed an important aspect which is the flexibility of to provide natural air ventilation in addition to control of heat and glare. A12 stated that, *"The quality of indoor environment cannot be maintained with fixed windows or by not paying attention to the importance of achieving thermal comfort"*.

Therefore the need of technology tools for the demonstration of a 3D digital prototype is important. Accordingly, whilst 20 of 21 interviewees mention the important role of

active technology, nevertheless, the role of transparency in the advanced technology of the smart dynamic glazing is still unclear when compared to static glazing.

20 out of 21 interviewees supported the use of active technology as in the smart dynamic glazing. However, 7 interviewees mentioned Photovoltaics as a type of smart dynamic glazing and 5 interviewees mentioned types of Chromogenics. 3 out of 21 had used Electrochromic as a type of smart dynamic glazing while 2 interviewees used other types called Photochromic. Nevertheless, 18 out of 21 interviewees were still sceptical about the role of transparency in improving functional design aspects, as shown in Figure 4.14.

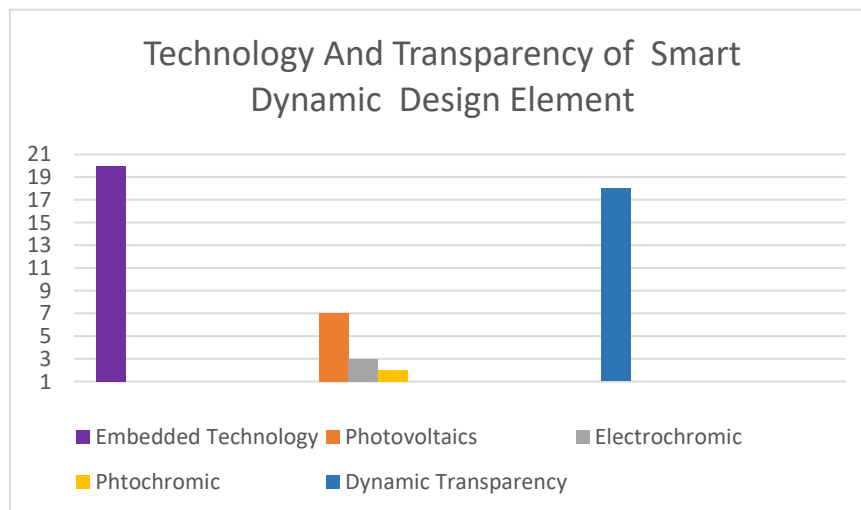


Figure 4.14 Opinions of the interviewees regarding smart dynamic glazing types and its integrated relationships with transparency and dynamic characteristics in design.

Thus, this research is focusing on the control of dynamic characteristics in smart glazing material such as Electrochromic (EC). This can be achieved through the role of the embedded technology within a multi-layered, transparent design pattern.

4.5.5 SECTION V – Issues and Challenges

This section discusses the major challenges concluded from the interviewees' point of view and from the practical issues which faced them. One of these issues is in the fixed image of the traditional design element *shanashil* and the dynamic characteristics of a switchable, reversible properties from transparent, to opaque are difficult for them to conceive.

All the interviewees suggested that the 3D model only shows the use of such element in a two storey building. They mentioned that such elements are used and can be used in different types of buildings and multi-storey buildings.

Interviewees were asked that, *do you think architects are aware of this type of material?*

It was found that 18 of interviewees are attached to the old image of the traditional design element. This issue is seen in the concentration on the integrated design relationships of design pattern and order such as lines, curves, circles, and arches including the ornament parts, colours, shades, and texture, as well as the type of material which once successfully delivered the idea of functional beauty. However, they were fully aware that the value of the traditional element is lost. Accordingly, there is a need to find other solutions that can restore part of the design value that used to provide a multifunctional material quality. Such solutions should take into consideration the use of other materials that can match the integrated relationships of the traditional design pattern, aesthetically as transparency, colour, texture, and ornament parts regarding lines, curves, and circles. As for functional aspects, sustainability itself can take a wide range of meanings that affects the quality of design regarding location, type of climate, control of private and public needs, light and shade, energy efficiency, cost and maintenance issues. However, 17 of the interviewees were clearly against the use of certain colours such as blue. In the case of 14 of the interviewees and they suggested the use of colours like black, grey, and white. For instance, A11 stated that, *"I am against the use of colours in the modern design material, and therefore I only recommend the use of white, black and grey. This is because in the culture of Baghdadi building, for instance the exterior of shanashil, did not include the use of colours it was only wood and fired brick. However, in the inside, the use of colours is a normal as part of the decoration like in ursi. This issue goes in parallel with the lifestyle of people in which the clothes were colourful but only within the privacy of their homes. I need to say that privacy played a strong part in people's lifestyle and by that is drawn the outlines of social and cultural aspects of the space"*. From a slightly different perspective, A12 and A14 agreed that privacy and order at that time played an important role in shaping the traditional design patterns, nevertheless, both mentioned the use of colours in glazing.

A12 highlighted that, *"the use of coloured glazing like blue and green in upper windows was meant to provide shade and less intensity of glare in order to have a comfortable indoor environment"*. A20 agreed but took it further by stating that, *"I use and have always used colours that are available to mix giving harmony between interiors and exteriors. The harmony in any design always depends objectively on the location, culture, and type of climate"*.

Furthermore, 13 of 21 interviewees argued that the use of *shanashil* was not just limited to one type of buildings. A10 explained that, *"If you observe the positioning of shanashil you notice that these elements are used by many architects in different types of building not just in facades` houses but also in multi-storey buildings such as office and governmental buildings"*.

Accordingly, the flexibility of the traditional elements allowed it to be attached to different types of building facades whether in a two storey building or a multi-storey one. This issue was followed by asking them, ***what would help in raising awareness towards using the smart dynamic glazing?***

The reasons for not using this type of glazing was varied. For instance, some architects mentioned the use of smart dynamic glazing such as Photovoltaics (PVs), however, they also mentioned limitations in the use of such material in the architectural façade. For instance, A12 mentioned durability specifically with the effect of the hot, arid climate on the performance and quality of the solar cell in addition to maintenance and cost issues. Others like A15 and A17 mentioned different types of smart glazing like Photochromic with cost and maintenance issues affecting the adaptability of design to match location and type of climate. A5 mentioned different examples of dynamic glazing and stated that, *"the Arab Institute de Monde building in France is an example of active technology as part of façade design. The shutters of the design reflect the inspiration of the screen pattern principles. Nevertheless, the same types are still associated with durability problems as well as maintenance, cost, and installation issues"*. A large amount of emphasis by 17 of the interviewees was also placed on the difficulties associated with keeping the essence of the traditional design pattern that once presented an integrated sustainable relationship environmentally, economically, and most importantly socially and culturally. The integrated part of the whole design relationships are demonstrated in the manipulation of privacy and public

state, and light and shade in addition to the type of material and the role of technology. Equally relevantly, the interviewees repeatedly voiced concerns relating to technical barriers that may not suit the sustainability aspects such as environmental, economic, social and cultural problems. Consequently, the introduction of new technology in the architectural transparent facade can often cause numerous budget problems due to performance, energy use, cost and maintenance affecting the quality of design aesthetically and functionally.

There is a need to define a common background between the design pattern of old traditional material like wood and static glazing, and others made of modern material like smart dynamic glazing. This is because clear understanding of the traditional pattern details within its order will enable a successful implementation of dynamic characteristics based on the use of smart dynamic glazing window, wall design material.

A17 expressed that, *"even if some architects are aware, of either the young generation or well experienced architects, still there is a need to raise awareness through workshops to educate the students, lecturers, and architects in order for them to be acquainted with the development of smart glazing and potentials of such dynamic characteristics"*.

A12, A10, A1, A2 and A13 all agreed with A16 who mentioned that awareness of economic aspects and energy efficiency are important by stating that, *"Some architects are aware of new materials but not in particular with the type of dynamic glazing. However, there will be an interest in such material if economic aspects are well explained especially if it means less time, effort, and energy consumption to the design process when compared to traditional materials. The media should take part as well, more conferences and exhibitions are needed to illustrate the potentials of new materials and their added value to design. Full and detailed documentation, cooperation with global organizations that cater for not only conservation issues, but also raising awareness to the material's` potential that add to sustainability aspects"*.

In addition, A11 and A18 explained that new materials always need time to be clearly understood not just by architects but the community as a whole. A18 noted that also added from a practical point of view that, *"in Iraq smart dynamic glazing is new, we*

need to see buildings, houses, hospitals using such elements to enrich Iraqi architects' experience. The community role is important to include to confirm the acceptance of new materials".

As a result, 19 of the interviewees found it hard to understand the added value of using smart glazing as an alternative to traditional materials. In this sense, A15 focused on the importance that architects should start thinking 'smart' in a way that differentiates between the static and dynamic state of design. A15 discussed that, *"more and continuous information is needed for better marketing directed at developers and construction companies as well as big house producers, related authorities and even schools of design and engineering. The architect's role is not as central in such decisions now as the traditional role. Perhaps there is a need to develop smart architects as well, specifically in their way of thinking".*

In relation to the embedded technology and transparency, 19 of interviewees found it difficult to understand the added value of dynamic material characteristics when compared to static glazing. Also, 17 of the interviewees found it hard to visualise the part of active, embedded technology when compared to added technology. Hence, 19 out of 21 interviewees were unable to realise the benefit of transparency in the smart dynamic glazing material. It is important to mention that although 3 out of 21 interviewees did work with switchable, reversible glazing properties, still the use of it was only initiated as required by the client's requirements not by the architects. This difficulty was noted by the researcher and therefore it needs to be explored further in the Post-Development Stage. The use of visualisation tools in the evaluation of a smart contemporary element are necessary not just to differentiate between the role of technology in the smart dynamic glazing material and the other in static glazing, but also to visualise the flexibility of dynamic characteristics associated with transparency, colour, and privacy. The same flexibility will be explored to show its added value in delivering a multifunctional design quality that combines both aesthetic and functional aspects to be in harmony with surroundings

Moreover, A12, A11 also highlighted that cooperation is important among various disciplines not just in architecture. A11 suggested that, *"there is a need to raise awareness by starting with universities providing workshops and sessions that discuss the potentials of such smart dynamic material in design. Also, there is a need to make*

steps that encourage cooperation between governmental and private sectors. For instance, the cooperation between ministries such as the Ministry of Environment, Ministry of Municipality and Public Work, Ministry of Housing and Construction, and Ministry of Industry always paying attention to details like cost, maintenance, and mass production. Moreover, different means of media as the visual media can add to educating the public to the flexibility of switchable properties of smart dynamic materials". A10 agrees with A18 that architects are aware of such materials, however, there is still a need for academic examples in universities. Also, there is a need to educate end-users, and architects through the examples of successful projects with successful design decisions.

As a result, the role of dynamic characteristics and their added value to design aesthetically and functionally, is still unclear. The interviewees repeatedly voiced concerns relating to aesthetic appreciation such as propriety of screen design pattern in terms of design order, proportion, line, arches, colours as well as technical barriers referring to environmental aspects, energy efficiency, cost and maintenance issues, location and type of climate. Consequently, the introduction of new active embedded technology is critical to design. This finding does not necessarily undermine the importance of smart material characteristics. The aesthetic aspects of screen design pattern will be further explored in the Post-Development Stage regarding design order, lines, arches, and colours, and to illustrate the added value of dynamic transparency that can combine aesthetic satisfaction, with social and cultural aspects. Therefore, there is a need to provide examples using a combination of visualisation tools to clearly demonstrate the impact of switchable, reversible properties in improving a multifunctional design quality regarding transparency, propriety of design order, colours, private and public needs, natural air ventilation, thermal comfort, and energy efficiency.

4.6 IMPACT OF TECHNOLOGY TOOLS IN THE INTERVIEW PROCESS

Each one of the design tools provides a clear illustration of a certain aspect of the contemporary window/wall/balcony design element that can be compared to the traditional version of the design.

The first tool used is Lumion 3D and provides an illustration of the 3D digital prototype and its facade elements, both traditional and contemporary window/wall/balcony design elements. It also helps to ease the communication between the researcher and the interviewees regarding aesthetic aspects such as the screen design pattern in terms of screen design pattern colour and order. In this sense, 18 of the interviewees explained that there are certain aesthetic aspects that are missing in the external façade in particular the traditional screen design order in terms of lines, curves, and arches. 3 of the interviewees did not comment because they did not share the same background. Moreover, the 18 interviewees explained that the choice of colour plays an important role in the design to express elegance and propriety to express the identity and values of the design including location and type of climate. A13 noted that, *"even though the material used is modern and different than the traditional material, still the use of any material should provide for the propriety of the design to suit the surroundings and express the identity of place"*.

The second tool Smart glazing VR helps the interviewees to engage and be part of the design process, since the first tool is not able to provide this. With this tool, 18 of the interviewees were able to choose the colours and observe the flexibility provided by the smart glazing material associated with the role of transparency, colour and privacy. The same tool provides a better illustration (navigation and control) for the indoor environment and to be able to observe the differences between traditional and smart material, such as in the integrated relationship of light and shade. The first tool could not provide this as shown previously in Figure 4.3 p. 146. Therefore, 18 of the interviewees acknowledged the flexibility provided by the smart glazing material regarding environmental aspects when compared to traditional material of shanashil. 3 of the interviewees did not comment because they did not share the same background. The 18 interviewees emphasised that flexibility is not in the options provided by the modern, active technology. In other words, it is in providing the needed colours to blend in harmony with surroundings, location and type of climate which is what traditional material used to provide. Even though the interviewees acknowledged the limitation of the new material to mimic the traditional colours, shades, and design order, they preferred colours of white, black, and grey to be used in the façade of the screen pattern.

The interviewees also were sceptical about the new material, particularly, the role of transparency in hot, arid climate. A18 expressed that, *"I have used a different type of smart glazing called Photochromic. Although the switchable transparency of the material was important for the design requirements, nevertheless, the efficiency of the smart dynamic glazing, cost and maintenance issues were critical to design quality due to the location and the type of the hot arid climate of Baghdad"*.

The third tool Revit Plugin is used to illustrate the predefined parameters for the interviewees to understand the integrated relationships between transparency, colour, privacy, and daylight. Such relationships promote a healthy, active environment with less energy consumption regarding lighting energy, and cooling loads. This tool is more about understanding the multifunctional quality of a smart contemporary window/wall/balcony that combines both aspects, aesthetic and functional, as shown previously in Section 4.3 and Figure 4.5 in p. 148.

As a result, a combination of three visualisation tools helped 18 of the interviewees to understand the multifunctional design quality provided by the dynamic characteristics of a contemporary design element. The same quality improves the flexibility of design in a way that takes into consideration both aesthetic and functional aspects. The first tool Lumion 3D enabled interviewees to observe the aesthetic aspects of smart dynamic material. The second tool smart glazing prototype VR enabled the interactivity for the interviewees to engage and be part of design process. Whilst the third tool Revit plugin enabled interviewees to check predefined parameters and properties that cater for a multifunctional design quality, both aesthetic and functional.

Accordingly, the use of these tools is critical as it enabled the interviewees to check the extended 3D element as well as the 2D of the screen design pattern details in terms of colour, texture, and order such as lines and arches.

Therefore, the value of using these tools is to ease communication between the researcher and the interviewees is:

- a) The use of Lumion 3D allowed the interviewees to observe the impact of dynamic characteristic, particularly the switchable, reversible properties

associated with aesthetic aspects of screen design pattern in terms of transparency, colour, privacy, and design order.

- b) Through the use smart glazing VR, the interviewees were able to interact and engage to be part of the design process. It enabled navigation to go inside the building and check: 1) the effect of light, heat, shade, and glare control as part of indoor and outdoor environment, 2) the dynamic characteristics of transparency and colour.
- c) The use of Revit plugin tool enhanced the interviewees` perception to understand the impact of such properties on the integrated design relationships with less energy consumption and enhance environmental control regarding the balance between day light needs, lighting energy, and cooling loads.

As a result this helped interviewees to visualize and understand the actual use of smart material to deliver a multifunctional design quality when compared to traditional elements and the way of using these tools in the design process.

4.7 METHOD OF ANALYSIS

Following the thematic analysis, the textual data in each transcript was broken into main subject categories. The aim was to capture dynamic characteristics and to explore possible integrated relationships for a flexible design pattern, which formed a basis for the interpretations as shown in Table 4.5.

Table 4.5 The main research themes, sub-themes, and sub-sub-themes.

Key Themes	Sub-Themes	Sub-sub-themes
1. The main characteristics of traditional elements shanashil	a) Meanings that are collectively integrated within sustainability aspects: 1) Elegance 2) Flexibility of screen design pattern 3) Functional beauty	Transparency, privacy, colour, and manipulation of light and shade of the screen pattern in traditional elements demonstrated in the use of natural material like wood.
	b) Sustainability aspects in traditional elements.	1) Environmental within economic aspects to deliver thermal comfort within

Key Themes	Sub-Themes	Sub-sub-themes
		control of indoor environment. 2) Social and cultural aspects.
	<p>c) Changes of design values and discontinuity of identity due to :</p> <p>Modern planning Changes of design pattern from rapid organic one to grid iron pattern to accommodate development of transportation means affecting both meanings of :</p> <p>i. Transparency ii. Privacy needs.</p>	<p>The need to develop new adaptable design strategies demonstrated in:</p> <p>1) The use of material. 2) Technology role.</p>
<p>2. The characteristics of smart material:</p> <p>a) Definition of smart material</p>	<p>Role of transparency as part of new adaptable strategies in design</p>	<p>Due to integrated relationships between aesthetic and functional aspects, smart material will be the link with continuity of traditional design through:</p> <ul style="list-style-type: none"> • Adaptability within surroundings • Focusing on environmental aspects. • Harmony with aesthetic aspects including social and cultural aspects.
<p>b) The dynamic characteristics of smart contemporary elements</p>	<p>i) Meanings that are collectively integrated within sustainability aspects:</p> <ul style="list-style-type: none"> • Elegance • Flexibility of design • Functional beauty 	<ul style="list-style-type: none"> • <i>Transparency in smart contemporary elements</i> • <i>Colour</i> • <i>Design order</i>
	<p>ii) <i>Sustainability aspects in smart contemporary elements</i></p>	<ul style="list-style-type: none"> • Environmental within economic aspects. • Social and cultural aspects
	<p>iii) <i>Active, embedded technology in smart contemporary elements.</i></p>	<p>Dynamic characteristics as part of active embedded technology within control of</p>

Key Themes	Sub-Themes	Sub-sub-themes
		<p>switchable, reversible properties to provide:</p> <ol style="list-style-type: none"> 1. Transparency while maintaining privacy needs. 2. Active technology and Energy efficiency taking into consideration the difference between static and dynamic glazing.
3. Issues and Challenges of Using Smart Dynamic Glazing Material	<ol style="list-style-type: none"> i. Transparency role as a window/wall/balcony element. ii. The role of active, embedded technology associated with switchable, reversible material properties regarding transparency, colour in delivering a multifunctional design quality. ii. Design order of the screen pattern in terms of lines, curves, arches, and texture. 	<p>Limitations regarding:</p> <ol style="list-style-type: none"> i. Aesthetic aspects: mimicking the essence of traditional design pattern order in terms of lines, curves, arches, colour and texture. ii. Functional aspects: like delivering sustainability aspects environmentally as well as socially and culturally with consideration of location, type of climate, energy efficiency, cost, and maintenance issues.

4.8 SUMMARY AND MAIN FINDINGS

The research study aimed at developing a method of visualising a smart, dynamic, transparent and multi-layered material used for a multifunctional window/wall/balcony design element. Thus, it is necessary to document the current understanding of smart material specifically in the role of transparency in design. This chapter revealed that architects and designers have a good understanding of the term

‘smart’ and its integrated relationship with the sustainability of design. However, there is still need for more work to define the action steps such as the implementation of such material as part of modern technology, to be designed in harmony with the surroundings. Moreover, it was clear that ‘smart material’ as a term, specifically in relation to its dynamic characteristics is not frequently used in design, and if so it is more of a general concept. The use of visualisation tools during the research interviews helped the interviewees to understand the 3D digital prototype as it enhanced the interactivity between the researcher and the interviewees. It made it easier for interviewees to add notes regarding the adaptability of screen design pattern and the use of smart glazing element in terms of colour, order, privacy and the role of switchable transparency in design.

This chapter has presented the results of semi-structured research interviews in order to explore the impact of dynamic characteristics of smart material and their added value to improve flexibility of a window/wall/balcony design element that delivers a multifunctional quality. Such quality caters for sustainable development as in the control of environmental aspects within social and cultural aspects. This is achieved in the switchable reversible properties regarding transparency while maintaining privacy needs. The conclusions drawn from the analysis of the interviews are summarised as:

- 18 of the interviewees did not favour the aesthetic aspects of smart glazing element in screen design pattern due to:
 - a) The abstraction and lack of propriety in illustrating the details of the design order when compared to the traditional one.
 - b) 17 of the interviewees were clearly against the use of certain colours such as blue. Further, 14 of the interviewees did not favour the use of colours in the design pattern although there were several colours provided the choice was mostly black, grey and white.
 - c) 16 of the interviewees argued that the aesthetic aspects are not presented in the modern façade due to a fixed image by architects and designers of the window/wall/balcony design element.

- 16 of interviews argued that the modern material out-weighed the traditional ones in its functional aspects particularly in the control of environmental aspects as in providing better energy efficiency.
- 18 of interviewees expressed that the role of transparency is critical in the screen of the design element due to screen pattern propriety regarding colour and order.
- Although 12 of the interviewees had concerns about the suitability of implementing a new modern material in terms of location, type of climate, cost and maintenance issues, the conclusions drawn are summarised below:
 - a) Transparency in its dynamic state, specifically the switchable, reversible properties was accepted by all interviewees since it provides more controllable environmental aspects as well as privacy and public needs.
 - b) 16 interviewees encouraged the use of smart glazing element in design to improve sustainability of environmental aspects.
- Regarding the role of technology in moving from traditional passive element and contemporary smart element with active, embedded technology, 19 of the interviewees were unclear about the role of embedded technology associated with dynamic transparency and colouration efficiency.
- There were issues in visualising the dynamic characteristics of smart glazing material when compared to static ones. Thus, the role of technology tools in presenting the dynamic characteristics in a 3D digital prototype are important to improve understanding.

This chapter has presented findings for the Development Stage of the research, that is, to demonstrate the dynamic characteristics of smart dynamic (glazing) material that can contribute to the implementation of a contemporary smart window/wall/balcony design element focusing on the role of change, transparency, and modern technology in the quality of design. While this chapter explored the screen design limitations of a smart contemporary smart window/wall/balcony element in comparison to the traditional one and their impact on the sustainability

aspects environmentally, socially and culturally from an architectural design perspective, the following chapter will evaluate the role of the dynamic characteristics from architects' perspectives in improving design quality regarding order, colour, and transparency role. The Post-Development Stage provided an opportunity to refine and evaluate the visualisation tools in order to be able to discuss the flexibility of dynamic characteristics in a smart contemporary design element that can combine aesthetic satisfaction with sustainability of environmental, social and cultural aspects in harmony with the screen design pattern.

Chapter Five

5 Post-Development Stage

5.1 INTRODUCTION

In the Development Stage, this study developed and assessed a contemporary design approach demonstrated in two models for a smart window/wall/balcony design element these were further developed in the Post-Development Stage using three technology tools as follows:

- 1) First one depends on Lumion 3D video demonstration as shown in Figures 5.1, 5.2, 5.3.



Figure 5.1 The use of smart window/wall/balcony elements in a typical example of Baghdadi houses.



Figure 5.2 The impact a smart window/wall/balcony element in improving the quality of indoor environment through the control of transparency, order, colour, heat, light, glare reduction, and energy efficiency.



Figure 5.3 demonstrates the dsitribution of smart window/wall/balcony elements in a multi-storey building which expresses the changing state from transparent to semi-transparent to opaque.

This impact is seen in the flexibility within control of dynamic material characteristics and the integrated relationships with daylight and energy consumption to provide better energy savings for a comfortable, healthy, and active environment.

- 2) The second tool used the smart dynamic glazing VR prototype to illustrate two models using contemporary window/wall/balcony design elements, as shown in Figures 5.4 and 5.5.



Figure 5.4 The use of Smart Serious Game for two contemporary models two storey building type, and a multi-storey building type.

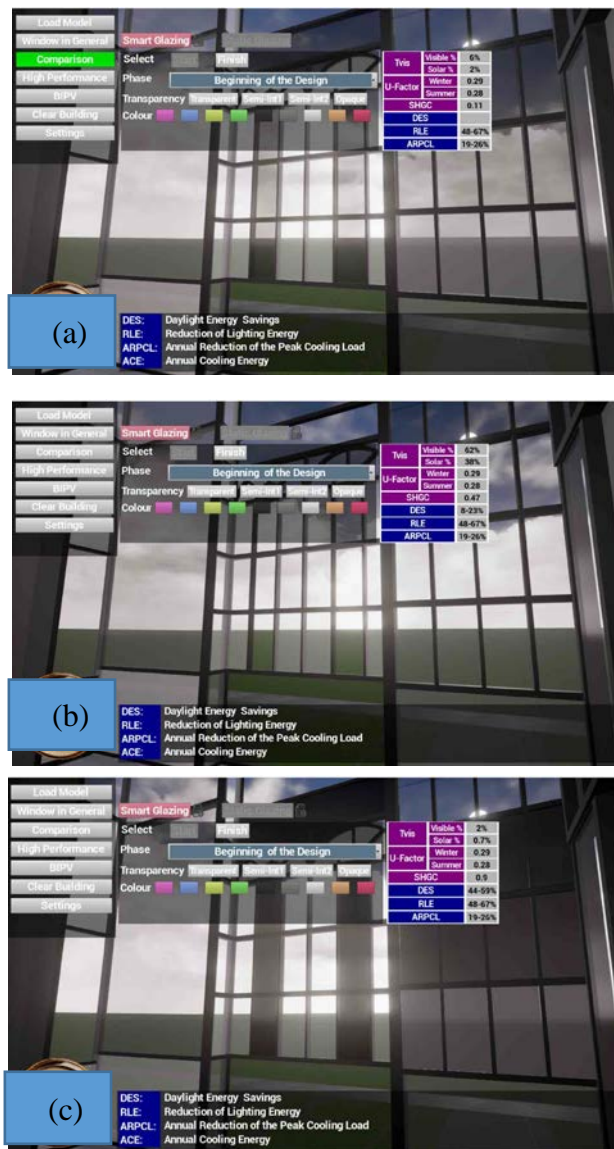


Figure 5.5 (a, b, c) Demonstrates the impact of dynamic glazing properties on the quality of indoor environment to deliver environmental control and thermal comfort using the colours of black, grey, and white.

- 3) The third tool used is the customised Revit plugin tool to illustrate the smart glazing property of 3D models, as shown in Figure 5.6.

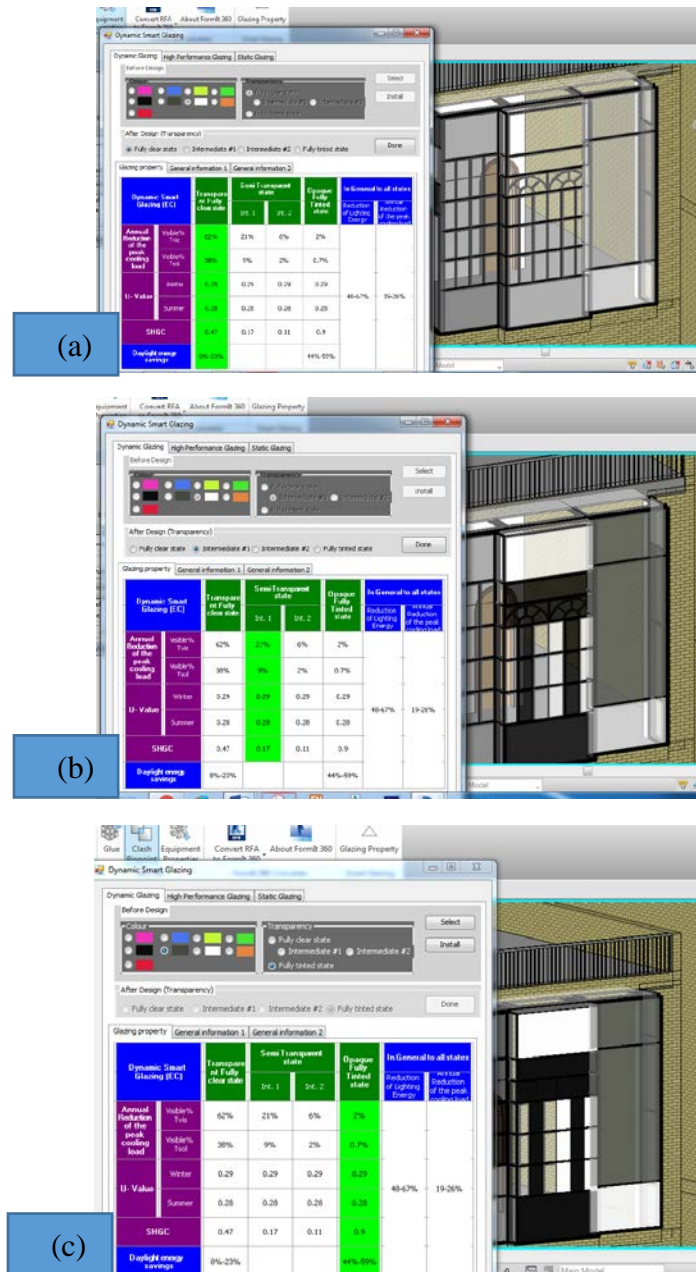


Figure 5.6 The use of Revit plugin tool to demonstrate the impact of switchable properties. (a) the transparent state, (b) the semi-transparent, (c) the opaque state of the smart glazing element.

To verify the relevance of the findings from the Development Stage and Post-Development work, feedback from Architects and Consultants was sought to confirm and refine the findings, or otherwise reject the design. 6 participants were selected from the original participants in the main data collection phase who demonstrated detailed knowledge and familiarity with traditional elements as well as the use of modern material and they expressed their willingness to be contacted for further participation in the Post-Development Stage.

The participants in this evaluation phase A10, A11, A12, A13, A15, and A18 (details in Table 4.2 page 157) were also contacted in advance and provided with the relevant information and new changes in the screen design pattern such as the colour order and type of buildings provided to ensure that they had some degree of familiarity with the modified subject under investigation. In most cases, a pre-interview meeting was organised to discuss the relevant issues of the study and to clarify what was required during the evaluation phase.

An evaluation form was provided to the participants containing a 3D digital prototype of the contemporary design approach for a smart window/wall/balcony design element, as seen in Figures 5.1, 5.2, and 5.3, and the images of the modified design element mimicking the traditional screen pattern design proposed in this Chapter. The questions of Post-Development evaluation stage are presented in Appendix C for further clarification.

The evaluation form contained a semi structured set of questions on key issues concerning the added value of the dynamic characteristics of a smart window/wall/balcony design element such as: the relationship between transparency and the ideas of elegance, flexibility, and functional beauty, the role of transparency if it provides efficient design in terms of environmental, social and cultural aspects. These questions are important to illustrate the usefulness of such material to improve the flexibility of design by delivering a multifunctional quality. It also discusses whether the design adjustments are clearly expressed in screen pattern colour, order and proportion with propriety regarding location and type of climate. The evaluation form also contained a question about final suggestions and comments to give the participants an opportunity to express any further views.

5.2 THE DYNAMIC CHARACTERISTICS OF SMART CONTEMPORARY ELEMENTS

After completing adjustments taking into consideration the role of mimicking the essence of the screen pattern context to match collectively the surroundings in order, lines, arches, symmetry, and colour, it was possible to derive a list of dynamic characteristics of smart material that improves the flexibility of design. The objective of this section is to determine the dynamic characteristics and their integrated relationship with the transparency of smart glazing. This objective is achieved by considering the switchable properties of a window/wall/balcony design element regarding transparency and colouration efficiency, and delivering a multifunctional quality. To achieve this objective, the interview results are discussed with respect to the questions asked (Appendix C).

i. Transparency in smart contemporary elements

According to the use of the contemporary window/wall/balcony design element illustrated in the both models of the typical example of Baghdadi house and the multi-storey building, the interviewees were first asked, about three parts that affected the design quality. These parts were about elegance, flexibility, and functional beauty related to transparency in a contemporary design element as follows:

a) Which of the following aspects reflect the elegance in a contemporary element that once existed in the traditional element (shanashil)?

Regarding the idea of elegance, the contemporary approach was successful in using the transparency of the smart dynamic glazing to reflect an elegant order that improves the flexibility of the screen design pattern. For instance, A18 agreed that the idea of elegance is expressed in all design aspects. A11 stated that, "*Elegance of design is seen in the multi-layered aspect within the order, and proportion that mimick the essence of traditional design. It is more than one idea, or layer of delivering the design element like the way of treating them in a multi-storey building. It is also taking the role of colour and transparency as an essential part of screen design pattern*". Similarly, A13 and A15 agreed with A11 that the contemporary models are elegant with the use of smart dynamic characteristics specifically in their multi-layered construction, visibility and use of colours. In addition, A18 expressed

that, "the design is elegant in all aspects regarding colour, visibility, order, and the choice of a multi-layered material".

Accordingly, A10 stated that, "*all design aspects provide for elegance. This is an order designed to provide integration in all effective issues*".

However, some interviewees expressed different opinions in terms of colours. For example, although A12 explained that, "*the elegant design is presented in the order, visibility and use of colours*". Nevertheless, A12 also mentioned that, "*other colours like blue and green can also be part of the screen design pattern. But the shade of these colours is important to blend with the harmony of the surroundings including other materials (local baked brick), location, and type of climate*". Hence, it is important to pay attention not just to the colour but also to the shade of it to deliver harmony to the design context as a whole. A15 also mentioned that some colours such as black is too intense and not favoured. A15 also agreed with A12 by suggesting different shades of grey for the mimicking of the traditional order to be elegant and successful in blending with the surroundings.

Notwithstanding, all of the interviewees accepted the use of smart dynamic glazing as an elegant option specifically in representing the order of the screen design pattern. This is because the elegant order is flexible to reflect part of the design beauty as in symmetry, repetition of lines, circles, and arches which the traditional pattern used to deliver. Furthermore, it is considered a better adjustment to the expression of the design element regarding location, and type of climate. This issue has improved the aesthetic aspects of the architectural design. 5 of 6 interviewees agreed the colours used white, black and grey are suitable for the screen design pattern. However, 2 of these 5 interviewees argued that more colours with certain shades are needed to deliver better elegance to design. Hence, the role of colour needs more development for the embedded technology to be able to illustrate more colours and shades to blend with unity with the surroundings including location and type of climate.

b) Which of the following aspects reflect the design exuberance that once existed in the traditional element (shanashil)?

5 out of 6 interviewees agreed that contemporary elements reflected design flexibility of screen pattern in all aspects. With the same focus, A11 stated that, "*Flexibility is*

seen to a certain degree like the integrated design relationship between colours, order, light and shade, within the role of transparency while maintaining privacy". Moreover, A10 argued that, *"all aspects provide the necessary requirements to improve flexibility in design"*. Further, A10 explained that the screen design pattern of the design elements delivers flexibility to architectural design by combining both aesthetic and functional aspects. A12 and A13 also agreed that the use of dynamic glazing in the implementation of *shanashil* provided flexibility in all aspects particularly transparency within privacy, air ventilation as well as light, heat, shade, and glare control.

A15 discussed the fact that the design flexibility is important to be able to understand in the manipulation of both transparency and light and shade. From a slightly different perspective, A18 reflected that, *"it is the light and shade and their integrated relationships that is responsible for the design flexibility"*. However, A18 argued that flexibility of design is still only in the functional aspects and that more effort is needed concerning the aesthetics. This claim focused in particular on the positioning of the design elements in the architectural façade.

The majority agreed that use of dynamic glazing in the implementation of *shanashil* provided flexibility in all aspects particularly transparency within privacy as well as light and shade. Nevertheless, more effort is need concerning the flexibility of aesthetic aspects regarding colours, lines, and textures.

c) Which of the following aspects reflected the idea of functional beauty that once existed in the traditional element (shanashil)?

The interviewees favoured the idea of functional beauty that is applied in design elements, nevertheless, each participant had a different interpretation of the role of function.

A12 expressed that functional beauty is seen in most aspects regarding transparency, privacy, and colour specifically in the role of material used. A12 stated that, *"the application of shanashil in the two models reflected both aesthetic and functional aspects"*. Equally relevantly, A11 argued that, *"Functional beauty is in the role of maintaining private and public needs for the success of a beautiful window/wall/balcony design element in the facade. Such beauty is at the same time*

integrated to the function of the design façade not only to its aesthetic one. The flexibility within control of environmental aspects such as heat, light, glare, and natural air ventilation is improving the design quality, aesthetically and functionally". A13 also agreed that the idea of functional beauty is better expressed in the contemporary element. A13 stated that, "the design elements now are more appropriate since they reflect part of order that the traditional elements used to provide. Also the colours are more appropriate to the surroundings. Such details are important to notice in order to preserve identity of design that belong to location and type of climate".

A10 argued that, *"yes to a certain extent the design element reflects the idea of Functional beauty".* With the same meaning, A18 noted the role of material and the integrated relationship of light, shade, heat, and glare are what reflects the idea of functional beauty. A18 argued that, *"the idea of functional beauty still needs more to reflect the importance of flexibility in design in a way that equals the transparency role and the change of colour from semi-transparent to opaque for privacy needs, as in the positioning of the design elements to reflect part of the image of what traditional elements used to be. This claim is important for the design quality to be complete, aesthetically and functionally "*. A15 agreed with A18 that it is the role of the material used, specifically in the smart dynamic glazing which provides for the idea of functional beauty.

All interviewees agreed on the elegant expression of aesthetic aspects, in particular the overall order in screen design pattern. However, 2 of the interviewees although accepting the choice of colours, still demanded more development to deliver various shades and colours like blue and green but with shades that match the pattern components with the surroundings, location and type of climate. More importantly, 5 of the interviewees agreed that the role of transparency is still critical even with the use of a smart multi-layered design element.

As for flexibility of design, 5 interviewees agreed that all aspects including the integrated relationship between transparency, colour, and privacy is very important to consider in design. However, all the interviewees acknowledge that the light and shade relationship is delivered in the screen design pattern even when compared to the traditional screen. 4 of the interviewees agreed that the idea of functional beauty

is seen in transparency, privacy, and type of material used, yet 2 of the interviewees still think that more development is needed in the colour, order and positioning of design elements in the façade, as seen in Figure 5.7.

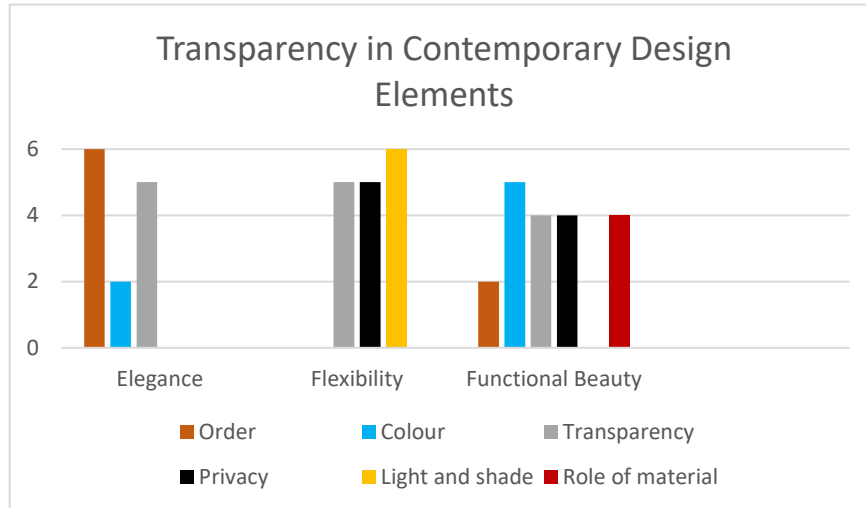


Figure 5.7 Opinions of the interviewees regarding aesthetic aspects.

ii. Sustainability aspects in smart contemporary design elements

Each interviewee was asked, **which aspects of sustainability were reflected in the contemporary models?** All interviewees' answers were in favour of the environmental aspect, however, 5 of the interviewees argued that two aspects specifically environmental with social and cultural sustainability were reflected in contemporary elements. A11 stated that, "*Sustainability of design is demonstrated to a certain limit in the social and cultural aspects regarding order, colour, and privacy including environmental aspects*". Furthermore, A10 agreed that the design reflected the aspects of sustainability, environmentally, socially, and culturally within economic aspects when compared to the use of materials (wood and static glazing) in traditional elements.

Moreover, A12 and A18 agreed that sustainability in the contemporary models delivered both environmental with social and cultural aspects. A15 argued that the design approach is still more sustainable in the environmental aspect, within certain limits, to economic aspects. Nevertheless, the role of transparency is still critical to all the interviewees. Equally relevantly, A18 expressed that some issues regarding the

use of transparency, due to the role of modern technology can have a negative impact on the dynamic characteristics of design. In this sense, A18 stated, *"although such dynamic glazing material can have a positive impact on design quality specifically in energy efficiency as in less consumption of energy in the long run, still the modern technology will impose challenges in using them as a replacement for other materials like static glazing types. This claim is because of the cost that it is still expensive when compared to other types"*.

This issue means that more effort is needed regarding both transparency and economic aspects of the material to blend in unity with the surroundings to reflect all aspects of sustainability. As a result, 5 interviewees agreed that the environmental aspects are now more in tune with social and culture aspects. However, 3 interviewees are still sceptical about the economic aspects. In addition, 5 of interviewees are still critical in understanding the transparency role as part of modern active technology that is embedded in the design element. 5 of the interviewees agreed that both the environmental aspects, with social and cultural aspects are improved which in return improves flexibility of the contemporary window/wall/balcony design element. However, 3 interviewees are still sceptical about the economic aspects while 3 were encouraging the use of smart glazing in architectural facade. In addition, 5 of interviewees are still critical in understanding the role of transparency within the use of active embedded technology regarding efficiency, cost and maintenance, as shown in Figure 5.8.

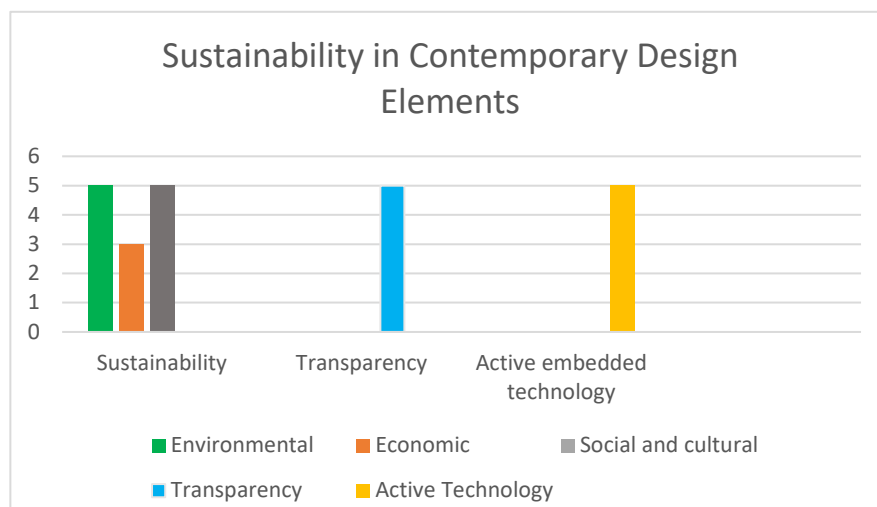


Figure 5.8 Opinions of the interviewees regarding sustainability aspects and integrated relationships with transparency and active embedded technology in design.

iii. Comments and suggestions regarding the contemporary design element in both aesthetic and functional aspects.

5 of the interviewees agreed that the contemporary approach does combine the aesthetic and functional design aspects. Also 5 of the interviewees agreed that the flexibility in the contemporary elements is improved in reviving the environmental control in terms of heat, light, shade, glare reduction, and air ventilation. The use of visualisation tools in the evaluation of the smart glazing elements allowed the interviewees to realise the integrated relationships of the dynamic characteristics not just for the 2D pure form of the screen design pattern in terms of lines, arches, and colours but also for the 3D pure figure of the extended smart contemporary elements as part of the external facade. The flexibility and quality of the contemporary design element is enhanced to provide the balance needed between aesthetic and functional aspects. This is due to the role of the dynamic material characteristic in delivering aesthetic satisfaction taking into consideration the sustainability of environmental, social, and cultural aspects.

However, most of the suggestions were about the positioning of the contemporary design element on the façade. Nevertheless, the interviewees suggested several options that were all possible due to the flexibility of transparent, multi-layered material role in design. Accordingly, this smart material provided the aesthetic and functional aspects due to the flexibility in its dynamic characteristics associated with, role of material, transparency, active embedded technology, and colour.

A good example is seen in which there were three suggestions for the positioning of elements as well as the arrangement of design order in the façade. One suggestion was given by A12, as shown in Figure 5.9. The other two suggestions were given by A18, as seen in Figure 5.10.



Figure 5.9 Two suggestions for the positioning of the design element by A18.



Figure 5.10 Positioning of design element using the smart dynamic glazing material by A12.

A12 agreed with A18 that the contemporary models need more improvement in their aesthetic aspects to complete the idea of functional beauty. In this sense, A18 stated that, *"aesthetic improvements are needed. In addition, more types of building are needed to be studied such as offices, residential, commercial, cultural buildings, and others"*.

In terms of the role of colour in the design pattern, other interviewees such as A10, A13, A15 suggested different shades of the same colour as in grey in order to mimic the traditional design in its use of wood and different shades of that material. Hence, more development in the future for the dynamic characteristics of smart glazing to be developed such as in terms of design order and proportion

5 of the interviewees argued that clarity was an important demand in design, for instance, A18 had worked with such smart glazing material and suggested that tinted glass, which is part of the multi-layered smart dynamic glazing, should be made with more clarity for the design adaptability to be complete, aesthetically and functionally.

A11 expressed that more development for the flexibility of dynamic characteristics of material is needed to widen its potentials of saving the design with a heritage and cultural identity like providing better energy efficiency, less cost, and more option for colours and order (lines, curves, and circles for the design to blend in harmony with the surroundings regarding location and type of climate and maintain continuity of architectural design traditions.

A18 and A15 also argued that aesthetic aspects need more development in a way that reflects the essence of design in which traditional material, in particular (wood) used to provide in terms of colour, shade, and texture. Further, A10 argued that there is a need for more innovation and authenticity in design. Designers have to focus and elaborate many ways for the integration of different materials such as ones that mimic the wood to be successfully adapted to the changes of design needs.

Other issues were important to consider such as the type of material, cost and maintenance issues. A12 agreed with A10 who commented that, *"Cost maybe one of the obstacles for using these smart materials with modern technology. Workmanship and possibility of mass production will be another item to be discussed. All of this may cause limitation to use of such elements with the design diversity (shapes and sizes) proposals. Also individual production will limit the use of these elements. I would say that other problems like in limitations of buildings` regulations such as the land use, aesthetic, and environmental regulations. Unavailability of criteria for glass widows use, and lack of façade design criteria. What is available is the work of*

individual and academic research in this field such as the regulations of availability of land, facades, floor-area ratio (FAR)".

A12 added that, *"Other problems like in limitations of street control regarding By-laws such as (availability of land), facades, floor-area ratio (FAR) and other Iraqi regulations present another problem to implement such design proposals".*

Accordingly, 5 of the interviewees expressed that flexibility in the complexity of contemporary screen design pattern is successful in delivering various potentials for the design order. Nevertheless, the role of transparency is still critical in design. Thus, there is a need in the future, to understand more about the potentials of active technology when embedded in a transparent, multi-layered material in order to improve the flexibility of design with a multifunctional quality.

5.3 MAIN FINDING OF EVALUATION

According to the interviews, the role of technological tools Lumion 3D, Revit plugin tool, and smart glazing VR prototype are important to ease the visualisation of 3D prototype. The dynamic characteristics of the smart glazing element need to be demonstrated in a way that engages the interviewees to be part of design process, before and after. This was important to illustrate the integrated relationship between switchable transparency and colour specifically for its impact on the efficiency and effectiveness of design, aesthetically and functionally. The use of the smart dynamic material as well as the positioning of the window/wall/balcony design element were clear in the expression of the architectural façade, aesthetically and functionally. This is discussed in the following aspects:

- 1) All the interviewees acknowledged that change is inevitable and that it has changed the meanings of transparency and privacy due to changes in people's needs, activities and lifestyle.
- 2) 5 of the interviewees of the interviewees agreed that the contemporary approach does combine the aesthetic and functional design aspects due to:
 - a. The screen design pattern expresses part of the traditional order for the design identity and values to be clear as shown in the interviewees' answers regarding design colours, and order such as lines and arches.

Moreover, the positioning of dynamic characteristics of smart glazing element is flexible and successful to be applied in different building types with different shapes and sizes.

- b. The use of dynamic characteristics was agreed by 5 of the interviewees in the choice of colours such as black, grey, and white. It was appropriate when compared to the traditional design and in harmony with surroundings. Other colours were considered to not conform to the surroundings.
 - c. The evaluation suggests for the contemporary window/wall/balcony elements to focus on the positioning of design elements in architectural façade including the control of environmental aspects. Thus, the design approach is flexible in adjusting and controlling the design pattern by elegant order that mimics the traditional version. This is seen in the design alternatives of the interviewees' suggestions for the demonstration of the same elements in the architectural façade building, as in Figures 5.10, and 5.11
- 3) The combination of three visualisation tools improved the flexibility of design by:
- a. The use of tools clearly illustrated the added value of using the dynamic characteristic of smart glazing to improve the flexibility and quality of design elements, aesthetically and functionally.
 - b. The use of tools provided better communication among the interviewees (architect) not just to interact but also to engage and part of the design process by providing to suggestions for the positioning of smart contemporary elements in the façade. The two suggestions are made by 2 interviewees out of 6 in Figures 5.10, and 5.11.
- 4) Limitation of the contemporary models:
- a. There is a need for the demonstration of smart glazing materials in real projects to clearly illustrate their added value and encourage the use of switchable, reversible properties associated with transparency and colouration efficiency in design.

- b. More workshops, media role, are needed to spread the awareness to change the fixed image and perception by illustrating the benefits of implementing the dynamic characteristics of a smart glazing material in architectural facades to deliver a multifunctional design quality. The same quality should take into consideration the integrated relationship between energy efficiency issues and the role of design sustainability environmentally, socially and culturally in a way that blends in harmony with the surroundings.
- 5) More development is needed in the dynamic characteristics of smart material regarding their qualities, aesthetically and functionally. This issue is reflected in the following aspects:
 - a. Further development is needed for the embedded technology to be able to illustrate different colours, shades, and textures.
 - b. Further development regarding the environmental control to include different seasons of the year in order to match the changes of the surrounding environment. This is important to improve the flexibility of design in order to obtain better adaptability to changes of the surroundings
 - c. In the future, more development is needed regarding integration with other materials such as wood. Notwithstanding, it is important for material characteristics not just to be dynamic but more importantly flexible with control of their properties including the transparency role in design. This development is essential for the window/wall/balcony design element to deliver a multifunctional quality, aesthetically and functionally.
 - d. More development is required for the economic aspects to be affordable and improve other sustainability aspects regarding environmental, social and cultural ones.

In conclusion, the development of the dynamic material characteristics will give the utmost of its potentials for the continuity of traditional design and identity of place. This chapter described the qualitative methods with the aid of technological tools to visualize the added value of the dynamic characteristics attached to a 3D digital prototype. It also outlined that the role of technology and modern material are inevitable in design. For contemporary elements, it is important to mimic the essence

of traditional order, colours, and shades in design. The dynamic characteristic is effective in delivering privacy and energy efficiency associated with the need of aesthetic satisfaction and the sustainability of social and cultural aspects. Also the positioning of the smart window/wall/window glazing element can be demonstrated in different shapes and sizes. In addition, the use of colours and shades particularly black, grey and white improved the aesthetic aspects to suit the surroundings but to a certain extent.

Hence, more development is needed in the future to improve the flexibility of the design pattern in terms of order, ornament parts, colours, shades, and textures. Other issues such as cost, energy efficiency, and integration with other materials should be considered to match the changes of the surroundings regarding location and type of climate.

Chapter Six

6 Discussion

6.1 INTRODUCTION

This chapter discusses the findings of this research, and evaluates it against the original objectives. The conclusions drawn are presented and the limitations discussed, along with the contribution to knowledge is outlined. The last section of the chapter suggests recommendations for future research.

The demand for a new contemporary design approach to restore certain aspects of design identity and value in shanashil façade features means finding new adaptable design strategies to replace the old traditional materials such as wood and static glazing. This is to revive the environmental control and thermal comfort that traditional elements used to provide taking into consideration aesthetic satisfaction that blends in harmony with social and cultural aspects. Literature shows the failing attempt in protecting the design sustainability of the old material (traditional elements) while keeping aesthetic satisfaction in parallel with the inevitable changes associated with modern planning, transportation means, industrial and technological advancement. This is in line with Abu-Gazzeh (1993), Al-Ahbabi and Neama (2011), Al-Haidary (2008), Al-Thahab et al. (2014), Bianca (2000), Boake (2015), Eben Saleh (1997), Heynen (2000), Karanouh, Miranda, and Lyle (2011), Levine and Hughes (2008), Sherzad (2002), Thiel-Siling & Bachmann (1998), Warren & Fethi (1982), Willis (2015).

Accordingly, the study proposes the use of smart glazing material with dynamic characteristics to mimic certain aspects of traditional design elements of shanashil especially their multifunctional design quality, but not in their physical appearance. Although dynamic glazing material can mimic the traditional shanashil screen pattern in its appearance to a certain extent regarding transparency, privacy, order, lines, arches and colours this research is not about copying and pasting the traditional window/wall/ balcony element in its use of material. The aim is to mimic the essence of the main material characteristics that used to provide effective flexibility of aesthetic satisfaction within sustainability of the social and cultural aspects. This is

achieved based on the biomimetics approach to deliver a multifunctional quality taking into consideration the role of sustainability in design.

Therefore, an innovative contemporary approach has been adopted through using a smart material with dynamic characteristics that are transparent, switchable, and multi-layered in design. The same design approach takes into consideration the role of active, embedded technology integrated in a contemporary window/wall/balcony design element. This is achieved through switchable, reversible properties associated with transparency and colouration efficiency. The role of active, embedded technology as well as technology tools Lumion 3D, Smart glazing VR prototype, and BIM Tools (Revit plugin tool) are fundamental in order to visualise the dynamic characteristics of a smart design element.

In order to investigate the applicability of such material in comparison to traditional ones, the dynamic characteristics were evaluated and discussed with users (architects and designers) who are professionals in several aspects of architectural design covering the aesthetic aspects of dynamic transparency, the sustainability aspects of dynamic transparency, differences between dynamic and static glazing, transparency and the role of active embedded technology, dynamic transparency and integration with other materials, and the visualisation tools demonstrating the dynamic characteristic.

The smart contemporary elements were attached to a 3D digital prototype to enable the visualisation of their dynamic characteristics in order to be evaluated by the professionals interviewed. The key findings are discussed below with respect to Design Science stages and the original research objectives:

Pre-Development Stage

6.1.1 OBJECTIVE 1

To identify the main characteristics of the traditional design element shanashil and search for new adaptable strategies to improve the flexibility of a new window/wall/balcony design element.

To achieve this objective, identifying the main characteristics and understand the success that traditional element shanashil used to provide environmentally, socially

and culturally is important. Accordingly, Chapter 2 reviewed the design characteristics of traditional window/wall/balcony design elements and focused on highlighting the role of traditional elements in architecture that expressed the identity of design in a way that reflects its time, place and culture. This brought out the important role of an elegant transparency and complexity of screen design pattern while maintaining the needs of privacy, shading, light and glare control. Aesthetic satisfaction in the traditional window/wall/balcony design elements was achieved through adaptable design strategies that maintain harmony with surroundings, such as the role of traditional material (wood), design order, colour, and texture. However, the success of traditional elements was based more on the performance, particularly the environmental control that it provided in terms of comfort, natural ventilation, and energy efficiency rather than the decorative use of materials.

The main characteristics of traditional element shanashil that used to deliver a multifunctional design quality and by that catered for the idea of functional beauty are as follows:

- The design element itself extended from first floor and upper floors providing an elegant 2D to 3D perspective through the decorative details and structure of the window/wall/balcony element as a whole.
- The elegant design of the screen pattern is associated with the role of material (wood), colour, texture, and the propriety of design order in terms of lines, curves, and arches.
- The design element provided the needed privacy for the occupants while maintain a sufficient view with surroundings from three sides to enable visual communication among neighbours through their screened windows to deliver a successful sustainable design, socially and culturally.
- It used to provide environmental control through thermal comfort associated with the control of heat, and natural air ventilation to deliver a comfortable indoor environment in old cities` design of small houses and narrow streets.
- Control of the amount of light, shade and glare. Also the decorative pattern made by light and shade reflecting the same decorative pattern of screen design in the room forms an essential aesthetic aspect of the design element.

- The extension of the traditional element shanashil provided shadings not just for the exterior walls of the lower floor from sun heat and rain but also for pedestrians on the narrow streets and alleys.

To aid this work, a review of the history and background to the development of pattern in relation to the aspects of elegance, exuberance and functional beauty was identified. However, an important finding was that new trends of traditional elements even in the use of modern materials are focusing on the aesthetic aspects while abandoning the environmental control. This way of design affects the idea of functional beauty. It was suggested that any change that does not add to the essence of the object will be useless for the purpose it is made for. Therefore, there is a need to use new materials that can revive the environmental control within sustainability of social and cultural aspects in order to develop a multifunctional design quality. However, any creative process is incomplete without truly understanding the details within the layers of each pattern. It is essential to understand that flexibility in traditional pattern of shanashil is in understanding its integrated design relationships between 2D pure Form and 3D pure Figure to provide the balance that enhances design quality, aesthetically and functionally.

Pre-Development Stage

6.1.2 OBJECTIVE 2

To determine which smart dynamic material characteristics can deliver a multifunctional design quality taking into consideration the role of sustainability aspects of an architectural facade.

The work undertaken in Chapter 3 encouraged the researcher to develop an understanding of the potential mimicking nature's adaptable strategies using a contemporary, interdisciplinary approach that combines bioinspired design and biomimetic strategies. This inspiration revealed that the design pattern of natural examples are often dynamic, multi-layered and adaptable to the changes of the surrounding environment by using minimum resources to achieve maximum performance. It was suggested through the Pre-Development Stage that the dynamic characteristics of the smart glazing material mimics the characteristics of natural materials.

Accordingly, two types of smart dynamic glazing were reviewed in Chapter 3. Literature, however, showed the main conclusion drawn from this review was that when compared to static glazing, the smart dynamic glazing material not only provided switchable, reversible properties regarding transparency and colouration efficiency, but also flexibility within the environmental aspects associated with solar and visible transmittance, solar heat gain (SHGC), and U-value. Such aspects improve the quality of indoor environment as well as the sustainability of design by providing less energy consumption through the integrated relationship between daylight needs, lighting energy, and HVAC requirements (cooling loads). The review determined the main (dynamic) characteristics of smart material that are as follows:

1. Concerning the functional aspects:
 - This type of smart element improves the quality of indoor environment by providing better environmental control and thermal comfort in terms of air ventilation, light, heat, and glare control.
 - The switchable, reversible properties associated with transparency, colour and privacy provide better energy efficiency with less energy consumption through the balance between daylight needs, lighting energy, and HVAC requirements (cooling loads).
2. Concerning the aesthetic aspects:
 - The switchable, reversible properties improve the flexibility of a smart contemporary design element through the integrated relationships between transparency state and colour.
 - The same properties provide a sufficient view to be in touch with surrounding environment while maintaining privacy needs.
3. Concerning the role of active embedded technology:
 - When compared to static glazing in its fixed properties, the application of smart dynamic glazing material in both the commercial and residential sector could save about 4.5% of the annual energy use in the United States.
 - The coatings of smart dynamic glazing material can be multi-layered with more complex layers that provide better clarity and stability of design quality.

- It improves the sustainability of design by using minimum energy to achieve energy efficiency because it requires a small power to switch states.
- This way of design also improves thermal and visual comfort by enjoying more of the daylight and at the same time reducing lighting energy, cooling energy and peak electric demand.
- It reduces cost and maintenance issues by less use of materials and also by reducing the need for blinds and shading devices.

An important conclusion drawn was that the role of advanced technology and visualisation tools is essential in the interpretation process between biomimetic strategies and manmade design, and that the role of technology tools is vital in the visualisation of the dynamic characteristics in design.

This research proposed a conceptual framework that focuses on the switchable, reversible properties associated with transparency, colour and privacy brought together to develop a smart contemporary window/wall/balcony design element. Such properties improve the flexibility of design by delivering better energy efficiency through the balance between daylight needs, lighting energy, and cooling loads.

Development Stage

6.1.3 OBJECTIVE 3

To develop and visualise the characteristics of a smart dynamic material that can contribute to the implementation of a new window/wall/balcony design element.

To achieve this objective, the researcher reviewed the material characteristics of a smart dynamic glazing element in the type of Chromogenics such as Electrochromic (EC) as a material that combines aesthetic and functional aspects through the integrated design relationship between transparency, colour, and environmental sustainability in design. The objective was achieved through the literature in Chapters 2 and 3 and the empirical data as presented in Chapters 4 and 5.

The issues associated with identifying the dynamic characteristics of a smart glazing material were based on the integrated design relationships in terms of the screen

design pattern, role of material, transparency, privacy, colour, and design order. The issues were presented in Chapter 4 and grouped into five aspects as follows: 1) elegance; 2) Exuberance; 3) Functional Beauty; 4) Two sustainability aspects - environmental, social / cultural. The Development Stage of the integrated design relationships is illustrated in Table 6.1.

The findings revealed that environmental control is revived through the use of smart dynamic glazing element. However, the consistency of screen pattern regarding design order, colour, and shades was still critical. Such consistency is important to deliver aesthetic satisfaction within the sustainability of social and cultural aspects.

When discussing transparency, the traditional elements provided transparency and privacy in a way that was considered successful to the screen design pattern in terms of environmental, economic, social and cultural aspects. This is because the material characteristics of the traditional elements shanashil (wood) led to the balance in delivering aesthetic satisfaction within sustainability of social and cultural aspects.

In this sense, the research study acknowledges the fact that the old material (wood) produces a sort of transparency which is presented in a window/wall/balcony design element through integrated relationships between aesthetic and functional design aspects. The resultant transparency provided the flexibility to deliver a multifunctional quality which made the old design element as a distinctive feature in the façade of traditional Baghdadi Buildings which is imprinted deeply in the mind of interviewees.

Table 6.1 Development Stage of a smart contemporary design element.

Development Stage: Screen design pattern	Traditional window/wall/balcony element (shanashil)	Smart contemporary window/wall/balcony element	conclusion
1)Elegance	✓ Complexity of design in its double sided measures: role of material colour, shades, design order, texture, light and shade.	✗ Lack of elegance aspect regarding propriety of design order, and colour.	Due to critical design issues associated with role of transparency, design order, and colour, the design of screen pattern needs to be evaluated.
2)Exuberance	✓ Screen design pattern delivered flexibility and beauty between	✗ Lack of flexibility regarding aesthetic satisfaction of screen	

Development Stage: Screen design pattern		Traditional window/wall/balcony element (shanashil)	Smart contemporary window/wall/balcony element	conclusion
		2D pure form and 3D pure figure.	design pattern, order and colour	
3)Functional Beauty		✓ Combined both aesthetic and functional aspects: propriety of material colour, order, light, shade, air ventilation, privacy and public needs.	✗ Lack of aesthetic satisfaction in screen design pattern, order and colour	
4) Sustainability	a. Environmental aspects	✗ Used to provide environmental control through natural air ventilation, light, shade and glare control.	✓ Revive environmental control providing thermal comfort through switchable, transparency, colour, and privacy to deliver the balance between daylight needs, lighting energy, and cooling loads.	The use of smart dynamic glazing material improve the environment aspects of sustainable design.
	b. Social and cultural	✓ Harmony with surrounding, location and type of climate: Role of material, colour, shades, design order, transparency and privacy.	✗ Lack of design harmony regarding propriety of screen design pattern order, and colour.	Due to critical issues associated with role of transparency, design order, and colour, the design of screen pattern needs to be evaluated.

The main aim of the questions given was to illustrate the differences in advantages and disadvantages of each one. These aspects are summarised with respect to the original research objectives.

6.1.3.1 The Aesthetic Aspects of Dynamic Transparency

In relation to aesthetic aspects, 18 of the interviewees favoured the traditional elements. This is because of the integrated relationship between the transparency meaning, order, texture, and colour as an essential part of screen pattern. As for the perception of the contemporary smart element, 18 of the interviewees found it difficult to understand the transparency role of the new material in the screen design pattern in relation to order, colour, and texture. This is because of the expression of

aesthetic aspects associated with the use of natural material (wood) in the traditional design pattern. Similarly, the design pattern had an elegant order that combined the parts such as lines, curves, and circles in unity within the design context as a whole. It delivered a conscious sense that conveyed functionality and it was visually satisfying to the whole regarding the arrangement of architectural elements with the other principles of symmetry, beauty of the details, and propriety. Similarly, the use of wood provided flexibility as in the manipulation of form and function regarding 2D screen ornaments, to 3D balcony shapes and sizes. Colour also played an important role in design. This issue is seen in the elegant colour and shades of wood that blended in harmony with the surroundings regarding location, and type of climate including local materials such as baked (fired) brick. This is in line with Alfetal (2001), Al-Khafaji and Al-Qaisi (2012), Colletti, (2010), Critchlow (1999), Lincourt (1999), Pallasmaa (2012), Picon (2013), Rahim and Jamelle (2007), Reisner (2010), Venturi (1977), and Warren and Fethi (1982).

Nevertheless, it is important to understand that the success of the design material was not just in its flexibility to deliver different ornaments, shapes or sizes. It was more about expressing the meaning of transparency with environmental control as an integral part in design, aesthetically and functionally. This issue is explained in the potentials of wood as the material part of nature, particularly, in its woven technique and braided wall strategy based on mimicking nature's strategies of intertwining of tree branches. The same woven strategy is responsible for the manipulation of transparency within control of elegant double sided measures between private and public needs, light and shade. It allowed for design variety in terms of ornament parts which supported manipulation of form and function, shapes and sizes. It also provided for a comfortable, healthy, active environment through the control of light, shade, protect from sun heat and rain while allowing air ventilation through the openings. All of this is in line with Allen and Iano (2011), Almaiyah and Elkadi (2012), Almusaed and Almssad, (2015), Bruckner (2011a), Fathy (1986), Gruber (2011b), Hagan (2001), and Kenzari & Elsheshtawy (2003).

Nevertheless, all of this has changed due to the loss of functional aspects of shanashil which affected the idea of its functional beauty. Such a result is because of the changes associated with modern planning that changed the organic design pattern, narrow

streets and lanes, into a one with wide streets. In this sense, the traditional elements lost their value by losing the environmental control that used to control shade and the amount of heat in hot, arid climates. This is in line with Al-Ahbab (2011), Al-Bayati (2011), Alfetal (2001), Al-Haidary (2008), Al Silq (2011), Fethi and Al-Madfa (1984), Ihsan Fethi (1977), Nouri (2014), and Warren & Fethi (1982). The research author agrees that wood was once flexible and affective in a way that reflected the idea of functional beauty as part of the traditional, irregular pattern. Accordingly, the traditional elements lost its value and by that the identity as a distinctive part of the architectural façade. Therefore, there is a need for a different material that can restore part of the design value in its environmental control to deliver a healthy, active environment.

6.1.3.2 The Sustainability Aspects of Dynamic Transparency

It is fundamental to understand that the integrated relationships between aspects of sustainability that made the traditional shanashil successful and effective as a window/wall/balcony design element. Therefore, there is a need to illustrate and assess the benefits that such relationships in terms of the design material characteristics.

6.1.3.2.1 *Sustainability of social and cultural design aspects*

In relation to social and cultural aspects, 18 of the interviewees favoured traditional material (wood) as part of the identity and a distinctive feature of the design element. However, wood itself is not part of the surrounding environment, because the wood called Saj (teak) that was a distinctive feature of traditional Baghdadi houses was imported from other places throughout the world such as Southeast Asia. This strategy by the builders was necessary at that time to overcome the challenges in the hot, arid climate of Baghdad known for termite attack. The shanashil design allowed neighbours to socialize in the traditional, irregular pattern of streets and helped as a way of communication. Most houses were often of the same height (two storey buildings) to maintain a traditional order protecting the privacy among neighbours and the traditional design element allowed the development of social relations due to its flexibility. It also provided environmental control as in shading to the nearby houses and pedestrians in a way that blended in harmony with the surroundings

(narrow streets and lanes) including local materials and type of climate, as described by Alfetal (2001), Al-Haidary (2008), Al-Khafaji, (2002), Fathy (1986), Fethi and Al-Madfai (1984), Nouri (2014), and Warren and Fethi (1982).

Therefore, there is a need for a different strategy in design that mimics the adaptability in traditional design elements to suit the changes of the pattern context as a whole.

6.1.3.2.2 *Sustainability of environmental aspects*

In relation to environmental sustainability, 17 of the interviewees favoured the use of wood in the contemporary expression of traditional screen pattern, order, texture, colours, and shades. In other words, they favoured a material that mimics the appearance of the traditional screen pattern over the use of glass which is the contemporary one. This is because of the following reasons:

1. Wood as a material is both organic and natural. The material characteristics of wood used to provide strength and flexibility that made it possible to deliver transparency as part of the elegant screen design pattern. This is observed in the traditional design and ornaments in terms of line, circles, curves, and arches that blended in harmony with the surroundings. The design transparency delivered a multifunctional quality due to the characteristics of material, aesthetically and functionally. This is supported by Al-Ahbabi (2010), Al silq (2011), Burger et al. (2012), Fathy (1986), Oliver (1997), Roaf (2014), and Warren and Fethi (1982).

2. Wood was useful and accommodated differing types of climate and termite attack but was also the lightweight. The builders, at that time made full use of it to cover part of the building façades specifically in first floor. The material in closed, extended, wooden balconies situated on the first floor, provided natural air ventilation and better protection from sun heat, glare, rain, in addition to low cost and maintenance issues. It provided shading to pedestrians and the building façades particularly on the ground floor at the same time. This is supported by many authors (Alfetal, 2001; Al-Haidary, 2008; Al-Khafaji & Al-Qaisi, 2012; Fethi & Al-Madfai, 1984; Al-Ahbabi & Neama, 2011; Oliver, 1997; Warren & Fethi, 1982).

3. Reducing the energy consumption because of the use of renewable resources such as wood as a base material in shanashil, which at that time reduced the need for more

than one material. It also reduced the energy consumption through a decreased need of non-renewable energy to produce other materials like baked (fired) brick, since the wood was used in first floors while brick was used in the ground floor. This issue also added at the same time to the economic aspects, again this fact was supported by many authors (Almusaed & Almssad, 2015; Fethi & Al-Madfai, 1984b; Warren & Fethi, 1982).

Accordingly, the material characteristics were considered crucial to the success of the traditional elements and that the flexibility of design is important in delivering a multifunctional quality, aesthetically and functionally.

The replication of traditional elements is now impossible due to the cost, time, and effort. As a result, the adaptability of both old elements and their material are now inadequate in their function. Such design elements are considered pieces of arts or pieces in museums. Thus, there is a need for new material with better adaptable strategies.

Glass, in comparison to wood, adds positively to both the environmental and economic aspects since it is a durable, recyclable material that requires low level of water and generates little waste. The vast majority of glass products are recyclable at the end of their lives. In recent life-cycle studies, it has shown that windows represent a very minor share of a building's environmental impact from the beginning, before and after the design process. This way of design contributes to even lower environmental impact. Glass waste when recycled helps in economising both raw materials and energy in the manufacturing new glass products. More importantly, the transparency of glass in building façades is necessary to enjoy the outside view, supply daylight needs, air ventilation, and to be in touch with the surroundings to ensure a healthy, and active environment. This is consistent with Elkadi (2006), Saint-Gobain Glass (2016), Goncalves and Margarido (2015), Pilkington (2013), Roaf (2014), and Rotherham (2008, 2013).

It is also important to realise that glass is more flexible in its properties since it can be multi-layered. It can also be modified by different treatments such as soft, or hard coatings. However, transparency and clarity are still an issue which are better provided for in soft coatings while hard coatings are more durable. This is supported

by many authors (Chiba, Takahashi, Kageyama, & Oda, 2005; Del Re, Gouttebaron, Dauchot, & Hecq, 2004; Hammarberg & Roos, 2003; Reidinger, Rydzek, Scherdel, Arduini-Schuster, & Manara, 2009).

Other details are needed to obtain and optimize thermal comfort such as building shape, location and orientation of the façade, interior layout, and effect of trees regarding their location, type, size, and shape. This issue is mentioned by many authors (Al-Asad & Musa, 2004; Al-musaed, Almssad, Harith, Nathir, & Ameer, 2007; Mahmoud, 2010; Nouri, 2014).

6.1.3.3 Differences between Dynamic and Static Glazing

18 of the interviewees were sceptical about the role of transparency in the contemporary element including location and type of climate. However, 16 of the interviewees identified the added value of a new modern material to design sustainability regarding environmental aspects when compared to traditional elements wood and static glazing, but 12 of them were sceptical about the economic aspects of the new material. This is because windows in buildings are responsible for a significant proportion of all energy used in buildings, covering both heating and cooling needs in commercial and residential buildings. Recent lifecycle studies (Cetiner & Özkan, 2005; Hassouneh, Alshboul, & Al-Salaymeh, 2010; Roaf, 2014; Sekhar & Lim Cher Toon, 1998; Yaşar & Kalfa, 2012) have shown that design decision regarding the role of windows has a much bigger impact during the use of the building from the beginning of design process to the end of construction phase taking into consideration location and type of climate. Although windows have less impact at the beginning of design process, windows will have a big impact in wasting energy, or requiring more energy to provide thermal comfort if they are badly designed. Accordingly, window design as part of the building skin used to be at a minimum size in order to limit the heat gain or heat loss. Nevertheless, there is the constant demand to develop windows with advanced thermal properties. This is consistent with Roaf (2014), Sanders and Podbelski (2009), and Sassi (2004). Hence, there is a need to avoid design limitations by using a smart material with better adaptable strategies that are not fixed.

The material characteristics suggested in this research are not about using renewable energy or generating energy. The dynamic characteristics are about delivering a sustainable design that is flexible and effective with a minimum of energy consumption regarding lighting energy, and HVAC requirements as in cooling loads. This means that the transparency of the material should be dynamic through an integrated relationship with colour and privacy to enable the balance between the need of daylight, the use of lighting, heat gain, and glare reduction. 19 of the interviewees found it hard to acknowledge the added value of dynamic material characteristics when compared to the static one. Even though 3 of them had used the switchable, reversible glazing properties in their projects, it was still only initiated based on the client's requirements. The dynamic characteristics of the smart glazing can deliver better flexibility with control of the indoor environment and allow change of its transparency state to deliver a multifunctional quality. The focus is on the dynamic state of transparency with colour efficiency and its impact in controlling and delivering more than one option in terms of visible transmittance, solar transmittance, U-Value, and Solar heat gain. The same switchable, reversible properties are within the need for privacy and glare reduction. However, the colouration properties are still new and more future research is needed to provide a greater range of colours and shades to match certain design requirements regarding location, temperature, and type of climate. This is in line with many authors (Niklasson & Granqvist, 2007; Sullivan, Rubin, & Selkowitz, 1997).

All those options mentioned have an integrated relationship with the amount of energy consumption in providing a comfortable environment associated with daylight and energy savings. The impact on design is observed in less consumption of lighting energy, and the HVAC requirements especially the cooling loads. Similarly, the characteristics of smart material and its impact on the environment should not be observed in isolation from other environmental, economic, or social and cultural aspects. However, more research is needed to address the efficiency of smart materials in cold climates. This is consistent with Baetens et al. (2010), Fischer et al. (2004), Jelle et al. (2012), Lampert (1998), Sanders and Podbelski (2009), and Sbar et al. (2012). The use of such smart dynamic window/wall/balcony glazing elements can provide a reduction in the annual energy consumption regarding lighting energy and cooling loads. It also can reduce the material throughput, through the use of one

single material in order to provide more efficiency as well as flexibility with control of smart design elements in the façade. Thus, dynamic transparency is flexible in the design aspects in a way that provides a multifunctional quality.

6.1.3.4 Transparency and the role of active embedded technology

When reviewing the role of technology, 17 of the interviewees found it hard to understand the overall impact of active, embedded technology as part of the smart dynamic glazing in design. Static glazing is limited in that it requires the need for added elements like blinds and shading devices to provide privacy, shade and glare reduction, and whilst people choose glass in buildings in order to enjoy the view, they rarely open their blinds. Furthermore, the use of shading devices whether natural like trees, or internal or external shading devices, add to the cost and maintenance of design and more importantly, durability is not a guarantee in design. This is consistent with Al-musaed et al. (2007), Hee et al. (2015), Sanders and Podbelski (2009), Sanders and Wiedenmaier (2014), Sbar et al. (2012), and The Architects Collaborative (1981), and U.S. Green Building Council (2016).

Chromogenic smart dynamic glazing is more flexible not just in its transparent multi-layered material but also in its switchable, reversible properties associated with transparency state and colouration efficiency. When compared to other types of smart dynamic glazing such as Photovoltaics (PVs) particularly in Building Integrated Photovoltaics (BIPV), there are many limitations regarding the efficiency of the material characteristics such as transparency, colour, and type of climate. A good example is shown regarding dust storms in which dust can affect the efficiency of solar cells. Moreover, although various types of transparent, semi-transparent, and opaque material with a certain number of dark shade colours can be obtained, still transparency affects the efficiency and performance of the solar cell. Further, there are no switchable properties regarding transparency and they are fixed in location because it depends on the amount of solar radiation. This is in line with Polysolar (2014), Sayyah, Horenstein, and Mazumder (2014), Sick, and Erge (1996), Sissakian, Al-Ansari and Knutsson (2013), UNPIO (2013), and Van Berkel et al. (2014).

The same switchable properties affect the factors of solar and visible transmittance, solar heat gain SHGC and UV. All of these factors provide flexibility in controlling

the indoor environment, aesthetically and functionally. This is supported by Baetens et al. (2010), Gillaspie, Tenent, and Dillon (2010), Lampert (2003), Sanders and Podbelski, (2009).

Accordingly, the smart material of dynamic glazing is considered as a useful adaptable strategy in design to match the changes of the surroundings. However, there is a need to understand that the quality of dynamic characteristics in Chromogenic types differ according to several aspects or types. A good example is shown in Electrochromic which provides better flexibility due to its switchable, reversible properties when compared to Photochromic, and Thermochromic. Photochromic although it provides the advantage of controlling the transparency state, the switchable, reversible properties depend on the function of light intensity. There are problems associated with quality regarding clarity and durability, and installation issues due to fixed threshold units. Also, there is no seasonal selectivity to allow solar gain in the winter. As for Thermochromic, this type is based on a function of temperature which also has problems of clarity, clouded appearance, and a fixed threshold unit.

Both types are not able to provide flexibility in the control of material characteristics because they are limited to outdoor weather conditions when compared to the Electrochromic (EC) type. This will affect the design flexibility in façade elements. This is supported by many authors (Ander, 2003; Lampert, 1998; Selkowitz & Lampert, 1989).

There is a necessity to clarify the issue that the selection of dynamic characteristics of smart material with a background of reviving the traditional design element is focused on its multifunctional quality rather than just the aesthetic ones. Nevertheless, the research showed that from aesthetic point of view there is a need for the dynamic characteristics to mimic the traditional elements particularly in the screen pattern. Such material characteristics need to be more flexible to blend in harmony with the surroundings as in the arrangement of design order, colours, and shades. This is important for the design element to match the changes of the surroundings by delivering a multifunctional quality.

The dynamic transparency is expressed in a design pattern that can mimic the elegant order in the traditional design pattern to a certain extent, because the technological role is still in its infancy. Moreover, glass is different to wood and its ability to be woven. However, the smart dynamic glazing properties provide better flexibility with control of its indoor environment. This method of design outweighs the design limitations in its aesthetic aspects by providing better environmental control that matches the changes of the surroundings. This important beneficial point is in delivering a dynamic, elegant, healthy environment when compared to the traditional whether in wood or static glazing.

6.1.3.5 Dynamic Transparency and integration with other materials

18 of the interviewees favoured integration between transparency and other materials like wood. There have been several attempts in integrating materials that share common characteristics to improve design quality such as in EC and BIPV. However, until now integration with a smart material that is transparent, multi-layered, and possessing switchable, reversible properties as one of the main material characteristics in design, is still not successful. This is due to the number of issues that are needed to be addressed, such as durability, and colouration efficiency (Benson, Crandall, Deb, & Stone 1995; Deb et al., 2001; Lampert, 2003). Therefore, the flexibility produced in this type of material is provided by the control of its properties (visible transmittance, solar transmittance, U-Value, and Solar heat gain) associated with transparency and colour.

However, the dynamic characteristics of smart glazing material need to be more flexible in the future to express the aesthetic aspects associated with colour, shade, texture, and ornamental parts to support the sustainability of social and cultural aspects. So that the material can be more in harmony with the surroundings without affecting the design identity and values, aesthetically and functionally.

In conclusion, the role of transparency is an important part of material characteristics needed to deliver aesthetic satisfaction within sustainability of social and cultural aspects whether in a traditional, modern, or a contemporary design element.

6.1.3.6 The Visualization Tools Demonstrating the Dynamic Characteristics

20 out of 21 interviewees supported the use of active embedded technology in the smart dynamic glazing material. Nevertheless, 18 out of 21 interviewees were still sceptical about the role of dynamic transparency even when compared to static one in design due to the fixed image associated with traditional elements shanashil. In addition, due to the newness of dynamic material characteristics and the type of active embedded technology in design, the use of visualisation tools was vital to provide clear illustration of the dynamic characteristics and its impact in design. However, it is important to identify that one single tool was not enough to provide clear illustration for the potentials provided by a smart dynamic glazing element, both aesthetically and functionally.

Accordingly, 18 of the interviewees could not visualise the dynamic characteristics in design without the need of visualisation tools such as Lumion 3D, 3D smart glazing prototype VR, and Revit plugin tool were used to introduce the smart glazing elements attached to a 3D digital building model to increase the visualisation of switchable properties and its added value to design, aesthetically and functionally.

There was a difficulty in visualising the integrated relationships between traditional principles reinforced by identity and cultural values, and the dynamic characteristics of contemporary elements. Thus, it was necessary to involve the interviewees to be part of the design process and therefore be able to understand the impact of smart glazing material. The design needed an accurate perspective with the support of visualisation tools that illustrated the value of switchable properties in a smart window/wall/balcony element. This accords with the work of Coulton and Rasmussen (1977), and Gulling (2008).

As a result, three visualisation tools were utilised in this research study to deliver a better communication mechanism between the researcher and the interviewees. Such tools illustrate the differences between static and dynamic characteristics in a smart contemporary window/wall/balcony design element. The use of these tools gave architects and designers a different approach to configure and visualise the smart dynamic glazing element attached to a 3D digital prototype.

First, the research utilised a video playback demonstration using the Lumion 3D tool with Revit models. However, there is no flexibility to comprehend the added value of the switchable, reversible properties of dynamic smart characteristics in a window/wall/balcony design element. The users have no way to interact with this static video presentation which is a serious limitation (Cardaso, 2015).

Therefore, the second tool involved the application using the Smart glazing VR prototype based on serious game technology concept. This tool provided a better interaction, not only allowing the user to configure the smart glazing property but also in visualising the result in a more realistic lighting and shadow conditions, and an intuitive, natural way to navigate the scene, as mentioned by GAIA (2010), and Mittring (2012).

The third tool concerns the application developed via the Revit plugin approach provides the most common user interface inside the Revit environment. Architects who are familiar with this environment can quickly configure and set the glazing property in the most efficient way, as found by Palsbo & Harty (2013), and Ward (1994).

This fact separates the three tools showing that Lumion 3D is more suitable to observe the aesthetic aspects of the screen design pattern in the external façade. Whilst the smart glazing VR approach is more suitable to the presentation style as it provides interactivity needed to engage the end user to be part of the design process. The Revit Plugin tool is more suitable for engineering applications using a static way of design that illustrate both aesthetic and functional aspects.

Therefore, a single tool is not enough to understand the added value of dynamic material characteristics in design. A combination of visualisation tools is needed in order to illustrate potentials of a smart contemporary window/wall/balcony element that can improve design flexibility by delivering a multifunctional quality, aesthetically and functionally.

Post-Development Stage

6.1.4 OBJECTIVE 4

To assess the relative importance of window/wall/balcony element characteristics in both the traditional form and a contemporary design.

In order to fulfil objective 4, the final version of the smart dynamic window/wall/balcony element was modified in the Post-Development Stage (chapter 5). The research evaluated the smart glazing material in comparison to the traditional in terms of pattern, order and colour by presenting revised visualisation to 6 of the previous interviewees. Specific questions were asked concerning the integrated design relationships of elegance, exuberance, functional beauty and the two sustainability aspects- environmental, and social /cultural to see if the revised design satisfies the design needs, both aesthetically and functionally. The interview also focused on the role of transparency associated with the use of modern technology and smart material in design. The main aim of the questions was to illustrate the impact of change including the advantages and disadvantages of each one.

As a result, the consistency of screen design pattern was achieved to a certain extent according to 5 of the interviewees in Chapter (5) regarding aesthetic satisfaction of screen design pattern, order and colour. This revised design also improves the functional aspects through reviving environmental control to blend in harmony with the sustainability of social and cultural aspects.

Four questions have emerged at the end of the Development Stage (chapter 4), and they are answered in the Post-Development Stage as part of evaluation which was evidenced by the 6 interviews with the aid of visualisation tools in design. These questions are as follows:

- How can the aesthetic aspects of dynamic transparency provide satisfaction among users?

The aesthetic aspects of screen design pattern and order provide satisfaction when they mimic the traditional design element in terms of colours, lines, and arches to blend in harmony with surroundings. This is in order to reflect the design identity and values, socially and culturally. This is achieved in the Post-Development

Stage, the evaluation of a smart contemporary design element (Chapter 5) and is mentioned in Table 6.2.

- How can the sustainability aspects of dynamic transparency in modern material be effective enough to be used in façade design?

The design sustainability is improved through the use of dynamic material characteristics by reviving the environmental control in façade design to provide thermal comfort associated with heat, glare, light, and natural air ventilation. This is achieved in the Post-Development Stage, the evaluation of a smart contemporary design element (Chapter 5) and is mentioned in Table 6.2.

- How can the concept of transparency be understood with the role of active embedded technology?

The implementation of swithable, reversible properties associated with transparency and colour as an integral part of a smart dynamic glazing element in the external façade improves the quality of indoor environment.

This way of design provides better energy efficiency means for the architectural façade to be responsive to the changes of the surroundings through the balance between daylight needs and less energy consumption regarding lighting energy, and HVAC requirements (cooling loads). This is achieved in the Post-Development Stage, the evaluation of a smart contemporary design element (Chapter 5) and is mentioned in Table 6.2.

- How can the role of technological tools enhance the visualisation in the design process of the dynamic characteristics of a smart contemporary window/wall/balcony element in design among the end-users?

The role of advanced technology is important to understand the difference between static glazing and smart dynamic glazing properties in terms of Visible Transmittance (T_{vis}), Solar Transmittance (T_{sol}), Solar Heat Gaining (SHGC), and U-value. This is clearly presented in the use of a combination of three visualisation tools to improve the design interactivity by engaging the architects and designers to realise the impact of dynamic material characteristics and

therefore improve the flexibility of design, both aesthetically and functionally. This is achieved in both the Development Stage (Chapter 4), and Post-Development Stage, the evaluation of a smart contemporary design element (Chapter 5) and is mentioned in Table 6.3.

The issues were presented in Chapter 5 and grouped into five aspects as follows: 1) elegance; 2) Exuberance; 3) Functional Beauty; 4) Two sustainability aspects- environmental, social / cultural. These were illustrated in Table 6.1 page 229 and this is now revisited in The Post-Development Stage of the integrated design relationships in Table 6.2.

Table 6.2 demonstrates the Post-Development Stage of a smart contemporary design element.

Post-Development Stage: Screen design pattern		Traditional window/wall/balcony element (shanashil)	Smart contemporary window/wall/balcony element	conclusion
1)Elegance		✓ Complexity of design in its double sided measures such as: Role of material colour, shades, design order, texture, light and shade.	✓ To a certain extent, elegance aspect is improved regarding design order in lines and arches, and choice of colours (black, white and grey).	<p>The use of smart dynamic glazing material improves design quality, both aesthetically and functionally. This is achieved through:</p> <p>a. the propriety of design order, lines and arches.</p> <p>b. The choice of colours(black, white and grey).</p> <p>However, due to limitations associated with role of transparency, design order, colours and shades, Other screen design pattern issues need to be addressed in the future.</p>
2)Exuberance		✓ Screen design pattern delivered flexibility and beauty between 2D pure form and 3D pure figure.	✓ To a certain extent, the 2D screen design pattern is improved to match the 3D of design element.	
3)Functional Beauty		✓ Combined both aesthetic and functional aspects: propriety of material colour, order, light, shade, air ventilation, privacy and public needs.	✓ To a certain extent, the screen pattern order and colour improve the aesthetic aspects to match the propriety of design, location and type of climate.	
4) Sustainability	a. Environmental aspects	✗ Used to provide environmental control through natural air ventilation, light, shade and glare control.	✓ Revive environmental control by providing thermal comfort through switchable, transparency, colour, and privacy to deliver the balance between daylight needs, lighting	

Post-Development Stage: Screen design pattern		Traditional window/wall/balcony element (shanashil)	Smart contemporary window/wall/balcony element	conclusion
			energy, and cooling loads.	
	b. Social and cultural	✓ Harmony with surrounding, location and type of climate: Role of material, colour, design order, transparency and privacy.	✓ To a certain extent, screen design pattern, order and colour blends in harmony with surroundings to achieve aesthetic satisfaction within sustainability of social and cultural.	

6.1.5 OBJECTIVE 5

To further refine the set of visualisation tools for the window/wall/balcony element to provide designer interactivity.

An innovative design approach has been adapted in both the Development and Post-Development Stage to clearly illustrate the dynamic material characteristics of a smart contemporary window/wall/balcony element using visualisation tools.

In order to ease the visualization of the dynamic material characteristics, a combination of three visualization tools was used to engage the interviewees to be part of design process which can be considered as an innovative contemporary approach in design. 2 architects in the Post-Development Stage provided suggestions as part of the evaluation of a smart contemporary design element for the positioning of the contemporary design elements associated with the role of screen design pattern in the external façade which are as follows:

- The design elements can be applied to a two storey building or multi-storey one and can be used in different types such as residential and office buildings.
- The flexibility of design element and material can provide different sizes between small and large design elements (shanashil).
- Propriety of design order is achieved by mimicking the traditional screen design pattern in terms of lines symmetry, arches repetition, ornament parts, and texture as well as the choice of shades and colours (white, grey, and black).

These suggestions are discussed in Post-Development Stage (Chapter 5) section 5.2 and depicted in Figures 5.9 and 5.10 (p. 222).

The use of the technological tools has potentials to provide better communication and allow interactivity in the design process. They also ease the visualisation of a smart contemporary window/wall/balcony element and help to identify added value to the quality of the design, both aesthetically and functionally in Table 6.3.

Table 6.3 The added value of using the visualisation tools in design.

Visualization tools	Added value in design
Lumion 3D	Observe the aesthetic aspects of smart dynamic material in a smart contemporary design element.
Smart glazing prototype VR	Enable the interactivity for the interviewees to engage and be part of design process.
Revit plugin tool	Enable interviewees to check predefined design parameters and realise the functional aspects.

Accordingly, the research study not only identified the difference between static and dynamic material characteristics and its impact in a smart contemporary window/wall/balcony element from an empirical perspective, but also identified the integrated design relationship between aesthetic and functional aspects.

This is achieved through the use of a combination of three visualization tools that enhance the design interactivity by engaging architects and designers to observe two aspects of the screen design pattern:

- Aesthetic aspects associated with propriety of design order that mimic the traditional design element in terms of lines, arches as well as the choice of colours to blend in harmony with surroundings.
- Functional aspects associated with predefined switchable properties regarding transparency and colour to provide thermal comfort and environmental control in

terms of Visible Transmittance (T_{vis}), Solar Transmittance (T_{sol}), Solar Heat Gain (SHGC), and U-value.

6.1.6 OBJECTIVE 6

To provide recommendations for architects in the implementation of a contemporary smart dynamic material window/wall/balcony design element with consideration of future sustainable development.

From all the previously discussed objectives the researcher is now able to provide a series of conclusions, contribution to knowledge, limitations, and recommendations and these are now given in Chapter 7.

Chapter Seven

7 Conclusions and Recommendations

7.1 CONCLUSIONS OF THE RESEARCH

This research focused on the dynamic material characteristics that can enhance design flexibility to deliver a multifunctional window/wall/balcony design element. This stems from the problem of losing the distinctive features of the shanashil and affecting the identity of the overall design. The contribution of such material's characteristics adds to the design value by delivering aesthetic satisfaction within sustainability of social and cultural aspects. The use of smart dynamic glazing material is an innovative contemporary approach to mimic the flexibility of the traditional characteristics that the screen design pattern of shanashil used to provide by reviving the environmental control, taking into consideration the sustainability of social and cultural aspects. The following key conclusions can be drawn:

1. Concerning the aesthetic aspects:
 - The success of the traditional design element shanashil was not just in the flexibility of its multifunctional window/wall/balcony design material, but also in the control of its use which was responsible for the idea of elegance, exuberance, and functional beauty.
 - Flexibility of a design (element) is not about how large the dimensions are, or in its abstract details, but in its ability to mimic the design context both socially and culturally within an order in terms of colour, texture, lines, and curves.
2. Concerning the functional aspects:
 - Sustainability of design is about the balance between using the minimum of energy resources to achieve maximum performance for creating an efficient, healthy, and active environment.
 - There is a lack of knowledge of the potential in such smart, dynamic transparent, multi-layered material which make its use less favourable or common among architects.

- Transparency is important to implement as part of the new adaptable design strategy in order to deliver environmental control. However, the transparency role is still not accepted in architectural design to replace the perception of traditional material.
3. Through the use of visualisation tools in design:
- The use of visualisation tools provides a clearer understanding of the integrated design relationships between 3D extended window/wall/balcony element and 2D of screen design pattern.
 - The use of a combination of visualization tools enables a better communication among experts, architects and designers to understand the possibilities, and limitations of smart dynamic material to deliver a multifunctional quality, aesthetically and functionally.

By concluding the above, this research has also contributed to knowledge in a number of ways.

7.2 CONTRIBUTION TO KNOWLEDGE

This research has been successful in identifying the characteristics of smart dynamic material inspired from biomimetic strategies and used them to visualise an innovative and contemporary window/wall/balcony element with a multifunctional design quality. Therefore, this research has contributed to the knowledge in the following ways:

1. Concerning the aesthetic aspects of the smart dynamic material:
 - a) Explored how the control of environmental aspects can be revived through the integration of dynamic transparency in a smart material to deliver a contemporary window/wall/balcony design element in hot, arid climates.
 - b) Identified the dynamic characteristics that help for the continuity of traditional design with the identity of the place, socially and culturally.
 - c) The research has raised awareness of the continuity of order, ornament parts, colour and texture when applying modern technology to traditional elements.

2. Concerning the functional aspects of smart dynamic material:
 - a) The existing knowledge to differentiate between dynamic and static material characteristics was lacking and this research has raised a view of such a difference through the application of a smart, transparent, and multi-layered material in a contemporary window/wall/balcony design element.
 - b) The research has determined an added value in dynamic material characteristics over the traditional material through the role of switchable, reversible properties in the smart dynamic glazing that improves the energy efficiency in design.
3. Through the use of the visualization tools in design:
 - a) No single visualization tool is currently capable of providing all aspects needed to demonstrate the dynamic material characteristics of a smart design element, therefore a combination of three different tools is brought together by the researcher.
 - b) The combination of tools provide a better communication medium for experts, architects, and designers to explore the possibilities, as well as the limitations, in the application of a smart dynamic material as an innovative contemporary version of window/wall/balcony element.
 - c) The use of the visualization tools delivers a better understanding of the integrated design relationships between 3D extended window/wall/balcony element and 2D of screen design pattern, both aesthetically and functionally.

7.3 LIMITATION OF THE RESEARCH

The research is focused primarily on the flexibility of using the dynamic characteristics of smart glazing in a window/wall/balcony element in a hot, arid climate. There are a number of limitations in this research that on reflection the researcher acknowledges and are as follows:

- Due to time and practical limitations, the dynamic characteristics could not then be implemented on a live building project. This would have provided further feedback on the material characteristics in terms of colour, texture, and design order in relation to location.

- In terms of aesthetic aspects, the dynamic characteristics associated with transparency and colouration are limited to certain colours and shades, and the smart dynamic glazing visualisation needs to be developed in order to demonstrate more colours, shades, and textures to blend in harmony with differing surroundings. Potentially other properties than those mentioned in this research would emerge if this study has been expanded to cover traditional design elements in other locations and countries.
- The expensiveness of the modern dynamic material hinders its use when suggested as an alternative to traditional material with static glazing. The cost benefit in terms of decreased energy consumption through less use of lighting energy and HVAC specifically (cooling loads) for hot, arid climates was not fully explored.

7.4 FUTURE RESEARCH RECOMMENDATIONS

Whilst this study has provided a contemporary design pattern of smart dynamic characteristics to facilitate the use of a multifunctional window/wall/ balcony element mimicking the traditional material characteristics of shanashil in its appearance and function. The following areas of study would benefit from further research:

1. Development of technological tools to enhance the visualisation of the flexibility in the smart dynamic glazing material.
2. Smart dynamic materials to express a wider range of colours, shades, and textures to blend in harmony with the surroundings in differing locations.
3. Further studies are required on the flexibility of smart dynamic glazing material in differing climatic zones.
4. The recommendations of this study should be implemented on real projects.

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Appendices

Appendix A:

Development Stage: Semi-structured interview guide

PhD study: A Contemporary Design Approach Using Bio-inspired Material

Interview Script

Remember to take the interviewees through the consent form and sign it. Explain that the interview questions will be divided into four (4) parts. The main question of the interview is:

How do the interviewees (architects and designers) choose their material for the facade?

Will they depend on:

a. Aesthetic aspects b. Functional aspects c. both d. others.

Each interview will focus on how do architects choose their material with comparison between the characteristics of traditional and contemporary design elements.

The use of visualisation tools is important to ease the visualisation of the window/wall/balcony design element using a modern material instead of the traditional material. The design tools help to deliver clear understanding of the 3D digital prototype, and communication between the interviewees and the researcher.

Therefore, there will be a demonstration of two models, one with traditional elements and the other with modern material. Three different design tools are used to ease the visualisation of the dynamic characteristics of smart glazing material.

First tool is Lumion 3D: This tool enables the interviewees to observe the switchable, reversible properties of a smart contemporary element associated with transparency and colour when compared to traditional elements. The two models presented are residential buildings demonstrating the typical example of Baghdadi houses with a focus on its distinctive feature called *shanashil*. The first model represents the *shanashil* in its traditional closed wooden window/wall/balcony with

role of change regarding modern planning and the use of cars and parking lots, as shown in Figure (1).



Figure (1) illustrates the window/wall balcony elements shanashil as a distinctive façade feature in modern planning that accommodates the use of cars and wide streets.

The second model will demonstrate the use of smart dynamic glazing material instead of the old material to illustrate their added value to design and restore part of the lost value in traditional element, as shown in Figure (2).

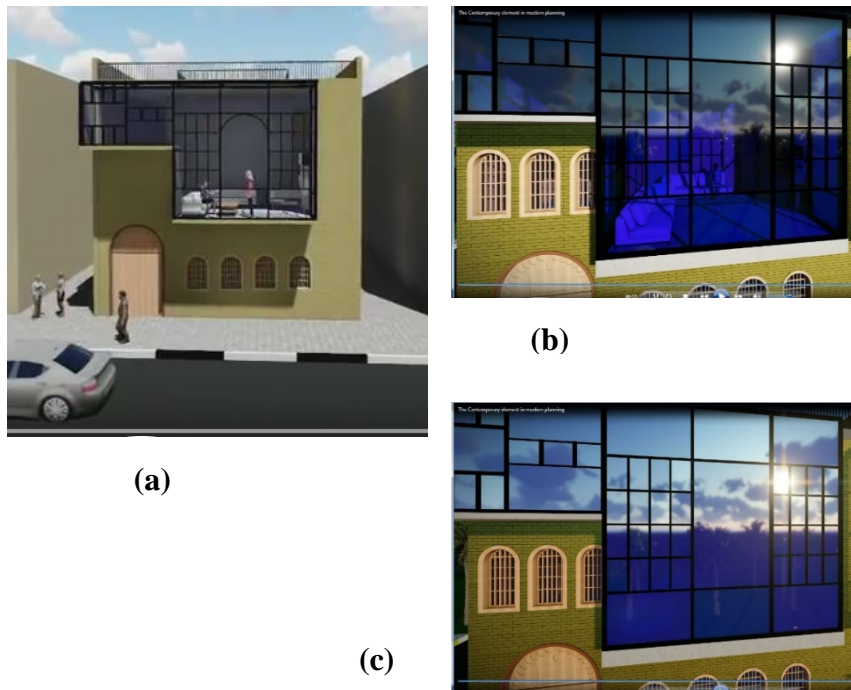


Figure (2) illustrates the use of modern smart dynamic glazing material in the window/wall/balcony elements instead of traditional material wood. It provides three states: (a) is the transparent state, (b) is the semi-transparent state, (c) is the opaque state.

Smart Glazing VR Prototype: This tool is to enable the interviewees to engage and be part of the design process, and in order to understand the impact of switchable transparency, colour, and privacy before and after design process. Figure (3) shows the difference regarding the indoor environment particularly in the effect of light and shade while using this visualisation tool.

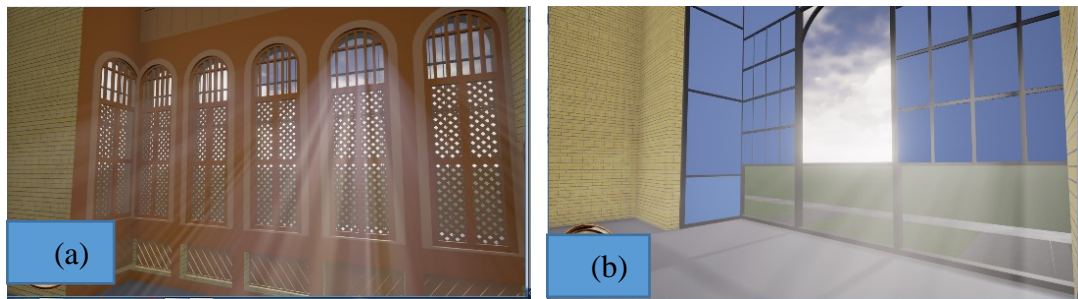


Figure (3) in scenes (a), and (b) illustrates the difference in the manipulation of light and shade aspect between two versions of the two storey buildings` examples using traditional materials in (a). (b) shows the impact of modern material on design quality, aesthetically and functionally.

Revit Plugin tool: This is used to demonstrate the smart contemporary design element using predefined parameters focusing on providing less energy consumption through the integrated relationship between daylight, lighting energy, and cooling load. This is shown in Figure (4).

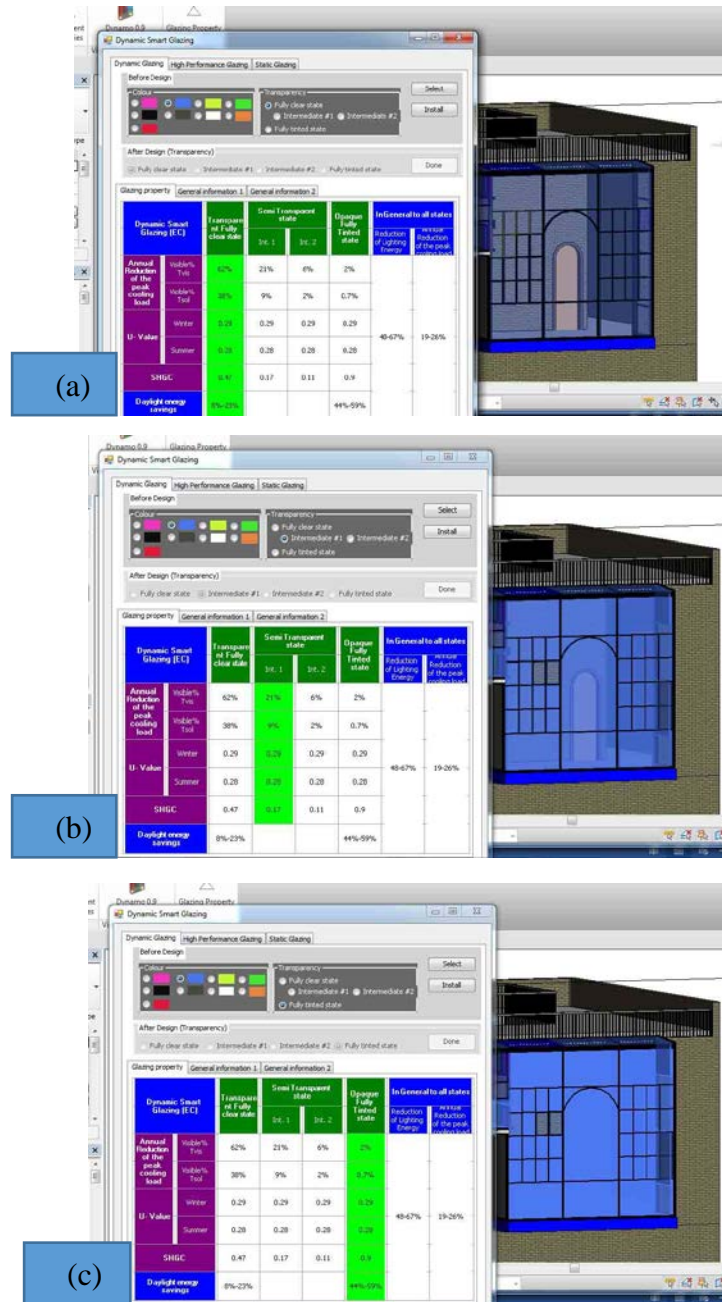


Figure (4) in scenes (a), (b), and (c) illustrates the use of Revit tools and plug in to express the impact of switchable, reversible properties from (transparent state in (a), to semi-transparent in (b), to opaque in (c)).

Moreover, the questions in part 1 will discuss the background of the interviewees focusing on their knowledge and experience in architectural design. The questions in part 2 will discuss the role of traditional elements that used to deliver in design, both aesthetically and functionally. Whilst the questions in part 3 and 4 will discuss the definition, advantages, and disadvantages of the use of the smart material. Further, it

is essential to understand how the interviewees think of using smart dynamic glazing being applied to traditional elements (*shanashil*) as an alternative to old materials.

If there is any repetition within these questions, it is due to the nature of the research subject that interferes with the expertise and the experience of the architects and designers in a way that caters for the part-to-whole relationships of design.

PART ONE (BACKGROUND)

Field of specialty: in general and specifically

Job Title (academic/private):

Years of experience:

Where (Type of organization(s) :

Responsibilities/ Type of expertise:

Type of projects:

- a) Housing, b) Office Buildings, c) Exhibitions, d) Museums, e) Health Facilities, f) Others or all

PART TWO

The second part of the interview script will be discussing the first model. The model illustrates traditional design approach through the use of old materials. It will also discuss the characteristics of the material used within the traditional model, and whether lost value of social and cultural aspects can be restored.

1. What are the distinctive feature(s) of the traditional design element *shanashil* in traditional Baghdadi Buildings?

- Manipulation of privacy needs
- Screen pattern in its ornamentation and manipulation of light and shade
- Type of material like wood
- Colours
- Heat and glare control
- Natural air ventilation
- All of the above
- None of the above

If none of these aspects reflect the distinctive features, do you suggest any other aspects?

2. What quality such feature(s) brings to design?
 - Aesthetic quality
 - Functional quality
 - Both
3. What aspects of elegance do you think the traditional model provides in its illustration of design element *shanashil* ?
 - Multi layered
 - Double sided measures
 - Order
 - Visibility
 - All of the above
 - None of the above

If none of these aspects reflect elegance, do you suggest any other aspects?

4. What exuberance do you think the traditional model provides in terms of form, function, and aesthetics?
 - Manipulation of transparency
 - Manipulation of privacy and public state
 - Manipulation of light and shade
 - All of the above
 - None of the above

If none of these aspects reflect flexibility, do you suggest any other aspects?

5. What functional beauty do you think the traditional model provides through a combined aesthetic and functional design quality?
 - Private and public space
 - Transparency
 - Colours
 - Type of material like wood, and glass.
 - Light and shade
 - Air ventilation
 - Heat and glare control
 - All of the above
 - None of the above

If none of these aspects reflect the idea of functional beauty, do you suggest any other aspects?

6. What aspects of sustainability do you think the traditional model provides to design quality? In what aspect?
- Socially
 - Culturally
 - Environmentally
 - All of the above
 - None of the above

If none of these aspects reflect sustainability, do you suggest any other aspects?

7. Due to several issues, the value of environmental control and thermal comfort in such traditional element is lost. From your perspective, what are the issues that could be the reason behind its absence?
- Modernity
 - Technology
 - All of the above
 - None of the above

If none of these aspects reflect the loss issues, do you suggest any other aspects?

8. How do you think such changes affected the design value of traditional *shanshil*? In terms of material, or others?
9. What are the preferred features or characteristics that is appropriate as a replacement of traditional *shanashil*?
10. What design option(s) you may look for in such replacement features to provide more sustainable approach?

PART THREE

The third part of the interview will be discussing the definition of smart material based on the literature findings of the research subject. It will discuss the awareness of the interviewee of smart dynamic glazing material and if they are willing to use it as an alternative to static glazing and traditional material wood. It will also discuss the reservations of the interviewee regarding the choice of such material.

1. What is the definition of smart material from your own perspective as an architect? And how do you think smart material could be applied in architectural façade?
- For aesthetic use
 - For functional use
 - Or both
2. Would you consider using a (smart) glazing material that provides a multipurpose use (aesthetics and functional) instead of the traditional materials in

shanashil, as explained previously in the 3D prototype? What would be your reservation regarding the choice of such material?

3. Have you used or criticized a smart glazing material or something similar in relation to design issues? Could you give an example of that?
4. Would you think of using smart glazing materials such as smart dynamic glazing products with switchable properties like changing transparency, better environmental control in terms of heat, light, glare and air ventilation, and can replace traditional blinds, as explained previously in the 3D prototype?
5. What would be your reservation regarding the choice of this material?
6. For example, would you consider using smart dynamic glazing like Electrochromic as a smart window/wall/balcony design element instead of traditional materials in *shanashil*, as explained previously in the 3D prototype?

The interviewees to be shown the following:

Smart dynamic glazing Electrochromic EC is a smart multi-layered glass that is different than other types of conventional glazing know as static glazing, as shown in Figures (5), (6).

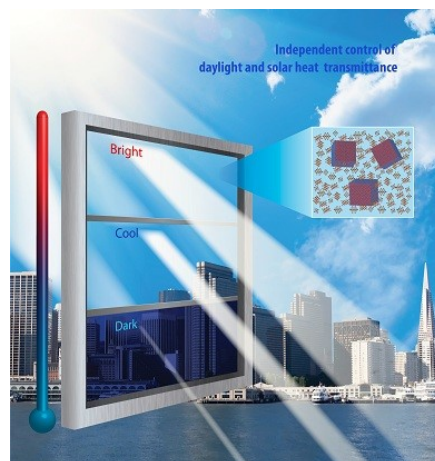


Figure (5) illustrates smart dynamic glazing which is a flexible design element (Sanders and Podbelski, 2009).

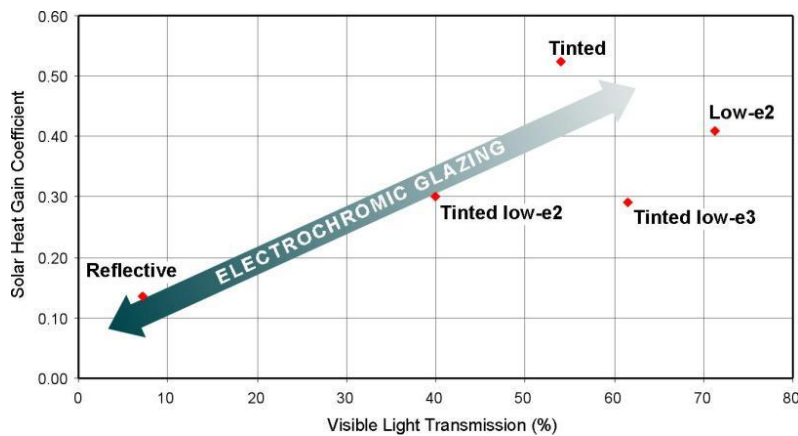


Figure (6) illustrates the dynamic range of an EC glazing in both visible light transmission (T_{vis}) and solar heat gain coefficient compared to some examples of generic static glass options available on the market today. With dynamic glass, designers do not have to make a compromise between SHGC and T_{vis} . With static glass, designers must pick one set of SHGC and T_{vis} properties and then stick with its fixed properties.

It provides and control switchable, reversible transparency state, from transparent to semi-transparent to opaque state through the role of embedded technology between the glass layers, as shown in Figure (7).

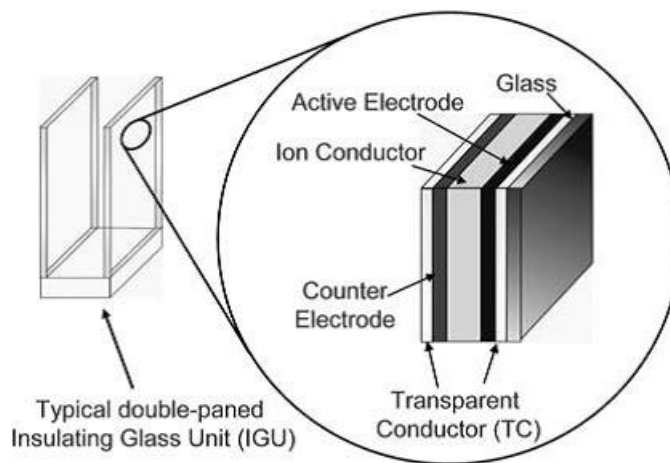


Figure (7) an IGU unit containing dynamic electrochromic layers where the functioning portion of the device is magnified, and the middle layer is the ion conductor or electrolyte, enabling ions to be shuttled between the active and counter electrodes.

The main characteristics of smart dynamic glazing:

- Used as a window, wall, and skylight design element to enjoy more of daylight, deliver air ventilation, and improve the quality of indoor environment.
- Flexible of private and public state due to control of glass transparency with minimum use of electricity.
- No need for blinds due to transparency needs, better healthy option in cleaning with no dirt harbour in comparison to traditional type of blinds and shading devices.
- Flexibility of threshold unit.
- Less in energy consumption due to the control of transparency and colour as well as private and public state that provide at the same time for less energy consumption in terms of lighting, and cooling loads in hot climate, as shown in Figures (8) and Table 1.

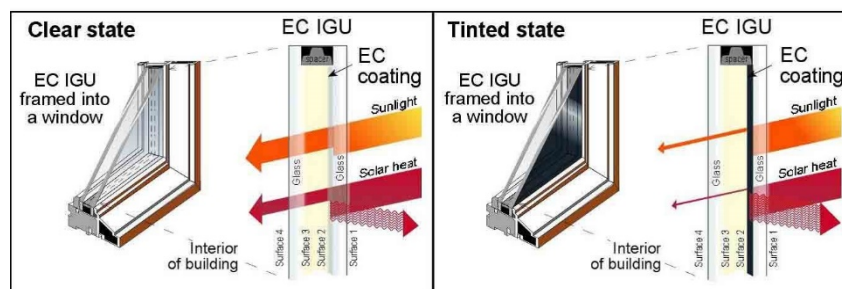


Figure (8) illustrates the switchable properties of dynamic glazing and its control of solar heat gain, visible and solar transmittance through the change of transparency level.

Table 1 illustrates the switchable optical and thermal dynamic properties of SAGE EC glazing product.

Key optical and thermal properties for SAGE EC IGUs.						
Product		Transmittance		U-Factor		SHGC
Level of tint	Inner Lite	Visible (%)	Solar (%)	Winter	Summer	
Clear	6 mm	62	38	0.29	0.28	0.47
Intermed. 1	Clear	21	9	0.29	0.28	0.17
Intermed. 2		6	2	0.29	0.28	0.11
Fully tinted		2	0.7	0.29	0.28	0.09

7. What would be your reservation regarding the choice of this material?
8. Are you familiar with other types of smart materials that are transparent and provide flexibility between transparent, to semi-transparent, to opaque through embedded technology?
9. Would you consider using other types of smart materials?

PART FOUR

This section will demonstrate the second model with a contemporary design approach through the use of two smart dynamic glazing material. In this approach, a 3D model will be presented demonstrating the changes of the design pattern as a whole like in the use of wide streets and cars

1. What aspects of elegance do you think the contemporary model provides in its illustration of *shanashil* using smart dynamic glazing?

- Multi layered
- Transparency
- Order
- Colour
- All of the above
- None of the above

If none of these aspects reflect elegance, do you suggest any other aspects?

2. What exuberance do you think the contemporary model provides in relation to form, function, and aesthetics?

- Manipulation of transparency
- Manipulation of privacy and public state
- Manipulation of light and shade
- All of the above
- None of the above

If none of these aspects reflect flexibility, do you suggest any other aspects?

3. What functional beauty do you think the contemporary model provides through a combined aesthetic and functional design quality?

- Private and public space
- Transparency
- Colours
- Type of material like wood, and glass.
- Light and shade
- Heat and glare control
- Air ventilation
- All of the above
- None of the above

If none of these aspects reflect functional beauty, do you suggest any other aspects?

4. What aspects of sustainability do you think the contemporary model provides to design quality?
- socially
 - culturally
 - environmentally
 - energy efficiency
 - All of the above
 - None of the above

If none of these aspects reflect sustainability, do you suggest any other aspects?

5. So do you agree that smart material would influence the traditional element in a more effective contemporary design approach?
6. Do you think architects are aware of this type of material?
7. What would help in raising the awareness towards using the smart dynamic glazing?

Appendix B: Sample of transcribed interview

Date: 18-9-2015

PhD Study: A Contemporary Design Approach Using Bioinspired Material

Part One: General information:

Field of specialty: Architect

Job Title (academic/private): consultant

Years of experience: 50 years

Where (Type of organization(s): university, governmental, and private practice

Responsibilities/ Type of expertise: Architectural design and urban planning

Type of projects: mixed projects

Part Two: The characteristics of traditional material

1) What are the distinctive feature(s) of the traditional design element *shanashil* in traditional Baghdadi House?

Interviewee: That is a very intricate question and I am not going to be difficult in my response. It is not an easy thing to answer. Speaking of *shanashil*, you cannot make a distinction for one feature over another. Each part of the element completing the other whether as a window or a wall. It provides satisfaction to design in terms of texture, colour, air ventilation, visual and social relations. However, I can say that the screen pattern in the design element is an important part as it is combining all the aspects in one efficient design that satisfy the needs of sustainability environmentally, economically, socially and culturally.

You are talking to someone who used to live in a house which contained these *shanashil*. I used to live in a house with these elements as part of the façade and I use to sit in the *shanashil* closed balcony to enjoy the privacy of its screen pattern while watching people on the street. So I can say all the options including the role of screen pattern. Because the screen reflects relationships of the parts that define the totality of *shanashil* design.

2) What quality such feature(s) brings to design?

Interviewee: the quality of such elements is in its presence as part of traditional architecture and part of vernacular architecture as well. I would say that it is both aesthetic and functional qualities. It is not just the builders who saw a good opportunity in such elements to improve the design options economically including cost and maintenance but also the people who demanded their presence in their houses and other buildings. The design and construction process of such elements used to take a long time to establish such element. It also needs to mention the set of skills and craftsmanship needed to work on that.

3) What aspects of elegance do you think the traditional model provides in its illustration of design element shanashil?

Interviewee: what do you mean about double sided measures?

Researcher: in this research study we define elegance as a double sided measures in a way that collectively caters to part-to-whole design relationships. For instance, *shanahsil* are mainly known for the design elements on the external and internal part of the façade design. In addition, there are many types and sizes of *shanashil* due to its flexibility in design. For instance, the interior façade is called *Kabishkan* which is a name usually known for small *shanashil* on the external façade. All these elements are part of traditional Baghdadi houses that used to have a courtyard were all rooms have openings on that court since the number of exterior façade and windows is limited.

Interviewee: I understand now. My answer to this question will include all the aspects mentioned. The *shanashil* are not just useful and elegant to the occupants alone in providing a comfortable space shielded from the outside environment like heat, rain, or noise but also it is in providing shades for pedestrians on the streets at the same time. This way of design delivers an elegant effect to design that adds to a friendly environment not just to individuals but to the community as a whole. The extended *shanashil* provides special correction for the outlines of the house plan. The old irregular pattern is usually known for its irregular land shapes and street. So the builder at that time designed a type of *shanashil* called angled *shanashil* to give special correction to the plan and by that he is correcting the façade at the same time.

4) What exuberance do you think the traditional model provides in terms of form, function, and aesthetics?

Interviewee: I choose all the options which are the manipulation of transparency, privacy, and light.

Researcher: do you suggest any other aspects?

Interviewee: no but you have to pay attention that wood as a material was familiar to builders for so long and more likely to be the first choice in every house at that time due to its light weight. Houses were relatively small and surrounded by others this meant less options in facades` numbers. So the extended closed balcony using the wood was an ultimate solution at that time. Other flexible properties as a natural organic material with the flexibility to produce certain shapes and sizes not just in exteriors but also in the interiors like in furniture. There used to be quite a number of skilled carpenters and builders who know how to use such material to present such beautiful elegant parts".

5) What functional beauty do you think the traditional model provides through a combined aesthetic and functional design quality?

Interviewee: I choose all the options again. The shanashil is made of wood basically for its lightweight in comparison to other materials like brick. This material in particular allowed for an extension of first floor and by that increased the house area which was relatively small. It is surrounded by other houses giving less options in facade numbers. As I mentioned previously, the extension by wood was an ultimate solution at that time with the flexibility to produce variety of design options not just in exteriors but also in the interiors".

6) What aspects of sustainability do you think the traditional model provides to design quality? In what aspect?

Interviewee: I must say that it is the environmental aspects. But you have to be quite careful here because you cannot separate the economic aspects. This is because of the role of the material, craftsmanship, and skills needed for maintenance. All of these are an important part for the design to be efficient and sustain its quality. As for environmental aspects, the location and type of climate is very important to consider. Both of those affected the choice of material in a way that delivered harmony with

the surroundings affecting the identity outlines of social and cultural aspects in terms of colour, texture, and type of material. The environmental aspect also affected the sustainability of economic aspects specifically in the type of material suited for the environment and type of craftsmanship that dealt with its production, cost, and maintenance.

7) Due to several issues, the value of such traditional element is lost. From your perspective, what are the issues that could be the reason behind its absence?

Interviewee: I do agree with the two options that are modernity and technology changes particularly modern changes. However, I must explain to you that it is not modernity. You should be more specific to note that it is the modern planning which is the reason behind the disappearance of such distinctive part of the identity and values in design. The modern villa house design replaced the old traditional one. This modern type in particular is made to accommodate the use of cars. In this way, the change of transportation means affected the design pattern as whole. So the traditional organic pattern is no more useful to convey people's lifestyle, and services.

8) How do you think such changes affected the design value of traditional *shanshil*? In terms of material, or others?

Interviewee: it is certainly a dramatic change in which the narrow streets and lanes are not satisfying anymore the cars' needs and requirements. The introverted design with narrow streets to suit pedestrians and packing animals is changed into an extroverted one with wide streets which was part of design order at that time. Now, cars and parking lots are important to match the society and family demands. The shanshil as an end result of such changes have lost its value because they used to work as part of the narrow streets and compact houses and layouts. This way of traditional design provided protection from heat to these elements that enabled them to provide more than one function including the aesthetic aspects. The functional aspects are mostly related to the environmental control to deliver a healthy, active environment.

9) What are the preferred features or characteristics that is appropriate as a replacement of traditional *shanashil*?

Interviewee: as I mentioned in the first question. It is the design of the screen pattern that made it distinctive than any other elements not just in Iraq but in other countries like Egypt and Morocco. So a replacement that can deliver the same qualities specifically the functional ones is preferred. Although the shanashil as an element is based on passive technology. Modern technology is important to consider as an option to improve the design features to suit the changes in design.

10) What design option(s) you may look for in such replacement features to provide more sustainable approach?

Interviewee: I would mention that the most important aspect is the ability to provide a comfortable space that is controlled in terms of light and heat. The one that was provided by traditional design and material is certainly not an effective quality at least from a functional point of view. Maybe in the type of material with the advanced technology such design option can improve the performance and efficiency of the design element.

Part Three: The definition and use of smart material in design

1) What is the definition of smart material from your own perspective as an architect? And how do you think smart material could be applied in architectural façade?

Interviewee: smart material is a material that provides climate and social solutions without the excessive or direct need of human intervention such as controlling the amount of heat and daylight. I also understand that the role of technology is inevitable to use in design. Any architect should always pay attention to development or sometimes the change in industrial products concerning building construction material and its effect on the design ideas and elements.

2) Would you consider using a (smart) material that provides a multipurpose use (aesthetics and functional) instead of the traditional materials in

***shanashil?* What would be your reservation regarding the choice of such material, as explained previously in the 3D prototypes?**

Interviewee: whether it is a smart material or any other material, I think the design sustainability as an idea and practice has integrated in all parts of the element. The environmental and economic aspect should be expressed in unity. The unity is not complete unless it takes into consideration the role of social and cultural aspects. These aspects provide the identity of the place which is closely related to location and type of climate.

3) Have you used or criticized a smart glazing material or something similar in relation to design issues? Could you give an example of that?

Interviewee: I can mention the PVs as a material that is known for being one of smart glazing types. This material in particular is highly recommended around the world for its part in producing energy from a renewable resource that is sunlight. The ability to make use of such material is intriguing to end-users including governments. As we all know, sunlight is abundantly available everywhere and it is remarkable because it is renewable which means less in pollution rates and adds to energy efficiency by making use of renewable energy on site. However, architects and designers should be careful when choosing such material as it is with any other material. From my experience as an architect and consultant in various projects mostly in Middle East, the use of modern technology regarding smart dynamic glazing like in Photovoltaics is more preferred on the roof of houses for better solar radiation amount. It will definitely improve sustainability of environment as in using renewable energy instead of non-renewable energy such as fossil fuel. This way of design will reduce the pollution, noise, and the cost of energy bills. However, the quality and efficiency of solar cell is a critical aspect in design that may not be suited to any location and type of climate. If a comparison is made between two countries, i.e. Iraq and another one like Abu Dhabi, both in the Middle East, one can find that the hot, arid climate as in Baghdad, Iraq is known for the dusty storms that affect the quality and performance of Photovoltaics solar cells. The dusty storms that occur in the Baghdad climate also adds to the cost and maintenance. In Abu Dhabi, the weather is also hot and, arid but known for its sand storms that have less effect on the performance of solar cells in comparison to the dusty storms of Baghdad. So **even** if the use of smart transparency

is integrated with better energy efficiency aspects, the Photovoltaics is still restricted in its efficiency and suitability to deliver the design needs.

Researcher: the material characteristics described in the 3D models are demonstrated in a material that is multi-layered with switchable, reversible transparency. Such transparency is controlled based on occupants needs whether manually or computer programming while in photovoltaics transparency is a constant with no ability to control the private or even daylight needs. As you mentioned still the better use is on the roof for the role of solar radiation.

Interviewee: Even if you are describing a different type with different characteristics that are more flexible to the use as window/wall/balcony element, still the role location and type of climate, and orientation are important to consider.

4) Would you think of using smart materials such as smart dynamic glazing products with switchable properties like changing transparency state and colour which can replace traditional blinds, as explained previously in the 3D prototypes?

Interviewee: Yes, I would suggest the use of such material if its properties are useful to improve design quality and environmental sustainability. Most importantly, if it is efficient and cost affective to suit design requirements regarding location and climatic requirements.

5) What would be your reservation regarding the choice of this material?

Interviewee: as I mentioned previously, the role of location, type of climate, cost and maintenance issues are very important to consider when to choose a material to be part of the design in the architectural façade.

6) Would you consider using smart dynamic glazing like glass as a smart window, wall design element instead of traditional materials in *shanashil*, as explained previously in the 3D prototype?

Interviewee: Yes, I would consider the use of smart material like dynamic glazing material. However, it is the same as I mentioned in the previous question. I understand that any design is not accepted unless it blends in unity with the surroundings.

7) These are some of the Figures to illustrate a type of smart dynamic glazing called Electrochromic as part of research approach and resources. What would be your reservation regarding the choice of this material?

I can see from Figures, Tables, and the 3D models that this material is flexible in the way that allows for more balance of daylight in addition to solar heat gain, solar and visible transmittance factors. However, I would like to ask a question that is crucial to quality of design. Are these materials suitable for hot, arid climate?

Researcher: from literature and available resources, this material is better used in hot climate. Its performance needs more research to be addressed enough regarding cold climate.

Interviewee: I have to ask you about the design quality of this type of smart dynamic windows. I have used many glazing types from early, as you may call, from single to advanced types of glazing. Is dynamic glazing in Electrochromic easy when opening the window or is it fixed? Because if it is fixed that would affect the air ventilation quality which is important to maintain fresh air for a healthy active environment.

Researcher: From the examples that discuss and illustrate that various applications of this dynamic type of smart glazing, it can be used in revolving doors and as a multipurpose window wall design element. Further, in no case did the maximum tensile stresses exceed the tensile strength of the glass material. Such windows prevent overheating of rooms during intense sunshine and therefore is better suited for hot climate. Moreover, protection against glare and harmful radiation are considered additional advantages. However, there is still a need for more effort to be made to improve durability and better transmittance ranges.

Interviewee: the reason I ask is in some types of smart glazing like in Photovoltaics are fixed to maintain it's the quality of its performance and absorb solar radiation.

Researcher: another advantage is that this type of smart glazing, the EC in particular has flexible threshold unit and it can be retrofit to old buildings while the use of PVs is still not flexible.

Interviewee: I understand but still the smart dynamic glazing needs to be used in real projects to check its performance regarding location and type of climate.

Researcher: this type of material in particular is flexible to include different layers and coatings like soft and hard coatings. It is produced only as double or triple glazing.

So single glazing is not an option in this type. Moreover, it is known for its performance in hot climate but still there is a need for more research that concerns its performance and efficiency in cold climate.

8) Are you familiar with other types of smart materials that are transparent and provide flexibility between transparent, to semi-transparent, to opaque through embedded technology?

Interviewee: No I am not.

9) Would you consider using other types of smart materials?

Interviewee: I do not mind using other types of smart materials including the dynamic glazing as long as it serves the design needs and match design requirements for location and type of climate.

Part Four: The dynamic characteristics of Smart glazing elements

1) What aspects of elegance do you think the contemporary model provides in its illustration of *shanashil* using smart dynamic glazing? If none of these aspects reflect elegance, do you suggest any other aspects?

Interviewee: I am trying to look at the features and order that used to define the design of screen pattern but the design is more into abstract lines and arches.

Researcher: in this contemporary design approach, the design pattern is not copying what old materials used to provide in terms of lines, curves and ornaments part. As you can see, the design is using smart dynamic glazing. So do you have a suggestion to express that in the design taking into consideration the use of glass as the main material in design?

Interviewee: if you can inspire from the traditional order, proportion, and lines in a way that expresses part of the traditional screen design pattern such as the order of vertical and horizontal parts, the symmetry of small arches, it will be more appropriate to reflect the essence of Bagahdadi buildings. At least the proportion of design parts if you can reflect it will give better unity and harmony of place identity and order. There is always an order that is related to the identity of place and time. Such order is important to be reflected even if it is in an abstract or a contemporary design approach using modern material like smart dynamic glazing.

Researcher: So do you suggest any other aspects?

Interviewee: I find the design attempt regarding transparency and colour in this design is limited. This is because of the relationship between them is to deliver privacy and environmental control. However, although I am not against the use of different colours like blue or green, I have to mention that the use of coloured glazing like blue and green in upper windows was meant to provide shade and less intensity of glare in order to have a comfortable indoor environment. Hence, if you look closely to the use of the colour in the traditional elements, you can see that it is more into the dark shades. This design choice is for a reason so it will blend in harmony with the surrounds and by that I mean the other materials like brick and wood including location and type of climate. The integrated relationship between daylight, glass colour, and indoor environment is considered so when the sunlight falls into the room through the dark shade glass, the light intensity, heat, and glare are reduced.

Researcher: in this research study, we are focusing on the meaning of transparency and how such meaning was to provide a multifunctional quality, aesthetically and functionally.

2) What exuberance do you think the contemporary model provides in relation to form, function, and aesthetics? If none of these aspects reflect flexibility, do you suggest any other aspects?

Interviewee: I choose the manipulation of transparency which also serves positively both privacy and daylight because both are important from a social and environmental point of view. From this perspective, the transparency is useful because it can be controlled depending on occupants' wishes and lifestyle needs.

Researcher: do you suggest any other aspects?

Interviewee: no but again I would prefer an integration between glass and other materials like wood. Could you use such type of glass with wood at least with wooden frames?

Researcher: regarding the integration issue, I need to explain that in this research study, this smart type of dynamic glazing is known for its flexible threshold unit and it can be retrofit to old buildings. As for the integration with other materials, there is a range of colours like black grey The essence of design quality is in the switchable properties in which transparency, clarity, and colours of design pattern, layers and parts are very important, thus, any integration with any material should share

compatible characteristics with other materials for the integration to be complete, aesthetically and functionally. There are attempts for integration of the EC material with PVs to improve durability and because they share compatible characteristics. Nevertheless, more research is still needed to overcome technical barriers that are crucial for the success of the design element.

3) What functional beauty do you think the contemporary model provides through a combined aesthetic and functional design quality? If none of these aspects reflect functional beauty, do you suggest any other aspects?

Interviewee: I am not talking about the technique that once created the *shanashil*. I am focusing on the design details that are part of any element such as the frieze, body, base and corbels including the screen pattern. These parts are important to consider the whole parts of that create the whole as part of the architectural façade.

4) What aspects of sustainability do you think the contemporary model provides to design quality? If none of these aspects reflect sustainability, do you suggest any other aspects?

Interviewee: I choose the sustainability of environmental aspects because there is more control of indoor environment regarding transparency role in design and its relationship with mentioned factors of solar heat gain, visible and solar transmittance. However, I am not sure about economic or social and cultural aspects. There are important issues to be considered when designing with new material and modern technology regarding durability, maintenance and cost issues. In addition, there are other critical issues associated with design suitability such as location, orientation, and type of climate.

5) So do you agree that smart material would influence the traditional element in a more efficient and effective contemporary design approach?

Interviewee: Yes I agree particularly in terms of environmental sustainability and role of switchable transparency in design. But I must mention that the 3D model seems limited in the way it captures the design element. As I can see you have displayed only one type of buildings which are the two storey house, why is that?

Researcher: the 3D model present the typical example of Baghdadi buildings which is the two storey house. I am focusing on the role of the design element particularly

in the type of smart dynamic glazing called Chromogenic. The dynamic characteristic of this material are important to improve flexibility within control of a range of certain properties like in the solar heat gain, visible and solar transmittance, and U-Value. These switchable, reversible properties have integrated relationships with transparency and colour to deliver better energy savings and consumptions through its impact on daylight and cooling loads for hot climate. This way adds to the design quality particularly in energy efficiency. The same flexibility delivers a multifunctional quality, aesthetically and functionally. The 3D contemporary model presents.

Interviewee: this element in particular has played an important part in the work of many architects that incorporate their inspiration in various types of building such as multi-storey buildings like in residential and governmental ones. You mention that such material is different than other types of smart dynamic glazing, I still have concerns regarding technical barriers and cost issues. The issues also include the suitability of such material to location and climatic requirements in hot arid climate like in Baghdad.

6) Do you think architects are aware of this type of material?

Interviewee: no I do not think the awareness is enough even with the role of advanced technology. Some architects may know about smart material but not in particular with smart glazing. This is because you are talking about a different type of technology that is new to the field. It still needs more research about the role of such material with the embedded technology in the market particularly in the application of architectural design.

7) What would help in raising the awareness towards using the smart dynamic glazing?

Interviewee: From my experience working in ministries and governments, I suggest cooperation is important between ministries, and governmental institutes like municipalities. More conferences and exhibitions regarding the subject of smart glazing in dynamic design will raising the awareness in this growing field of window design. The media or let us say visual media needs to play a role in educating architects and designers with a hint to its rewarding potentials regarding economics that means less time, effort, and energy consumption to the design and construction

process when compared to traditional materials in the long run. I would also suggest more workshops, sessions and lectures. Raising awareness should include students, lecturers, and architects in order to be familiar with needs to develop such smart glazing and understand its potentials to suit certain design needs and requirements regarding location and type of climate. I would concentrate on issues like durability specifically with the effect of the hot, arid climate as well as cost and maintenance issues are important to address.

Appendix C: Post-Development

Evaluation Of The Form

Background

The need to understand the essence of traditional design elements (*shanashil*) is fundamental to identify the main characteristic of traditional materials which once were behind the success of such elements. This issue is important for the revival of traditional architectural elements to be successful in design, aesthetically and functionally. This claim is achieved by the replacement of new available advanced material which have the ability of environmental control (energy efficiency by less consumption of lighting energy and cooling loads) within an order that blends in harmony with surroundings.

Accordingly, the research study demonstrates one of the possibilities for the reuse of traditional architectural elements using smart dynamic glazing material to deliver a multifunctional quality for different building types. In this sense, the research study starts with the most typical example of traditional buildings which is the Baghdadi houses, as shown in Figure (a). Then the next model expand it to a new building facades of a multi storey buildings, for instance, office building, or governmental, as shown in Figure (b). Moreover, the design order as well as the colours used in the design element are the most neutral and most possible for the building façade to blend in harmony with surroundings regarding location and type of climate.

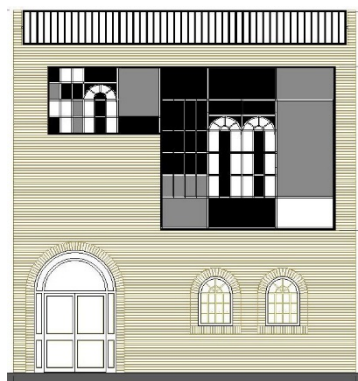


Figure (a) illustrates the use of the smart window, wall design element to deliver a multifunctional quality in a Baghdadi façade's house.



Figure (b) illustrates the use of the smart window, wall design element to deliver a multifunctional quality in a multi-storey façade's building.

Q1: In the above models, a contemporary design approach is achieved. Which of the following aspects reflect the elegance that once existed in the traditional elements (*shanashil*), as explained previously in the 3D prototypes?

- Multi-layered
- Double sided measures
- Order
- Visibility
- Colour
- All of the above
- None of the above

If none of these aspects reflect elegance, do you suggest any other aspects?

Q2: Do the above models reflect exuberance which once existed in the traditional design elements (*shanashil*)? If the answer is yes, which of the following aspects reflect that, as explained previously in the 3D prototypes?

- Manipulation of transparency
- Manipulation of privacy and public state
- Manipulation of light and shade
- All of the above
- None of the above

If none of these aspects reflect flexibility, do you suggest any other aspects?

Q3: From your perspective, do you think this contemporary model represents functional beauty through a combined aesthetic and functional design quality? If the answer is yes, which of the following aspects reflect that?

- Private and public space
- Transparency
- Colours
- Type of material (smart dynamic glazing)
- Light and shade
- Air ventilation
- Heat and glare control
-
- All of the above
- None of the above

If none of these aspects reflect functional beauty, do you suggest any other aspects?

Q4: From your perspective, do you think this model represents a contemporary design approach of the traditional design element (*shanashil*) regarding sustainability aspects? If the answer is yes, which of the following aspects reflect that?

- Environmental
- economic
- Social and cultural
- All of the above
- None of the above

If none of these aspects reflect sustainability, do you suggest any other aspects?

Q5: Would you describe the above models as being useful and clear for the architectural design academics and practitioners (architects and designers) to assist them in visualizing an efficient and more flexible design element, aesthetically and functionally? If not, would you please suggest any improvements of the design?

- Aesthetic aspects
- Functional aspects
- both

Q6: Any final comments or suggestions?

Appendix D: Example Of The Interviewees` Comments

Part One: General information:

Field of specialty: Architect

Job Title (academic/private): Professor

Years of experience: 35 years

Where (Type of organization(s): University

Responsibilities/ Type of expertise: Professor, Consultant

Type of projects: mixed projects

Part Two: The dynamic characteristics of Smart glazing elements

Q1: In the above models, a contemporary design approach is achieved. Which of the following aspects reflect the elegance that once existed in the traditional elements (*shanashil*)? If none of these aspects reflect elegance, do you suggest any other aspects?

Interviewee: I can say Elegance of design is seen in the multi-layered aspect within the order, and proportion that mimic the essence of traditional design. It is more than one idea, or layer of delivering the design element like the way of treating them in a multi-storey building. It is also taking the role of colour and transparency as an essential part of screen design pattern. I would note that the colours used to express the screen pattern are elegant regarding black, white, and grey. The traditional elements used to be more neutral in its colours and shades to the materials and environment. This way of design reflects the identity of design and values blending in harmony with the surroundings. The colours are chosen to suit the type of climate mostly known for its dusty weather as well as the community traditions.

Researcher: do you suggest any other aspects?

Interviewee: No but I would prefer more colours and shades that reflect the ones seen in the traditional material such as wood and local materials such as brick.

Q2: Do the above models reflect the flexibility which once existed in the traditional design elements (*shanashil*)? If the answer is yes, which of the following aspects reflect that?

Interviewee: flexibility is seen to a certain degree like the integrated design relationship between colours, light and shade, within the role of transparency while maintaining privacy. The meaning of transparency is important to understand not just with its close relationship with privacy but also to deliver a health environment through the option of enjoying the daylight with the ability of reducing glare. Such quality is important to be delivered in various building types not just in houses but also multi-storey buildings like in residential and commercial buildings.

Q3: From your perspective, do you think this contemporary model represents functional beauty through a combined aesthetic and functional design quality? If the answer is yes, which of the following aspects reflect that?

Interviewee: functional beauty is in the role of maintaining private and public needs for the success of traditional window/wall/balcony design element in the facade. Such beauty is at the same time integrated to the function of the design façade not to its aesthetic one. The flexibility within control of environmental aspects is improving the design quality, aesthetically and functionally.

Q4: From your perspective, do you think this model represents a contemporary design approach of the traditional design element (*shanashil*) regarding sustainability aspects? If the answer is yes, which of the following aspects reflect that?

If none of these aspects reflect sustainability, do you suggest any other aspects?

Interviewee: Sustainability of design is demonstrated to a certain limit in the social and cultural aspects regarding order, colour, and privacy including environmental aspects.

Q5: Would you describe the above models as being useful and clear for the architectural design academics and practitioners (architects and designers) to assist them in visualizing an efficient and more flexible design element, aesthetically and functionally? If not, would you please suggest any improvements of the design?

Interviewee: I would suggest more development to be carried out on flexibility of dynamic characteristics of material to widen its potentials in heritage and cultural identity. Also providing better energy efficiency, less cost, and more options for colours and order (lines, curves, circles, and ornament parts for the design) is needed

to blend in harmony with the surroundings regarding location, type of climate, and maintain continuity of architectural traditions.

Q6: Any final comments or suggestions?

Interviewee: cost may be one of the obstacles for using these smart materials with modern technology. Workmanship and possibility of mass production will be another item to be discussed. All of this may cause limitation to use of such elements with the design diversity (shapes and sizes) proposals. Also individual production will limit the use of these elements. I would say that other problems like insufficient building regulations regarding land use, aesthetic, and environmental aspects. Also the lack of criteria for glass widows and façade design criteria are other deficiencies. What is available is the work of individual and academic research in this field such as the regulations of availability of land, facades, floor-area ratio (FAR).

Appendix F: List of PUBLICATIONS

- T. Alqalami: Bio-inspired Design Material: A Multipurpose Case Study, 12th International Post-Graduate Research Conference, University of Salford, UK, June, 2015.
- T. Alqalami: Bio-Inspired Design Material: A Multipurpose Case Study, Building Information Modelling BIM 2015 conference of Wessex Institute of Technology, Witpress , University of the West of England, Bristol, UK, 11th, Sept. 2015, pp. 567-577.