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Application of the Choosing by Advantages Decision System to Enhance User-Involvement in the Design Process

by

Zoya Evans Kpamma

(B.Sc., PG. Dip. Architecture; M.Sc. Construction Management)

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DOCTOR OF PHILOSOPHY

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DECLARATION

I hereby declare that this submission is my own work towards the award of a PhD. Construction Management and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Kpamma, Evans Zoya (ID: 20287734)

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Signature

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Date

Certified by:

Dr. Theophilus Adjei-Kumi (Supervisor)

………………………
Signature

………………………..
Date

Prof. Joshua Ayarkwa (Supervisor)

………………………
Signature

………………………..
Date

Certified by:

Dr. Theophilus Adjei-Kumi (Head of Department)

………………………
Signature

………………………..
Date

ABSTRACT

Activities at the design stage of the construction project delivery process have been found to significantly impact value generation and delivery. There is, thus, the need to adopt design management practices to enhance the value of construction projects. One dimension of meeting the value requirements of construction projects is the involvement of stakeholders, such as users, in design process. Even though various aspects of stakeholder involvement have been researched, limited knowledge exists on how stakeholders can participate in a process to gain insights into their needs and establish their values. Little is also known of how the involvement of stakeholders can be staged, such that project participants can interact and discuss needs and concerns. This results in the need to explore an innovative strategy, in the form of a userinvolvement framework, to create a space where designers and other stakeholders, such as users, can collaboratively define and generate project value. Since the design process is punctuated by various instances of decisions, such a framework should incorporate a group decision-making process, such as choosing by advantages (CBA). The aim of this research addresses this need by ultimately proposing a user-involvement framework that incorporates the CBA decision system. The objectives of the research, thus, included: to identify the potential in CBA to foster collaboration between designers and users; to identify strategies to incorporate CBA in a user-involvement framework; to design a user-involvement framework incorporating CBA; to evaluate the practicality of the framework; and to reflect the contribution of the framework to theory. In line with the constructive research paradigm, the design of the framework was based on a combination of theoretical and empirical knowledge. Theoretical knowledge originated from reviewing literature on participatory design, lean design, design process management, team process, and the CBA decision system. Empirical knowledge emanated from three exploratory case studies involving the application of CBA by respective design teams to involve users in typical design decisions for some selected projects. The resulting framework, known as CBA-incorporated User-involvement Framework (CBAUF), is made up of six performance episodes linked by reciprocal dependency loops. The performance episodes include, i) compose a team; ii) define project value; iii) identify and anticipate decision-making frames; iv) enforce decisionmaking frames (apply CBA); v) implement decisions (deliver virtual value); and vi) run product (experience virtual value). The workability of CBAUF was demonstrated in an evaluation case study with respect to its completeness, simplicity, elegance, efficiency, operationality and generality. Among others, the research contributes to knowledge by providing: i) an empirical evaluation of the collaborative attributes of the CBA decision system; ii) an analysis of the functioning of the CBA decision system in the context of the wicked problems in participatory design; and iii) An insight into how CBA could be combined with other lean design tools such as Target Value Design (TVD), Set Based Design (SBD), A3 and Building Information Modeling (BIM) to enhance collaboration between designers and users for project value

generation. Based on the contributions to knowledge, the discussion on the application of CBA in lean design can be expanded to include exploring the integration of CBAUF with more lean tools such as the Last Planner System (LPS) and Dependency Structure Matrix (DSM) towards waste minimization in design process by improving design process schedule predictability.

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LIST OF ABBREVIATIONS

AfDB	African Development Bank
ADepT	Analytical Design Planning Technique
Adv.	Advantage
AEC	Architecture, Engineering and Construction
AHP	Analytical Hierarchy Process
AS	Abstract Space
ASCE	American Society of Civil Engineers
BIM	Building Information Modeling
CBA	Choosing By Advantages
CBAUF	CBA-incorporated User-involvement Framework
CIB	International Council for Research and Innovation in Building and Construction
CS	Concrete Space
DMI	Design Management Institute
DSIP	Development of Skills for Industry Project
DSM	Dependency Structure Matrix
DSR	Design Science Research
FAST	Functional Analysis System Technique
FPS	Functional Performance Specification
GDS	Group Decision Support
GETFUND	Ghana Education Trust Fund
GOG	Government of Government
HVAC	Heating, Ventilating, and Air Conditioning
ICIDA	International Conference on Infrastructural Development in Africa
IGF	Internally Generated Funds
IGLC	International Group for Lean Construction

IMOI	Input-Mediator-Output-Input
Imp.	Importance
I-P-O	Input – Process – Output
IoA	Importance of Advantages
ISO	International Standards Organization
LPDS	Lean Project Delivery System
LPS	Last Planner System
MCDA	Multi-Criteria Decision Analysis
PDCA	Plan-Do-Check-Act
POP	Plaster of Paris
QFD	Quality Function Deployment
SBD	Set Based Design
SMART	Simple Multi-Attribute Rating Technique
TC	Target Costing
T & G	Tongue and Groove
TVD	Target Value Design
VE	Value Engineering
VM	Value Management
WRC	Weight, Rate and Calculate

LIST OF PUBLICATIONS FROM THE RESEARCH

i) Kpamma, Z. E., Adjei-Kumi, T., Ayarkwa, J., & Adinyira, E. (2016). Participatory design, wicked problems, choosing by advantages. *Engineering, Construction and Architectural Management* (in press).

ii) Kpamma, Z. E., Adjei-Kumi, T., Ayarkwa, J., & Adinyira, E. (2016). An exploration of the choosing by advantages decision system as a user engagement tool in participatory design. *Architectural Engineering and Design Management, 12*(1) 51-66. DOI:10.1080/17452007.2015.1095710.

iii) Kpamma, Z. E., Adinyira, E., Ayarkwa, J., & Adjei-Kumi, T. (2015). Application of the CBA Decision System to Manage User Preferences in the Design Process. *J. Prof. Issues Eng. Educ. Pract.* (ASCE). DOI: 10.1061/(ASCE) EI.1943-5541.0000258.

iv) Kpamma, Z. E., Adjei-Kumi, T., Ayarkwa, J., & Adinyira, E. (2015). Development of a user- involvement framework for design process: An exploration of the design science research paradigm. *Proceedings, 4th International Conference on Infrastructural Development in Africa (ICIDA),* Kumasi, Ghana.

v) Kpamma, Z. E., Adjei-Kumi, T., Ayarkwa, J., & Adinyira, E. (2014). Creating, sustaining and optimizing the collaborative realm for participatory design. *Proceedings, 22nd annual conference of the International Group for Lean Construction (IGLC- 22*), Oslo, Norway.

vi) Kpamma, Z. E., Adjei-Kumi, T., Ayarkwa, J., & Adinyira, E. (2014). Enhancing user-involvement through a multi-criteria decision aid: A lean design research agenda**.** *Proceedings, 22nd annual conference of the International Group for Lean Construction (IGLC- 22),* Oslo, Norway.

DEDICATION

To Mosobil Kpamma and Mary Kpamma

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CHAPTER ONE

INTRODUCTION

1.1 Background

The increasing need for delivery of value in construction project delivery process makes it imperative for project teams, especially at the design stage, to pursue decisions which will lead to value generation for clients and end-users. It is crucial for participants involved in the design and construction of buildings to demonstrate value to clients and other stakeholders (Prins, 2009). A lot of attention is given to design process in the Architecture-Engineering-Construction (AEC) sector due to its strong impact on the entire project (Emmitt, 2011; Chua and Tyagi, 2001). Several investigations have indicated that a large percentage of defects in buildings arise from decisions or actions at the design phase (Barrett & Barrett, 2004; Andi & Minato, 2003; Hansen and Vanegas, 2003; Tilley et al., 2002; Cornick, 1991). It has also been established that design has a lot of impact on the level of efficiency during the production stage of construction projects (Brookfield et al., 2004; Emmitt et al., 2004; Love and Li, 2000;
Fergunson, 1986).

According to Undurraga (1996), design deficiencies account for about 20-25% of the total construction time wasted. Nearly 78% of quality problems of AEC projects are design related (Koskela, 1992). In relation to cost overruns, design related causes constitute the major category (Josephson et al, 1996). Westring (1997) attributes delays in construction projects in Ghana, among others, to delays in preparation of drawings and technical specifications. Tilley & McFallan (2000) found that design and documentation deficiencies were directly responsible for approximately 50% of all variations, contract disputes and cost overruns.

The foregoing evidence of the significant contribution of the design process to the success of the construction process and the performance of the construction product, leads to the need for a greater attention to issues of design management. A number of problems have been observed to be associated with design management (El. Reifi et al., 2013; Tribelsky and Sacks, 2007; Austin et al., 2002; Huovila et al., 1997; Coles, 1990), and the adoption of lean practices in design could be a step towards addressing these problems (Hansen and Olsson, 2011; Pasquire and Salvatierra-Garrido, 2011). However Emmitt (2011), Zimina et al. (2012), as well as El. Reifi and Emmitt (2013) observed some level of paucity of theoretical work in design management, especially, lean design management. Lack of empirical evidence on the application of lean design practices has also been observed (Emmitt, 2011; Jørgensen, 2006). This research, among others, is expected to i) make a contribution to theoretical knowledge in lean design management; ii) provide some empirical evidence on the application of some lean practices in design management.

A basic objective of lean design is to produce the best design to meet clients' needs in order to support effectiveness, efficiency and user satisfaction (Hansen and Olsson, 2011). Lean design should create real value for clients and building users alike (Emmitt et al., 2004). Hansen and Olsson (2011) further argue that the ultimate consequence of lean thinking in design is the usability of the completed product and how the building supports the core business. The needs of the user are therefore cardinal in the pursuit of lean design. Ballard and Zabelle (2000) identified one of the guiding principles for lean design as:

"multidisciplinary design teams that also include end-user representatives". The involvement of stakeholders, such as users, in the construction project delivery process, especially at the design stage, contributes immensely to project process stability and value generation (Pasquire and Salvatierra-Garrido, 2011; Yang et al., 2009; Luck, 2003; Sanoff, 2000).

Lean design is also concerned with improvement in the decision-making process in order to encourage participation in design, avoid the problems of uncertainty, and reduce waste at the construction stage (Pasquire and Salvatierra-Garrido, 2011; Emmitt et al., 2004). In lean design management, the design team must use a decision-making system that allows stakeholders, such as users, a voice in the design process (Lee et al., 2010). There is, thus, the need to develop a user-involvement framework that incorporates a participative and transparent decision-making system, in line with lean construction tenets. Existing user-involvement frameworks (e.g. Storvang and Clarke, 2014; Oijevaar et al., 2009; Zwemmer, 2008; Kjølle et al., 2005; Shen et al., 2004; Sanoff, 2000) fall short of adequately addressing this need. This research, therefore, explores a multi-criteria decision aid, known as Choosing By Advantages (CBA), to incorporate it in a proposed user-involvement framework. The CBA decision-making system is observed to be participative, transparent and auditable (Arroyo et al., 2014, 2013; Mossman, 2012; Parrish and Tommelein, 2009; Macomber et al., 2006).

1.2 Statement of Problem

This research sought to address various problems related to design process management, stakeholder involvement and lean design. The problems, among others, include, less application of lean principles in design management, limited knowledge on stakeholder involvement in design process, inadequate prescriptive studies in design process management and limited diffusion of lean practices in Ghana.

1.2.1 Limited Research and Application of Lean Principles in Design Management

Several studies (e.g. Emmitt, 2011; Ballard 2008; Tunstall, 2006; Bertelsen and Emmitt, 2005; Tilly 2005; Hansen and Vanegas, 2003; Green, 1996) point to the significant contribution of the design process to the problems of low quality, increased cost, and waste generation in construction process. Notwithstanding the substantial impact of the design stage on the general success of construction project delivery, and the importance of managing this stage effectively, much effort, with initiatives such as lean thinking, have been and continue to be concentrated on the construction phase to the neglect of the design phase (El. Reifi et al. 2013; Emmitt, 2011; Jørgensen, 2006). It has been proven that within the literature of lean thinking, the design stage is under-researched compared to the construction phase (Lee et al., 2012; Arayici et al., 2011; Jacomit and Granja, 2011; Liu et al., 2011; Sacks et al., 2010). The need therefore arises for more research in the application of lean principles in design management.

1.2.2 Limited Knowledge on Managing Stakeholder Participation in Design Process

One dimension of the pursuit of lean thinking in design management is the generation of value for clients and users through the involvement of stakeholders, such as users in the design process (Caixeta et al. 2013; Hansen and Olsson, 2011; Christoffersen and Emmitt, 2009). Various aspects of stakeholder involvement in the construction industry have received attention in existing literature. These include stakeholder management, interests, characteristics, influence and conflicts (e.g. Yan et al., 2011a, 2011b; Bourne and Walker, 2005; Sanoff, 2000); mapping (e.g. Sanders, 2006; Bourne and Walker, 2005; Newcombe, 2003); uncertainty and menaces (e.g. Ward and Chapman, 2008; Chapman and Ward, 2003) effects and implications (Olander, 2007; Sanoff, 2000); identification, grouping and representation (e.g. Aapaoja and Haapasalo, 2014; Storvang and Clarke, 2014; Crane and Ruebottom, 2012). Limited knowledge, however, exists on how stakeholders can participate in a process to gain insights into their needs and establish their values (Storvang and Clarke, 2014; Ha˚kanson and Ingemansson, 2013; Ivory, 2004, 2005). Furthermore, little is known of how the involvement of stakeholders can be staged, such that stakeholders can meet, interact and discuss values, needs and concerns (Thyssen et al., 2010; Barrett and Stanley, 1999). The Architecture, Engineering and Construction (AEC) industry therefore needs innovative tools for engaging stakeholders, such as users, especially during design process.

1.2.3 Inadequate Prescriptive Studies in Design Process Management

Research in design management, within the AEC industry, is generally in two dimensions (Zerjav et al., 2013). One dimension is focused on the macro-level aspect of managing design as a *business organization* (Emmitt, 1999), and the other dimension concentrates on the micro-level portion of managing design as a *process* (Kagioglou et al., 2000). Even though, in practice, there is a connection between management of design as a process and as an organization, some difference exists, especially in relation to the approaches to studies at the two levels. Whereas most studies in organizationlevel design management focus on the normative approach of prescribing pragmatic concepts that can be implemented in design practice (e.g. Baldwin et al., 2008), studies in process-level design management have largely ended in descriptive narratives of design practice (e.g. Luck,

2012; Dorst, 2011). Addressing the problem of limited prescriptive studies in design management, at the process-level, requires a research focus such as development of a framework for managing user-involvement in
participatory design process.

1.2.4 Emergent State of CBA and Less Diffusion of Lean Practices in Ghana

In the general context of lean construction practice and research, the CBA decision system still remains one of the lean tools that have received less attention (Arroyo et al., 2014; SmartMarket Report, 2013). This calls for more research on CBA, such as, its potential to create a space for effective collaboration between users and designers. In the specific context of Ghana, the problem extends to the fact that there is generally a low level of familiarity with the concept of lean construction in the construction industry (Kpamma and Adjei-Kumi, 2011; Kpamma, 2010). A myriad of obstacles have also been identified as possible challenges against the implementation of lean construction in Ghana (Ayarkwa et al., 2012). Little empirical work, if any, therefore exists on the case application of lean construction concepts in the Ghanaian context.

1.3 Concepts and Terminologies

This research fundamentally explores the collaborative potentials of the CBA decisionmaking system and how to incorporate it in a user-involvement framework for design process. The research, thus, falls within the broad domain of i) design management, ii) value generation, iii) user-involvement and iv) decision-making. Clarifying the concepts and terms within these domains will lead to a proper understanding of the research framework. It is expected that with the standardisation of a shared language, the process of building and understanding the theoretical underpinnings of user-involvement, the CBA decision system, and lean design management, will be enhanced.

1.3.1 Design Management

Design management, according to the Design Management Institute (DMI, 2012), involves "the on-going processes, business decisions and strategies that enable innovation and create effectively-designed products, services, communications, environments and brands that enhance our quality of life and provide organizational success". Design management could either be at the macro-level with a focus on managing design business or at the micro-level, focused on managing the design process (Zerjav et al., 2013). The description of design management as managing the design resources required for delivering design as a product (Emmitt, 2007) is in respect of macro-level management. Tzortzopoulos and Cooper (2007) highlight process-level management in their description of design management as, undertaken to establish managerial practices focused on improving the design process, thus creating effective processes towards the development of high-quality innovative products. This research, centered on enhancing user participation in design process, is more oriented towards process-level design management.

Figure 1.1 illustrates the context within which design management generally takes place in the overall scheme of construction project delivery, and demonstrates the importance of communication and collaboration among various stakeholders such as users and designers.

Inception

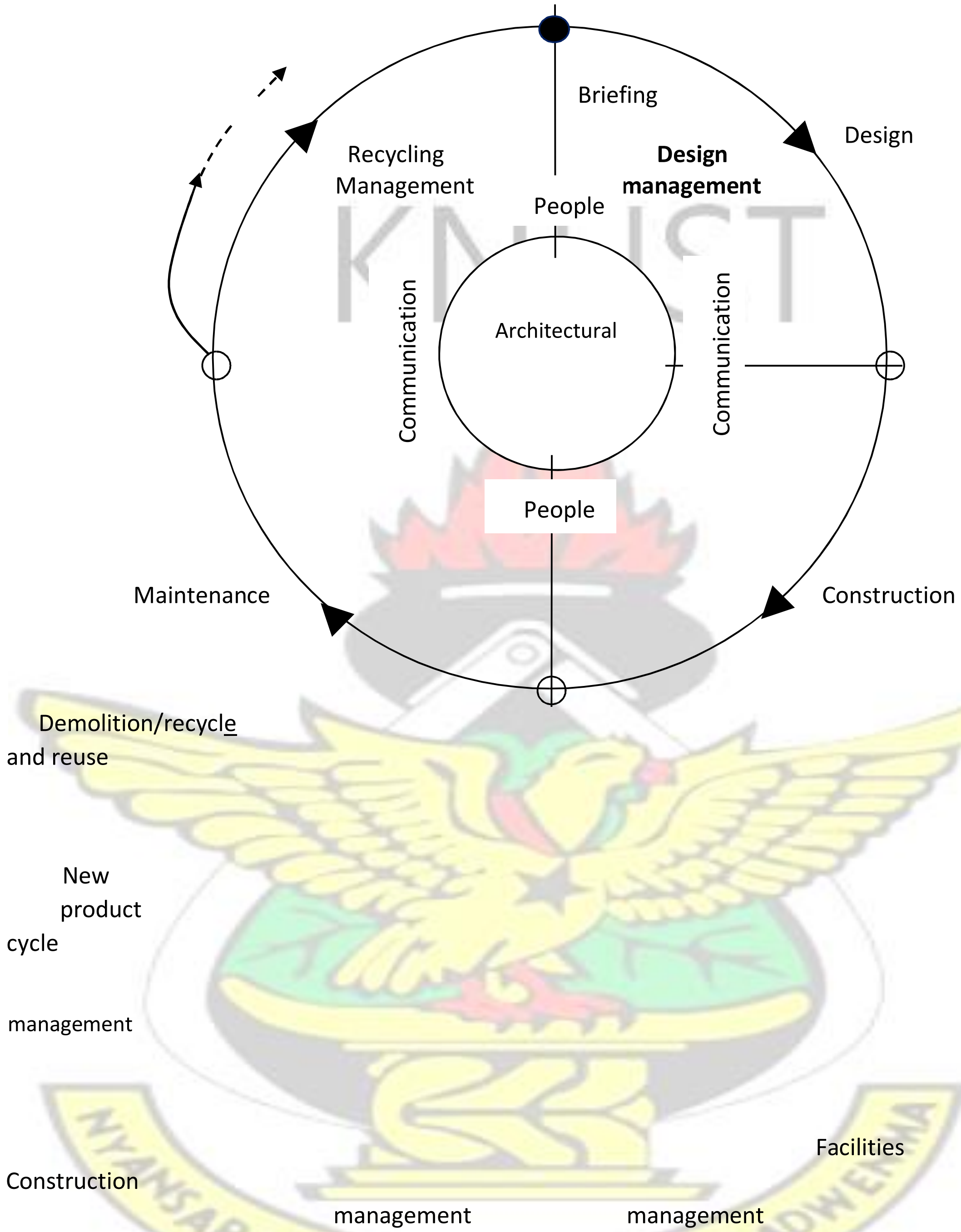

Figure 1.1: Design management within the project framework (Emmitt, 2002)

A fundamental concern of design management is value generation for the customer/client, which involves integration of specialist knowledge and timing of key decisions (Kestle et al., 2011). This, Kestle et al. (2011) further point out, is achieved by means of an integrated team approach to the way in which the project is designed, constructed, implemented and managed.

Design management, in line with these concerns, has been very much related to an attention to systematic design methods, focusing on the outcome of design decisions (i.e. the product) and the activity of designing (i.e. the process) (Lawson et al, 2003; Press and Cooper, 2002; Cross, 1999). The need to consider the whole life cycle of projects during design therefore became apparent, leading to the concept of architectural management as the pivot of the project execution framework (Figure 1.1).

1.3.2 Lean Design Management

The management of design has generally been seen to be problematic in the Architecture, Engineering and Construction (AEC) industry (Emmitt, 2011; Ballard and Koskela, 1998). Problems in design management, among others, include poor communication, deficient or missing input information, lack of coordination between disciplines, erratic decision, poor briefing and insufficient technical knowledge of designers (El. Reifi et al., 2013; Tribelsky and Sacks, 2007; Austin et al., 2002; Tzortzopoulos and Formoso, 1999; Huovila et al., 1997; Coles, 1990).

The problems with design management have a link with the fact that the design process has generally been managed by the traditional project management methods (Tilly, 2005; Lahdenperä & Tanhuanpää, 2000). According to Ballard & Koskela (1998), the traditional project management approach fails to provide a workable solution to the challenges of managing the design process due to the fundamental principles of project management being based solely on the transformation model / theory of production. The transformation model is a theoretical model that implicitly links production to only inputs being converted into outputs (Koskela & Howell, 2002). Even though this view of production has some obvious benefits from a contractual perspective, the problem with an exclusive use of this model is that it fails to consider the issues of material and information flows, as well as value generation for the customer and end-users at the same time (Koskela & Howell 2002; Koskela 2000).

Lean design management considers not only the transformation of inputs to outputs, but also the material and information flows, and the generation of value for the customers and end-users involved in design process (Koskela & Howell, 2002; Ballard and Zabelle, 2000; Koskela, 2000). Even though improving design process efficiency is significant from the perspective of the internal design team, the ultimate aim of any lean design management strategy should be to maximize overall client and end-user value from the project (Tilly, 2005). Lean design management, according to Hansen and Olsson (2011), has at least two main objectives: to find the best design to meet clients' needs in order to support effectiveness, efficiency and user satisfaction; and to define systems, structures and materials to ensure effective streamlined construction.

A complete approach to lean design management includes some additional significant factors to design management such as sustainable development and ways to achieve it (London, 2002; Garnett, 1999; Huovila and Koskela, 1998; Green, 1994). It is believed that while traditional design and construction focuses on cost, performance and quality objectives, sustainable design and construction, by comparison, focuses on value generation, minimization of resource depletion, minimization of environmental degradation and a focus on information flow management (Kestle, 2009). Emmitt et al. (2004) argue that moving lean thinking upstream – at the briefing, conceptual and detailed design stages – should create significant potential to deliver value throughout the whole construction process by creating a synergy between design, manufacturing and construction. Ultimately, lean thinking in design should result in the usability of the final construction product, and its support of the core business of users (Hansen and Olsson, 2011).

1.3.3 The Concept of Value in Design

Value generation to clients and end-users, as one of the central concerns of lean design management, is well documented in literature (e.g. Pasquire and Salvatierra-Garrido., 2011; Emmitt et al., 2004; Koskela & Howell, 2002; Ballard and Zabelle, 2000; Koskela, 2000). Value in this context, according to Hansen and Olsson (2011), relates to how the use of the building supports the core business. Womack and Jones (1996), in their book, *Lean Thinking*, define the concept of value as "a capability provided to a customer at the right time and at an appropriate price, as defined in each case by the customer". In the view of Christoffersen (2003) value is what an individual or organization places on a process, and the outcome of that process. The values to be addressed in architectural design encompass a wide range, differing from concerns in the public and professional domain (cultural, ethical, aesthetical, philosophical and social dimensions) to concerns in the client and user domain (organizational, functional, technical and economic aspects) (Prins, 2009).

In pursuit of the generation and delivery of value in the construction project delivery process, Bertelsen et al. (2002) developed the value-based building process model known as the 7C's model (Figure 1.2).

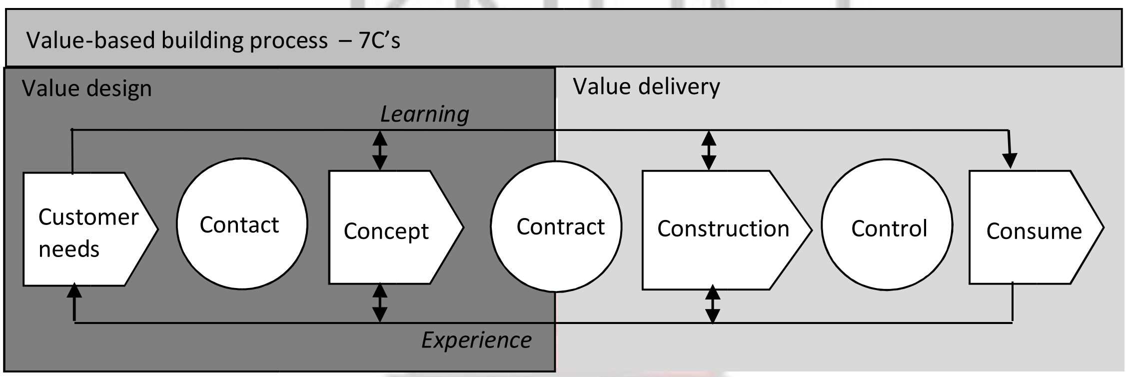

Figure 1.2: The 7C's model (Bertelsen et al., 2002)

The design process in this model is segmented into the two main phases of value design and value delivery. It is at the value design phase that the client's wishes and requirements are determined and specified. These values are developed into a number of conceptual design alternatives, before entering the value delivery phase of the process. The value delivery phase is where the best design alternative, which maximizes the client/customer value, is transformed through production. The concern at the delivery phase is to deliver the specified product in the best way, with minimum waste, using value chain mapping (Bertelsen et al., 2002). Value delivery comprises the final (detail) design and the construction of the project. The value design and value delivery phases often overlap in practice, and the transition between them is through the formal contract phase (Christoffersen and Emmit, 2009). The value delivered at the construction phase depends largely on what is generated at the design phase. Thus, initiatives such as involving users in design process to contribute to appropriately defining value at the design stage are crucial.

1.3.4 User-Involvement in Design

The fundamental model of everything lean is to never lose sight of the value to the end customer, as it is the end customer that ultimately decides if what is produced is actually of value (Björnfot and Bakken, 2013; Pasquire and Salvatierra-Garrido, 2011). In line with this argument, Prins (2009) observed that in the design process, architects work together with other actors, such as clients and users, to arrive at a design that is convincing to the client and all other stakeholders such as users. Hansen and Olsson (2011) also argue that for projects where specific and detailed knowledge of current, as well as, future activities and capacities is essential, involvement of users such as employees is required.

Poor integration of specialist user and stakeholder knowledge, according to Kestle (2009), can have severe consequences, such as, incorrect definition of user needs, leading to low value generation for the client and end-users. Tilly (2005) pointed out the relevance of user-involvement in lean design, indicating that lean thinking in design improves the design process through customer and end-user involvement. A lean design manager should have an understanding of the entire process, clearly identifying when and how to engage stakeholders, such as users, in the design process (Pasquire and Salvatierra-Garrido., 2011).

The value of the product of design, according to Jensen (2005), emanates from a cooperative creation process between the designer and the user. The activity of design, therefore, goes beyond a value-generating process, in terms of translating predetermined needs and requirements into building specifications, to a value-discovering process (Allinson, 1997). Consequently, involving clients and users in the design process to assist in discovering value, remains pertinent. Caixeta et al. (2013) corroborates the benefit of involving users in design, and point out the significant role played by users in designing activities and flows for healthcare buildings.

The response to the significance of involving users in design has led to some attempts to develop frameworks and guidelines for involving users in design process (e.g. Storvang and Clarke, 2014; Oijevaar et al., 2009; Zwemmer, 2008; Emmitt et al., 2005; Kjølle et al., 2005). Little attention has however been given to an elaborate incorporation of a decision-making system (especially that which reflects the lean tenets of transparency, respect and collaboration) in those frameworks. Given the crucial role decisions and decision-making play in design process, the argument of this research is for the development of a user-involvement framework that incorporates a multi-criteria decision system, such as CBA, to promote transparency and collaboration between users and designers.

1.3.5 Decision-Making and Design Process

Pre-construction is one of the most vigorous and essential stages of decision-making in the construction industry (Abraham et al., 2013). Designs in the AEC industry could be viewed as graphical expressions of an array of interconnected decisions. Design generally progresses with decisions and end with decisions. This is supported in the design process map of Lawson (2006) as shown in Figure 1.3. In Lawson's design process map, there are 4 stages which start with analysis and end with a *decision*.

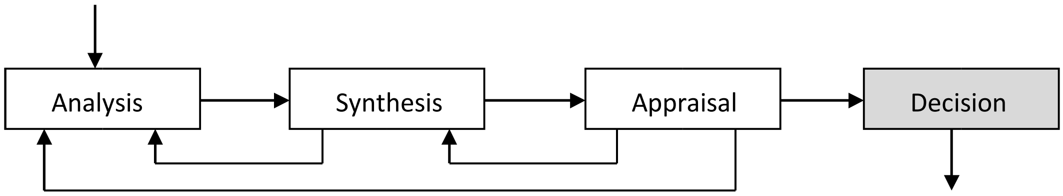

Figure1.3: Map of the design process (Lawson, 2006)

The analysis stage involves exploring the relationships and patterns in available information, organizing and ordering them to create a problem. The synthesis generates the response to such problems, and the appraisal evaluates the solution against the objectives found in the analysis stage for a *decision or several ones* to be finally made. Rosas (2013) describes the stages of analysis, synthesis and appraisal as sub processes towards *making a decision.*

Decisions as a crucial element in design process also manifests in the analogy of manufacturing process and design process, in which Bølviken et al. (2010) indicate that whereas the manufacturing process is completed with a physical action, the design task or process ends by means of a decision. Decision-making has also been found to play a crucial role in the management of the reciprocal interdependencies found in design process as a complex system. In the management of the reciprocal interdependencies in design, decisions are required to be made in ending design as an inherently expandable task, making trade-offs during design, as well as making or concluding negotiations and dialog in design process (Koskela et al., 2013; Bølviken et al., 2010).

Besides having significant impact on fabrication and construction, strategic decisions reached, during various stages of design, also impacts the value generated to meet user expectations and concerns (Kestle, 2009). Whelton et al. (2001) refer to design not only as an independent process, but a collaborative decision-making process. In relation to lean design practice, one concern, among others, is the improvement in the decisionmaking process during design (Emmitt et al., 2004). In improving the decision-making process, Emmitt et al. (2004) recommends interactive workshops with the participation of stakeholders as a key activity to create consensus. This recommendation by Emmitt et al. however leads to the question of what decision-making approach stakeholders should employ during these workshops to optimize decision outcomes, at the same time, create the required collaborative atmosphere among stakeholders for consensus building. This question is a motive behind this research.

In the Lean Project Delivery System (LPDS™), the job of the project delivery team, in addition to providing what the customers want, also involves assisting the customers *decide* on what they want (Kestle et al., 2011). Knowledge of the timing and kind of decisions to be made is central to the success of any project (Hansen and Olsson, 2011). A project management methodology to this, according to Blyth and Worthington (2010), include a method for fixing decisions progressively throughout the project.

From the foregoing, it is evident that decision as a product, and decision-making as a process, are critical elements of design process and have tremendous impact on the outcome of construction projects. Decision-making methods influence decisions, decisions result in actions, and finally actions lead to outcomes. Therefore if outcomes matter, then the decision-making methods also matter (Suhr, 1999). This undoubtedly establishes the basis for the argument that, beyond providing a space (e.g. in the form of workshops) for users to be involved in design process, there is a need for a further step towards an explicit definition of a decision-making system to guide the interaction of participants in the workshop space. In this study a multi-criteria decision system, namely CBA, is empirically explored to establish its collaborative attributes and identify strategies for incorporating it in a user-involvement framework.

1.3.6 The Choosing By Advantages (CBA) Decision System

The multifaceted character of decision-making in the AEC sector, and the involvement of various stakeholders, such as designers and users, often leads to decision tasks with many objectives. The nature of these decision tasks requires a set of methods known as multi-criteria decision-analysis (MCDA) (Abraham et al., 2013). The elementary framework MCDA generally involves disintegrating the decision problem into components, appraising each component independently, and reintegrating the components to provide complete understanding and recommendations (Seppälä et al., 2002).

CBA is one, among other MCDAs that are value-based. Decision-making in CBA is however distinctively based on comparing the explicit advantages of alternatives to establish the importance of the advantages (Suhr, 1999). Even though the seminal application of the CBA decision system is largely attributed to the U.S. Forest Service, its prevalence in the construction industry, especially in lean construction research and practice, is growing steadily (Arroyo et al., 2012, 2013; Parrish and Tommelein, 2009; Macomber et al., 2006). CBA creates a participatory, transparent and collaborative atmosphere for auditable decisions in design and construction (Arroyo et al., 2013; Mossman, 2012).

Arroyo et al. (2012, 2013, 2014), Abraham et al. (2013) as well as Parish and Tommelein (2009) studied the applications of CBA in the AEC sector, and the features that distinguish decision-making methods in AEC, concluding that CBA was a superior value-based decision-making method compared to others, such as, Analytic Hierarchy Process (AHP) because, among others, CBA is more explicit and transparent. Existing studies on the application of CBA in the AEC sector include decisions on green-roof systems (Grant and Jones, 2008), choice of viscous damping walls (Nguyen et al., 2009), choice of materials for sustainable design (Arroyo et al., 2012, 2013, 2014,
2015), and selection of a rebar terminator in steel reinforcement design (Parish and Tommelein, 2009). In all these investigations little attention was paid to employing CBA to foster collaboration between designers and users in participatory design. Besides, most of the studies have focused on design decisions at the detailed and production design phases, with less attention on the conceptual design phase. This research responds to these gaps, in CBA research, by undertaking exploratory studies involving the application of CBA by designers to engage users in design decisions at various stages of design, including the conceptual design stage.

1.4 Relevance of Research

1.4.1 Need for User-Oriented Research is Design Management

The involvement of stakeholders, such as users, in the construction project delivery process, especially at the design stage, contributes immensely to project process stability and value generation. This observation has, admittedly, appeared in several AEC literature (e.g. Pasquire and Salvatierra-Garrido, 2011; Yang et al., 2009; Luck et al., 2003; Sanoff, 2000). However the continued exploration of the subject of user participation, for several decades, is testimony of not only the positive impact of userinvolvement in design and decision-making, but also the continuous generation of fresh insight and knowledge in these continued investigations (Luck et al., 2003). The need for more user-oriented research in the construction industry is further evidenced in an initiative by the International Council for Research and Innovation in Building and Construction (CIB) to increase research focus on clients and users by establishing a new working commission, W118, in 2010 (Jensen et al., 2011).

1.4.2 Provision of a Practical and Systematic Guide for Stakeholder-Involvement

A user-involvement framework which explicitly incorporates the CBA decision system is the final construct of this research. This construct is expected to provide a practical structured guide on how designers could collaborate with stakeholders, such as users, during participatory design. Even though the primary focus of the research is on designer-user collaboration, the findings of the research could be extended to manage collaboration among other stakeholders during other stages of the construction project delivery process.

1.4.3 Contribution to Theory of Lean Design Management

The research is also expected to make a contribution to theory of lean design management, especially with respect to fostering collaboration in design teams by creating an atmosphere of trust, transparency and respect, through the application of the CBA decision system. Paucity in theory of lean design management has been observed by several researchers (Kpamma et al., 2014b; Lee et al., 2012; Arayici et al., 2011; Emmitt, 2011; Jacomit and Granja, 2011; Liu et al., 2011; Sacks et al., 2010). The essence of theory (e.g. in lean design management) has been outlined by Koskela (1999) to, among others, include: giving explanation and understanding to an observed phenomenon; giving prediction of future behaviour; providing basis to construct tools to analyze, design and control; providing direction to the source of further progress.

1.4.4 Contribution to Knowledge on CBA Application

A number of studies have been carried out on the application of CBA in the choice of some building components and materials (Arroyo et al., 2012, 2013; Nguyen et al., 2009; Parish and Tommelein, 2009; Grant and Jones, 2008), nonetheless, the CBA decision system is still considered as one of the tools that has received less attention in terms of lean construction research and practice (Arroyo et al., 2014; SmartMarket Report, 2013). The outcome of this research should therefore be significant in contributing to knowledge on the application of CBA, especially as a lean construction tool, to foster collaboration among project teams.

1.4.5 Contribution to Diffusion of Lean Practices in Ghana

Within the context of the construction industry in Ghana, Kpamma and Adjei-Kumi (2011) observed a low level of diffusion of lean practices among Ghanaian firms, while Ayarkwa et al., (2012) discovered a myriad of obstacles that could obstruct lean thinking implementation. There has, to date, been little (if any) empirical documentation on the application of emergent lean tools, such as, CBA in Ghana. The process and outcome of this research should contribute to a diffusion of knowledge on the application of CBA, particularly as a lean design tool, in Ghana towards reducing waste and increasing value in the construction industry in Ghana.

1.5 Research Questions

The main question guiding the research was:

How can the CBA decision-making system be incorporated in a framework to enhance user-involvement in design process?

In answering the main question, the following specific questions had to be answered:

- Why is CBA able to foster collaboration between designers and users?
- What strategies can be adopted to incorporate CBA in a user-involvement framework?
- How can a user-involvement framework incorporating CBA be structured?
- How workable is the framework in a real context of design process?
- How does the framework contribute to theories of lean design and design process management?

1.6 Research Aim and Objectives

The aim of the research was to develop a user-involvement framework, incorporating the CBA decision system, for the building design process.

The specific objectives included:

i. To identify the potential in CBA to foster collaboration between designers and users.

ii. To identify strategies to incorporate CBA in a user-involvement framework.

iii. To design a user-involvement framework incorporating CBA. iv. To evaluate the practicality of the user-involvement framework.

v. To identify the contribution of the framework to theories of lean design and design process management.

1.7 Scope of Research

The research is restricted to user-involvement and decision-making during the design of only buildings. One reason for focusing on buildings is that, the study is within the domain of lean design, and as observed by Jørgensen (2006), the existing body of research on lean thinking in construction appear to largely concentrate on buildings. This potentially provides a more robust theoretical foundation for any empirical research on lean thinking application in building design and construction, compared to civil works. Besides, in the context of the environment (i.e. Ghana) where the research data was collected, there were more construction projects involving buildings, compared to civil construction projects, thus offering the researcher more options and flexibility in the choice of building projects to undertake the research. It is however anticipated that findings from the study could, to some extent, be applicable to the design of civil construction projects.

In the domain of design management, the study was more concerned with the microlevel aspect of design management which focuses more on managing design as a process, in contrast to macro-level design management which focuses on managing design as a business organisation. Unlike in macro-level design management whereby most studies have concentrated on the normative approach of prescribing practical concepts that can be implemented in design practice (e.g. Baldwin et al., 2008), most studies in process-level design management have mainly ended in descriptive accounts of design practice (Luck, 2012; Dorst, 2011). More prescriptive studies, focused on process-level design, is, thus, pertinent.

The empirical studies in the research involved the application of the CBA decision system to make typical design decisions for some selected projects. However in analysing these studies, the primary focus of the research was on the decision processes and how that impacted team collaboration and consensus building, and not necessarily the decision outcome. Changing the input data, for instance, in any of the cases of CBA application could alter the final decision outcome, but in the context of this research, it is the established procedure of the CBA application, and how that fosters team collaboration, which is the concern.

Different methods of CBA for various types of decisions, ranging from very simple to very complex decisions exist (Suhr, 1999). This research focused on the *tabular method* considered as most appropriate for decisions in building design (Arroyo, 2014). Decisions in building design, which involve mutually exclusive alternatives that might not share the same cost, are viewed as moderately complex in the context of CBA application.

There are various levels and intensities of user-involvement. These levels range from informative, whereby users are mere providers of information, to participative, whereby users actively take part in decision-making. This research concentrated more on participative involvement, in which case the focus was on how a space could be created for users to effectively influence design decisions.

1.8 Research Methodology

The research sought to answer a question on 'how things ought to be', with respect to a user-involvement framework for design process. An answer to this question should follow the *constructive research* approach, leading to the development of an innovative solution to an existent problem (Koskela, 2008; Hevner et al., 2004). In contrast to the methodology of the natural sciences, the focus of which is on *explaining* how things are, constructive research falls within the domain of the design or artificial sciences (Simon, 1969) with a methodological focus on *prescribing* innovative constructs to influence what ought to be.

Given the fact that an innovative construct is the typical output of constructive research, it is recommended that the research takes the form of evaluating the performance of interventions or artifacts (e.g. CBA) implemented within the context of the intended use (Van Aken, 2004). A typical approach to study and test an intervention is multiple case studies (Van Aken 2004; Lukka 2003).

In line with the action-oriented principles of constructive research, whereby the researcher is required to directly operate in the field (Van Aken, 2004; Lukka, 2003; Keizer et al., 2002), an action research approach was adopted. 'Action research' is a process of organizational change that uses 'a spiral of steps, each of which is composed of a circle of planning, action, and fact finding about the result of the action' (Lewin, 1946). The traditional role of the researcher as an observer and analyst is expanded, in action research, to include participation in what is being observed and analysed (Zimina et al., 2012). The objective of action research is to develop a practice, and is historically linked to organizational development / organizational change (French and Bell, 1973). This objective corresponds with the primary objective of this research, which is to change a social practice in the designer-user collaboration, using a framework whose experimentation and development involves the researcher.

Research in CBA, value generation and participatory design are associated with existing literature and practice of lean construction (e.g. Arroyo et al., 2013; Parish and Tommelein, 2009; Emmitt, 2005). Epistemologically action research is consistent with the lean construction philosophy, since in both cases the most efficient way to obtain knowledge is through participant experiment in a real setting, systemically reflecting on what works and what does not (Zimina et al., 2012). Fundamental to both, is the Plan-

Do-Check-Act (PDCA) cycle of Shewhart (1931).

A central element of constructive research is to combine theory with empirical studies to develop a construct (Lukka, 2003). Empirical studies, in this research, were based on case studies, while theoretical knowledge fundamentally relied on review of literature in participatory design, design process management, lean design and team processes. The final construct, after being verified, was expected to contribute to theories of userinvolvement, design process management, lean design management, collaborative design and the CBA decision system.

1.9 Dissertation Structure

The scheme of the dissertation structure is shown in Figure 1.4. Six chapters are contained in the dissertation. Chapter 1 presents an introduction to the research whereby the theoretical background and an outline of the research are spelt out. Chapter 2 reviews literature on research relevant to user-involvement, design process management, team functioning, lean design and the CBA decision system. A detailed outline of the research method and strategy is presented in chapter 3. Findings from exploratory case studies are presented and discussed in chapter 4. Based on the findings from the empirical data and literature review, a user-involvement framework, incorporating the CBA decision is presented and validated in chapter 5. Chapter 6 contains a summary of the outcome of research and conclusion

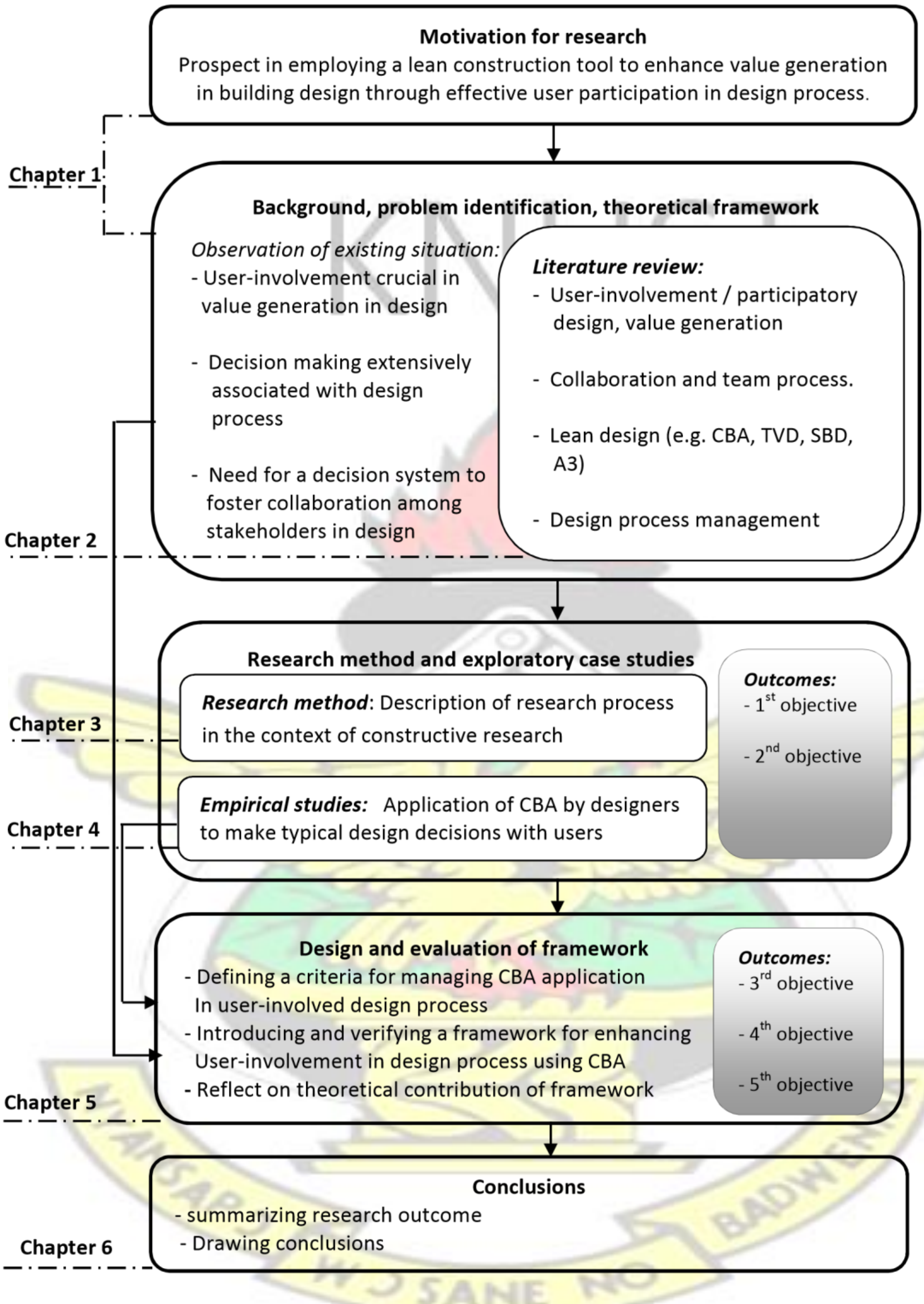

Figure1.4: Structure of dissertation

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature, mainly on participatory design, application of the CBA system, design process management, team process and some lean design concepts. The literature review, among others, is expected to fundamentally serve the following purposes: i) help understand the present state of knowledge in participatory design, the CBA decision system, lead design and design process management; 2) provide a lexis and theoretical foundation, for this research, that is consistent with previous and current research in the field of user-involvement, CBA and lean design; 3) put the original contribution of the research in context.

2.2 The Concept of Participatory Design and User-Involvement

Participatory design, according to Sanders (2006), is an approach to design that attempts to actively involve beneficiaries of design in the design process to ensure that the designed product/service meets their needs. Sanders (2006) further points out the position of user-involvement in the space of participatory design by explaining that participatory design endeavour to involve the actual 'users' throughout the design development process to an allowable extent.

Even though the concept of participatory design and user involvement are believed to have evolved in the 1960's based on the Scandinavian commitment to the ideals of democracy in work organizations (Jensen, 2006; Sanders, 2006; Granath, 2001; Damodaran, 1996), there is historical evidence of earlier attempts, particularly in the wake of the modernist movement, to shift focus from the design of objects to the design of the *use* of those objects, so that they become functional to the needs of users. Modernism brought with it, a frown on what was seen as a preoccupation with the phenomenon of form and decoration of objects (with little relevance on the needs of people and society) in favour of a new agenda in which the well-being of people became the central focus in the design of appliances and houses (Redstrom, 2005).

The need for the transition from "form to function", to address the needs of the user, is expressed in writings by some pioneers of modernism. The paradigm, "form follows function", by Sullivan (1986) rendered *form* a subordinate of *function,* thus prioritizing functionality to the user. Gropius (1926) states: "The Bauhaus wants to serve in the development of present-day housing, from the simplest household appliances to the finished dwelling. In the conviction that household appliances and furnishings must be rationally related to each other, the Bauhaus is seeking - by systematic practical and theoretical research in the formal, technical and economic fields - to derive the design of an object from its natural functions and relationship". Mies van der Rhoe (1964) expressed a similar sentiment: "I do not oppose form, but only form as a goal. Form as a goal always ends in formalism. For this striving is directed not towards an inside, but towards an outside. But only a living inside has a living outside. Only intensity of life has intensity of form. Every How is carried by a what".

In relation to the link of participatory design and user-involvement to the Scandinavian ideals of work place democracy, the notion is that the workforce should be active participants in all decisions which affect their daily working lives, including the design of their working environment (Jensen, 2006; Damodaran, 1996). Granath (2001) observed that the emergence of the phenomenon of participation of users in design represented a transition from a "power-based" to a "knowledge-based" process. A central objective of participatory design, according to Redstrom (2005), is to reduce the separation between designers and users so that through the dynamics of the process, the people (or some) who might be 'users' will be changed to also become 'designers'.

The importance of participatory design is evidenced in literature. Cross (1972) states: "(t)here is certainly a need for new approaches to design if we are to arrest the escalating problems of the man-made world, and citizen participation in decisionmaking could possibly provide a necessary reorientation". Lee (2006) also spelt out the significance of participatory design as improving designer-user relationship, inspiring the designers, and making designs functional and satisfactory to users. Participatory approaches to design, especially at the early stages, create a shared understanding between users and designers, therefore avoiding later disagreements with the design outcomes and the associated changes downstream the construction delivery process
(Caixeta, 2013).

An important question on what constitutes an authentic participatory design remains pertinent (Jensen, 2006). A conclusion from an investigation of a Norwegian hospital project, by Jensø (1999), point to the fact that genuine participation requires some degree of involvement in decision making. Muller and Kuhn (1993) have also indicated that authentic participatory design maintains a clear workplace democracy by going beyond a "mere involvement" to a real and active worker participation in design activities and decisions. Similarly, Sanoff (2000) point out that, one main purpose of user participation in design is to involve users in the decision-making processes to result in an increase in their trust and confidence in the design process. This, Sanoff further asserts, will lead to the users' acceptance of the final outcome. A decision-making approach which creates transparency and allows for effective participation of stakeholders is therefore essential in ensuring a genuine user-involvement in participatory design. This research seeks to rely on the participative attributes of the CBA decision system to enhance user-involvement in design process.

2.2.1 Who Constitutes the User to be involved?

In formulating a framework for the involvement of users in design, an adequate understanding of who constitute the *user* in this context is required. A user, in the traditional sense, describes someone who directly interacts with a system or any other kind of product (ISO 9241-11, 1998, cited in Ågerfalk, 2001; Shackel, 1984). Granath (2001) refer to *users* as "those who actually use the building in their everyday activities". He goes further to explain that users include all people working in a building such as staff, management and service personnel. Granath however excludes visitors or those who find themselves in the building just to utilize a certain service delivered in the building (e.g. pupils/students in a school; patients in a hospital or mere visitors).

In relation to the benefit of involving non-staff users, such as visitors, for generating value in health care design, a finding by Caixeta et al. (2013) agrees with the position of Granath (2001). According to the finding, non-staff users cannot bring relevant data to the efficiency of delivering care. Caixeta et al. (2013) further argue that the non-staff users, such as patients, do not spend enough time at the building to have a deep knowledge on it to benefit the design process, especially in relation to operational efficiency.

Olsson et al. (2010), as well as Bertelsen and Emmitt (2005) however sees the subtraction of the visitor category of users, as an oversimplification of "user" as a term, and goes ahead to propose a model that structure user categorization based on a supply chain approach (Figure 2.1).

User Groups					
Owners / Clients	Facilities management and service personnel (operating the building	Management of the organisation based in the building	Service providers (e.g. teachers in a school, doctors and nurses in a hospital)	Service receivers (pupils in school, patients in a hospital)	Indirect service receivers (e.g. pupil's parents, patients' relatives)

Figure 2.1: Various user groups (Based on Olsson et al., 2010)

In line with this categorization, Zwemmer (2008) in a formulation of a strategic framework for briefing and design also grouped users into three main categories based on their level of knowledge and strategic influence on the project (Figure 2.2). The first group, known as *external stakeholders* (e.g. neighbors, client suppliers, union representatives etc.), are people who could have an interest in the project, and may influence the strategic phase of the project, but are not a direct member of the client organization. The second group is known as the *user study group* and is made of people who have a specific amount of knowledge on the operational requirements and internal processes of the building (e.g. construction, technical, and processes) such as technical and production staff. This user group provides specific project information which leads to a better understanding of the general user-processes of the building.

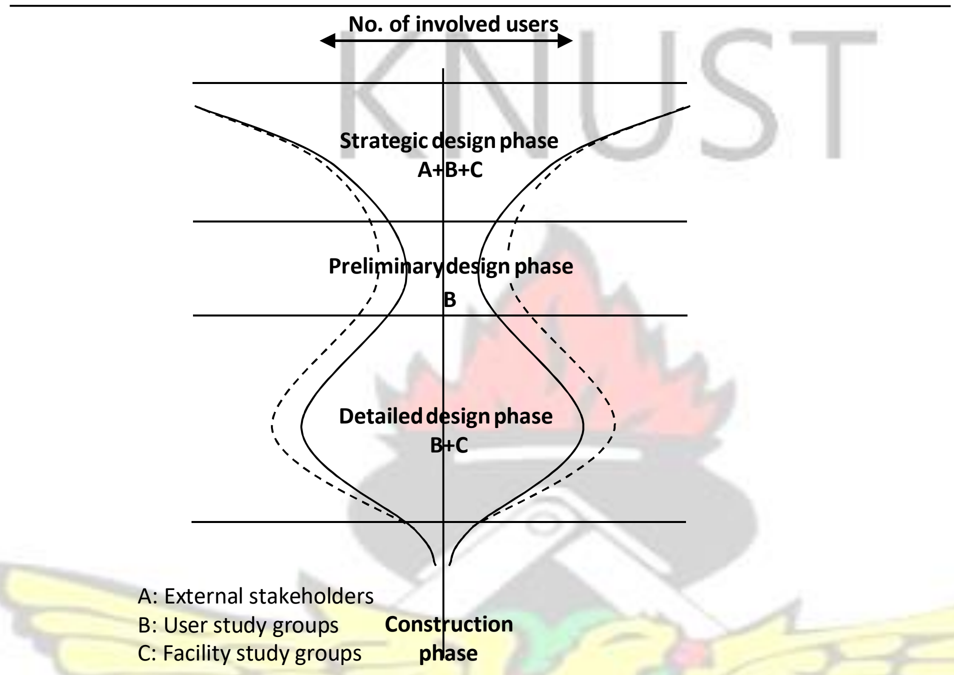

Figure 2.2: Involvement of user groups across various phases of design (Zwemmer, 2008)

The third user group is the *facility study group* which consists primarily of the employees and managers who are motivated to collaborate with designers in the detailed briefing and design phase. The third user group, regarded as experts in their working processes, could play an important role in evaluating their existing working spaces and providing valuable information for designers of a new facility.

It follows, from the various opinions, that there are various categories of users with varying degree of interests and interaction with a building. The type of information required also varies across the various phases of design of a building. The depth, credibility and relevance of the design information, is therefore user-group and projectphase dependent. The number of users also varies according to the size and nature of project (as indicated by the broken curve in Figure 2.2). This requires the design manager or facilitator to undertake a critical examination of the design and particular design activity to choose the appropriate user group.

2.2.2 Forms of User-involvement

"Involvement" as a term is generic, encompassing a range of varying degrees of participation. Each degree of participation depends on the relationship between the user and service provider, such as the designer, as well as their respective degree of influence in decision-making (Kujala, 2003; Arnstein, 1969). Damodaran (1996) presented three forms of user-involvement as a continuum, to represent the varying range of degrees of participation. These include informative, consultative and participative forms of user-involvement (Figure 2.3).

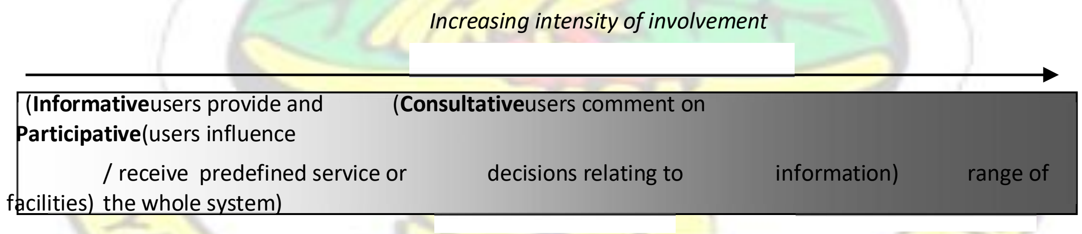

Figure 2.3: Forms of User involvement (adapted from Damodaran, 1996)

The informative form, which is the lower level of involvement, is the instance whereby users give and / or receive information. The consultative form represents the intermediate level in which case users are allowed to comment on predefined facilities. The high level of involvement is the participative form, where users are given the opportunity to influence decisions in relation to the whole system.

Three concepts of involvement have also been identified by Granath (2001) based on his observation of worker involvement in decision-making processes. The first concept is *formal participation* in design whereby involvement occurs through union representatives. Here, users elect representatives to the decision-making process. The second concept, which is the data collection method, is comparable to the informative model of Damodaran (1996), in which case interviews are used to extract information from users. The challenge with this concept, as observed by Zwemmer (2008), is that even though users are directly involved, they have difficulty understanding the questions and proposals of the designers. The use of boundary objects such as animations with good representative techniques could address this challenge of the users. The third concept, *co-design* (Figure 2.4), is comparable to the participative form

in Damodaran (1996).

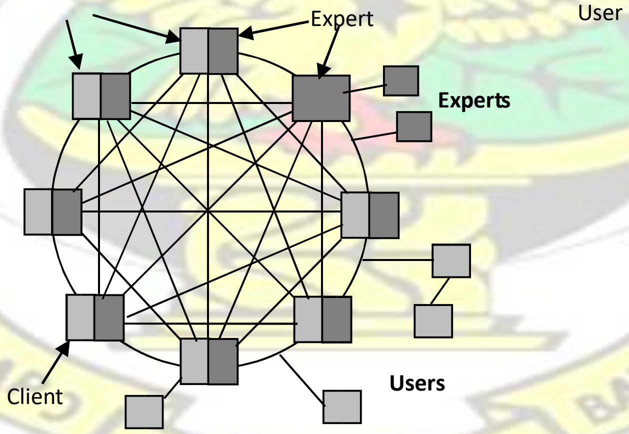

Figure 2.4: Web of Communication in Co-design (Granath, 2001)

The space, in this instance, is created for the users to operate as experts, thus, increasing their level of commitment. The process of co-design is also seen as a way of opening the team for mutual learning resulting in users, clients and designers collaboratively contributing to the output.

Wulz (1986) elaborately partitions user-involvement into seven different levels (Figure 2.5). These levels fall under the broad categories of passive participation and active participation. *Passive participation* comprises representation, questionnaire, and regionalism.

Passive participation → Active participation

Method / Tool	**Level of participation**						
	Representation	Questionnaire	Regionalism	Dialogue	Alternative	Co-design	Selfdecision
Survey (general population)		●					
Survey (local population)			●				
Interview				●			
Voting					●		
Post occupancy evaluation						●	
Workshop						●	
Focus groups						●	
Planning cell						●	
Self-build							●

Figure 2.5: Levels of participation (Wulz, 1986)

Active participation comprises dialogue, alternative, co-design and self-decision. The tools of engagement for active participation include voting, post occupancy evaluation, workshop, focus group, planning cell, and self-build (Wulz, 1986). There is however the need to explicitly define a decision-making approach in these proposed tools of engagement. Even though voting is a decision-making approach, it does not promote dialogue, transparency and trust, required for team collaboration. This research explores the collaborative potential of a decision-making system, such as CBA, for adoption in user engagement tools such as workshops.

2.2.3 The Collaborative Philosophy of User Participation in Design

The willingness of the expert designer and the experienced user to collaboratively merge their respective domains of existence or operation is central to ensuring a genuine participatory design. Lee (2006) relied on the concept of "*concrete space*" and "*abstract space*" by the French Marxist philosopher, Henri Lefebvre, to illustrate the need for a collaborative overlap of the domain of the user and that of the designer for an effective participatory design (Figure 2.6).

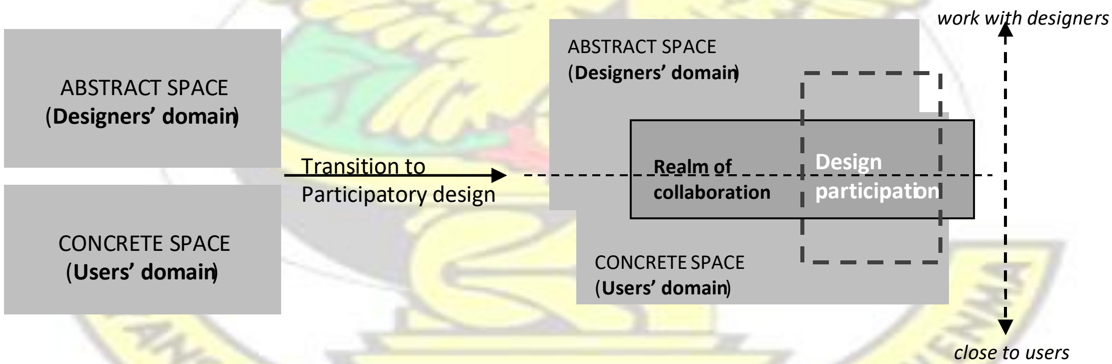

Figure 2.6: Collaboration of abstract and concrete spaces for participatory design (adapted from Lee, 2006)

The concept of "concrete space" and "abstract space" was employed by Lefebvre (1970) to illustrate a disturbing urban design problem: "*the extraordinary passivity of the people most directly involved, those who are affected by projects, influenced by strategies*". Based on Lefebvre's social space concept, Lee (2006) defined "concrete space" as the space in which we live and experience (i.e. the people's world), while "abstract space" was defined as the space of vision and geometry characteristically utilised by experts, such as planners and architects to interpret cites, and create the physical environment in the concrete space by means of the tools of abstraction and representation. Therefore in a typical building design process, the domain of the user is the Concrete Space (CS) while the domain of the designer/architect is the Abstract Space (AS). The activity of participatory design accordingly occurs in the realm where AS overlaps CS. Even though various forms of participatory design techniques (i.e. design for innovation; design for collaboration; design for emancipation; and design for motivation) have been proposed by Lee (2006), it is apparent that the general concept of user participation is underpinned by the creation of a collaborative design environment through the integration of the AS and CS.

The creation of the collaborative realm, between AS and CS for participatory design, however leaves a pertinent question of how to foster and stabilize the realm of collaboration to make it effective. Three specific concerns emanate for the attention of this research. The first concern is the source of the pull between CS and AS to create the realm of collaboration. The second concern is to stabilize the collaborative realm to prevent it from fragmentation. The third concern is to ensure that a sound and optimum decision emanates from the collaborative realm.

i. Creating the Collaborative Realm

The mediatory role of the client and her advisers, between the demand side (i.e. owner, investors, managers, employees, visitors etc.) and the supply side (architects, engineers, contractors, material suppliers and service providers), as presented in Jensen (2002), is a possible source of pull, between CS and AS, to foster collaboration (Figure 2.7). This mediatory role of the client to foster an overlap between CS and AS agrees with Bertelsen et al. (2002), who point out the possibility of the client acting as a change agent in the building process as against a more passive role as a procurer.

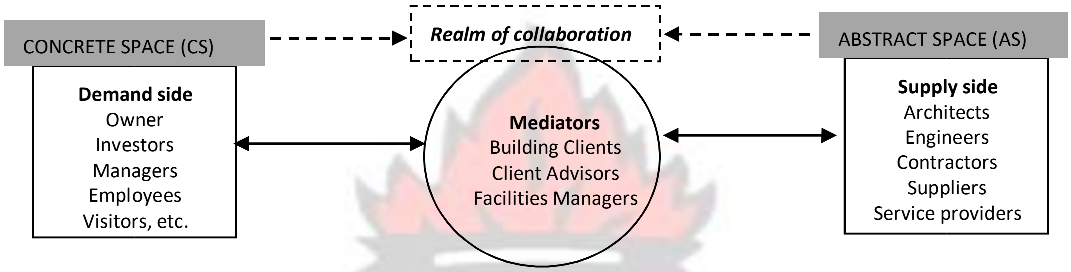

Figure 2.7: Client as a mediator and a source of pull between CS and AS (Jensen, 2002)

Some shortcomings however exist in the possible pull role of the client as a mediator between AS and CS. Disappointment resulting from the ineffectiveness of the collaborative realm to produce the desired result of participatory design could discourage further collaboration, thus rendering the pull role of the client ineffective. Granath (2001) for instance observes that, research and practice in Scandinavia indicates that disappointment from the results of collaboration in participatory design not only discourages the users from further participation in design, but also discourages the architect. This justifies the need for a research into the adoption of a decision system to make participatory design effective and encourage users and designers to continue to collaborate.

The organization of workshops, involving designers and users, could also be one of the strategies to create a field of pull between the AS and CS. A number of userinvolvement studies (Storvang and Clarke, 2014; Christoffersen and Emmitt, 2009; Zwemmer, 2008) have recommended workshops as a forum for fostering collaboration between AS and CS. Kjølle et al. (2005) and Shipton et al. (2014) also identify the use of boundary objects as a means of creating a better environment in which different actors, such as those of AS and CS, cooperate. Boundary objects, according to Carlsen et al. (2004), are "objects that become shared foci for the attention and explorative activities of people with initially different interests, expertise and language". Models, computer animations and prototypes are examples of boundary objects.

One other way of fostering the pull between AS and CS, to create the realm of collaboration, is the use of incentives and incentive systems. Several definitions of incentives and incentive systems have been presented (Schöttle and Gehbauer, 2012; Kuhl, 2007; Becker, 1995; Beyer, 1990; Rosenstiel, 1975; Wild, 1973). However in the context of this study, the definition of an incentive, by Beyer (1990), as a stimulus which activates certain behaviour; and that of an incentive system, by Schöttle and Gehbauer (2012), as the sum of all monetary and non-monetary incentives that foster collaboration between different parties such as designers and users was adopted. Incentives of the incentive system should motivate construction project parities, such as designers and users, to move away from their uncooperative posture to a cooperative path to ensure an overlap of AS and CS (Schöttle and Gehbauer, 2012). It has further been observed that, incentives must necessarily represent value to the recipients in order to cause a motivation towards an action such as collaboration (Kossbiel, 1994).

Even though monetary incentives (wages, bonuses etc.) and non-monetary incentives (social contact, information access, social approval etc.) may play a complimentary role in establishing collaboration, as explained by Schöttle and Gehbauer (2012), monetary incentives, according to Deming (2000), has only a short term effect. Monetary incentives have also been observed to impair intrinsic motivation (Darrington and Howell, 2010; Schulz, 2000). Unlike extrinsic motivation which arises out of external incentives, such as wages, intrinsic motivation is a motivation an individual receives from performing the task at stake, and emanates from personal values and desires. Darrington and Howell (2010) see intrinsic motivation as highly significant to the achievement of lean project delivery. The proposition of this research is that, the adoption of a decision-making system, such as CBA, with its perceived attributes of being transparent and participative, provides an intrinsic incentive to foster an overlap of CS and AS.

ii. Sustaining the Collaborative Realm

A Successful pursuit of participatory design requires the creation of collective intelligence through the sustenance of a collaborative atmosphere among the various stakeholders in the design process. Collaboration creates cohesive teams to foster shared cognition leading to collective intelligence (Conklin, 2005; Ensley & Pearce, 2001). Some natural forces have however been identified to put collaboration in difficulty, thus challenging any attempt at collective intelligence. Conklin (2005) refers to these forces as forces of fragmentation, suggesting social complexity and wicked problems in participatory design as a possible source of these forces. One of the important measures of dampening the effect of these forces, to ensure the sustainability of collaboration, is to create a space characterized by a culture of trust, respect and transparency, with less conflict, among stakeholders. While Lichtig (2005) proposes the concept of rational contracts to build an association robust enough to survive the unavoidable conflicts and challenges that would come up during project delivery, Zwemmer (2008) suggested the use of feedback as a strategy to retain users' commitment to the collaborative process.

The teams in the collaborative realm are socially complex, and comprise members with different histories, backgrounds and capabilities. Characterized by these diverse orientations, the task, according to Howell (2013), is to manage the balance between the cooperation and competition among the members of these teams. The reliance on noneconomic incentives, such as equity and fairness, for individual motivation, is one of the strategies for managing this balance (Howell, 2013). Even though notable theories of individual motivation such as Bentham's *Carrot and Stick* (Bentham, 1789), Maslow's *Hierarchy of Needs* (Maslow, 1943), Herzberg's *Two Factor* (Herzberg, 1959) and Pink's *Self Development Theory* (Pink, 2010) overlook the power of the spirit of equity or fairness in teams, Bowles (2008) has demonstrated how the drive for fairness is a more powerful motivation, among individuals working in groups, compared to financial motivation (Howell, 2013).

One of the major activities that take place in the collaborative realm during participatory design is making decisions on various aspects of design. The method by which decisions are made within the realm of collaboration could therefore play a critical role in providing an intrinsic motivation to sustain the cohesion of the collaborative realm. Following the identification of equity and fairness as major sources of intrinsic motivation (Howell, 2013;

Bowles, 2008) for individuals to operate optimally in groups, there is the need to explore decision-making systems that encourage fairness and equity, for adoption in the collaborative realm of participatory design.

iii. Optimizing the Collaborative Realm

The essence of creating the realm of collaboration, by overlapping the abstract space and the concrete space, is to generate an atmosphere for effective user participation and to, ultimately, produce designs that aptly serve their functions and meet the needs of users. Due to the fact that decision-making is a key activity in participatory design, the effectiveness of the collaboration will depend on the soundness of those decisions, and the quality of the accompanying outcomes. If outcomes matter, then the decisionmaking methods also matter (Suhr, 1999). There is, thus, the need (as is the subject of this research) to explore a decision-making system to enhance decision outcomes from the collaborative realm. CBA, which, according to Howell (2013), affords project organisations with a system for producing sound, reliable and grounded choices, is worthy of exploration.

2.2.4 A Conceptual Model for Creating, Sustaining and Optimizing the Collaborative Realm

A conceptual model for creating, sustaining and optimizing the collaborative realm, for effective participatory design, through the involvement of users, is presented. This conceptual model has been published in the proceedings of the 22nd annual conference of the International Group for Lean Construction (IGLC) (Kpamma et al., 2014a). The model is founded on a number of concepts discussed in the foregoing section. Notable among these concepts include: Henri Lefebvre's concept of "concrete space" and "abstract space" based on which Lee (2006) proposed the collaborative realm; the concept of the mediatory role of the clients and her advisers (Jensen, 2002); forms of user-involvement (Damodaran, 1996); concepts of collaboration and motivation by Schöttle and Gehbauer (2012), Bowles (2008), Darrington and Howell (2010), Howell (2013), Lichtig (2005) and Deming (2000).

The core component of the conceptual model (Figure 2.8) is the collaborative realm, arising out of the overlap between AS and CS.

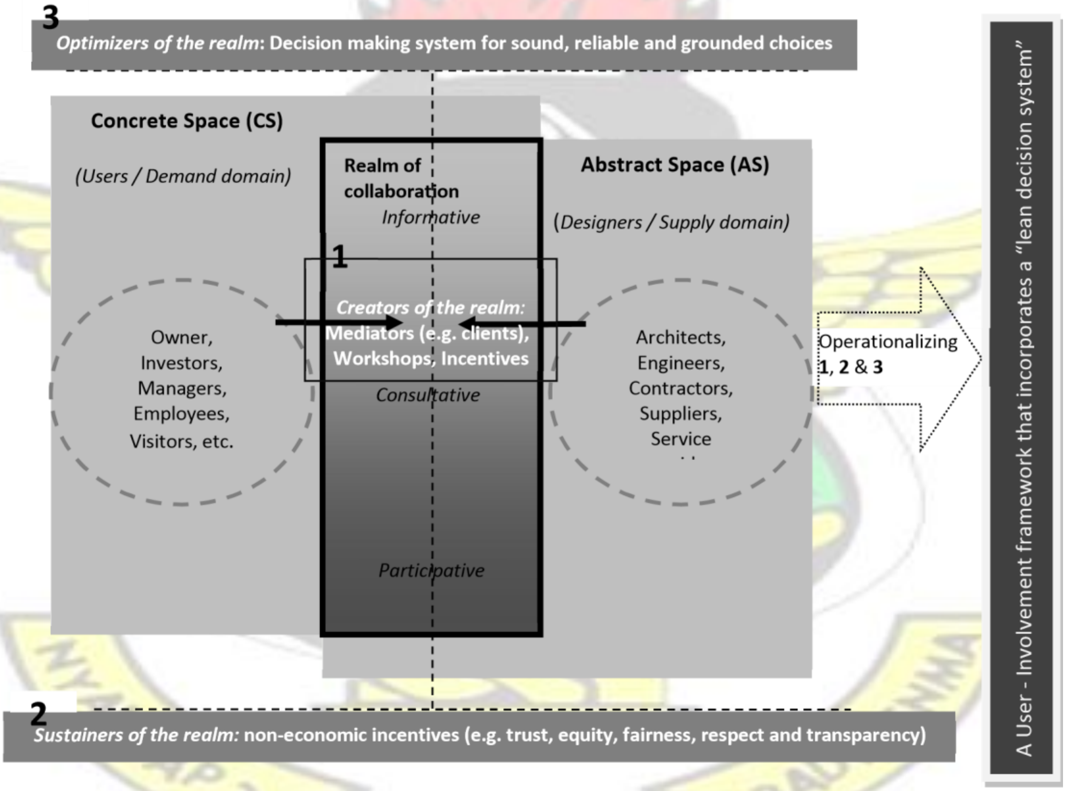

Figure 2.8: Conceptual model for creating, sustaining and optimizing the collaborative realm for participatory design (Kpamma et al., 2014a)

The creation, sustenance and optimisation of the realm depend on the operation of three zones in the model (i.e. 1, 2 & 3). The collaborative realm is expected to be generated in "zone 1" through the action of mediators (e.g. clients and their advisers), organisation of workshops and use of incentives (i.e. non-economic, trust-based incentives).

The elements of mediators, workshops and incentives, in "zone 1", therefore collectively or individually form the "pull (s)" that act between AS and CS to bring them together to create the collaborative realm. It should be noted that, incentives in "zone 1" refers to intrinsic incentives which, according to Schöttle and Gehbauer (2012), are non-monetary, and are based on personal desires and values. They spontaneously emanate from performing the task.

Sustaining and stabilising the collaborative realm to prevent it from fragmentation is addressed by "zone 2" which also relies on the use of non-economic incentives, such as the creation of an atmosphere of trust, equity, fairness and respect. This component of the model utilises the intrinsic incentives, as a source of motivation, to maintain individuals, balance their diversities and sustain their desired contribution in the collaborative realm. "Zone 2" of the model is therefore a container of the non-economic incentives of fairness, trust, equity, respect etc.

The effectiveness of the collaborative realm depends on putting mechanisms in place to optimise its output after it has been created and sustained. "Zone 3" of the model contains elements that are expected to optimise the outcome of the realm. Given the fact that the design process is characterised by a myriad of decisions and any outcome of design is an output of decisions (see Lawson, 2006), a quest to optimise the operations of the collaborative realm will require an attention to the decision system adopted. Contained in "zone 3" of the model is a decision system that leads to sound, reliable and grounded choices.

It is apparent that the various zones of the conceptual model largely rely on elements that agree with lean project delivery practices. These elements include intrinsic incentives (e.g. fairness, equity, trust, transparency and respect), as well as adoption of a decision system for sound, reliable and grounded choices. Due to the important place of decisions in the design process, it implies that attempting to enforce zones 1, 2 & 3, of the model, to create, sustain and optimise the collaborative realm, will require an attention to the decision system to be employed. In line with the aim of this research, a user-involvement framework which incorporates a lean decision-making system should be developed to enforce zones 1, 2 & 3 of the model.

2.2.5 Existing Frameworks for stakeholder /user involvement

Various attempts have been made to develop frameworks for managing stakeholder participation in the construction project delivery process. Workshops remain popular in most of the existing stakeholder-involvement frameworks, as a means of integrating the domain of the designer and that of the user to foster collaborative design. The workshops provide a forum to stimulate dialogue, conversation and learning between designers and other stakeholders, such as users (Storvang and Clarke, 2014; Thomson et al., 2012; Thyssen et al., 2010). The group interactions that take place in the workshops are essentially meant to build a common understanding, in the form of collective intelligence, among stakeholders (Sanoff, 2007). Table 2.1 summarizes the features of some of these frameworks.

Table 2.1: Existing stakeholder / user involvement frameworks

Authors	Main Features	Decisionmaking System Explicit?	Remarks
Storvang and Clarke, 2014	- Workshops as main collaborative forum - Identification of stakeholders and their roles - Use of boundary objects to facilitate shared understanding	No	Contains very useful outline for managing stakeholderinvolvement process, but fails to elaborate a group decision-making approach
Kjølle et al., 2005	- Workshops as main collaborative forum - Use of boundary objects to facilitate group interaction	No	It is illustrative on use of boundary objects to enhance interaction but fails to provide a comprehensive decision system for design process management
Oijevaar et al., 2009	- Stratification of user-groups - Varied user-group roles across design phases - Workshops as main collaborative forum	No	It indicates participation by various user-groups across design phases but fails to provide a comprehensive decision system for design management at the process level
Emmitt et al., 2005	- Focus on all project stake- holders - Workshops as main collaborative forum - Key attention on value generation	yes, but not detailed enough	The decision system is based on weighting values and is at variance to the lean decision system (i.e. CBA). It is not explicit on user-group stratification and their roles.
PMI, 2008	- Stakeholder identification - Explicit on requirement Collection tools: workshops, focus groups, interviews, brainstorming - Reliance on project charter	No	It suggests the need for group Decision-making but fails to detail an appropriate decision system

Zwemmer, 2008	- Stratification of user-groups. - Varied user-group roles across design phases. - Workshops as main collaborative forum. - Strategic for large clients. - Special focus on briefing.	No	It distinguishes user-groups and indicates their roles throughout the process. it however lacks a group decision-making system
Jensen, 2002	- Stratification of varied user- group roles across design phases; - Workshops as main collaborative forum	No	Identified user-groups are mainly managers and staff representatives. it fails to incorporate a group decision-making system
Sanoff, 2000	- Presents various methods, - Techniques and processes of Participation - Focused on community participation in design	No	It encourages collaborative decision-making, but the decision approach is not well defined except for a proposal of planning games for group decision making

Limited knowledge, however, exist on a structured framework to effectively manage the activities in these workshops, especially with respect to group decision-making. Effectively managing the processes in these workshops, apart from contributing to sustaining the collaborative realm, between the designers and users, should also lead to desirable decisions outcomes from the workshops. Storvang and Clarke (2014) share this observation and propose a framework to make activities in the workshops more structured. Some elements of this framework include identifying the various stakeholders, defining the social processes (i.e. the specific activities to be undertaken), and establishing the technical considerations (e.g. use of boundary objects). Even though these elements of the framework are useful, there is still the need for these elements to be linked to an explicit decision approach, such as CBA, to further refine the structure of the workshop process.

The value universe model, proposed by Christoffersen and Emmitt (2009), outlines a series of workshops when involving stakeholders in design, and proposes a "standard value agenda" as the decision-making framework in the workshops. This decisionmaking framework identifies more with traditional approaches such as AHP, and essentially involves weighting values (options) in a decision matrix to find the solution that, in the view of the workshop participants, offers the best value. In an effort to ensure that the kind of decision-making approach in these workshops yields sound decisions and promotes consensus building among stakeholders, this research explores the CBA decision system as an emergent decision system, in the AEC industry, capable of nurturing an atmosphere of transparency, respect, trust and knowledge sharing.

The workshops that are organized for participatory design are described as sociotechnical spaces in which a variety of voices and a diversity of opinions operate (Clausen and Yoshinaka, 2007). The knowledge and power bases of the stakeholders who operate in these socio-technical spaces are however asymmetric, and it requires an effort to get them (i.e. stakeholders) to meet on truly equal terms (Storvang and Clarke, 2014). One strategy of reducing the knowledge and power distances among stakeholders in socio-technical spaces is to use boundary objects.

Boundary objects are artifacts that become shared foci for the attention of people with initially different interests, expertise and language (Carlsen et al., 2004). Boundary objects are employed to aid and facilitate communication, translation, dialogue and interaction among professional and non-professional stakeholders in participatory design (Shipton et al., 2014; Kjølle and Blakstad, 2011; Chinyio and Akintoye, 2008; Kjølle et al., 2005). Examples of boundary objects include drawings, models, prototypes, computer animations and materials. In the application of value-based decision systems, such as CBA, whereby communication, negotiation and dialogue are key elements of the process, the use of boundary objects could play a crucial role in providing a common understanding of the attributes of various alternative solutions.

2.2.6 Value Management / Engineering

Value management (VM) is a process in which the functional benefits of a product, process or service are made explicit and appraised in line with the value system of the client (Kelly, 2007). A related concept to VM is Value Engineering (VE) which is employed as a technique to identify new approaches to meet client requirements, reduce costs and ensure increased technical competence (Green and Moss, 1998). Whereas VM efforts generally concentrate on "creating" value, especially at the early stages of the project, VE techniques are used to "deliver" value at the production stage, with particular focus on reducing cost (Green, 1994).

A number of techniques have been developed for VM and VE (Shen et al., 2004; Kelly et al., 2004; Dell'Isola, 1982). These techniques, which are team-based processes, employ function analysis to promote a shared understanding of project requirements. Examples include the job plan technique, the Function Analysis System Technique (FAST), Functional Performance Specification (FPS) and Quality Function Deployment (QFD).

The job plan technique seeks to rationalize the clients brief by identifying the functions of key elements and spaces (Kelly and Male, 1993). FAST is based on the intuitive logic in relationships among functions displayed graphically (Bytheway, 2007). FAST enables a logically sequential display of functions for their dependency to be verified rigorously. FPS is composed of a document by which an inquirer needs are expressed in terms of user-related functions and constraints (European Commission, 1995). For each of these functions, evaluation criteria are defined together with respective projected degrees of satisfaction, with a certain level flexibility assigned (Masson, 2001). QFD translates customer needs into design solutions (Wu and Chen, 2002). It is a systematic process that provides a structure to develop a product to meet customer needs (Loenen and Mroczkowski, 2010).

The emphasis given to function analysis, as a means of translating customer requirements, however views design problems as well-defined and static (e.g. Green 1992; 1994). In contrast, Green (1994) proposes the Simple Multi-Attribute Rating Technique (SMART). The general framework for SMART follows the concept of Group Decision Support (GDS) which refers to "any designed process that supports a group of people seeking individually to make sense of, and collectively act in a situation in which they have power" (Bryant, 1993). SMART creates a learning atmosphere for stakeholders to reach a common understanding of the strategic objectives of a project and represent them in an explicit and organized manner (Green and Moss, 1998; Green, 1997). Although decision analyses form the basis of SMART, its primary concern is with decision structuring rather than decision-making (Shen et al., 2004).

Having created a shared understanding of customer needs, by employing the identified techniques, the next task in the VM process is to explore alternative means of achieving the required functions. At this point, various value creation/improvement options are generated. These options are evaluated to choose the appropriate one. The CBA decision system is explored, in this research, as a possible approach to collaboratively decide on generated options in the VM process.

Value vs. Cost

Value and cost are popular considerations of decision-making within the AEC sector. Even though the project team in desiring to achieve project objectives simultaneously considers cost, there is the need to isolate cost, as an element of decision-making, from real value. Arroyo (2014) made the following observations in this regard:

i. Cost is a limitation not a 'value'. The permissible cost of a specific project is characteristically assigned limits, mostly as a result of prospects of return on investment (in the case of private sector), or as a result of constraints on public sector budget. Considering cost should not mean choosing the alternative with the least cost, but rather the alternative that best meets the project objects within financial limits. Cost does not necessarily embody 'value', and should, thus, not be evaluated as similar to the qualities of the alternatives.

ii. Cost can be shifted across decision contexts. Within a particular project, it is possible to allocate cost in diverse ways. Cost can be moved between building systems and the constituents of those systems. In choosing a lighting system, for instance, the project team may first evaluate which option they prefer in terms of energy efficiency, aesthetics, illuminance, before deciding how much agreeable to the client to spend on an option that offers greater 'value'.

iii. Cost is adjustable. It is not an inherent feature of an option. The cost of a light bulb, for instance, depends on the quantity in demand, the terms of delivery, the location of purchase, and the market conditions. An option's cost can be negotiated with suppliers, or by altering the design.

2.2.7 Team Functioning Process

The phenomenon of involving users and other stakeholders in design process is a typical setting of team process. A team is defined as "a distinguishable set of two or more people who interact dynamically, independently, and adaptively toward a common and value goal/objective/mission, who have been assigned specific roles or functions to perform, and who have a limited lifespan of membership" (Salas, et al., 1992). Teams are generally viewed as systems that are complex, adaptive and dynamic (McGrath et al., 2000), existing in diverse contexts over their duration (Ilgen et al., 2005).

Even though several models of team process exist, with a variation in detail, most of them fundamentally follow the traditional Input-Process-Output (I-P-O) scheme (Campion et al, 1993; Steiner, 1972; McGrath, 1984; Hackman, 1987). *Inputs*, such as team members and organizational character, refer to existent conditions preceding a performance episode. Performance episodes are "distinguishable episodes of time over which performance accrues, and feedback is available" (Mathieu et al., 2000). *Processes* describe the manner in which team inputs are transformed into outcomes.

Outcomes are the consequences and by-products of team activity valued by one or more stakeholders. There are three primary types of outcomes: i) performance (e.g. quality and quantity), ii) team endurance, and iii) members' affective reactions (Hackman, 1990).

Contemporary works on team process (e.g. Ilgen et al., 2005; Marks et al., 2001; Moreland 1996), however, present the classical I-P-O framework as inadequate for characterizing team functioning. One observed deficiency in the I-P-O model is that many of the mediatory factors that intercede and transfer the effect of inputs to outcomes are not processes, but emergent cognitive or affective states (Ilgen et al., 2005; Marks et al., 2001). It has also been observed that the I-P-O model simplifies team process to a one sequence linear route, from inputs to outcomes, even though feedback loops potentially exist (Ilgen et al., 2005). The I-P-O scheme also tends to propose a linear progress of main effect influences, proceeding from one category (I, P, or O) to the next, despite the fact that some Interactions have been observed between various inputs and processes (I x P); between various processes (P x P); and between inputs or processes and emergent states (De Dreu & Weingart, 2003; Colquitt et al. 2002; Taggar, 2002; Witt et al., 2001; Stewart & Barrick, 2000). Emergent states are constructs that develop within the duration of the team and impact team outcomes.

In response to the identified limitations in the I-P-O model, Ilgen et al. (2005) propose an alternative model in the form of input-mediator-output-input (IMOI) model. The substitution of "M" for "P" mirrors the wider range of variables that perform the essential mediatory role of transferring the effects of inputs to outcomes. The incorporation of the extra "I", at the end of the model overtly invokes the concept of recurrent causal feedback.

Removal of the hyphen between letters simply suggests that the causal linkages may not be linear or additive, but rather nonlinear or conditional (Ilgen et al., 2005). This model is expected to form a crucial theoretical basis for the development of a user-involvement framework for design process.

2.2.8 Mental Models in Participatory Design

One of the important elements of team functioning is the concept of mental models. The advent of the concept of mental models dates back to ancient Greek philosophy, and is linked to studies in the cognitive aspects of human behaviour. In the view of Craik (1943), the mind constructs small scale models of reality known as mental models. These models are structured knowledge representations that enable individuals to interact with their environment based on their knowledge, experience and expectations (Badke-Schaub et al., 2007). Mental models play the crucial role of helping people to describe, explain and predict events in their environment (Mathieu et al., 2000; Rouse and Morris, 1986; Johnson-Laird, 1983).

Various levels of mental models exist among design teams. These, according to BadkeSchaub et al. (2007) and Neumann et al. (2006), include the task model, the process model, the group model, the competence model and the context model. The task model refers to a person's stored knowledge on a particular design task, and the associated knowledge about the equipment and technology required to perform the task. Product knowledge, which relates to information about the object to be designed, forms part of the task model. The process model relates to knowledge on how to solve a design task through some problem solving approaches and some particular design methods. Group or team model refer to knowledge about team mates, their abilities and the assigned roles and responsibilities. Competence model refers to the general confidence in how far a team is able to perform its task. The context model refers to all the knowledge on the background which reflects the given situation such as the employed media of communication, facilities and so on.

In team settings, as in participatory design, the focus moves beyond individual mental models to shared or team mental models. Shared mental models are described as knowledge or believe structures that are shared by team members to enable them formulate precise descriptions and anticipations about a task, and to coordinate their actions as well as adjust their behaviour to the dictates of the task and other members of the team (Cannon-Bowers et al., 1993; Klimoski and Mohammed, 1994). ‘Shared mental models’, as a term, does not just refer to multiple levels or sets of shared knowledge, or simply an aggregation of individual mental models, but also refer to a synergistic functional combination of the team’s mental functioning representing similarity, overlap and complementarity (Langan-Fox et al., 2004).

There is a tendency for team processes, such as decision-making and communication in participatory design, to be influenced by shared mental models (Kraiger and Wenzel, 1997). Significantly divergent mental models imply that, team members would work towards different objectives and predict different future situations, thus, leading to difficulty in coordinating team effort. On the other hand, very similar mental models means that team members would work towards common objectives with a shared cognition of how the team will function (Mathieu et al., 2000).

Badke-Schaub et al. (2007) however contend that, the level of sharedness of mental models should be specific to the domain of operation of a team. Depending on the domain, a team either functions as a creative team or a tactical team (Larson and LaFasto, 1989). The basic feature of tactical teams is the clarity of the task to be performed. The team process, in this case, is directive, with highly focused tasks, unambiguous role definition, and precise operational standards. Creative teams, on the contrary, are characterized by autonomy, and team members are required to explore possibilities and alternatives such that ideas are not discarded prematurely.

In particular reference to participatory design teams, which are creative by nature, the observation is that, different views and diversity of thinking could foster a creative problem-solving process, and thus, improve the resulting solution (Badke-Schaub et al., 2007). Alternatively, it has also been observed that it is beneficial, for efficient team performance, to allow some level of sharedness of the team and task models among the design team (Gilson and Shalley, 2004). Discussing a design problem definition and requirements of a product enables a common understanding among design teams in their search for a solution (Badke-Schaub et al., 2007). Enhancing creativity within design teams, at the same time ensuring an efficient team performance, requires a balance of the level of sharedness among the various dimensions of mental models: team, task, process, context and competence. Generally efficient team performance calls for more sharedness in team, process, context and competence models, while creativity requires less sharedness in the task models.

2.2.9 Wicked Problems in Participatory Design

Wicked problems refer to problems with the character of being difficult to resolve due to the absence of a precise definition of the problem and its solution (Rittel & Webber, 1973 and Simon, 1969). The phenomenon of wicked problems, with an endless set of possible solutions, results in a propensity for diverse and conflicting individual perspectives, especially in group decision making as in participatory design. The wickedness of the problems of design is one of the fundamental threats to collaboration in participatory design (Conklin, 2005).

Wicked problems are ill-structured (Simon, 1984) and without a definite set of solutions (Rittel & Webber, 1973). In distinguishing wicked problems from tame problems, Rittel & Webber identified ten features characteristic of wicked problems: i) *no definitive formulation of the problem*; ii) *no stopping rule for the problem*; iii) *solutions to the problems are not true or false, but good or bad*; iv) *there is no immediate and no ultimate test of the solution to the problem*; v) *every solution to the problem is a "oneshort" operation*; vi) *problems do not have an inexhaustively describable set of potential solutions*; vii) *every problem is essentially unique;* viii) *every problem is a symptom of another problem*; ix) *the existence of a discrepancy representing a wicked problem can be explained in numerous ways*; x) *the planner has no right to be wrong.*

Detailed explanation of these features can be found in several sources (e.g. Farrell & Hooker, 2013; Conklin, 2005; Whelton & Ballard, 2002; Rittel & Webber, 1973). These features have however been condensed into the methodological implications of three states of wicked problems. These three states include *finitude*, *complexity* and *normativity* (Farrell & Hooker, 2013).

The condition of *finitude* relates to the existence of constraints around the cognitive capacity of individuals and groups. These cognitive constraints, in addition to resource limitations, present a profound restraint on individual and team ability. Ignorance, according to Farrell & Hooker (2013), is one of the indicators of cognitive finitude. Some areas of ignorance include the concepts required to specify facts and true theories, as well as the criteria for correctly deciding them (Farrell & Hooker, 2013). Rittel and Webber's wicked problem features, as listed in *i), ii), vi), vii), viii), ix)* above, are contained in this condition. In the context of participatory design, the condition of finitude tends to restrain the abilities of designers and other stakeholders in establishing a definite description to a design problem, and exploring all the potential design solutions towards getting the best. This results in a situation of inexhaustive set of possible solutions. The recommendation is that in the midst of these inexhaustively describable solutions for every design problem, the rational approach, especially when constrained by time, is to stop pursuing the best possible solution, but initiate a pursuit of an accessible and satisfactory solution, from a set of possibilities defined and agreed by all stakeholders (see Farrell and Hooker, 2013; Whelton and Ballard, 2010).

The condition of *complexity* is in relation to the diversity of elements within a system, and the multifaceted interdependencies linking these elements. The situation of complexity increases with more number and diversity of elements in a given system. An increase in the number and diversity of stakeholders in participatory design, for instance, makes design a more complex process. Farrell & Hooker (2013) identifies two consequences of a complex system. One is the fact that it will always be difficult to untangle the effects of some particular actions from those of other co-occurring interactions. The other is the fact that outcomes of processes are impossible to envisage, thus intensifying our ignorance and aggravating the limits resulting from finite resources. Rittel and Webber's wicked problem features, as listed in *ii), iv), v),vii), vii)* above, are contained in this condition. In team processes, such as participatory design, the situation of complexity arising, for instance, from the divergent mental models of stakeholders could be managed by encouraging collaboration, especially in group decision-making.

The situation of *normativity* results from the inextricable link between norms and values in the formulation or resolution of problems. This inextricable link between norms and values is habitually adversarial, because "what is expected" is often in conflict with "what is innately held". This situation of conflict could manifest either within individual participants or among participants (e.g. in participatory design), and emerging from the conflict towards problem resolution, requires some comprise. Rittel and Webber's wicked problem feature, as listed in *ii), iii), viii), ix)* above, is contained in this condition. A group decision-making approach that relies extensively on objective data, and is guided by transparency, respect and dialogue, could be exploited to manage this condition of wicked problems.

2.3 Lean Design

Lean design is a design management paradigm that incorporates lean production principles to the process of design to ensure design process efficiency and quality design outcomes (Tilly, 2005; Brookfield et al., 2004). Even though, fundamentally, they refer to the same thing, *lean design* is sometimes referred to as *lean design management* in order to emphasize the management aspect of the process (Jørgensen, 2006). The pursuit of lean design is generally viewed in two dimensions: i) the adoption of systems, tools and initiatives to manage waste and promote efficiency in producing the design itself and/or in utilizing resources across the project supply chain; and ii) the adoption of systems, tools and initiatives to determine and generate value to customers, other than focusing on resource utilization and delivery/completion times (Hansen and Olsson, 2011; Jørgensen, 2006).

Premier research on lean design is seen to have been more concerned with the first dimension, particularly focusing on structuring design tasks to avoid negative iteration and improve flow. Studies in this aspect of lean design have noticeably concentrated on the application of Design Structure Matrix (DSM) (Choo et al., 2004; Austin et al., 2000; Hammond et al., 2000), batch size reduction and pull techniques (e.g. Ballard 2002; Ballard & Zabelle, 2000; Tzortzopoulos & Formoso, 1999; Ballard & Koskela, 1998), and the Last Planner System (LPS) (e.g. Ballard 2000; 2002).

Research on the customer value dimension of lean design is also beginning to emerge. Examples of specific areas that have received attention include management of the project definition processes (e.g. Emmitt et al., 2005, 2004; Whelton, 2004; Ballard, 2003), and application of target costs to construction (Jacomit and Granja, 2011; Ballard, 2006; Granja et al., 2005; Jørgensen, 2005; Ballard & Reiser, 2004; Kern and Fomoso, 2004; Nicolini et al., 2000).

In the context of the Lean Project Delivery System (LPDS^{TM}) (Figure 2.9), developed to apply lean principles across the entire construction project delivery process, lean design phase forms an integral part.

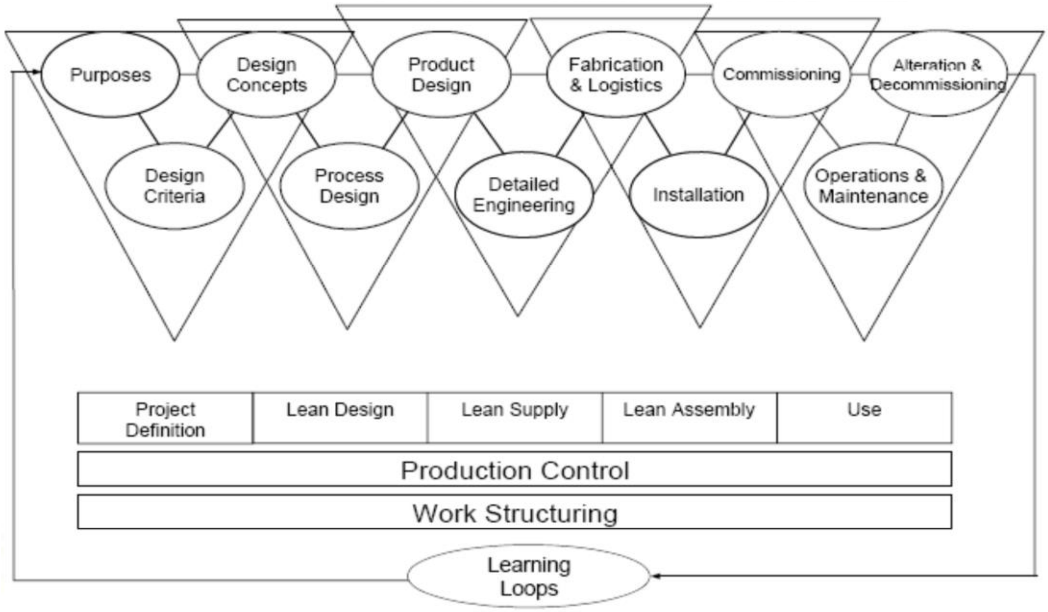

Figure 2.9: Lean Project Delivery System (Ballard, 2003)

The lean design phase begins after purposes, criteria and concepts of the project are aligned at the project definition phase; and ends when process and product design are aligned with project definition. Lean design, within the LPDSTM, encourages integration and collaboration among the various project stakeholders during the design process to ensure waste minimisation and value maximisation.

2.3.1 Lean Design Tools and Methods

Various tools and methods, based on Toyota design practices, have been adopted to design products and processes in other industries, such as construction. These tools and methods seek to reduce waste and increase customer value in the project delivery process. Lean tools and methods function effectively in integrated project delivery systems, where there is high collaboration among project stakeholders (Arroyo, 2014).

Some of the lean design tools include, A3 reports, Target Value Design (TVD), SetBased Design (SBD), Building Information Modeling (BIM) and CBA.

2.3.1.1 A3 Reports

A3 reports are employed to display relevant information on an A3 size sheet for effective team communication and collaborative decision-making. The origin of A3, in lean practice, is linked to the Toyota management system of Plan-Do-Check-Act (PDCA) (Sobek II and Smalley, 2008). In the PDCA cycle (Deming, 2000; Shewhart, 1939), measures taken in each phase is displayed on A3, thus serving as a decisionmaking aid (Parrish, 2009). Figure 2.10 shows a template for an A3 report. There could, however, be some modification to this template depending on the situation.

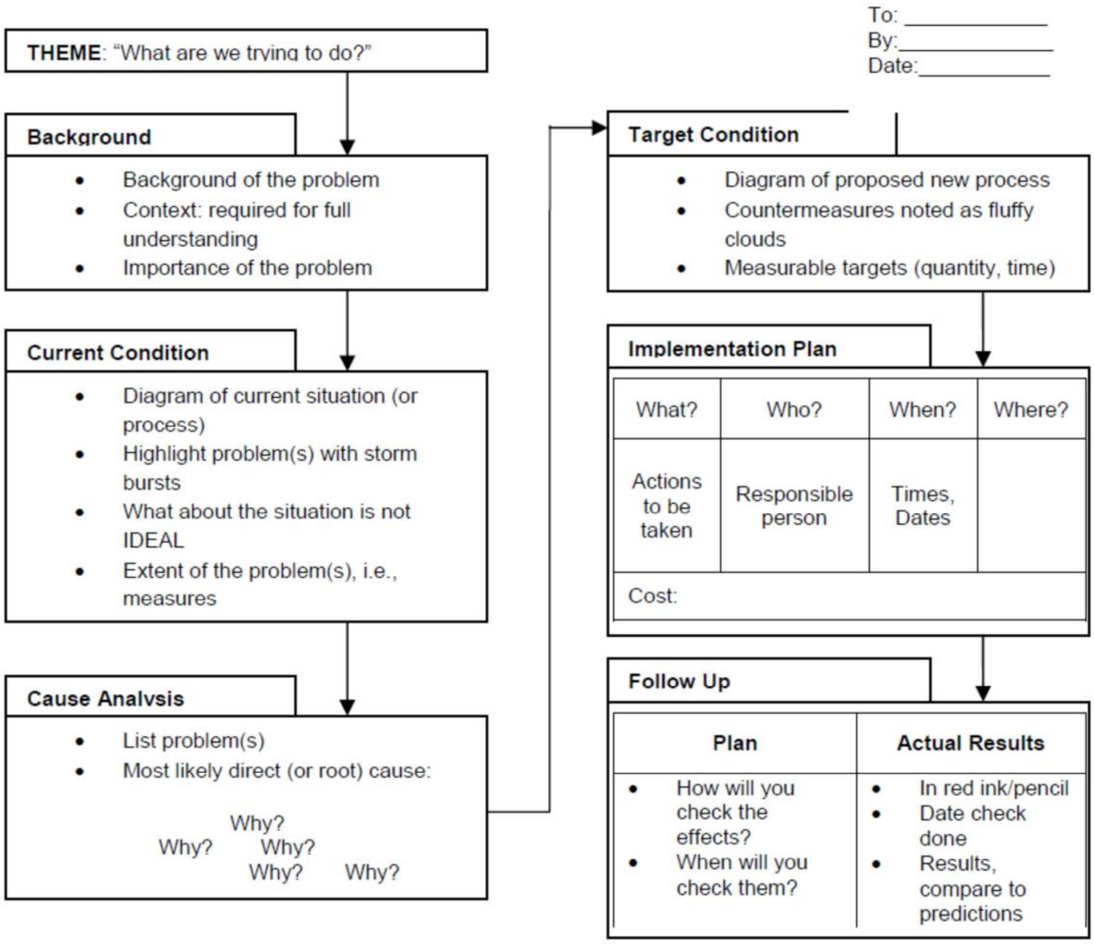

Figure 2.10: A3 report template (Sobek II, 2008)

According to Sobek II (2008), the specific steps in the A3 problem-solving process include: (1) Identify a problem or need, (2) Carry out research to comprehend the current situation, (3) Undertake root cause analysis, (4) formulate solutions to respond to root causes, (5) Develop a target state, (6) Construct an execution plan, (7) formulate a follow-up plan with predicted outcomes, (8) Discuss plans with all affected parties, (9) Obtain approval for implementation, (10) Implement plans, and (11) Appraise the results. A3s are used by Toyota across organizational levels as communication tools

(Morgan and Liker, 2006).

The purpose of A3, it should be noted, is not only to produce a piece of paper that documents the PDCA cycle, but more significantly, it supports stakeholders, within an organization, as they explore alternatives and develop ideas for discourse. A3 reports also improve transparency, and allow continuous improvement among the stakeholders. The documentation aspect of A3 assists stakeholders to learn from previous decisions to create better decisions and ultimately better outcomes in the future (Arroyo, 2014).

2.3.1.2 Target Value Design

The main idea behind Target Value Design (TVD) is to ensure that the design process is driven by a quest to achieve a target value, in the form of a desired performance for a building project, at specified cost limits agreed with the owner (Zimina et al., 2012). TVD, which has its roots in Target Costing, employed in the manufacturing sector (Yook et al., 2005; Nicolini et al., 2000), is basically concerned with self-imposing necessity as a means to innovation and continuous improvement (Arroyo, 2014). TVD focuses on understanding the purpose of the product of the design, with an emphasis on designing to minimize waste and increase value for clients/users. The TVD process is collaborative, such that, stakeholders are involved in the early stages of the design process to allow for a collective definition of the ends, means, and purposes that will drive the design of the building (Zimina et al., 2012).

One of the crucial stages in the TVD process is the project definition phase (Figure 2.11). The client, in this phase, produces the business case for the project.

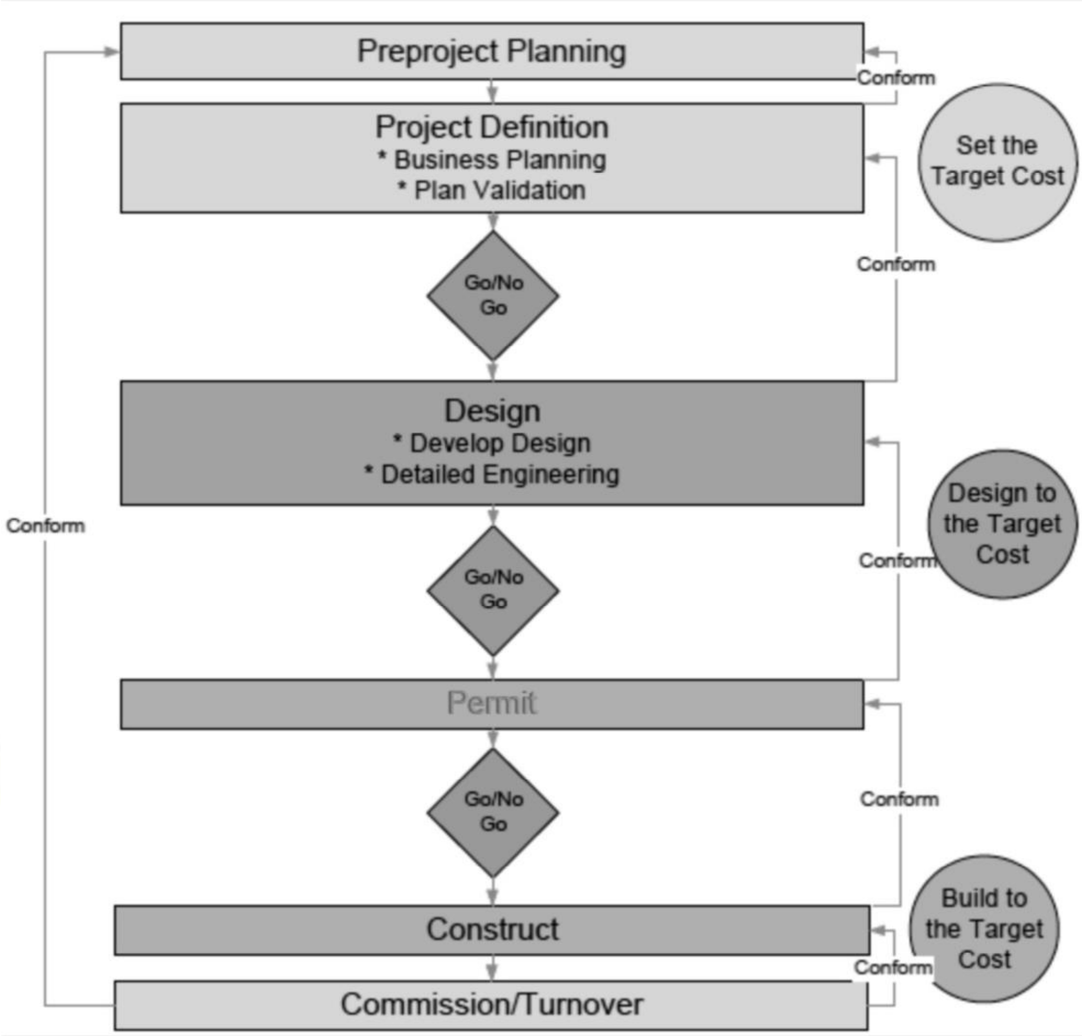

Figure 2.11: Target Value Design process scheme (Ballard, 2008)

In order to boost transparency and trust among stakeholders, the business case is revealed to the rest of the members of the team. It is worthwhile to dedicate significant time and effort to project definition activities, at the pre-design stage, with the key downstream players involved in business planning.

The objective of this approach is to define value (i.e. desired features and functions) of the building project, and the financial constraints (i.e. what the client is able and willing to pay to get this value). Considerable results could be realized if much attention is paid to the early stages of the project (Ballard and Reiser, 2004). The design is done if the 'allowable cost' (the amount of cost that the owner is willing to expend in the project) is lower than the target cost (Zimina et al., 2012).

In adopting TVD, the decision-making process ought to be linked to the value and target cost of the alternatives evaluated for the entire project. Even though in TVD the target cost is assigned for the entire project, the design team can reallocate and segment the cost into different building systems towards optimizing the overall 'value'. The design team may, for instance, choose to increase the cost on the insulation of exteriors walls and reduce the cost on the HVAC system, if that delivers a greater 'value' for the project (Arroyo, 2014).

The major distinguishing features of TVD from the traditional cost and contract management practices reflect in (i) the project definition process - TVD roots target cost into the allowable cost and client's business goals as well as engaging designers and builders in validating the business plan; (ii) cost and target management - design to cost and value, decentralized management; (iii) a systemic approach to project management that aligns project organization, an operation system based on lean principles and commercial terms (Zimina et al., 2012).

2.3.1.3 Set-Based Design

Traditional design process tends to hastily converge on a point in the solution space, and then continuously modify that solution until it meets the design objectives. The subsequent iterations, to refine the point solution, that come with the traditional pointbased approach to design process may not only be time consuming, but also lead to a suboptimal final design (Sobek II et al., 1999). In contrast to the traditional point-based design approach, SBD starts by considering a broad set of possible design solutions and progressively tapering the set to finally converge on a desirable solution. SBD seeks to reduce negative iteration in design process through the design team's collaborative exploration of design alternatives, and keeping those alternatives open until the last responsible moment (Parrish, 2009).

The design team, in SBD, is expected to postpone commitment to decisions on alternatives, to allow time to explore and evaluate as many feasible design solutions as possible (Singer et al., 2009). In doing so, the team should make sure that all factors and criteria are applied to all alternatives with consistency (Figure 2.12).

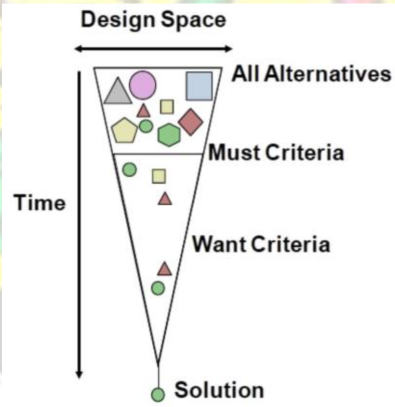

Figure 2.12: Set-Based Design Process (Parrish, 2009).

The generation or exploration of alternatives starts from the owners need. There is a period in the design process in which the team needs to keep all alternative paths open up to the moment when the selection of an alternative path can be pursued with enough confidence. The design team needs to be able to anticipate the respective outcomes of the various alternatives before making a decision after which exploration of new alternatives ensues (Figure 2.13).

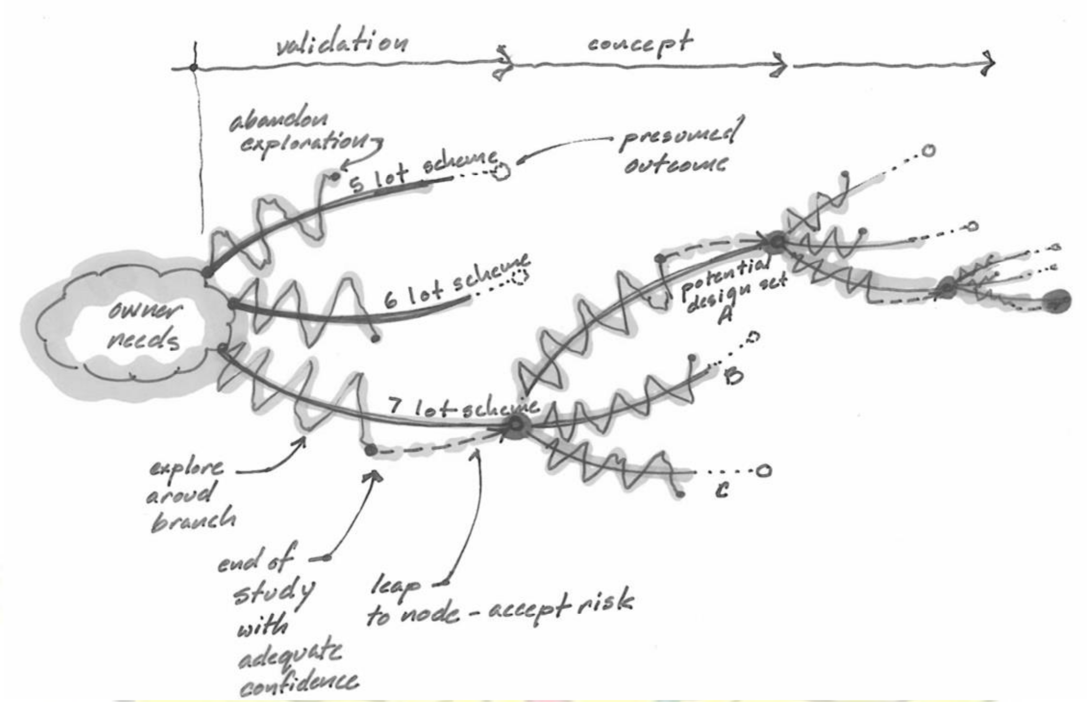

Figure 2.13: Set-based design and decision-making timing (Mar, 2009 in Arroyo, 2014).

It is not sufficient, in SBD, to merely generate alternative solutions, but pursuing a decision approach to make the best choice among the alternatives. In deciding among alternatives, stakeholders explore tradeoffs by designing and prototyping or simulating alternatives solutions. When the decision is obvious, unimportant, or subjective, best guesses are made based on judgment and experience; else, the required investment is made to obtain quantifiable data to guide the decision (Sobek II et al., 1999).

2.3.1.4 Building Information Modeling (BIM)

BIM is an n-dimensional modeling technology, with associated set of processes, which compiles information on a building (i.e. the interrelated elements, construction process and performance) to enhance communication among project teams (Al Hattab and Hamzeh, 2013; Eastman et al. 2008). BIM relies on various intelligent computer imaging tools to model various dimensions of information on building projects (e.g. 3D, 4D, 5D and 6D). 3D models are primarily the regular static models with databases on building form, component and material information. 4D models are smarter representations of real activities involved in a project. 4D models link individual components and assemblies of 3D models with time (schedule) related information. 5D models link individual components of 3D models with time and information related to cost. 6D models link the components and assemblies of 3D models with elements of project life-cycle information.

One significant benefit in the use of BIM, especially with respect to Set-Based Design, is that, designers are able to develop alternative designs more quickly by simply altering single components, or systems. Furthermore, BIM provides a shared language, especially in participatory design, for stakeholders, to understand how the building fits together and functions (Parrish, 2009). In employing boundary objects to enhance communication in participatory design, BIM could play a significant role.

2.3.2 Lean Decision-making Approach

A lean decision-making approach is centered on enhancing collaboration among stakeholders in the decision-making process to maximize value and reduce waste. Among the various decision approaches in the AEC sector, CBA is recognized as one that is most aligned with lean project delivery (Arroyo, 2014). CBA, for instance, postpones value judgment on alternatives as long as possible, and is capable of complementing Set-Based Design, towards generating value in design process (Parrish, 2009; Thanopoulos, 2012). Some other decision approaches, such as AHP, in contrast, fix the weights of factors early in the decision process. CBA also separates value form cost in its application, and could therefore be an appropriate complement in Target Value Design decisions (Arroyo, 2014). The distinguishing characteristics of lean and non-lean decision-making approaches are shown in Table 2.2.

Table 2.2: Differences between lean and none-lean decision approach

Consideration	**Decision-making approach**	
	Non-Lean	***Lean***
Decision-making outcomes	Short term thinking	Long term thinking
Stakeholder participation	Decision-making is in a closed circle. A decide, present and defend approach	Early involvement and collaboration among stakeholders
Systems interrelation	Individual win method. Each member of the design team optimizes his/her part.	A group approach. Optimizes the collective, not chunks.
Generation of alternatives and decision timing	Point-based design: Explore alternatives and pass it to the stage. Repeat the process a stage at a time.	Set-based design: consider options in multidisciplinary teams, but delay design decisions until the last responsible moment in order to evaluate as many feasible options as possible using factors and criteria for all.
Management of subjectivity	Subjective weighting of factors is made early on the decisionsmaking process, and is based on assumptions and general categorization.	Subjective decisions are based on anchored questions and are postponed until the last phase of the decisions-making process.
Display of information	Does not openly indicate everyone's choice. Some applications evaluate the importance of the stakeholders.	Eliciting preferences with visualizations helps to build consensus among stakeholders.

Transparency of final decision	The weighting of the factors makes it difficult to know the important differences between the alternatives in the decision.	Transparent process. The advantages of alternatives are discussed and agreed among stakeholders. Clearly states the paramount advantage.
Documentation	Decisions are based on past experience and intuition; little or no documentation is used.	A3 reports are used to clearly state problem in context, include key information and recommendations. This document is distributed to relevant stakeholders

(Arroyo, 2014a)

2.4 The Choosing By Advantages Decision System

Choosing By Advantages is a value-based multi-criteria decision analysis method in which decision-making is based on the comparisons among the advantages of alternatives (Suhr, 1999). Unlike the conventional approaches to decision making in the AEC sector, such as AHP, application of the CBA system is concerned with identifying factors which expose substantial differences between alternatives, without focusing on assigning importance to the factors (Arroyo, et al., 2014; Suhr 1999). CBA decisions which are based on Importance of Advantages (IoAs), and not a comparison of advantages to disadvantages, avoids a common way of double counting factors (Suhr, 1999). Upon establishing the advantages of each alternative, stakeholders proceed to measure the importance of these advantages by comparing them before they are weighted. The weighting process, it should be noted, is only applied on the advantages, and not disadvantages, criteria, attributes, or other types of data (Arroyo et al., 2014; Parish and Tommelein, 2009; Suhr, 1999). The CBA process is guided by four principles (Suhr, 1999): (1) decision makers must learn and skillfully use sound methods of decision making; (2) decisions must be based on the importance of the advantage; (3) decisions must be anchored to the relevant facts; (4) different types of decisions call for different sound methods of decision making.

Various methods of CBA exist for almost all types of decisions, ranging from very simple to very complex. These include *instant CBA* for simple decisions involving two mutually exclusive alternatives, *two-list method* for two mutually exclusive alternatives of equal cost, and the *tabular method* for moderately complex decisions involving more than two mutually exclusive alternatives (Suhr, 1999). This research explores the tabular method considered as appropriate for decisions in building design. Decisions in building design, which involve mutually exclusive alternatives that might not share the same cost, are viewed as moderately complex (Arroyo, 2014). Table 2.3 contains the core terms in the tabular CBA application process, with their respective definitions.

Table 2.3: CBA terminologies

Terminology	***Definition***
Alternative	A person, thing or plan which is a subject of choice
Factor	Element part or component of a decision
Criteria	A decision rule or a guideline on which a judgment is based
Attribute	A characteristic, quality or quantity of an alternative
Advantage	The beneficial difference between the attributes of two alternatives

(Arroyo et al., 2013; Suhr, 1999)

Tabular CBA application process involves five phases: 1) stage setting, 2) innovation, 3) decision-making, 4) reconsideration 5) implementation (Table 2.4).

Table 2.4: Phases of CBA application system

Phase	**Description**	**Activities**
1	Stage setting	Defining the purpose, and identifying the issues, criteria and stakeholders of the decision.
2	Innovation	Identifying the alternatives and making the differences between them visible and tangible.

3	Decision-making	Listing the advantages of each alternative, deciding the importance of each advantage and choosing the alternative with the greatest importance of advantages, before considering the resource implications of the alternatives and making the draft decision.
4	Reconsideration	Reviewing the draft decision to check that it really is what is wanted, changing it if appropriate and then committing to the choice.
5	Implementation	Doing what is necessary to realise the decision in reality.

(Suhr, 1999)

The actual decision-making process takes place in phase 3 of the CBA decision system. The various steps associated with this phase are shown in Figure 2.14.

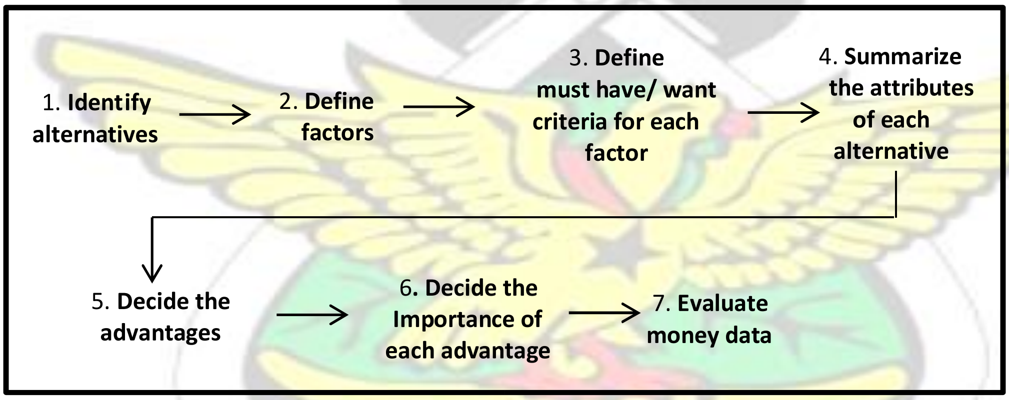

Figure 2.14: CBA decision-making steps (Arroyo et al., 2013)

In the *first step*, stakeholders explore and select alternatives that are likely to serve the purpose of the decision. In the *second step*, they define factors in order to distinguish between the alternatives. In the *third step*, stakeholders settle on the criterion in each factor. The criterion is used to evaluate the attributes of the alternatives. A criterion could either be a desirable (want) or a mandatory (must). Alternatives that fail to satisfy a 'must' criterion are not considered in the subsequent steps. In the *fourth step*, the attributes of each alternative are summarized by stakeholders. In the *fifth step*, the stakeholders identify the least preferred attribute with respect to each criterion, and then decide on the advantage of each alternative's attribute relative to the least-preferred one.

In the *sixth step*, the stakeholders decide on the importance of each advantage (IoA). The first task in this step is for stakeholders to select the paramount advantage, which is the most important advantage among all. They then use the paramount advantage to assign an IoA scale, with the IoA of any least-preferred attribute always getting a zero relative to itself. The paramount advantage could, for instance, be assigned a scale of 100 or 10. Stakeholders rely on this scale to weigh other advantages. The final activity in the sixth step is the summation of the IoA for each alternative. In the *seventh and final step*, stakeholders evaluate cost data by comparing the total IoA for each alternative with the respective estimated cost of that alternative. Even though the alternative with the highest IoA should literally be the obvious choice, the cost evaluation puts the final decision within budgetary contexts of the project.

Going through the various steps is expected to be highly collaborative among the various stakeholders (Arroyo et al., 2013). After an alternative has been chosen, the group is expected to take time to reconsider their decision by undertaking a holistic analysis into the decision-making process. The possible questions that arise at the point of reconsideration include: i) Are there any additional alternatives to be considered? ii) Does the importance of advantages correctly represent the views of stakeholders?

Determining the IoA is a process that involves some subjective sentiments. Suhr (1999) however propose a number of considerations which could guide stakeholders in assigning importance to advantages:

i. The objective and setting of the decision. The context-based nature of CBA requires the process to begin with identifying an objective to be achieved and the alternatives judged relative to the setting of the decision.

ii. Knowledge of client/user needs and values. The expectations and concerns of users and other stakeholders is an essential guide in deciding IoA.

iii. The greatness of the advantages. An advantage close to zero has an importance close to zero. Greater advantages should correspondingly have greater importance.

iv. The magnitudes of the scales of measure of the attributes. Usually the relationship between attributes, advantages and IoAs are nonlinear.

2.5 Process-level Design Management

Research in design management, within the AEC industry, is generally in two dimensions (Zerjav et al., 2013). One dimension is focused on the macro-level aspect of managing design as a *business organization* (Emmitt, 1999), and the other dimension concentrates on the micro-level portion of managing design as a *process* (Kagioglou et al., 2000). Even though, in practice, there is a connection between management of design as a process and as an organization, some difference exists, especially in relation to the approaches to studies at the two levels. Whereas most studies in organizationlevel design management focus on the normative approach of prescribing pragmatic concepts that can be implemented in design practice (e.g. Baldwin et al., 2008), studies in process-level design management have largely ended in descriptive narratives of design practice (Luck, 2012; Dorst, 2011).

In addressing the issue of limited prescriptive studies in design process management, the research focus was to develop a framework for managing user-involvement in participatory design process. In line with the concept of reflective practice in design process (Dong et al., 2013; Valkenburg and Dorst, 1998; Schön, 1984), one strategy of managing design process is to identify decision-making frames, within the design process to define the context for design activity (Zerjav et al., 2013). Frames, here, refer to the context of managerial decision-making which makes it possible for observable design action in the domain of design activity (Zerjav et al., 2013).

In accordance with this concept of design process management, the entire design process can be partitioned into recurring episodes of design activity occurring in corresponding decision-making frames (Figure 2.15).

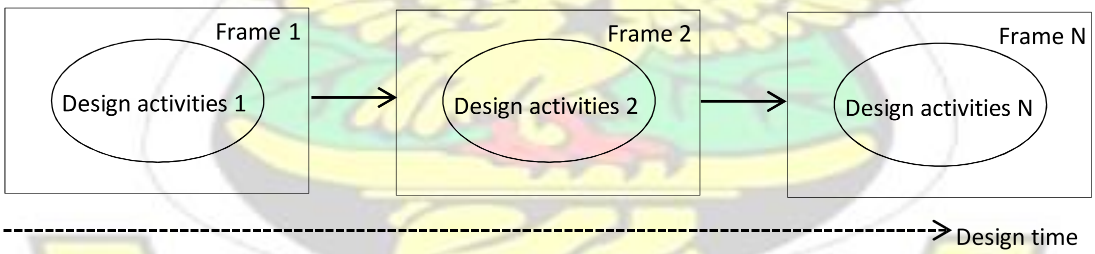

Figure 2.15: Decision-making frames in design processs (Zerjav et al., 2013)

This agrees with the GDS methodology of staging “a series of decision conferences timed to coincide with the decision pinch-points which punctuate the building design process” (Green, 1996). It should therefore be the concern of process-level design management to identify and enforce frames for present design activities, and to anticipate subsequent frames for ensuing design activities.

Predicting the frames likely to emerge in subsequent series of design activity empowers the design manager to direct ongoing design activity in a more informed way (Zerjav et al., 2013). The design manager is expected to rely on established requirements to enact the decision-making frames within which design activity occurs. While it is acknowledged that there are difficulties in explicitly representing the frames onto observable action (Stumpf & McDonnell, 2002), it is also contended that managerial decision-making is based on observable action (Zerjav et al., 2013).

A primary concern of design management is, however, the outcome of design decisions within the identified frames (Lawson et al, 2003; Cross, 1999). Therefore, as Suhr (1999) asserts, if the outcome of these design decisions matters, then the decisionmaking approach also matters. It is, thus, pertinent to explore and incorporate an appropriate decision-making system across the various frames. This decision-making system, while ensuring that the output from each decision-making frame is sound, should also enhance collaboration and consensus building among stakeholders.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explores and presents the Design Science Research (DSR) paradigm in designing the research, which is aimed at developing a construct, in the form of a userinvolvement framework that integrates the CBA decision system. DSR, also known as constructive research, is a research approach intended to create innovative constructions to solve real world problems, and in doing so, contributes to the theory of the discipline in which it is applied (AlSehaimi et al., 2013; Koskela, 2008; Van Aken, 2004; Lukka, 2003). The theoretical and practical rationale behind the adoption of DSR, for this research, was discussed in a paper presented at the 4th International Conference on Infrastructural Development in Africa (ICIDA) (Kpamma et al., 2015a).

3.2 The paradigm of Design Science Research

The nature of the effect of a given research is fundamentally subject to its research paradigm. "Research paradigm" denotes a blend of the research questions, the methodologies adopted, and the nature of the expected research products (Van Aken, 2004). A good insight into the character of a given science is highly significant to the success of that science since the research questions tackled, methodologies used, and outcomes produced are crucial concerns (Koskela, 2008).

The foundation of most academic research in management is based on the impression that "understanding" is the mission of all science (Van Aken, 2004). "To understand" is to be able to describe, explain and probably predict (Emory, 1985; Nagel, 1979). Several non-positivists also support the view that the mission of every science is to generate a certain public understanding of a particular phenomenon (Peirce, 1960). However, understanding a given problem only provides a foundation to its solution. The ensuing step should involve formulating solutions which have been proven workable. Van Aken (2004) indicates that, "understanding the source of resistance to certain organizational changes still leaves undone, the task of developing sound change programmes".

The methodology for the natural and social sciences whereby the focus is on "how things are", disregards the question of "how things ought to be" (Koskela, 2008). An answer to the question of "how things ought to be" should lead to developing innovative solutions to existent problems. The emergence of a research paradigm, the mission of which is not just a description and explanation of the world, but a transformation of it with innovations, manifest in various fields (Koskela, 2008; Boland and Colloby, 2004;
Hevner et al., 2004; Van Aken, 2004; March and Smith, 1995; Kasanen, et al., 1993).

Premier authors on DSR make reference to Simon (1969) on "artificial sciences" as the seminal contribution to the scientific theory of design science. Koskela (2008) however traces the history of the theory of design science to the Aristotelian concept of "science of production". Aristotle in his classification of knowledge identified productive science as one, among two other categories of knowledge, described as theoretical knowledge and practical sciences (Barnes, 2000). Theoretical knowledge is pursued to establish truth while the practical sciences concentrate on how to act in various situations. On the other hand the "science of production' which is of instrumental nature, is tailored towards making useful artifacts in various fields such as poetry, medicine, and housebuilding (Koskela, 2008).

3.2.1 Methodological Position of DSR

DSR is positioned in the context of the conceptual, nomothetical, action-oriented, and decision-oriented research approaches (Figure 3.1) (Neilimo and Näsi, 1980 in Lukka, 2003). Two approaches draw close to design science approach. The first is the decision-oriented approach, in which its link with theoretical analysis and thinking is shared with the design science approach. The decision-oriented approach however relies on the method of deduction, while design science employs heuristics to construct innovations whose practicality has to be verified.

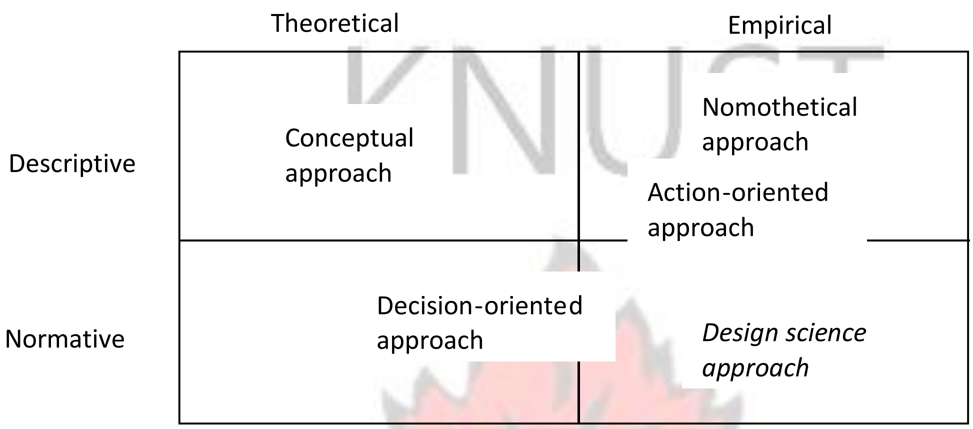

Figure 3.1: The methodological position of design science research (Lukka, 2003)

The other approach that draws closer to design science is the action-oriented approach whereby direct empirical connections and the use of case-studies are common. In both approaches the researcher operates directly in the field involving the application of ethnographic methods such as observation, interviews and analysis of archives. Actionoriented studies and the design science approach are however differentiated by the fact that, the product of action-oriented approach is mainly a description of an in-depth understanding of a phenomenon with the absence of the problem solving prescription that characterizes design science approach (Lukka, 2003).

3.3 The Research Design in the Context of Design Science

DSR is characterized by the nature of the research questions or objectives (Koskela, 2008). A research objective presented by words such as design, build, change, improve, *develop* (as is the case in this research), enhance or introduce may be classified as DSR (Järvinen, 2004). The fundamental approach to DSR is to build and evaluate (Koskela, 2008; March and Smith, 1995). This involves designing and building the construct, and then checking to ensure that the problem for which the construct was built can be solved. All human artifacts, such as models, diagrams, plans, organization structures, commercial products, and information system designs are constructs (Lukka, 2003). The construct to be developed in this research is a user-involvement *framework* for design process.

In designing the research to develop the framework the various phases of DSR, according to Lukka (2003), were followed (Figure 3.2). The first phase of the research involved identifying an area which, apart from being practically relevant should also contribute to theories of user-involvement and lean design and design process management.

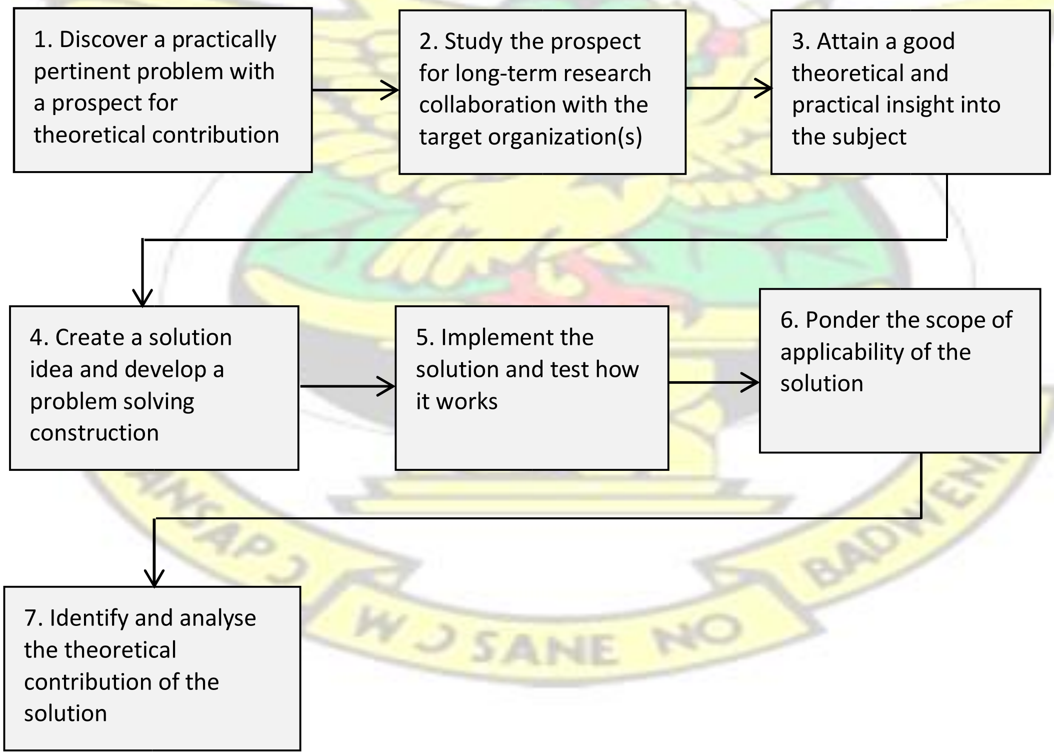

Figure 3.2: Various Stages of DSR (Lukka, 2003)

Preliminary literature review indicated that the issue of user-involvement in design process was of practical relevance towards value generation in building design and construction (Björnfot and Bakken, 2013; Pasquire and Salvatierra-Garrido, 2011), and needed further research (Storvang and Clarke, 2014; Jensen et al., 2011; Thyssen et al., 2010; Barrett and Stanley, 1999).

The need for user-oriented research in the construction industry is also evidenced in an initiative by CIB to increase research focus on clients and users by establishing a new working commission, W118, in 2010. In relation to CBA, research on its application in user-involvement, apart from contributing to the under-analyzed area of incorporating CBA in user-involvement frameworks, is also responsive to the recognition of CBA as a lean construction tool that has received a relatively less attention in terms of research and application (Arroyo et al., 2014; SmartMarket Report, 2013).

The second phase was to identify target organizations with the potential of long-term cooperation with the research team. These target organizations were building design firms and user-groups involved in three different projects. The researcher, in this context whereby experiential knowledge is essential (due to the action-oriented nature of DSR), typically became a member of the organization expected to be devoted to the research question (Van Aken 2004; Lukka 2003). The researcher relied on his experience in architectural practice to facilitate his integration in the target organizations, such as the design firms.

In the third phase, a deep understanding of the practical and theoretical attributes of the research area was obtained. This involved a rigorous theoretical review, especially on the concept of participatory design, the CBA decision system, lean design and design process management. A case application of the CBA decision system in the selected projects was undertaken for an in-depth understanding of the practical functioning of CBA in various design contexts.

The fourth phase involved developing an innovative solution, in the form of a construct, to solve the identified problem of little work on decision-oriented user-involvement frameworks. Bunge (1967), in line with his philosophy of technology, describes innovative constructs as technological rules. A technological rule, Bung (1967) explains, is an instruction to perform a finite number of acts in a given order and with a given aim. The developed construct or technological rule, in this research, is a userinvolvement framework that incorporates the CBA decision system. This stage is seen as very crucial since the development of an innovative construct is a necessary endproduct of every constructive research.

The framework was tested in the fifth phase for its practicality. This phase relied on the pragmatic notion of truth, which argues that whatever works in reality is true (Lukka, 2003; James, 1955). The validity of the framework was tested by piloting it within a real life context through case studies. This phase of the research also called for a high level of collective commitment and collaboration on the part of both the researcher and project team members.

The range of applicability of the framework was reflected upon in the sixth stage. The researcher, at this stage, had to step back from the empirical work to ponder over lessons learnt with the target organizations, and to what extent the framework could be transferrable to other contexts. Even though the framework is specifically meant to facilitate designer-user collaboration, there is a great potential to adopt and adapt it in other contexts of stakeholder collaborations and design process management.

The final phase, which was a crucial exercise from an academic standpoint, involved recognizing and analyzing the theoretical contribution of the research project. The research was expected to contribute to the theories of lean design management, userinvolvement, the CBA decision system and design process management. Paucity in lean design management theory has been observed by several researchers (Lee et al., 2012; Arayici et al., 2011; Emmitt, 2011; Jacomit and Granja, 2011; Liu et al., 2011; Sacks et al., 2010). Scarcity in the theory of CBA application has also been observed in Arroyo et al. (2014), as well as SmartMarket Report (2013).

The significance of theory in various disciplines has been outlined by Koskela (1999). These, among others, include: providing an explanation and understanding to an observed behaviour; providing a prediction of future behaviour; and providing a basis for building tools for analyzing, designing and controlling. In establishing the link between a research and its theoretical contribution, the main options include the development of a new theory, the refinement of an existing theory, the testing of an existing theory or the illustration of an existing theory (Keating, 1995; Lukka, 1999 in

Lukka 2003).

3.3.1 Methodological Framework for the Research

Two key activities were pursued in the research. These activities included *building* and *evaluating* (Koskela, 2008; March and Smith, 1995) (Figure 3.3). In Building, theory was combined with empirical studies to develop a user-involvement framework that integrates the CBA decision system. The component of theory was based on reviewing literature in participatory design, the CBA application system, and design management. The empirical studies took the form of case studies involving the application of the

CBA decision system to make typical design decisions when users are involved.

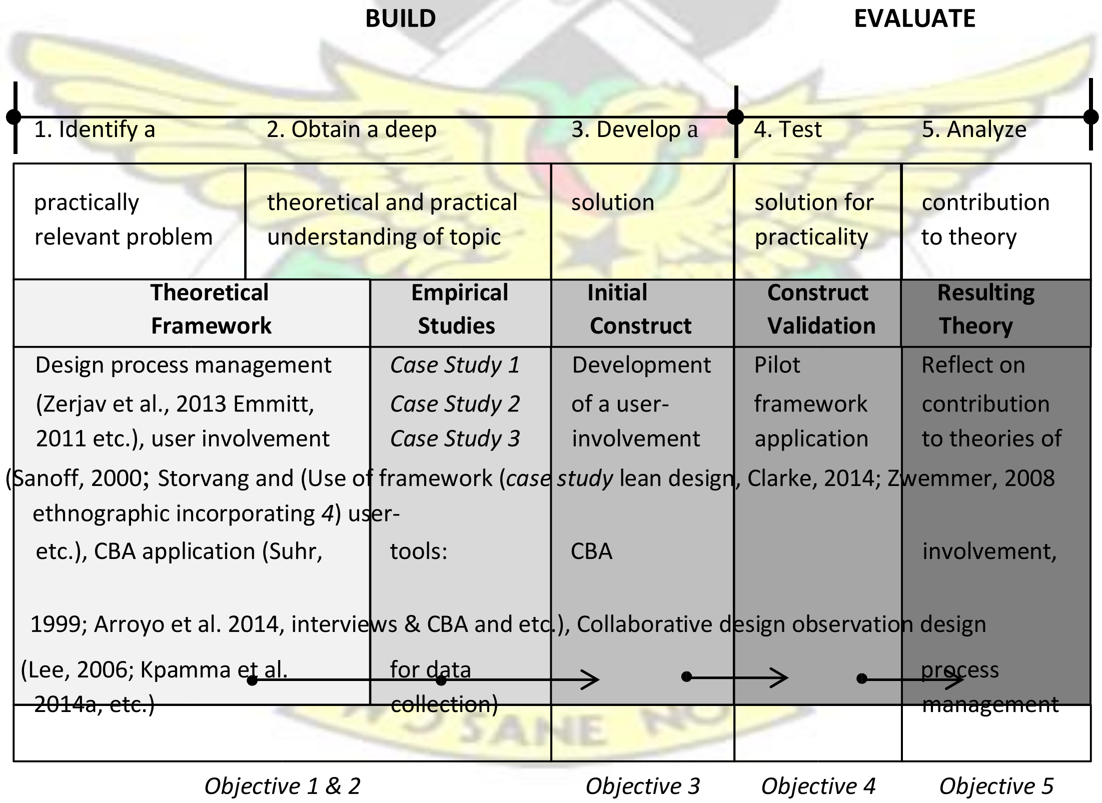

Figure 3.3: Scheme of methodological framework of the research

In Evaluating, the developed framework was tested to verify its practical applicability and contribution to theory. The test of the framework for its practical validity involved applying it in a real context by conducting case studies. The theoretical contribution of the framework would be evaluated in terms of development, test, and illustration of theories within the disciplines of lean design management, user-involvement, the CBA decision system and design process management.

3.4 Case Studies

Given the fact that an innovative construct is the typical output of a DSR, it is recommended that the research takes the form of assessing the performance of interventions or artifacts, executed within the context of the intended use (Van Aken, 2004). A typical research approach to study and test a construction is multiple case studies (Van Aken, 2004; Lukka, 2003). These multiple case studies constitute the empirical studies and construct validation in the methodological framework (Figure 3.3). A case study is a research approach intended to create an in-depth and intense knowledge about a situation or question by considering the real physical and social context of the case (Yin, 2014; Christiaans et al., 2004; Robson, 2002; Meredith, 1998).

The application of multiple cases to build up knowledge for designing a construct generally follows a reflective cycle (Van Aken, 1994 cited in Van Aken, 2004) as in Figure 3.4.

5. Test and refine in
subsequent cases

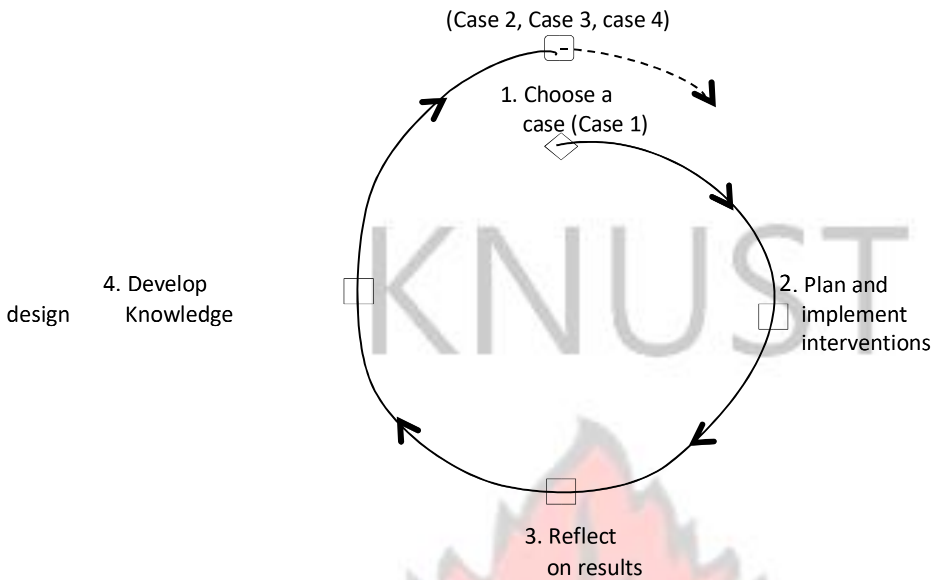

Figure 3.4: Reflective cycle of multiple case studies

The steps in the reflective cycle include choosing a case, planning and implementing interventions, reflecting on the results, and developing design knowledge to be tested and refined in subsequent cases. The evidence from multiple cases, compared to single cases, is often regarded as more credible, and the overall study is therefore seen as more robust (Herriott and Firestone, 1983 in Yin, 1994).

3.4.1 Number and Choice of Case Studies

The guiding principle in determining the number of case studies was based on the logic of literal replication, in contrast to the logic of sampling associated with quantitative surveys. The replication logic is comparable to the logic behind multiple experiments (Hersen and Barlow, 1976 in Yin, 1994). A significant finding, having been discovered from a single experiment, leads to an ensuing and enticing endeavor to replicate this finding by conducting a second, third, and even more experiments (Yin, 1994). While some replications might attempt to repeat the exact conditions of the first experiment, other replications might just alter one or two experimental conditions considered inconsequential to the original finding so as to establish whether the finding could still be duplicated. Yin (1994) sees these replications as confirmations of a robust research finding.

In literal replications whereby cases are selected to predict similar results for the purposes of corroboration, Yin (1994) suggests that the number of cases is generally discretionary and judgmental. He further notes that the number is influenced by the level of confidence one wants to obtain on the results of the multiple cases (the larger the number of cases, the greater the confidence). Nevertheless, he recommends 2 or 3 cases in situations where the theory being tested with the case is straightforward, and the issue at hand does not require an extreme degree of certainty. The key theory behind this research is the reliance on the CBA decision system to create, sustain and optimize the collaborative realm for participatory design (Kpamma et al., 2014a). The first set of case studies employed in this research were exploratory with an explicit focus on evaluating, confirming and establishing the merit of the CBA decision system as a means of promoting participatory design. Three exploratory case studies were, thus, selected for the research based on Yin (1994). A fourth case study was further undertaken to evaluate the practicality of the resulting framework.

Going by the concept of reflective cycle of multiple case studies, as discussed above, the first stage in each cycle involved the choice of the case study. The fundamental considerations in choosing a case study for the various cycles included:

- The potential for long term research cooperation with project participants such as the design team and users Lukka (2003). Given the nature of DSR, which requires a sustained collaboration between the researcher and the research subjects, the focus was on identifying projects in which the researcher could sustain a research partnership with the project participants, at least within the period of the research.
- Projects with high user stake whereby the outcome of the project could greatly influence or be influenced by users.

The projects identified for the exploratory case studies included:

- A theatre expansion project at Techiman Holy Family Hospital (*case 1*),
- A lecture theatre project at Takoradi Polytechnic (*case 2*),
- A lecture hall complex project at Sunyani Polytechnic (*case 3*).

The project for the framework evaluation was:

- A future central administration building for the Sunyani Polytechnic (*case 4*).

The project in case 1 was an initiative of the hospital and jointly funded by the hospital Rotary International. The project in case 2 was part of other projects under the Development of Skills for Industry Project (DSIP) by the Government of Ghana (GOG) with donor support from the African Development Bank (AfDB). The project in case 3 was another GOG supported project with funding from the Ghana Education Trust Fund (GETFUND). The 4th case study project was initiated by the Sunyani polytechnic itself with Internally Generated Funds (IGF) as the expected main source of funding.

The choice of these projects for the case study was justified, not only by a high level of user stake in the projects, but also due to the fact that the architectural design consultants on the projects had special interest in the subject of user-involvement, based on their experience in previous projects. There was therefore a possibility for the research to develop long-term research collaboration with these consultants as is required in constructive research. Table 3.1 is a summary of the general project information for the case studies.

In the second stage of the reflective cycle, the main intervention in the selected exploratory case study projects was the use of CBA by the design team to involve users to make typical conceptual and detailed design decisions during the design of those projects:

Table 3.1: General profile of projects in case studies

	Exploratory case studies			*Evaluation case study*
	Case 1	Case 2	Case 3	Case 4
Project Name	Theatre Expansion and Improvement Project	Development of Skills for Industry Project (DSIP)	Remodeling of HCIM Block Lecture Hall Phase (III)	Future central administration project
Location	Techiman	Takoradi	Sunyani	Sunyani
Project Type	Addition and improvement of operating theatre spaces	Construction of a 3storey lecture theatre	Construction of Lecture Hall/offices	Construction of a new administration building
Clients	Techiman Holy Family Hospital	Takoradi Polytechnic	Sunyani Polytechnic	Sunyani Polytechnic
Funding Agency	Rotary International / Techiman Holy Family Hospital	African Development Bank (AfDB)	Ghana Education Trust Fund (GETFUND)	Sunyani Polytechnic

Major Functions	- Operating theatres - Rest rooms - Sterilization unit - Scrub rooms - Recovery wards - Washrooms	- Lecture rooms - Offices - Washrooms	- Lecture rooms - Offices - Washrooms	- Offices - Conference Rooms - waiting areas - washrooms - parking
Architectural Design Consultants	Beong Integrated Services, Sunyani	Florart Ventures, Kumasi	Building and Road Research Institute, Kumasi	Development office, Sunyani Polytechnic, Sunyani
Focus of case study	Application of CBA to involve users to make a conceptual design decision	Application of CBA to involve users to decide on window opening systems	Application of CBA to involve users to choose a ceiling finish	Application of a user-involvement framework for evaluation

- *Case 1* involved the application of CBA to involve users to select a conceptual design option.
- *Case 2* involved the application of CBA to involve users to decide on a window operating system for a lecture theatre project.
- *Case 3* involved the application of CBA to engage users to decide on a material for the ceiling finish for the project. In
- *Case 4,* however, involved applying a proposed framework across the design process of the project to enhance the participation of users.

The results of the exploratory case studies were used to address the following research questions:

i) Why is CBA able to foster collaboration between designers and users?

ii) What strategies can be adopted to incorporate CBA in a user-involvement framework?

The knowledge obtained from the case studies was combined with relevant theory to form the basis for the design of a user-involvement framework to answer the following research question:

iii) How can a user-involvement framework incorporating CBA be structured? The outcome of the evaluation case study was used to answer the following research questions:

iv) How workable is the framework in a real context of design process?

v) How does the framework contribute to theories of lean design and design process management?

3.3.2 Data Collection from Case Studies

Data for the case studies primarily relied on the organization of workshops, whereby the designers and users collaboratively applied CBA to make typical design decisions. In obtaining the data from these workshops, the research relied on multiple sources of evidence. A major strength of case study research is the opportunity to rely on diverse sources of evidence in data collection (Yin, 1994). Data from the case study was collected by using ethnographic tools, such as, participant observation, direct observation and interviews. In order to ensure credibility of findings, participant and direct observation were used to verify interviews; interviews and direct observation were used to verify participant observation; while interviews and participant observation were used to verify direct observation.

Participant observation involved observations that were made from the active participation of the researcher in the workshops for the respective case studies, either as a facilitator or a member of the design team. The role as a participant observer made it possible for the researcher to gain access to certain events or research subjects that otherwise would have been difficult to obtain for the research. Another advantage of being a participant observer was the opportunity to perceive reality (in terms of CBA application) as an insider rather than an external observer. This opportunity of experiencing reality, as a participant observer, is argued as being invaluable in creating a precise depiction of a case study phenomenon (Yin, 2003). Participant observation also provided an opportunity for elements of group interaction (e.g. changes or shifting in opinions, values concerns or language) to be closely studied (Storvang and Clarke, 2014).

In employing direct observation, the researcher had to step back in some instances and observe the interaction among other workshop participants during the CBA application workshops. In order to enrich the direct observation, the proceedings of the respective workshops were video-taped and later analyzed. Direct observation was carried out to provide additional information (to that obtained from participant observation) primarily on the phenomenon of employing CBA to enable user-designer collaboration.

The key target group for the interviews was the participants (i.e. users and designers) in the workshops. These interviews were conducted to corroborate information obtained from both participant observation and direct observation. The interviews which were open-ended were used to solicit the opinion of the participants on the collaborative attributes of the CBA decision system. The opinion of the respondents was also sought on how CBA decision system can be incorporated in a stakeholder involvement framework.

The research also relied on some documentation on the projects under the case studies for data collection. The documentation which was mainly obtained from the design consultants included drawings, design briefs, and some correspondence between the consultants and the clients. It was from some of these documents that the background and goal of the respective projects were established. The researcher also relied on the documentation to identify the key needs of the clients and prospective users of the projects.

3.3.3 Analysis of Data

Data analysis in case studies involves examining, categorizing, tabulating, and testing evidence to address the initial propositions of a study (Yin, 2003). Data analysis generally means searching for patterns in the collected data (Neuman, 1997). The ultimate goal of case studies is to uncover patterns, determine meanings, construct conclusions and build theory (Patton & Appelbaum, 2003). Once a pattern is established, Neuman (1997) further indicates, it is interpreted in terms of a social theory or the setting in which it occurred.

In analyzing the data from the case studies in this research, the researcher employed the technique of cross-case synthesis and pattern matching by relying on the main theoretical proposition in this research. The reliance on theoretical propositions for case study analysis helps in building a strong focus on the relevant data in the research (Yin, 2003). The propositions, Yin further asserts, also aid to organize the entire case study and to define alternate explanations. The main theoretical proposition in this research was that, "the CBA decision system should be incorporated in a user-involvement framework, because it is capable of creating, sustaining and optimizing the collaborative realm in participatory design". Using this theoretical proposition as a guide, results of the three case studies were synthetized to match the various patterns that emerged. Across the three case studies, the primary focus was on tracing how the CBA decision system promotes an atmosphere of trust, respect, transparency, knowledge sharing and consensus building, to enhance collaboration between designers and users during participatory design.

CHAPTER FOUR

EXPLORATORY CASE STUDIES

4.1 Introduction

This chapter presents three case studies which sought to fundamentally explore the collaborative potential in CBA to enhance user participation in design process, as well as obtain knowledge on strategies to incorporate CBA in a user-involvement framework. The focus, therefore, was not to attempt to judge the result of the decisions in the case studies, but rather, how the decision system created a space for effective collaboration among stakeholders in participatory design. Furthermore, the case studies did not address issues on quality and availability of decision data which is a constraint to the effectiveness of multi-criteria decision methods. Nevertheless, even with adequate decision data, methods influence outcomes (Arroyo et al., 2014).

The findings and analysis of these case studies are expected to address objectives i) and ii) of this research. The first case study was on a theatre expansion project at Techiman Holy Family Hospital; the second case study was on a lecture theatre complex project at Takoradi Polytechnic; the third case study was on a lecture hall/offices project at Sunyani Polytechnic, Sunyani. In each of the three case studies, the CBA decision system was applied for designers to engage users in making typical design decisions in the context of the respective projects.

4.2 Case Study 1

This case study was the first attempt by the researcher to establish the potential of the CBA decision system to create a space for consensus building between designers and users in participatory design, specifically at the conceptual design stage. Apart from the fact that previous research on CBA application has paid less attention on its (CBA) specific potential in enhancing user-designer collaboration, little research has also been carried out on CBA application at the conceptual design stage. Regarding CBA application at the conceptual design stage, Arroyo et al. (2014), for instance, predicted possible challenges due to likely difficulties in knowing and defining certain attributes of conceptual design alternatives. This case study however presents a real case in which designers employed the CBA decision system to build consensus with users in the choice of a conceptual design option for a health care project. Some findings from this case study have been published in the *Journal of Professional Issues in Engineering Education and Practice* (ASCE) (Kpamma et al., 2016a).

4.2.1 Background of Case Study 1

This case study involved a theatre building expansion project at the Holy Family Hospital in Techiman. The location of the project for the case study, the Techiman municipality, is not only one of the brisk commercial towns in Ghana, but also a transition hub for commuters between the northern and southern halves of Ghana. Travellers between Ghana and landlocked West African countries such as Burkina Faso, Niger and Mali pass through Techiman. The health care services provided by this hospital are therefore accessible, not only to the inhabitants of Techiman and its environs, but also to a lot of visitors and commuters.

In line with a continuous improvement policy, as well as an increasing number of patient intake within the hospital, the expansion of the theatre building (Figure 4.1a & b) was one of many projects being undertaken by the hospital.

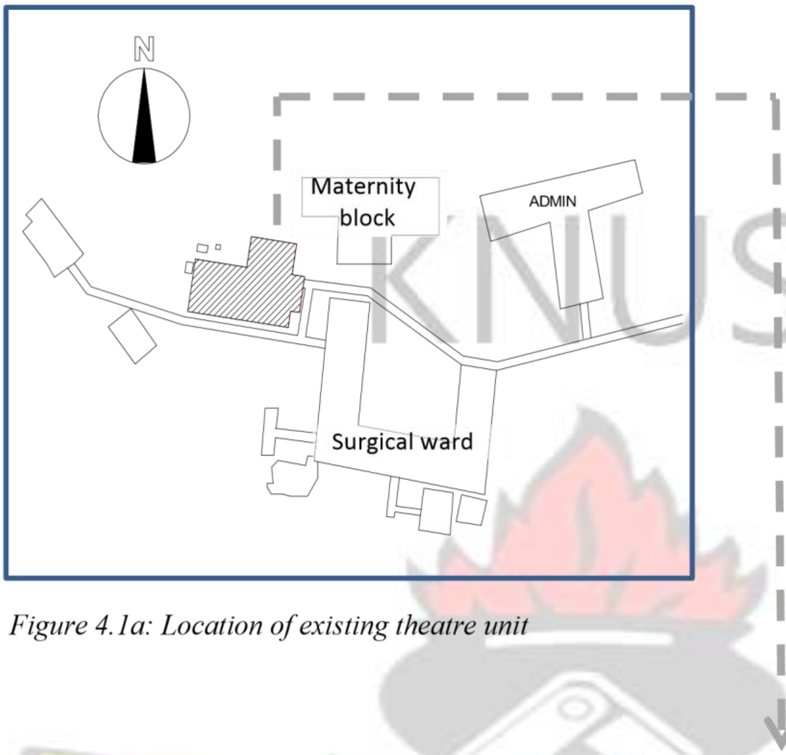

Figure 4.1a: Location of existing theatre unit

Figure 4.1b: Image of existing theatre unit

The primary objective of the theatre building expansion project was to create additional space for extra operating theatres while maintaining a sterile work environment, and an efficient activity flow. One other concern of the management of the hospital was to ensure that during the execution of the project, there would be less interference with ongoing activities within the existing theatre.

The presence of other building structures around the existing theatre building offered a limitation in relation to the direction in which the expansion was to take place. The eastern and southern ends of the building were, for instance, occupied by existing structures and therefore offered less potential for major expansion in those directions. Left with the options of either expanding towards the western end or northern end, the management of the hospital in consultation with the theatre staff, initially settled on undertaking the expansion towards the northern end. This initial decision by the management of the hospital was apparently informed by their opinion that it offered a better potential for a compact design, with the potential of ensuring a good link between the extended zone and the existing zone to ensure a better activity flow. Another consideration was that, this direction of expansion, in the view of management, would reduce the impact of a 5% slope along the east-west axis of the site on the project.

It is worth noting that the initial decision by management of the hospital, to expand towards the northern end, was prior to the engagement of the services of the design team. The design team was therefore approached with a predetermined concept by the client, regarding the direction of expansion. Focused on ensuring that the one year planned duration for the entire project was met, the client requested the design team to go ahead and speedily develop detailed designs within the confines of the predetermined concept of expansion.

The design team in developing a detailed design, based on the concept submitted to them by the client, also started exploring a second concept of expansion towards the western end. This resulted in two conceptual design options primarily differentiated by the direction of major expansion as shown in Figure 4.2. Option 1 was the predetermined concept submitted to the design team by the client, and option 2 was the concept which came up after the design team was engaged.

Figure 4.2: Conceptual design options

The emergence of option 2 however occurred at a time the client and users had almost gotten fixated to option 1. Apart from seeing what, in their opinion, was a workable detailed design that began to emerge from option 1, they also felt that considering a second option could affect the project schedule and its budget. The client had also discussed and agreed on option 1 with a partner financier of the project. The design team was therefore faced with the challenge of getting the client and other stakeholders to consider option 2 as a possible alternative to adopt. The intervention to solve this challenge was to organize a seminar to introduce the project stakeholders to the CBA decision system. It was agreed, after the CBA seminar, that a workshop involving the design team, management, and clinical users of the theatre be organized to apply CBA to decide between options 1 and 2. Due to the action-oriented nature of this research, the researcher was embedded in the design team to particularly play the key role of introducing stakeholders to CBA and facilitate the workshop.

4.2.2 Application of CBA to Decide on the Design Options

A workshop, facilitated by the researcher, was organized to apply CBA to decide on the two conceptual design options. The key participants in the workshop were two members of the design team and representatives of the user group (i.e. management and clinical users of the theatre building). User-group referred to those who engaged in recurrent use and management of the theatre. Representatives of management in the workshop were made up of the administrator, medical director, estate officer, accountant and chaplain. The clinical users were represented by a general surgeon, two theatre nurses, a medical officer and the medical director who also doubled as an obstetrics and gynecology specialist. The proceedings of the workshop were videotaped for the interaction between the participants to be analyzed later for the purposes of data collection. There were also follow up interviews with the participants of the workshop for more research data.

In line with the CBA steps, the first step in the workshop was the identification of the decision alternatives as option 1 and option 2 (Figure 19). The limitation of the decision process to these two alternatives, apart from being occasioned by the aforementioned restrictions in other directions of expansion, also identifies with the recommendation (Farrell and Hooker, 2013; Whelton and Ballard, 2010) that in the midst of the inexhaustively describable solutions for every design problem, the rational approach, especially when constrained by time, is to stop pursuing the best possible solution, but initiate a pursuit for an accessible and satisfactory solution, from a set of possibilities defined and agreed by all stakeholders.

Seven factors were identified in the second step of the process to help differentiate the design alternatives. This was followed by a definition of criteria, in the third step, to serve as a basis for judging the alternatives relative to the identified factors. The first column of Table 4.1 contains a summary of the identified factors and the respective criteria.

Factor 1 (Interference with surrounding structures): One of the guiding principles of the project was to undertake the expansion in such a way that there was minimal interference with existing surrounding structures. This was not only to ensure that many demolitions and relocations were avoided, but also to ensure that the use of other facilities around the theatre building was not inconvenienced. The participants therefore agreed that the criterion should be "less interference with surrounding structures is better".

Table 4.1: CBA table for case study1

Factor / Criterion	Option 1	Option 2
1. Interference with surrounding structures	*Attribute*: interferes with septictank and oxygen reservoir	*Attribute:* interferes with only abandoned water tank
Criterion: less is better	*Adv.:* Imp: 0	*Adv.:* ***interferes only with a non-functional structure*** Imp: 5
2. Area of added space	*Attribute*: 169.84m^2	*Attribute:* 286.61m^2

Criterion: more is better	*Adv.:* Imp: 0	*Adv.:* ***116.77m² more space*** Imp: 10
3. Interference with ongoing clinical work	*Attribute*: will involve more demolitions within existing building, with extension more in the sight of existing spaces	*Attribute:* will involve less demolitions within existing building with extension less in the sight of existing spaces
Criterion: less is better	*Adv.:* Imp: 0	*Adv.:* ***will involve less interference with ongoing clinical work*** Imp: 7
4. Ventilation across the unit *Criterion:* more is better	*Attribute*: _will lead to a blockage of windows which are air entry/exit points at the northern end of the existing building	*Attribute*: will not result in any blockage of entry/exit point for air circulation
	Adv.: Imp: 0	*Adv.:* ***will allow for more ventilation*** Imp: 9
5. Area of open space used	*Attribute*: 169.84m²	*Attribute*: 286.61m²
Criterion: less is better	*Adv.:* ***116.77m² less*** Imp: 1	*Adv.:* Imp: 0
6. Integration potential of roofs *Criterion:* higher is better	*Attribute*: _will require altering the pitch of current roof to integrate well with a workable roof over extension	*Attribute*: a workable roof over extension could take the current pitch of existing roof and still integrate well.
	Adv.: Imp: 0	*Adv.:* ***higher potential for integration of roofs*** Imp: 10
7. Flow potential *Criterion:* higher is better	*Attribute*: __a tendency fort flow w patien route to interfere withnd staff flo other activities	*Attribute*: allows for well-defined routes of flow without potential conflicts
	Adv.: Imp: 0	*Adv.:* ***higher potential for efficient flow*** Imp: 4
Total IoA	1	45

Factor 2 (Area of added space): One of the primary reasons for undertaking the theatre extension was to create more space to accommodate more operating theatres and ancillary facilities. The stakeholders therefore agreed that more accrued area was desirable. The agreed criterion was thus, "more added space is better".

Factor 3 (Interference with ongoing clinical activities): It was the intention of management and staff of the hospital to ensure that while the execution of the expansion project went on, surgical cases could still be carried out within the existing theatre spaces. Activities associated with the expansion project were therefore expected to have the possible minimum disturbance on ongoing clinical activities within existing theatre spaces. “Less interference with ongoing clinical activities” was therefore agreed as the criterion.

Factor 4 (Ventilation across the block): The project was located within a climatic zone that was largely warm and humid. Natural ventilation was therefore important in maintaining comfort and the well-being of occupants within the theatre. Even though mechanical air-conditioning is an option and possibly mandatory for creating special conditions within some spaces such as the operating theatre rooms, reliance on natural ventilation still remained critical because it is more sustainable within an environment where power was expensive and its supply remained erratic. It was therefore the concern of participants to ensure that in undertaking the project, major exit and entry points for the passage of air across the building would not be blocked. Therefore the criterion was “more natural air passage is better”.

Factor 5 (Area of open space used): In the midst of the ongoing and intended projects being undertaken by the hospital, there was a general concern of ensuring that the layout of the hospital was not congested with structures. Open spaces and vegetation within the hospital, as a general principle, was therefore to be conserved as much as possible. Projects which would interfere less with existing open spaces were preferred.
The set criterion was “less interference with open space is better”.

Factor 6 (Integration potential of roofs): Another consideration that came up was to ensure that the new roof that would come over the extended portion of the theatre would integrate well with the roof of the existing structure without significant alterations to the existing roof. A major alteration of the existing roof to integrate well with a new roof would not only affect the budget and schedule of the project, but would also lead to some interference with ongoing activities within the existing theatre. The agreed criterion was "higher integration potential of roofs is better".

Factor 7 (Flow potential): Patient and resource flow contribute immensely to the efficiency of health care delivery as well as maintaining a sterile work area, which is essential in an operating theatre environment. It was therefore an objective of participants to ensure that when the expansion was completed, there would be an efficient flow of activities between the existed zone and the extended zone. The criterion was "higher flow potential is better".

Having identified the various factors and defined the respective criteria, the next step was to establish the attributes of each option. This involved an analysis of the conceptual designs with more detailed sketches that showed potential spatial arrangement and flow within each option. The respective attributes were then summarized in Table 4.1. The less preferred attributes were underlined and used as reference points for describing advantages. The alternative with the less preferred attribute for a particular factor, as shown in Table 4.1, does not possess an advantage for that factor.

The next step after identifying the advantages was to assign importance to these advantages. Characterized by an element of subjectivity, the process of deciding the importance of the advantages was collaborative and involved extensive discussions and persuasion among the participants (Figure 4.3).

Figure 4.3: User - designer collaboration in deciding the importance of advantages

A scale of 0 to 10 was used to rank the advantages according to their importance. The advantage with the paramount importance was assigned 10 and this formed the basis for ranking other advantages. Two advantages were identified by the participants as paramount and assigned 10 (Table 4.1). These were "116.77m^2 more space" and "higher potential for roof integration". Having assigned importance to all the advantages, the total importance of advantages (IoAs) of each design option was computed. Conceptual design option 2 had a far higher total IoA of 45 and became an obvious preferred option, pending cost evaluation, compared to the total IoA of 1 for design option 1.

The data on cost was evaluated by comparing the total IoA for each design option with their respective projected costs based on the gross floor area method. This was done by plotting total IoA against the estimated cost for each option (Figure 4.4).

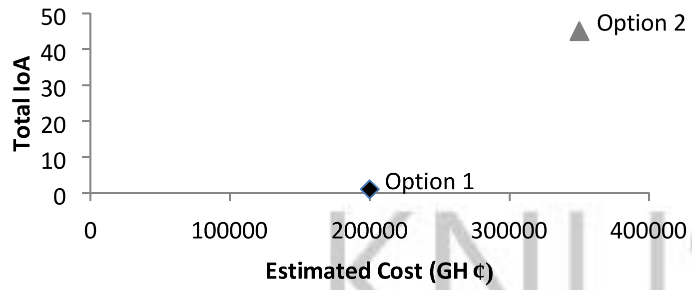

Figure 4.4: Cost evaluation for the design options

It is obvious from the graph that it cost more to realize option 2, and for that matter the decision was whether or not to incur more cost on a design option that provided far more advantages of about 98%. Going for option 1 probably appeared cheaper initially, but it was clear to the users that such a decision meant losing, among others, the advantages of not relocating the septic tank and oxygen reservoir, better natural ventilation, less interference with ongoing activities within existing theatre and higher potential for roof integration. Losing some of these advantages had the tendency of even increasing the estimated cost of Option 1. For instance, a new roof over the extension that could not integrate well with the old roof might lead to making alterations to the old roof therefore adding to cost. Relocating the septic tank and oxygen reservoir might also come with additional cost. The users, with the benefit of all these facts and data, preferred option 2 and rescinded the idea of continuing with option 1.

4.2.3 Discussion

The outcome of this case illustrates the effectiveness of CBA in being employed by designers to manage user user-preferences. One of the indicators of the success of using CBA in managing user preferences, in the case study, was the achievement in getting the client and users to willingly consider an alternate design concept other than the one they had initially settled on. Initially faced with a challenge of getting the client and users to consider an alternate design concept other than the one they had settled on, the remark: “our concept was a very bad concept”, which came from the medical director shortly after the CBA workshop, was a reflection of a user group that became willing to rescind its original choice in preference to a better alternative. Unlike the case would have been in applying other decision systems such as AHP, going through the CBA process of collectively establishing the real advantages associated with the design options presented a more concrete perspective to the users, regarding the beneficial difference between option 1 and option 2. Establishing advantages such as, a *gain in 116.77*m^2 *more space, allowing for more natural ventilation,* and *a higher potential for integration of roofs* created an explicit basis for the users’ spontaneous preference for option 2.

Another success in the application of the CBA decision system to manage user preferences laid in its ability to foster a collaborative interaction between the design team and the users during the decision process. Fostering a collaborative decision environment requires a MCDA method to avoid conflicts arising from trade-offs involving general descriptions like factors (Arroyo et al., 2014). In contrast to common decision approaches in the AEC sector such as WRC, the application of CBA lessened the propensity of conflicts among the stakeholders in their value judgment because the value judgment process was postponed until the advantages between the conceptual design options were collectively established based on objective data. As would have been the case in the application of WRC, a situation of abstraction with a tendency to create disagreements would have arisen if the stakeholders were to have undertaken the vague process of assigning relative ranking to identified factors such as "interference with ongoing clinical work" and "integration of potential roofs". However, having broken down the decision process further to establish advantages of the options, respective to these factors (in the case of the CBA application), it became more unambiguous, resulting in some consensus in deciding the importance of the advantages.

The CBA decision system was also successful in ensuring consensus in the choice of conceptual design option 2 due to its relatively simple and explicit nature which allowed for an intensive participation of all stakeholders in the decision making process. Compared to other decision making systems, the explicit and simple attribute of the CBA application process created an environment in which every step of the decision making process was understood and followed by all participants. The surgeon was for instance absent in an earlier seminar that introduced participants to CBA, and did not have the benefit of earlier exposure to CBA, but was able to participate actively in the decision process with very useful inputs especially at the point of deciding on the importance of advantages. Other approaches, such as AHP, require more laborious mathematical representations which would have been more challenging for participants to understand and participate actively. The relative simplicity in the CBA application process associates with the philosophy of Parsimony or Occam's razor which suggests that "keeping methods simpler is better" (Baker, 2013).

Another desirable effect of the CBA application process was the fact that it created a transparent and free atmosphere for mutual learning among the various stakeholders. On the part of the design team, some technical attributes of theatre design were learnt from the initial concept submitted by the users, even though that concept was eventually rejected. The users in presenting option 1, incorporated a layout that illustrated some "must have attributes" of the proposed theatre unit extension in relation to the brief, functional layout, as well as patient and resource flow. One other instance of knowledge sharing was the stage of deciding on the importance of the advantages. Stakeholders in relying on their respective expertise and experience, to influence assignment of certain importance to a particular advantage, ended up sharing some knowledge to the benefit of the entire group. The design team, based on their expertise and experience, for instance, indicated how natural ventilation across the theatre block (which was originally overlooked by users) could have been significantly impeded with the implementation of option 1.

One challenge that was observed, in the midst of the identified positive effects of the CBA decision system, was the task of establishing actual attributes of the conceptual design options. Greater effort and more time had to be spent, in some instances, to describe and agree on some attributes. A case in point was when the attributes of the options with respect to factors such as "integration potential of roofs" and "flow potential" were to be defined. This led to an extrapolation of the possible scenarios, when more detailed designs had been developed, for a better understanding and definition of the attributes by stakeholders. Given the fact that correct definition of attributes directly impacts the establishment of advantages of alternatives, there would be the need to explore better representative techniques (such as working models and simulations) for presenting conceptual designs alternatives when applying CBA, to allow for easy and precise definition of attributes.

Based on the findings of this case study, the CBA decision system has presented itself as a participative decision tool that is capable of fostering an atmosphere of collaboration between designers and users to arrive at design choices acceptable to all stakeholders. Besides its potential of optimizing design solutions among alternatives, CBA also created an atmosphere which enabled knowledge sharing between users and designers. In the development of a user-involvement framework for building design, prospects, therefore, exist for incorporating the CBA decision system.

4.3 Case Study 2

This case study was the second effort by the researcher to establish the potential in the CBA decision system to create a space for consensus building between designers and users in participatory design. Knowledge from this case study was also expected to form a basis for the design of a user-involvement framework. Unlike the first case study, the decision in this case study was at the detail design stage. Even though previous works exist on CBA application in detail design stage, little attention was specifically paid to its (i.e. CBA) potential in enhancing user-designer collaboration. Case 2 presents a real context in which designers employed the CBA decision system to build consensus with users in the choice of a window system for a project. Some findings from this case study have been published in *Architectural Engineering and Design Management*

(Kpamma et al., 2016b).

4.3.1 Background of Case Study 2

The case study project was the design of a 3-storey lecture theatre project at the Takoradi Polytechnic in Ghana (Figure 4.5). This project is one of other projects under the Development of Skills for Industry Project (DSIP) by the GOG with donor support from the Africa Development Bank (AfDB). The choice of this project for the case study was justified not only by a high level of user stake in the project, but also due to the fact that the architectural design consultants on the project had developed interests in subjects of user-involvement based on their experience in previous projects, such as a resettlement project for a mining community.

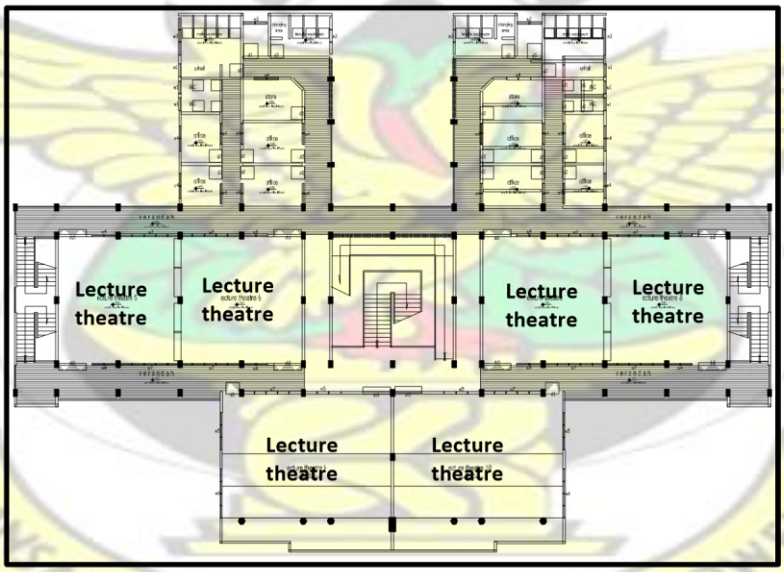

Figure 4.5: Typical floor layout of proposed lecture theatre complex project (courtesy: Florart Ventures / Promancon Consult)

The specific intervention in the case study was the application of CBA by the design team to engage users to make a typical design decision such as the choice of a mode of operation for window openings for the project. The design team, after being introduced to the CBA decision system by the researcher, accepted to apply CBA to engage potential users of the lecture theatre to decide on the mode of operation for a window system for the project. The focus of the case study on the choice of a window opening system was due to the proliferation of several window systems, especially in the construction industry market in Ghana, which often left designers and users in a dilemma regarding the choice of an appropriate system. The choice of this intervention in the case study was also as a result of the important role windows play in enhancing energy efficiency of buildings, particularly with respect to passive cooling and lighting, of a project that was located in a country where power supply remained expensive and erratic.

4.3.2 Application of CBA to Decide on the Window Options

A workshop was facilitated by the researcher to engage representatives of potential users and other stakeholders of the project to decide on the most appropriate mode of operation of window openings among a set of alternatives. The representatives were made up of two lecturers, two students, and a representative from the estate unit of the polytechnic. Other stakeholders included the development officer and the architect from the development office who constituted technical representatives of management. A specialist in window system fabrication and installation was also involved in the workshop for the team to benefit from his specialist knowledge and experience during the decision process.

In line with the first step of the CBA application system which involves identification of alternatives, five alternatives were identified by the stakeholders based on their availability in the Ghanaian market. These included sliding window, pivoted window, awning window, louvered window and casement window (Figure 4.6).

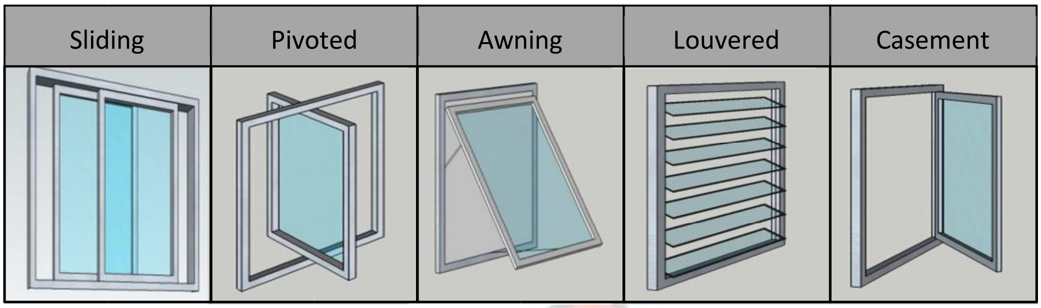

Figure 4.6: Window systems

After identifying the alternatives, nine factors and respective criteria were then defined to enable the stakeholders establish the differences among the alternatives (Table 4.2).

Table 4.2: CBA table for case study 2

Factor/Criterion	Sliding window	Pivoted window	Awning window	Louvered window	Casement window
1. Flexibility in opening / closing *Criterion:* higher is better	*Attribute*: allows for infinite degree of opening along the height of the window up to about 50% of the total area of the window.	*Attribute:* allows for infinite degree of opening along the height of the window and occurring simultaneously from the opposite vertical edges up to the total window area less the area of the edge of the sash.	*Attribute:* allows for infinite degree of opening from the bottom of the window along the width up to the allowable angle of tilt of the of the sash.	*Attribute:* allows for infinite degree of opening of louver blades along the width of the window up to about 90% of window area.	*Attribute:* Allows for various degree of opening along the height of opening up to about 100% of window area.
	Adv.: Imp: 0	*Adv.:* **allows for higher flexibility** Imp: 20	*Adv.:* **allows for higher flexibility** Imp:20	*Adv.:* **allows for much higher flexibility** Imp: 25	*Adv.:* **allows for higher flexibility** Imp:20
2. Familiarity to users *Criterion*: more is better	*Attribute*: It has received an increased attention in the past few years as a more contemporary system especially in the urban areas of Ghana.	*Attribute:* The use of this system is rare in Ghana and some of the users have not seen or had any experience with its use.	*Attribute:* It is an emergent system and is typical common with curtain wall systems in Ghana.	*Attribute:* It is the commonest glazing system for windows for various kinds of buildings in Ghana with almost all users having had experience with its use.	*Attribute:* It is very common with colonial buildings and rural architecture but has seen a rare use in contemporary buildings even though seem to be re-emerging.
	Adv.: **more familiar** Imp: 15	*Adv.:* Imp: 0	*Adv.:* Imp: 0	*Adv.:* **much more familiar** Imp:20	*Adv.:* **more familiar** Imp:15
3. Ease of cleaning *Criterion:* higher is better	*Attribute*: A generally wider pane of glass for each sash provides for a firmer surface but is however quite difficult to access the surface facing the exterior from the interior to clean.	*Attribute:* A generally wider pane of glass for a sash provides a firmer surface for cleaning while the mode of operation allows for easy access to both sides of sash to clean when cleaning from the interior space.	*Attribute:* A generally wider pane of glass for a sash provides a firmer surface for cleaning but however presents great difficulty in cleaning the surfaces facing outside from the interior space.	*Attribute:* The louvre blades are narrower panes of glass that are flexible and could break easily when cleaning but however offers better access to all surfaces of the louvre blades to clean.	*Attribute:* A generally wide pane of glass for each sash which could provide a firmer surface for cleaning but could pose a difficulty in accessing the exterior surface from inside to clean.
	Adv.: **easier to clean** Imp: 30	*Adv.:* **much easier to clean** Imp: 50	*Adv.:* Imp: 0	*Adv.:* **easier to clean** Imp: 30	*Adv.:* Imp: 0
4. Ventilation area *Criterion:* more is better	*Attribute*: Maximum area openable for ventilation is about up to 50% of window area.	*Attribute*: allows for up to about 95% of window area opened for ventilation	*Attribute:* allows for up to about 70% of window area to be opened for ventilation	*Attribute*: allows for up to about 90% of window area to be opened for ventilation	*Attribute*: allows for up to about 95% of window area to be opened for ventilation
	Adv.: Imp: 0	*Adv.:* **45% more open area** Imp: 100	*Adv.:* **20% more open area** Imp:50	*Adv.:* **40% more open area** Imp:90	*Adv.:* **45% more open area** Imp:100
5. Obstruction of surrounding space *Criterion:* less is better	*Attribute*: It doesn't project into any adjoining space beyond the thickness of the wall when opened.	*Attribute*: It projects up to about ½ the width of the sash simultaneously towards the interior and exterior adjoining spaces when fully opened.	*Attribute*: It projects up to about the full length of the window sash into the exterior adjoining space when fully opened.	*Attribute*: It doesn't project into any adjoining space beyond the thickness of the wall when opened.	*Attribute*: It projects up to about the full length of the window sash into the exterior adjoining space when fully opened.
	Adv.: **zero obstruction of adjoining space** Imp: **70**	*Adv.:* **less obstruction of adjoining spaces** Imp: 40	*Adv.:* Imp:0	*Adv.:* **zero obstruction of adjoining space** Imp:70	*Adv.:* Imp:0
6. Control of air flow direction *Criterion:* more is better	*Attribute*: sashes slide to create uninterrupted entry for air.	*Attribute*: some level of influence of air flow direction along the horizontal plane could be achieved by adjusting angle of rotation of sash.	*Attribute:* sashes tilt outwards to create uninterrupted entry of air.	*Attribute*: capable influencing air flow direction along the vertical plane by tilting louver blades at various angles.	*Attribute:* sashes tilt outwards to create uninterrupted entry of air.
	Adv.: Imp: **0**	*Adv.:* **more control of air flow direction** Imp: **20**	***Adv.:*** Imp: **0**	*Adv.:* **much more control of air flow direction** Imp: **30**	*Adv.:* Imp: 0
7. Seamlessness in closed position *Criterion:* more is better	*Attribute*: closed position depicts a vertical overlap at the edges of two sashes of continuous pane of glass in profiles.	*Attribute*: closed position depicts a sash of continuous pane of glass in a profile.	*Attribute:* closed position depicts a sash of continuous pane of glass in a profile.	*Attribute:* a series of louver blades overlap horizontally in closed position	*Attribute:* closed position depicts a sash of continuous pane of glass in a profile
	Adv.: **more seamless** Imp: 40	*Adv.:* **more seamless** Imp: 40	*Adv.:* **more seamless** Imp:40	*Adv.:* Imp: 0	*Adv.:* **more seamless** Imp: 40
8. Protection against rain *Criterion:* higher is better	*Attribute*: window sash slides to open and do not provide any protection to the opening against the ingress of moisture during rainfall.	*Attribute:* window sash rotates horizontally about a pivot to open and do not provide any protection to the opening against the ingress of moisture during rainfall.	*Attribute*: window sash projects over the opening when opened and therefore provides some protection for the opening against moisture ingress during rainfall.	*Attribute*: louver blades project over the opening when opened and therefore provides some protection to the opening against the ingress of moisture during rainfall.	*Attribute*: window sash swing horizontally about the side to open and do not offer any protection to the opening against the ingress of moisture during rainfall.
	Adv.: Imp: 0	*Adv.:* Imp: 0	*Adv.:* **more protection** Imp: 20	*Adv.:* **more protection** Imp:20	*Adv.:* Imp:0
9. Ease of replacement *Criterion:* higher is better	*Attribute*: requires the replacement of entire pane within a sash when broken.	*Attribute*: requires the replacement of entire p ıne within a sash when broken.	*Attribute*: requires the replacement of entire pane within a sash when broken.	*Attribute*: requires the replacement of individual louver blades when they are broken.	*Attribute*: requires the replacement of entire pane within a sash when broken.
	Adv.: Imp: 0	*Adv.:* Imp: 0	*Adv.:* Imp: 0	*Adv.:* **Easier to replace** Imp: 50	*Adv.:* Imp: 0
Total IoA	**155**	**270**	**130**	**335**	**175**

Factor 1 (Flexibility in opening / closing): The extent to which a window system offers flexibility in opening or closing was considered. This factor arose out of the prevalence of varied environmental conditions which leads to the need for various degree of opening or closing a window. The criterion was thus “higher flexibility in closing/opening is better”.

Factor 2 (Familiarity to users): One of the drivers for an easy use and maintenance of a system is the familiarity of users of the system to it. Users of the proposed lecture theater were therefore expected to have some relative familiarity with the chosen window system. The criterion was therefore “more familiarity is better”.

Factor 3 (Ease of cleaning): Maintaining cleanliness of the window system does not only enhance a pleasant appearance, but also leads to maintaining a clearer surface which otherwise could have been coated with a film of dust resulting in some level of reduction in the passage of daylight. A system that will allow for easy and efficient cleaning was therefore a concern. The criterion was thus “higher ease of cleaning is better”.

Factor 4 (Ventilation area): One of the crucial functional requirements of a window is to allow for adequate passage of air, when opened, to enhance natural ventilation. The issue of natural ventilation is particularly curial for a project located within a warm humid climatic zone with unreliable power supply for mechanical cooling.
The criterion was “more ventilation area is better”.

Factor 5 (Obstruction of surrounding space): Some of the windows were to open into adjoining circulation spaces such as corridors. The operation of the window should therefore be such that it does obstruct the use of such spaces. There is for instance the tendency of the panes of some of the windows to project into these adjoining spaces to obstruct the use of those spaces. The criterion was “less obstruction of adjoining space is better”.

Factor 6 (Control of air flow direction): Even though the windows are expected to be the primary passage of air into the lecture theatre building, sometimes the direction of the flow of the air need to be controlled for the convenience and comfort of users. A higher flexibility in air control direction was therefore preferred and the criterion became “more control of air flow direction is better”.

Factor 7 (Seamlessness in closed position): Laps or breaks on the pane of a window system in closed position have the tendency of impacting the air-tightness and aesthetic appeal of the window. Continuous panes ensure better air-tightness, and seem more aesthetically appealing to users compared to strips of panes that overlap. Hence the criteria was “higher seamlessness in closed position is better”.

Factor 8 (Protection against rain): There was the need, especially in a lecture theatre environment, to ensure the wellbeing and comfort of occupants by allowing for passage of air across windows during rainfall. This could call for keeping windows opened during rainfall. There was therefore the need to explore a window system that could be kept opened, but adjusted to prevent the ingress of moisture during rainfall. The criterion was thus “higher protection against rain is better”.

Factor 9 (Ease of replacement): Windows, particularly those with glass panes, tend to be fragile and are subject to breakages and other forms of damage. There is therefore the need for economical and easy replacements. The criterion became
“higher ease of replacement is better”

Identification of the various factors was followed by definition of the respective criteria and the establishment of the attributes of each alternative mode of operation. This process relied on, i) the experience of the users in using and managing the use of lecture halls; ii) the expertise and experience of the window installation specialist, who apart from being a graduate of H.N.D. and BSc. Building Technology, also had thirteen years of experience in designing and fabricating window systems for various projects; iii) the expertise and experience of the architectural design team who were made of three architects with experience in designing and engaging stakeholders for various projects. The respective attributes were then summarized in Table 4.2. The least preferred attributes were noted and used as reference points to establish advantages. The alternative with the least preferred attribute for a particular factor has no advantage for that factor.

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The crucial activity of assigning importance to advantages followed identification of the advantages. The process of deciding the importance of the advantages, even though collaborative, was characterized by extensive deliberations and persuasion in an atmosphere of respect among the participants (Figure 4.7).

Figure 4.7: User - designer dialogue in deciding the importance of advantages

A scale of 0 to 100 was used to rank the advantages according to their importance. The advantage with the paramount importance (i.e. “45% more open area for ventilation”) was assigned 100 and this formed the basis for ranking other advantages. The total IoA for each window option was computed following assignment of importance to all advantages. Louvered window had the highest total IoA of 335 and became the preferred option, pending cost evaluation. In line with the practice of CBA application, the total IoA of the alternatives were compared to the respective estimated costs of the alternatives (Figure 4.8).

Figure 4.8: Comparison of IoA with respective initial cost of alternatives

The cost evaluation was based on preliminary rates provided by the window installation specialist who took part in the workshop. It turned out that the louvered window, in its basic form, costed less than the other window operating systems. The louvered window therefore became the preferred option since it was the system with the least preliminary cost and the highest total IoA.

4.3.3 Discussion

The participants consensually adopted the louvered system as the most appropriate system for the project. Going through the various CBA steps (from identifying the alternatives to deciding on the importance of advantages), created a collaborative space to stimulate dialogue among stakeholders, so that they can learn and understand one another's values, needs, interests and ideas. The collaborative attributes of CBA, as observed in this case study, tend to confirm the findings in case study 1.

One of the observed elements of collaboration, enhanced by the CBA application process, was the avoidance of conflicting trade-offs among general categories such as factors and criteria. Traditional decision approaches and VM techniques (e.g. AHP, FAST, FPS, SMART and QFD) focus on assessing the importance of high order abstractions such as factors and criteria, with the propensity for creating disagreement among teams. High order abstractions are less specific and explicit when deciding among them. Having to have judged factors, such as "control of air flow direction" and "familiarity to users", by assigning weights to them, could create ambiguity and breed disagreements among stakeholders. In the CBA process, participants postponed value judgment until the advantages among the alternatives were objectively established.

Another way by which the CBA process provided a collaborative environment, in this case study, was promoting transparency and respect among participants in the workshop. The prevalence of respect and transparency engendered trust, which tended to mitigate the forces of fragmentation against team cohesiveness.

Transparency manifested in the clarity, to the participants, of the trade-offs among the advantages. Other approaches, especially in the case of traditional function analysis techniques in VE, hardly decompose the decision process to the level of clearly and collaboratively establishing explicit advantages. The participants actively took part in weighing the advantages because there was enough clarity on the real benefits of what was weighed.

Respect among participants was enhanced by the balanced and participative nature of the CBA process, allowing for effective input from all participants in the workshop. Participants revealed, from the interviews, that an atmosphere of shared learning was created, therefore reducing the expert–user divide and allowing for mutual exchange of knowledge and experience, especially in deciding importance of advantages. This identifies with the concept of GDS which formed the basis for the development of SMART by Green (1994) to improve mutual learning in VM process.

Collaboration and participation in the workshop was also enhanced by the relative simple attribute of the CBA approach, making it possible for participants to understand and follow the process effectively. The simplicity of CBA was observed and corroborated by an interview with the participants. The ease with which stakeholders effectively participated in the CBA application process was after only one CBA training seminar for the stakeholders prior to the workshop, and the facilitation of the workshop by a key member of the research team. The simplicity of CBA further reflected in the fact that two of the participants who made useful and effective contributions to the decision making process during the workshop, especially in assigning importance to the advantages, did not have the benefit of the training seminar, and were actually encountering the CBA system for the first time.

One other benefit in the use of CBA to engage users in participatory design, as established from the case study, is the fact that the users and other stakeholders had the benefit of a documented rationale, in the form of explicit relative benefits, behind the choice of louvers. This could avert possible incidents of varying project specifications, particularly at the instance of users, with its attendant effects of creating budgetary uncertainties and destabilizing project flow, especially downstream. Documentation of the decision process and the decision rationale, according to the staff of the development office, would also provide useful information for future decisions in the maintenance and refurbishment of the building.

Findings from the study also illustrate how CBA thrives within the ill-defined problems in participatory design. Conventional approaches of VE assume design problems are well-defined and static, making it possible to explore optimum solutions with substantive data (Green, 1997). The ill-defined nature of design however calls for the GDS approach of constructing shared objectives and building consensus among stakeholders rather than exploring optimum solutions. Generation of a set of window systems, in the first step of the CBA process, illustrated how judgment was exercised by the stakeholders to collaboratively appraise and expand the solution set to five alternatives, based on availability in the Ghanaian market, before choosing louvers. This, for instance, identifies with the recommendation that in the midst of the inexhaustively describable solutions for ill-defined problems, the rational approach is not to pursue the best solution, but focus on an accessible and satisfactory solution, from a set of possibilities defined and agreed by all stakeholders (Farrell and Hooker, 2013).

Some challenges and limitations were observed in the case study. One challenge was the definition of the attributes for the various alternatives. Unlike other attributes of window openings (especially technical properties of materials such as heat and sound insulation) which would be expressed more explicitly in quantitative terms, the largely textually descriptive nature of these attributes appeared quite conceptual and imprecise, thus requiring more effort to define, and explain to all stakeholders. This suggests the need to use boundary objects, such as animations and models, to enhance description and understanding of attributes, especially for conceptual design decisions.

Furthermore factors that would lead to subjective definition of attributes for the alternatives were not considered. "Aesthetics" was, for instance, proposed as one of the factors, but was eventually omitted because participants could not objectively define the attributes of the alternatives with respect to aesthetics as a factor. The stakeholders could only rely on their consensual perception that there is a link between aesthetics and seamlessness of a window, to make-up for the issue of aesthetics in the factor, "Seamlessness in closed position".

Based on the findings of this case study, the CBA decision system has further presented itself, in line with findings in case study 1, as a participative decision tool that is capable of fostering an atmosphere of collaboration between designers and users to arrive at design choices acceptable to all stakeholders. Findings, among others, illustrate a number of collaborative attributes of the CBA decision system that could be exploited by designers to engage users in participatory design. The findings present a specific and practical insight into employing CBA for effective user engagement by designers.

4.4 Case Study 3

In line with the concept of literal replication and the principle of reflective cycle in multiple case studies (Van Aken, 2004; Yin, 1994), the third case study was conducted to further confirm the collaborative attributes of the CBA decision system and to refine knowledge obtained from the previous case studies towards the design of a user-involvement framework. Unlike the first and second case studies, the decision in this case study was focused more on material selection and specification. Even though previous studies exist on the application of CBA in the selection of materials in the AEC sector (Arroyo 2014; Arroyo et al., 2013; Parrish and Tommelein, 2009), attention on the potential of CBA in enhancing user-designer collaboration in the specification of materials was less precise.

4.4.1 Background of Case Study 3

The project for this case study, similar to the second case study, involved the design of a lecture hall complex, with offices, for Sunyani Polytechnic (Figure 4.9). This project is one of other projects being undertaken at the Polytechnic as part of infrastructural improvement for possible upgrade into a Technical University in line with government policy. The project was financed by GOG through Ghana Education Trust Fund (GETFUND). The choice of this project, like the previous case studies, resulted from the high user stake in the project, and the interest of stakeholders such as design consultants and potential users to collaborate in the research.

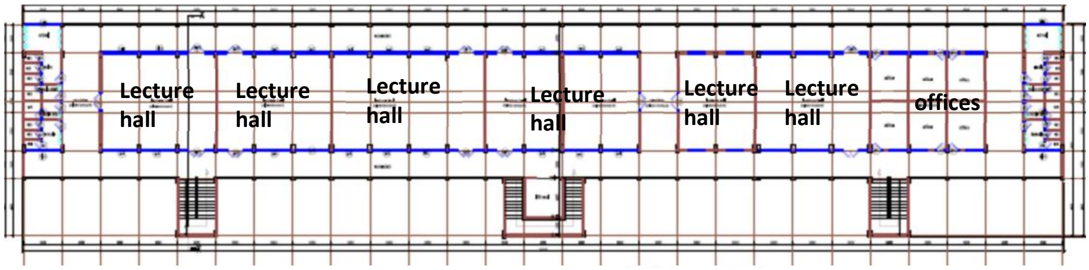


Figure 4.9: Typical floor layout of lecture hall complex (courtesy: BRRI)

This case study was conducted at a time the consultants had specified the various materials for the project. The case study, therefore, provided an opportunity to review the *process* of an initial decision, especially with respect to its (*process*) potential to create a space for effective user participation. The specific intervention in this case study was the application of the CBA decision system to incorporate the input of stakeholders, such as users, in the choice of a ceiling finish for the project.

The construction industry in Ghana, over the last few last years, has witnessed an influx of a variety of construction materials such as ceiling finishes. Architects and other project stakeholders, such as clients and users, continually face the challenge of choosing the appropriate material to meet peculiar project requirements. The CBA decision system was therefore adopted, in this case, to choose a ceiling finish for the project under consideration. Comparable to the previous case studies, the primary interest of the researcher, in this case study, was not just the outcome of the decision, but how the process created a space for potential users to collaborate with other project stakeholders, and effectively contribute to the decision-making process.

4.4.2 Application of CBA to Decide on the Ceiling Finish

The CBA application process, in the case study, started with a short seminar in which participants were introduced to the basic principles of tabular CBA application. A workshop was then facilitated by the researcher to engage representatives of potential users and other stakeholders of the project to choose a ceiling finish among a set of alternatives. The user representatives were made up of four lecturers, three students, and the principal assistant maintenance officer from the development office of the polytechnic. Unlike case1 and case 2, this case study made use of a web-based CBA software (Paramount decisions, 2015) in the application process. The use of the software was expected to create a shared database to enhance information sharing and collaboration among stakeholders.

One of the lecturers' representatives was included in the workshop not only as a potential user, but also as a result of his extensive theoretical and practical knowledge in ceiling systems. The other lecturers, apart from their respective background in construction and visual art (i.e. MSc. Construction Management; MTech Construction Technology; B-Tech Fashion and Textiles) also had respective experience of teaching in lecture halls for eleven, seven and four years. The three students were final year students of H.N.D. Building Technology who had been attending lectures and learning in lecture halls for three consecutive years. The principal assistant maintenance officer had not only been involved in managing the use and maintaining buildings in the polytechnic, but also had BSc. and PGDip. qualifications in Architecture. The researcher, apart from his role as the facilitator of the workshop also represented the project architect in the workshop. The researcher had earlier held separate and joint meetings with the project architect (consultants) and management of Sunyani polytechnic (clients) to obtain relevant project data for the workshop.

Following a series of discussions with the project consultants, the client and representatives of prospective users, seven alternatives were identified as possible ceiling finishes obtainable in the Ghanaian market for the project. These included paneled plywood, wooden T&G, plastic T&G, mineral fiber acoustic ceiling tiles, plasterboard, cement board and POP (Figure 4.10).

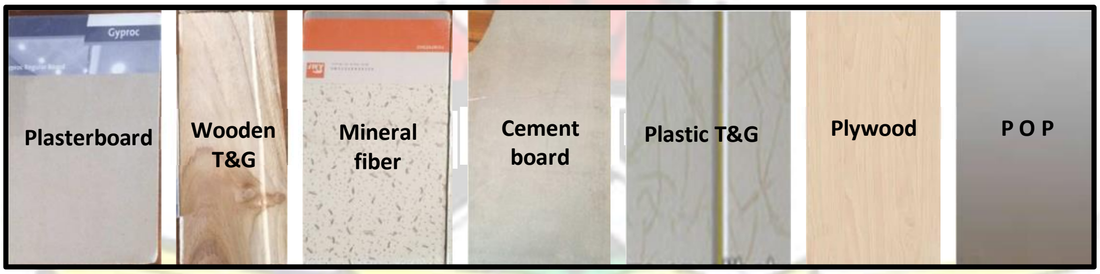


Figure 4.10: Alternative ceiling finishes

Ten factors and respective criteria were then defined to enable the stakeholders establish the differences among the alternatives (Table 4.3).

Factor 1 (Fire resistance): One of the elements of passively protecting a building against fire is material protection. In the event of fire outbreak, the materials are expected to retard burning to reduce the spread of fire and prevent untimely collapse of the building. The criterion was “higher is better”.

Table 4.3: CBA table for case study 3

Factor / Criterion	Paneled Plywood	Wooden T&G	Plastic T&G	Mineral Fiber (Acoustic Ceiling)	Plasterboard	Cement Board	POP
1. fire resistance	***Attribute***: flammable	***Attribute:*** less flammable	***Attribute:*** highly flammable	***Attribute:*** non-combustible	***Attribute:*** non-combustible	***Attribute:*** non-combustible	***Attribute:*** non-combustible
higher is better	***Adv.:*** more resistant Imp: 30	***Adv.:*** much more resistant Imp: 40	***Adv.:*** - Imp:	***Adv.:*** far much more resistant Imp: 58	***Adv.:*** far much more resistant Imp: 58	***Adv.:*** far much more resistant Imp: 58	***Adv.:*** far much more resistant Imp: 58
2.acoustic absorption (NRC)	***Attribute:*** 0.1	***Attribute:*** 0.1	***Attribute:*** 0.2	***Attribute:*** 0.75	***Attribute:*** 0.05	***Attribute:*** 0.04	***Attribute:*** 0.05
higher is better	***Adv.:*** 0.06 more Imp: 14	***Adv.:*** 0.06 more Imp: 14	***Adv.:*** 0.16more Imp: 24	***Adv.:*** 0.71more Imp: 78	***Adv.:*** 0.01more Imp: 5	***Adv.:*** - Imp:	***Adv.:*** 0.01more Imp: 5
3. moisture resistance	***Attribute:*** absorbs more moisture and degrades faster over time.	***Attribute:*** absorbs moisture and degrades over time.	***Attribute:*** moisture-proof	***Attribute:*** it absorbs far more moisture and degrades much faster over time.	***Attribute:*** in its basic form it absorbs moisture and degrades over time.	***Attribute:*** absorbs moisture but resistant to degradation.	***Attribute:*** in its basic form it absorbs moisture and degrades over time.
higher is better	***Adv.:*** more resistant Imp: 10	***Adv.:*** much more resistant Imp: 20	***Adv.:*** far far much more resistant Imp: 50	***Adv.:*** - Imp:	***Adv.:*** much more resistant Imp: 20	***Adv.:*** far much more resistant Imp: 45	***Adv.:*** far much more resistant Imp: 20
4. heat insulation (R-value)	***Attribute:*** 0.0352m2K/W	***Attribute:*** 0. 0512m2K/W	***Attribute:*** 0. 4122m2K/W	***Attribute:*** 0. 17m2K/W	***Attribute:*** 0.0632m2K/W	***Attribute:*** 0.0464 m2K/W	***Attribute:*** 0.079m2K/W
higher is better	***Adv.:*** - Imp:	***Adv.:*** 0.016m2K/W more Imp: 15	***Adv.:*** 0.377m2K/W more Imp: 100	***Adv.:*** 0.1348m2K/W more Imp: 60	***Adv.:*** 0.028m2K/W more Imp: 27	***Adv.:*** 0.0112m2K/W more Imp: 10	***Adv.:*** 0.0438m2K/W more Imp: 35
5. recyclability	***Attribute:*** there are established plants for recycling but the use of preservatives and finishes could make the process more complex.	***Attribute:*** there are established plants for recycling but the use of preservatives and finishes could make the process more complex.	***Attribute:*** there are established plants for recycling. PVC, a common material for producing them, is known for its good recycling properties.	***Attribute:*** there are established plants for recycling.	***Attribute:*** there are established plants for recycling.	***Attribute:*** recycling plants are now emerging	***Attribute:*** there are established plants for recycling.
higher is better	***Adv.:*** - Imp:	***Adv.:*** - Imp:	***Adv.:*** much more recyclable Imp: 15	***Adv.:*** much more recyclable Imp: 10	***Adv.:*** much more recyclable Imp: 10	***Adv.:*** more recyclable Imp: 5	***Adv.:*** much more recyclable Imp: 10
6. Flexibility in final surface finishing	***Attribute:*** final surface finish is not pre-determined, thus, increasing the degree of client/user influence on final color and texture.	***Attribute:*** final surface finish is not pre-determined, thus, increasing the degree of client/user influence on final color and texture.	***Attribute:*** final color and texture is predetermined, therefore limiting the degree of client/user influence.	***Attribute:*** final surface finish may be pre-determined, but some degree of client/user influence on final color and texture is allowable.	***Attribute:*** final surface finish is not pre-determined, thus, increasing the degree of client/user influence on final color and texture.	***Attribute:*** final surface finish is not pre-determined, thus, increasing the degree of client/user influence on final color and texture.	***Attribute:*** final surface finish is not pre-determined, thus increasing the degree of client/user influence on final color, pattern and texture.
higher is better	***Adv.:*** much more flexible Imp: 30	***Adv.:*** much more flexible Imp: 30	***Adv.:*** - Imp:	***Adv.:*** more flexible Imp: 20	***Adv.:*** much more flexible Imp: 30	***Adv.:*** much more flexible Imp: 30	***Adv.:*** far much more flexible Imp: 40
7. Ease of maintenance *higher is better*	***Attribute***: Can be cleaned with mild detergents subject to the surface finish; panels may be repainted /re-polished without affecting acoustic performance; easy to replace a defective panel	***Attribute***: Can be cleaned with mild detergents subject to the surface finish; strips may be repainted/repolished without affecting acoustic performance; difficult to replace a strip.	***Attribute***: The surface of the ceiling strips can be cleaned with a mild detergent. It is however more difficult to correct defects such as scratches on strips; very difficult to replace a defective strip.	***Attribute***: Can be cleaned with mild detergents subject to the surface finish; could be repainted, but care should be taken to avoid effect on acoustic performance; very easy to replace a tile.	***Attribute***: Can be cleaned with mild detergents subject to the surface finish; may be repainted without affecting acoustic performance; scratches and cracks can easily be sealed.	***Attribute***: Can be cleaned with mild detergents subject to the surface finish; may be repainted without affecting acoustic performance; scratches and cracks can easily be sealed.	***Attribute***: Can be cleaned with mild detergents subject to the surface finish; may be repainted without affecting acoustic performance; scratches and cracks can easily be sealed.
	Adv.: much easier to maintain Imp: 55	***Adv.:*** easier to maintain Imp: 45	***Adv.:*** - Imp:	***Adv.:*** far much easier to maintain Imp: 70	***Adv.:*** much easier to maintain Imp: 55	***Adv.:*** much easier to maintain Imp: 55	***Adv.:*** much easier to maintain Imp: 55
8. Speed of installation	***Attribute***: most components are prefabricated and assembled primarily by nailing; final surface finishing is onsite	***Attribute***: most components are prefabricated and assembled primarily by nailing; final surface finishing is onsite	***Attribute***: most components are prefabricated and assembled primarily by nailing	***Attribute***: most components are prefabricated and assembled primarily by nailing, screwing and lapping	***Attribute***: most components are prefabricate and assembled by nailing/screwing and finished using joint tapes and mastic compounds; final surface finishing is onsite	***Attribute***: most components are prefabricate and assembled by nailing/screwing and finished using joint tapes and mastic compounds; final surface finishing is onsite	***Attribute***: component materials are mixed and case on site; final surface finishing is onsite
faster is better	***Adv.:*** faster to install Imp: 50	***Adv.:*** faster to install Imp: 50	***Adv.:*** much faster to install Imp: 50	***Adv.:*** far much faster to install Imp: 75	***Adv.:*** faster to install Imp: 50	***Adv.:*** faster to install Imp: 50	***Adv.:*** Imp:
9. Impact resistance	***Attribute***: quite flexible and porous; able to resist scratches and cracks to some degree subject to final surface finish	***Attribute***: hard solid; able to resist scratches and cracks to some degree subject to final surface finish	***Attribute***: flexible and hollow core; quite prone to scratches, cracks and dents	***Attribute***: very soft and porous; highly prone to scratches, cracks and dents	***Attribute***: hard solid core; able to resist scratches and cracks to some degree subject to final surface finish	***Attribute***: very hard solid core; able to resist scratches and cracks to some degree subject to final surface finish	***Attribute***: hard solid core; able to resist scratches and cracks to some degree subject to final surface finish
more is better	***Adv.:*** more resistant Imp: 35	***Adv.:*** much more resistant Imp: 50	***Adv.:*** more resistant Imp: 35	***Adv.:***-	***Adv.:*** much more resistant Imp: 50	***Adv.:*** far much more resistant Imp: 65	***Adv.:*** much more resistant Imp: 50

10. weight	***Attribute***: 3.66kg/m2	***Attribute***: 13.50kg/m2	***Attribute***: 3.50kg/m2	***Attribute***: 7.26kg/m2	***Attribute***: 8.92kg/m2	***Attribute***: 10.35kg/m2	***Attribute***: 9.00kg/m2
less is better	***Adv.:*** 9.84kg/m2 less Imp: 51	***Adv.:-*** Imp:	***Adv.:-*** 10.00kg/m2 less Imp: 58	***Adv.:-*** 6.24kg/m2 less Imp: 38	***Adv.:-*** 4.58kg/m2 less Imp: 28	***Adv.:-*** 3.15kg/m2 less Imp: 18	***Adv.:-*** 4.50kg/m2 less Imp: 25
Total IoA	**345**	**264**	**342**	**409**	**333**	**376**	**298**

NB: *Adv. – Advantage, Imp.* **-** *Importance*

Factor 2 (Acoustic absorption): It is a fundamental requirement to reduce the incidence of noise arising from reverberation in spaces such as lecture halls. Noise from adjoining spaces, such as, upper and lower floors should also be reduced to a large degree. The criterion was thus "higher is better".

Factor 3 (Heat insulation: R-value): Ceiling finishes play a role in acting as a barrier against the transmission of heat from an upper space (e.g. roof space or upper floor) into a lower space. The criterion was "higher is better".

Factor 4 (Moisture resistance): Ceiling finishes are susceptible to contact with moisture arising from roof leakages or humidity within the ambient environment.
The criterion was "higher is better".

Factor 5 (Recyclability): As a measure to reduce the incidence of impact on the environment and ensure sustainability, construction material waste should be recyclable. The criterion was "higher is better".

Factor 6 (Flexibility in final surface finishing): The need may arise for a change in the colour and texture of the final finish of the ceiling. The criterion was therefore "higher is better".

Factor 7 (Ease of maintenance): There is the need to periodically maintain the ceiling through either outright replacement or surface regeneration. The criterion was "higher is better".

Factor 8 (speed of installation): It has become a fundamental requirement for construction projects to be delivered on time. The criterion was thus, “more is better”.

Factor 9 (impact resistance): During installation and use, ceiling finishes are prone to various forms of impact which could lead to defects such as scratches and cracks. The criterion was, “higher is better”.

Factor 10 (weight): A reduced weight of the individual components of a building contributes to a reduction in the dead load of the building. Light weight components are generally easier to handle and install. The criterion was “less is better”.

Identification of the various factors, with the respective criteria, was followed by the establishment of the attributes of each alternative. This data was entered in the software and the least preferred attribute, for each factor, was noted and used as reference points to establish advantages. The advantages were then ranked according to their importance within a scale of 0 to 100. Deciding the importance of advantages was characterized by dialogue and persuasion (Figure 4.11).

Figure 4.11: A dialogue on the importance of advantages

The advantage with the paramount importance (i.e. 0.377m2K/W more R-value) was assigned 100, forming the basis for ranking other advantages. The total IoA for each alternative was calculated following assignment of importance to all advantages. Mineral fiber acoustic ceiling had the highest total IoA of 409. Subject to budgetary considerations, mineral fiber acoustic ceiling became the most preferred option.

4.4.3 Discussion

This case study was conducted at a time the consultants had specified plasterboard ceiling finish for the project. They, however, did not go through a structured and organized process of involving stakeholders, such as users, to choose the ceiling finish as happened in the case study. When the process and result of the CBA application was discussed with the project consultants and other stakeholders, their general assessment of the case study was that, it offered a better opportunity for stakeholders to contribute to decision-making in design process even though the process appeared rigorous.

Findings from this case study were a further illustration of the collaborative attributes of the CBA decision system. The entire process, from identification of alternatives to deciding importance of advantages, allowed for effective stakeholder participation. This resulted in consensus, among the participants, in the choice of mineral fiber acoustic ceiling as the most preferred subject to cost evaluation.

One of the occasions that illustrated the attribute of the CBA decision system in creating a space of mutual respect, and allowing for effective user participation in decision-making, was when a user, in the workshop, justified and successfully persuaded a change in the definition of the R-value attributes. The R-value for each alternative was initially standardized to a unit thickness of 1mm, but this user argued that it was more prudent to, rather, relate the R-value of each alternative to its thickness at the point installation. The originally defined R-value attributes of mineral fiber acoustic tiles and plywood was, for instance, agreed to be respectively changed to 0.170 m^2 K/W per 10mm from 0.017m^2 K/W per mm; and to 0.0352 m^2/W per 6mm from 0.0058 m^2/W per mm.

The use of the web-based CBA software in this case study, unlike the first two case studies, provided a platform for enhanced collaboration and information sharing among stakeholders. In preparing the towards the actual decision workshop, CBA decision data such as alternatives, factors and attributes were proposed by the facilitator and shared with some of the participants via the platform of the CBA web-based software. This afforded the participants an opportunity to gain more insight and contribute effectively to the decision data. It was observed, for instance, that participants who had the benefit of prior insight into the decision data were generally more active contributors to the decision process.

Similar to the findings of the previous case studies, this case study demonstrated the potential of the CBA process to provide a documented rationale for design decisions. Documentation of decisions' rationale, in design process, eventually becomes a reference guide to decisions during the construction and maintenance of a building. The use of the web-based CBA software is particularly relevant in this regard since it provides a shared electronic database of the decision rationale of various design decisions.

The elements of knowledge sharing and mutual learning that characterized the CBA process in the previous case studies also manifested in this case study. The stages of definition of attributes and determination of importance of advantages created a space where participants shared knowledge based on their experience and expertise. One of the participants, the principal assistant maintenance officer from the development office of the polytechnic, for instance indicated that his participation in the workshop exposed him to more knowledge on the attributes and relative advantages of various ceiling materials which he was going to rely on to advice stakeholders on the selection of ceiling finish for a church project in which he was involved.

The number of alternatives and factors that were considered in this case made the process more laborious compared to the first two case studies. Comparatively more attributes had to be defined across more factors. Consequently the establishment of the advantages and the importance those advantages also became more intricate. The use of the web-based CBA software how facilitated the process, especially at the point of assigning importance the advantages and totally them.

Even though, Similar to the second case study, aesthetics was a potential factor for consideration, the inability of participants to objectively describe the attributes of the alternatives relative to aesthetics as a factor led to its deletion. The evaluation of an alternative's attribute, with respect to aesthetics as a factor, was seen to have very high subjective connotations. It was therefore challenging to explicitly differentiate alternatives based on aesthetics.

The findings of this case study, consistent with findings in the previous case studies, also presents the CBA decision system as a participative decision tool that creates an atmosphere for users to influence design decisions in line with their values. The openness and mutual respect that characterized the CBA application process were some of the incentives for participants, such as the user, to contribute freely to the decision-making process. The findings also present a precise and practical insight into the use of CBA to create a space for users to actively participate in design decisions.

4.5 Reflections across Case Studies

The respective participants in each of the cases agreed on the design decisions through a collaborative process. Observations and interview of participants in the case studies revealed that the CBA application process (from identifying the alternatives to deciding on the importance of advantages), encouraged an atmosphere of dialogue and conversation among stakeholders. This enabled stakeholders to learn and understand one another's values, needs, interests and ideas.

The transparency of the process which allowed for input from all stakeholders in generating alternatives, defining factors, establishing attributes, identifying advantages and deciding on importance of advantages, was instrumental in creating and sustaining the collaboration among the stakeholders. The process of deciding the importance of advantages, though associated with subjective sentiments, was grounded on objective data and allowed for knowledge sharing and respect among stakeholders. This promotes consensus building between designers and other stakeholders in participatory design.

Collaboration among stakeholders is fundamental to the success of participatory design. Collaboration creates cohesive teams to foster shared cognition for the creation of collective intelligence (Conklin, 2005; Ensley & Pearce, 2001). Some natural forces of fragmentation however make collaboration difficult, thus, challenging attempts at collective intelligence. One of the common elements of these forces of fragmentation, against collaboration, is the phenomenon of *wicked problems* in design (Conklin, 2005). In evaluating the collaborative attributes of the CBA decision system, it is, thus, essential to analyze, in detail, how the CBA application process responds to wicked problems in design.

4.5.1 CBA in the Context of Wicked Problems in Participatory Design

The phenomenon of wicked problems which is adversarial to collaboration is inextricably associated with design process, especially participatory design. The three case studies, as presented, reflect typical cases of wicked problems in participatory design. The CBA decision system was applied in the case studies to stimulate collaboration and enhance value generation in the implementation of the projects. The functioning of the CBA decision system (by virtue of its approach) is analysed relative to the features of wicked problems (Rittel & Webber, 1973) as contained in the three conditions of *finitude*, *complexity* and *normativity* identified by Farrell & Hooker (2013).

i) Finitude

The condition of *finitude* is related to the restricted nature of individual or collective cognition. This tends to restrain the abilities of individuals (or teams) to establish a definite description of a problem and explore all the potential solutions to the problem, towards getting the best. In the theatre expansion project (case 1), the problem was to generate a conceptual design for the extension of the existing theatre building to create more space and enhance efficient activity flow. This situation presented the stakeholders with inexhaustive possible descriptions of what constitute “more space” and “efficient flow”? A similar situation could be said of what confronted the team in the second and third case studies in their respective definition of “window opening systems” and “ceiling finishes”.

Under the condition of finitude, the respective teams in the three cases could certainly not have had a definitive formulation of the respective design problems before proceeding, especially when time was one of the elements of constraints. In this case, the rational approach, as Farrell & Hooker (2013) posit, is to cease searching for the definitive best (which is perpetually elusive), but focus on the satisfactorily available. However, in exploring a satisfactory definition of the problem, there is the need to adopt a participative approach, making room for effective stakeholder input, in order to sustain the collaborative atmosphere required for participatory design. In the three cases of CBA application, the process allowed for an intense participation of stakeholders at the outset of the process (i.e. the stage setting and innovative phases of CBA application). In the case of the theatre expansion project, the problem was defined through a series of discussions involving the design consultants and the user group, eventually resulting in the two conceptual design proposals: one emanating from the users (option 1), and the other form the design consultants (option 2). The lecture theatre project, in the second case, also saw cooperation between the designer and the other stakeholders in setting the stage for the decision, thus, leading to a consensual establishment of five window opening systems based on their availability in the Ghanaian construction industry market. In the third case study, the openness of the initial discussions on the design problem, to allow for effective stakeholder-involvement, was further enhanced by the sharing of the information among project stakeholders through the web-based CBA application, resulting in a collective agreement to consider seven alternative solutions.

Even though the respective final choices were *option 2* in case 1; *louvered system* in case 2; and *mineral fiber acoustic ceiling* in case 3, these choices, in the context of the condition of finitude, may just be the optimum choices among the defined alternatives (which could be infinitely more), but not the best among all possibilities. The implication is that there could always be a better option than what was respectively chosen in the three case studies. Nonetheless, due to the practical constraints of resources and time, the resolve of the respective teams was to reach a decision, good enough to be acceptable to all stakeholders.

An atmosphere of trust and transparency are popular non-economic incentives for building consensus in decision making such as these. In the CBA process, the aspect of objectively establishing the advantages of alternatives, based on factual data, before assigning importance to those advantages, creates a more realistic picture (compared to other decision systems such as AHP) of the potential benefits offered by each of the alternatives. This creates trust and transparency among stakeholders in the decision process. For example, advantages such as, *a gain in 116.77*m^2 *more space*, and *a higher potential for integration of roofs* (in case 1); *allows for more flexibility in opening/closing*, and *allows for up to 95% of area opened for ventilation* (in case 2); *0.377m2K/W more R-value*, and *3.50kg/m2 less weight* (in case 3), presents tangible perspectives regarding the benefits of the alternatives. As observed in the case studies and confirmed by interviews with participants, the transparent attribute of the CBA decision system was further enhanced by its simple and straightforward nature, allowing for a good understanding of the process, and consequent active participation of stakeholders in the process.

ii) Complexity

The foundation of the condition of *complexity* is the non-linearity associated with the design process, and the diversity of participants and stakeholders involved in the process. The three case studies typified the phenomenon of complexity, especially as a result of the number and diversity of the stakeholders involved in the projects, as well as the numerous feedback and feedforward loops in the design decision processes. One dimension of the situation of complexity is in respect of the fact that every design problem is unique in context, making it impossible to standardize design solutions or replicate them for different contexts. The uniqueness of each of the projects in the case studies originates from contexts which are infinite. These contexts, among others, include the location of the project, the target users, the purpose of the project, and the regulatory framework.

A central principle of the CBA decision system that reflected in the case studies is the principle of anchoring decisions to relevant facts. This essentially requires decisions to be contextualized, rather than being based on grenalisations and assumptions. CBA, to some extent, is therefore responsive to the phenomenon of uniqueness of every project. In the case of the theatre expansion project, the advantage, *better roof integration potential*, was assigned a paramount importance due to the special context of the project. In the special context of this project, work on the extension of the existing building was expected to be carried out with little interference on the activities within the current building. Another significant context, with respect to this advantage, was the desire of the clients, due to budgetary constraints, to implement the extension without being compelled to alter the existing roof over the existing theatre building. In the second case study, it was the contextualization of the decision that also lead to a significant importance of 70 assigned to an advantage such as, *zero obstruction of surrounding space*. The issue of obstruction of adjoining space when closing or opening a window became essential in this context because the layout of the proposed lecture theatre (Figure 4.5) was such that a substantial number of windows would open into an adjoining corridor. These corridors are not just circulation areas to be cleared of obstructions, but also, in the context of the Takoradi Polytechnic, occasionally provide space to accommodate a spillover of students from a lecture theatre during lectures.

The situation of complexity also manifested in the diversity of participants in the decision process in the three case studies. This has the tendency of fragmenting the collaborative atmosphere required in participatory decision-making, hence the need to adopt a decision approach that will foster collaboration among stakeholders.

Fostering a collaborative atmosphere requires a MCDA method to avoid conflicts arising from trade-offs involving general descriptions such as factors (Arroyo et al., 2014). In the CBA application process in the three projects, the establishment of the real advantages of alternatives provided a more explicit insight for participants to undertake trade-offs according to the importance of the established advantages. In contrast to conventional decision approaches in the AEC sector, such as AHP, the application of CBA decreased the tendency of disagreements among the stakeholders in their value judgment because the value judgment process was postponed until the advantages between the design options, in the respective cases, were mutually established based on objective data. A situation of abstraction with a tendency to create disagreements among stakeholders would have arisen in the application of AHP, for instance, if the stakeholders were to have undertaken the vague process of assigning relative ranking to identified factors such as, *interference with ongoing clinical work* (in case 1); *ease of cleaning* (in case 2) and *acoustic absorption* (in case 3).

The creation of an atmosphere of mutual learning to foster shared cognition in a socially complex system is one strategy to promote collaboration among stakeholders. In the three case studies, the simple and transparent attributes of the CBA decision system created a forum for participants to freely share their knowledge on some technical issues, especially during the stage of defining attributes and assigning importance to advantages. In attempting to justify why a particular level of importance should have been assigned to an advantage, some of the stakeholders ended up sharing their expert or experiential knowledge to the benefit of other stakeholders. In the theatre expansion project, for instance, the design consultants, during the stage of assigning importance to advantages, shared expert knowledge on several issues, including the *principles of enhancing natural ventilation*, while the user group shared experiential knowledge on issues such as *activity flow within an operating theatre building*.

iii) Normativity

The condition of *normativity*, arising from the divergence between norms and values of individuals or groups, is a threat to foster collaboration in participatory design. One measure of addressing this condition is to get stakeholders to compromise their positions to reach consensus. A decision approach that promotes dialogue, conversation and persuasion would play an important role in this situation. In the first case study for example, there was one moment when, out of the spirit of dialogue provided by the CBA application, the administrator of the hospital compromised his position of assigning an importance of "9" for an importance of "7" to the advantage, *will involve less interference with ongoing clinical work*. This compromise resulted from a persuasive rhetoric from the surgeon: "will you ever turn down an offer to renovate your theatre building just because of a short period of interference with ongoing activities which could even be temporarily transferred and carried out in an improvised space?", to which the administrator, nodding his head in agreement, spontaneously and repeatedly responded: "you have a point"! In the second case study it was also through an atmosphere of dialogue that the polytechnic architect changed his position of assigning an importance of "40" to an importance of "15" to the advantage, *more familiar to users*. This compromise also resulted from a persuasive explanation from one of the participants that, unlike other advantages that will remain relevant over the life of the project, the issue of familiarity with a window system becomes irrelevant after the user operates the system over a certain period. The effectiveness of the use of dialogue towards consensus, in the case studies, was largely supported by the grounded discourse, based on objective data and facts, rather than abstractions.

The phenomenon of wicked problems in participatory design remains inevitable. The problems are wicked because no definite description of them exists, and no definite solution for them can be found. The diversity of stakeholders involved in participatory design, as well as the situation of non-linearity associated with design process, leads to a condition of complexity within which wicked problems thrive. While acknowledging the fact that no definite solution could be formulated to address the wicked problems in participatory design, these problems could be managed through the application of the CBA decision system. Based on an analysis of three case studies involving the application of CBA in participatory design, it has been demonstrated that some attributes of the CBA decision system could be exploited to manage wicked problems in participatory design to some extent. Specifically the transparent and objective-based attributes of CBA, as well as its context-based approach, offers a potential to manage such wicked problem conditions as finitude, complexity and normativity.

4.5.2 Strategies for Incorporating CBA in a User-involvement Framework

Apart from establishing the collaborative potential of the CBA decision system, knowledge from the case studies further provides some insight to facilitate the incorporation of CBA in a user-involvement framework.

i) Pre-design activities

Pre-design activities, such as project definition, have, for instance, been identified to be strongly linked to the CBA process. The generation of design options in the case studies was, for example, guided by user/client requirements established at the project definition stage. The "ill-defined" feature of design problems, with the associated "inexhaustively describable" nature of design alternatives, particularly makes the definition of project requirements useful in controlling the generation of design options.

In case 1, for instance, client/user requirements, such as the need to maintain a sterile work environment, and ensure non-interference with ongoing clinical activities in the existing theatre during project execution, were established at the project definition stage, and served as critical considerations for stakeholders to determine IoAs during the CBA process. Pre-design activities should therefore be integral in applying CBA to involve stakeholders in design process.

ii) Boundary Objects

Another lesson from the case studies was the crucial role of communication in exploiting the collaborative potential of the CBA process, especially when involving users in design decisions. There should be a means for clients/users to effectively communicate their needs and requirements to the understanding of the design team. Likewise, there should be a means for designers to effectively communicate to other stakeholders, the various alternative design solutions they generate to meet project requirements.

The use of boundary objects, in the form of animations, models or simulations, could facilitate a shared understanding when designers interact with users at the predesign stage or during the application of CBA at various stages of design. Animated designs could, for example, enhance a shared understanding of the attributes of the design alternatives, among stakeholders, during the case studies. The attribute of an alternative is essentially the value of that alternative relative to a certain requirement; therefore a wrong appreciation of it (attribute) could be detrimental to the entire value discovering process of CBA application.

iii) Shared Mental Models

Consistent with existing theories on mental models and team performance (BadkeSchaub et al., 2007; Craik, 1943), mutual acquaintance among stakeholders, especially in relation to their respective values, capabilities and roles, was essential in facilitating the team processes in the case studies. The freer and friendlier interaction among stakeholders observed in case 1 and 3, compared to that in case 2, was attributable to a higher level of acquaintance among stakeholders in case 1and 3. Most of the stakeholders in case 1 and 3 have had a longer working relationship and were therefore more acquainted with one another compared to those in case 2.

An open atmosphere of interaction is unrestrictive, and encourages creativity among team members. Unrestricted creativity is particularly essential at the innovation phase of the CBA process where alternative design solutions are generated to meet user requirements. Knowledge of member expertise and capabilities also enhances team confidence in the process. The acceptance, by the stakeholders, of the use of CBA to decide on the alternatives in the case studies, even though they were not familiar with CBA, emanated from the confidence these stakeholders had in the design team based on their knowledge of the capabilities, expertise and values of the design team.

iv) Decision-Making Frames

CBA application requires a definition of a specific design problem. In the case studies, the CBA decision system was applied to precisely defined decision problems in the respective projects: "deciding on a direction of extension of an existing building" and "deciding on a window opening system". This aspect of CBA application is consistent with the design process management model of identifying decision-making frames corresponding to various episodes of design activity across the design process (Zerjav et al., 2013). The GDS methodology of staging a sequence of decision sessions scheduled to correspond with the decision pinchpoints which intersperse the building design process (Green, 1996) also agrees with this aspect of the CBA process.

The identified decision-making frame in case1 would be "create additional operating theatre spaces", containing the design activity, "extend existing building in a suitable direction". In case 2, the identified decision-making frame would be "provide window openings", containing the design activity, "specify/design a window opening system". In case 3 the identified decision-making frame would be "finish the ceiling system", containing the design activity, specify/design a ceiling finish. Even though the identified frames in the case studies were in respect of different projects, they could, hypothetically, represent a series of identified decision-making frames (F1, F2 and F3) containing various design activities (D1,

D2 and D3) across the design process of one project (Figure 4.9).

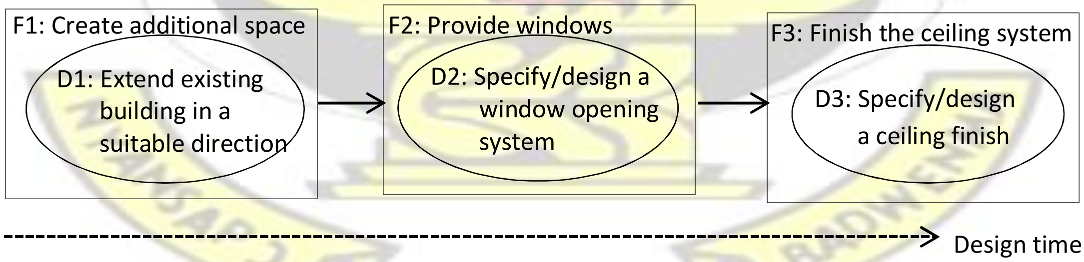


Figure 4.12: Hypothetical link of Decision-making frames across case studies

When the frames, with their associated design activities are identified, they could form the basis to plan and control CBA application in design process using techniques such as, DSM and Analytical Design Planning Technique (ADepT).

v) Combined Application of CBA with other Tools

The collaborative and value generating attributes of CBA could be complemented with the use of related lean tools, such as A3 reports, TVD and SBD. A3 reports are employed to display relevant information on an A3 size sheet for effective team communication and collaborative decision-making based on the PDCA cycle (Parish, 2009; Sobek II and Smalley, 2008). In the case studies, the use of A3 reports would be supportive to stakeholders as they explored alternatives and developed ideas for discourse in the CBA process.

The central idea behind TVD is to ensure that the design process is driven by a quest to achieve a target value in the form of a desired performance for a building project, within specified cost limits agreed with the owner (Zimina et al., 2012). TVD process, which is collaborative and starts at the early stages of design, could provide a significant guide in generating design options and deciding IoAs in CBA. SBD fundamentally encourages the act of considering a broad set of possible design solutions and progressively narrowing the set to a desirable solution. The design team, in SBD, is expected to postpone commitment to decisions on alternatives, to allow time to explore and evaluate as many feasible design solutions as possible (Singer et al., 2009). This identifies with the CBA process in the case studies whereby design options were generated based on established user requirements, and commitment to them differed until they were subjected to rigorous evaluation.

vi) CBA Application Constraints

Notwithstanding the collaborative and value generating potential in CBA, it may be impracticable to go through the structured process of CBA to involve users for every design decision, and for all projects. Based on experience from the case studies, time and resource insufficiency could pose a constraint. Admittedly it is more feasible to limit the CBA process to some category of projects and design decisions.

Projects which could possibly be considered for this process include: large and complex projects with a diversity of stakeholders who could influence and be influenced by the project; projects which lack clarity on project objectives, resulting in limited knowledge and the need for user input; projects, such as hospitals, which would eventually house specialized operations, and offer highly specialized services. In determining the kind of design decision to apply the CBA process, similar considerations of, high user stake in design decision; lack of adequate knowledge for decision; and high technical complexity of design decision could be a guide.

vii) Facilitator

Lessons from the case studies also illustrate the crucial role of a facilitator in the CBA application process, especially when stakeholders of diverse professional and social orientations are involved. The action researcher's role as a facilitator was instrumental in the following areas of the process: training participants in the CBA process; identifying and bringing relevant stakeholders together; planning and coordinating workshops and meetings; researching for decision data, especially on the attributes of alternatives.

Proficiency in CBA application, an understanding of design process, and good interpersonal skills are essential in the facilitator role. The facilitator, for instance, based on his experience in design process and stakeholder participation, should lead the process of identifying, anticipating and enforcing decision-making frames during the CBA process.

CHAPTER FIVE

DESIGN AND EVALUATION OF FRAMEWORK

5.1 Introduction

This chapter presents and evaluates a framework, known as CBA-incorporated Userinvolvement Framework (CBAUF), in fulfillment of objectives iii), iv) and v) of the research. Knowledge for the design of CBAUF was based on theory (e.g. lean design principles, design process management and team process) and empirical studies. Empirical design knowledge fundamentally evolved from reflections on the case studies presented in chapter four, while theoretical design knowledge originated from the literature review in chapter two. CBAUF was subjected to validation by testing its applicability in a real context through a case study.

5.2 The Framework (CBAUF)

The scheme of CBAUF (Figure 5.1) is fundamentally based on the IMOI model of team process (Ilgen et al., 2005). It is, therefore, made up of various *performanc*e *episodes* which are reciprocally interdependent and mutually connected with feedforward and feedback loops. Performance episodes are "distinguishable episodes of time over which performance accrues, and feedback is available" (Mathieu et al., 2000). Performance episodes rely on mediators (or processes) to transform inputs to outputs. The outputs, in turn, become inputs to successive performance episodes. Inputs are existing conditions, such as team members and organizational character, preceding a performance episode. Mediators are emergent cognitive or affective states that intercede and transfer the effect of inputs to outcomes (Ilgen et al., 2005). Mediators, in this context, replace *Process* in the traditional I-P-O model of team process. Outputs are the consequences and byproducts of team activity valued by one or more stakeholders (Mathieu et al., 2000).

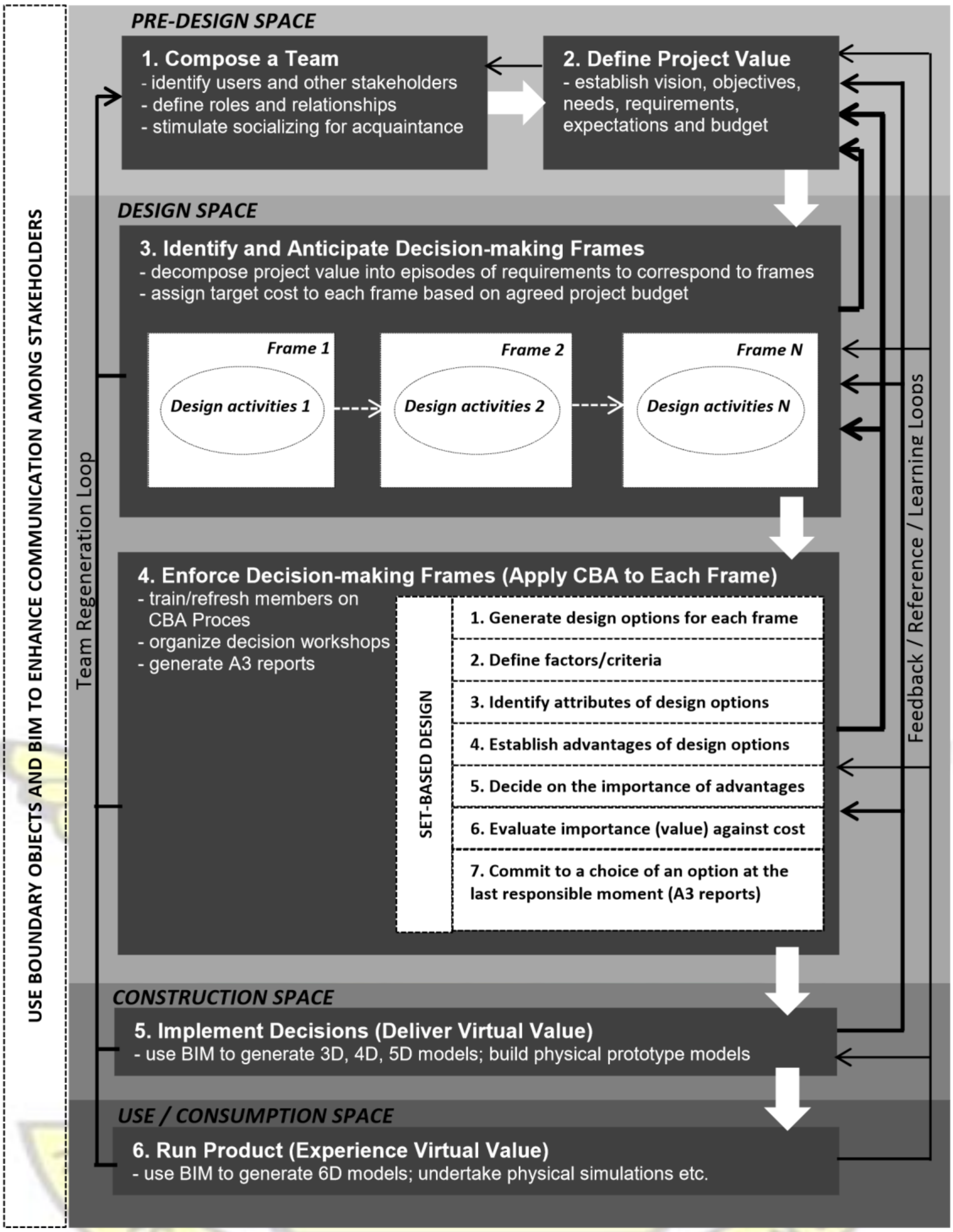


Figure 5.1: Scheme of CBA-incorporated User-involvement Framework (CBAUF)

CBAUF is made up of six main performance episodes: 1) compose a team; 2) define project value; 3) identify and anticipate decision-making frames; 4) enforce decision-making frames (apply CBA); 5) implement decisions (deliver virtual value); 6) run product (experience virtual value). The use of active verbs (e.g. *compose*, *define*, *identify/anticipate*, *enforce*, *implement* and *operate*) to describe the performance episodes provides a basis to evaluate the completion of each episode. The performance episodes occur in four spaces: predesign, design, construction and use / consumption.

5.2.1 Performance Episode 1: Compose a Team

This is the "stage setting" performance episode, whereby various user groups and other relevant stakeholders are identified. Expertise, experience, and connection with project, are essential considerations to identifying team members. The identified actors are brought together to socialize and build acquaintances, establish communication structures, and create team spirit. Member roles and relationships are defined at this stage. The crucial role of a facilitator /design manager, in coordinating the entire process, should be assigned and defined at this moment. Composing a team would require a collaborative initiative of the design team and client body, employing settings such as formal and informal meetings.

This episode is significant in constructing shared mental models among actors to enhance team coordination, as well as an orientation towards a collective vision and common objectives. The team, rather than remaining enduring, may go through a series of regenerations (e.g. in membership, orientation or structure) due to feedback resulting from outcomes in subsequent performance episodes. The type of user requirements established in the second episode could, for instance, lead to a reconstitution of the team, because of the need for a certain expertise to deliver a specific requirement.

5.2.2 Performance episode 2: Define Project Value

The key focus of the efforts in this episode is to establish user /client value. The team defines a collective vision and shared objectives for the project. Fundamental product values, with parameters, are discussed and established. Knowledge and experience from previous projects is useful at this point. A workshop, facilitated by a design manager, would provide appropriate setting for this activity. An atmosphere of collective dialogue should be stimulated in the workshop for members to explore and develop efficient and effective working relationships. Interviews and group discussions are useful tools for discovering user value at this stage. The outcome of this episode is a key reference to all subsequent episodes, and could lead to team regeneration in episode 1.

Value analysis techniques such as the job plan technique, FAST, FPS, SMART and QFD could be employed to create a shared understanding of user/client needs, and establish specific project requirements. The use of boundary objects at this stage facilitates a common understanding of user needs. Having collectively clarified the purposes and requirements of the project, the team should agree with the client on the specified cost limits for the project, in line with TVD practices. The constraints of cost limits should stimulate creativity within the team to develop affordable, but worthy alternative solutions to meet user/client requirements.

5.2.3 Performance episode 3: Identify and Anticipate Decision-making Frames

Meeting the requirements established at the value definition stage involves generating a number of mutually inclusive solutions. There is therefore the need to disintegrate the defined project value into various lots of user requirements or needs, in the context of identified decision-making frames corresponding to various episodes of design activities. Design activities within each frame which would fundamentally involve creating alternative design solutions should be geared towards fulfilling a defined lot of requirement(s), within a set cost limit. The overall TVD process is, therefore, in essence, broken-down into various packages within the frames.

The identification and anticipation of the frames should be a collaborative effort among stakeholders, and facilitated by a design manager who understands the various elements and disciplines of building design. A reciprocal interdependency exists between this episode and the subsequent episode, since the enforcement of an identified framework could form the basis to anticipate and eventually identify the next frame. The outcome of this episode could also lead to team regeneration as the actual design tasks, and required professional expertise and experience, would have been clearly established.

5.2.4 Performance episode 4: Enforce Decision-making Frames (Apply CBA to Each Frame)

This is the creative and decision-making moment of the entire process. The various episodes of design activity, identified in performance episode 3, are enforced at this stage by generating optional design solutions and evaluating the options using the CBA process. The generation and agreement on a solution set should involve all stakeholders, even though technical input from professional designers in the team could drive the process. Different views and diversity of thinking, arising from varied orientations in experience and expertise, is known to foster a creative problem-solving process and improve the resultant solution (Badke-Schaub et al., 2007). In line with SBD approaches, commitment to a particular design solution should be deferred until the last responsible moment of having completed a rigorous value evaluation of options.

The various steps in the CBA process should be guided by the general and specific requirements established in episodes 2 and 3. The first step of generating a solution set should, for instance, be fundamentally guided by the defined project value and objectives. Definition of factors/criteria should also be guided by the established user requirements. For example, a mandatory requirement should result in defining “must have” criteria relative to a particular factor. Assignment of IoA should, likewise, be carried out in reference to established user values and needs.

The use of boundary objects to create a shared understanding, especially on the attributes of the various design options, is essential at this stage. Designers should employ boundary objects, such as models and simulations, to explain the technical elements of the attributes of alternatives to other stakeholders, such as users. This will ensure effective user participation in establishing advantages and assigning IoAs.

The final outcome of this episode, respective to each frame, should be summarized in an A3 report for implementation in episode 5. The A3 report summaries the background to the final decision and provides a plan for implementation. A3 reports are useful reference documents, especially during the construction and operating stage of the project, because they contain the documented rationales behind various design decisions. A documented rationale to design decisions (in A3) becomes a useful reference to subsequent project decisions, such as client/user variations during construction, as well as maintenance decisions during the use of the building.

5.2.5 Performance episode 5: Implement Decisions (Deliver Virtual Value)

This is the stage where the value identified in episode 2, and generated in episodes 3 & 4 are delivered for use in episode 6. Even though the proposed framework fundamentally focuses on the design stage of construction project delivery, it incorporates the value delivery episode at the construction stage, largely as a virtual activity with the aid of computer imagery and simulation tools. This is to provide feedback on the practical implementation of the decisions generated in episode 4, especially with respect to buildability, physical appearance, delivery time and cost.

BIM tools would be useful at this stage. Various intelligent computer imaging tools would be useful at this stage to model various dimensions of information (e.g. 3D, 4D, 5D and 6D) on the building construction. BIM images, in this context, become boundary objects meant to generate a shared understanding on the deliverability of the decisions in the previous episodes. Physical simulations and tests could also be carried to, for instance, establish the constructability of design decisions. The input of other stakeholders, such as contractors, specialists and suppliers is beneficial at this stage.

5.2.6 Performance episode 6: Run Product (Experience Virtual Value)

This episode also relies on virtual activities to provide feedback to preceding episodes. It involves the use of physical and computer simulations to evaluate the performance and usability of the final product in meeting project requirements. Stakeholders, especially users, at this stage experience the result of their decisions and choices. 6D models, which relate the components and assemblies of 3D models with elements of project life-cycle information, would be relevant at this stage. Physical prototypes of design decisions could also be employed at this stage to test the usability of designs, especially with respect to functionality and robustness. Stakeholders, such as facilities managers would be required to make an input at this stage.

5.3 Evaluation of Framework

In line with constructive research process, there was the need to evaluate the workability of the construct, CBAUF, by rigorously demonstrating its utility, quality and efficacy (Hevner et al., 2004). Five methods have been proposed for evaluating constructs: observational, analytical, experimental, testing and descriptive (Hevner et al., 2004). Even though the observational evaluation method was largely adopted (especially for performance episodes 1, 2, 3 and 4), it was complemented by the descriptive method to evaluate some elements of the framework, especially in episodes 4 and 5. Through a case study, the observational method allowed for an indepth study of the construct in a business environment. The descriptive evaluation method was based on informed argument by relying on information from a knowledge base in the form of relevant literature (Lia and Ringerike, 2014; Hevner et al., 2004).

The observational case study involved the application of CBAUF in the design of a future administration building for the Sunyani Polytechnic. The choice of this project was not only as a result of the complexity of diverse stakeholder interests, but also due to the willingness of the project stakeholders to cooperate with the researcher in the case study. A key consideration for the choice of a project or organization for DSR is the willingness of the research subjects, or members of the organization, to cooperate in the research process (Lukka, 2003). The use of descriptive evaluation method to complement the observational case study was due to a limitation in the capacity of the team, in this case study, to implement the 4D,

5D and 6D elements of BIM in episodes 6 and 5.

5.3.1 Background of Observational Case study (Case 4)

Sunyani Polytechnic, which was converted from Sunyani Technical Institute, has, since its inception in 1997, grown in terms of student population, number of programmes and staffing. This growth has been associated with an increase in the complexity of the organizational and administrative structure of the polytechnic. The polytechnic, however, has had to rely on the old administration building (Figure 5.2), which originally served the Sunyani Technical Institute, to house its central administrative activities which have grown in size and complexity.

Figure 5.2: Existing Administration Block

A need has therefore arisen for the polytechnic to construct a new administration building, especially in view of the polytechnic's prospect of being upgraded to a technical university. The key intervention in this case study was to apply CBAUF to enhance the participation of users and other stakeholders in the design of the future administration building. Findings from the case study were expected to contribute to refining CBAUF. Apart from the researcher's own experience from being involved in the case study, participants were also interviewed to validate the applicability of

CBAUF.

5.3.2 Application of CBAUF in the Case Study

Team composition

In line with the first performance episode in CBAUF, a team was composed by the client towards generating designs for the project. The team was mainly composed of representatives of potential users of the future administration block (i.e. the vice rector, the registrar, the dean of school of engineering, the dean of students, senior assistant registrar in charge of admissions) and the design team (i.e. personnel from the development office, including the development officer and architect). Apart from a general expectation of actively taking part in the application of CBAUF on the project, the respective roles of the team members were defined. The user representatives were, for instance, primarily expected to provide information on their experience in the use of the current administration building, as well as their expectations on a future administration building. Members of the design team were also expected provide technical information, especially in relation to generation of design options. The researcher played the role of a facilitator, facilitating the entire application of CBAUF on the project. He, for example, introduced members of the team to CBAUF, and trained them on the CBA application process. Most of the team members, coming from the same institution, were largely familiar with one another, hence, not much effort was required to stimulate acquaintance among them.

Project value definition

The second performance episode was to define the value for the project. This fundamentally involved establishing project requirements to meet user needs within agreed budgetary limits. The user group representatives played a crucial role at this stage. The facilitator interviewed the user representatives to establish their needs and requirements in the design and construction of the new administration building. The administration building was identified as the epicenter of administrative and management activities within the campus, and should therefore provide a conducive environment for routine administrative work, as well as strategic management activities.

Apart from primarily providing serene office and meeting spaces, the administration building, in line with the strategic objectives of the polytechnic, was also expected to symbolize academic excellence and become a beacon of attraction of the general public to the polytechnic. In response to the energy policy of the polytechnic which fundamentally advocates efficient utilization of energy within buildings, another requirement of the project was to ensure energy efficiency in the use of the building when completed. Even though the overall budget for the project should have been established and agreed at this stage, especially in line with TVD practices, some administrative restraints posed a limitation for this to be carried out at the time of conducting the case study.

Identification and anticipation of decision-making frames

Having established the project objectives, the next performance episode was to compartmentalise the design process into various decision frames, with corresponding design activities, based on which CBA was applied for stakeholders to collaboratively engage in decision-making. Identifying and anticipating the decision-making frames were undertaken by the facilitator in consultation with the design team and user representatives. The process was guided by the established project requirements and the level of user stake in the design decisions. Essentially, the decision frames with high user interests, and a tendency (based on stakeholders' judgement) to influence project requirements were anticipated and identified. The identified decision frames with corresponding design activities are in Figure 5.3.

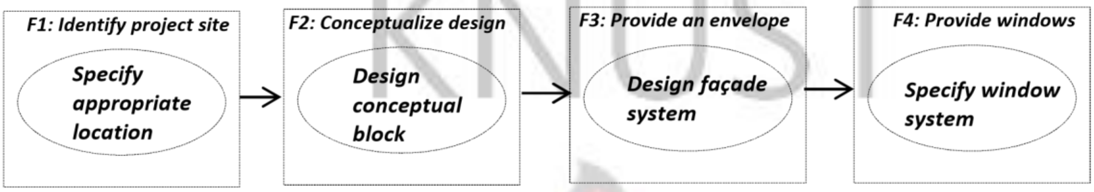


Figure 5.3: Compartmentalization of design process into decisio n-making frames

The specific requirements within each frame, towards meeting the overall project value, were defined. A target cost within each frame (based on the agreed total budget for the project) should have been defined at this stage, but for the restrictions in defining an overall project budget in performance episode 2.

Enforcement of decision-making frames (Application of CBA)

The next performance episode in the design process was to enforce the identified decision-making frames. This is where the CBA process was employed by the designers to engage the user representatives to arrive at a consensual decision within each frame.

Frame 1

The enforcement of the first decision-making frame, F1, involved determining an appropriate location for the new administration block (Figure 5.4).

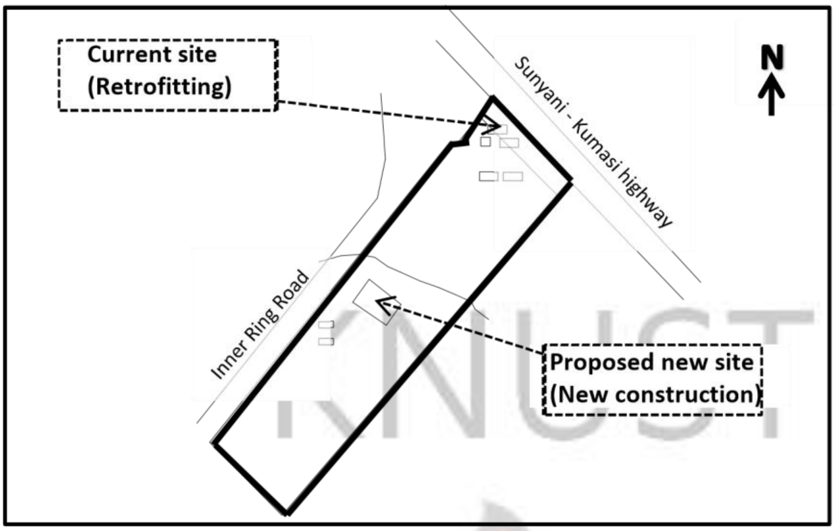


Figure 5.4: Proposed alternative locations of project within the campus

Guided by the established project requirements, the stakeholders agreed to consider two options for siting the project. This decision frame was particularly crucial due to the sharp diversity of opinion, among stakeholders, regarding the two options. The first option, which appeared quite popular among stakeholders, was to maintain the current location by retrofitting the existing administration building to meet the defined project value. The second option was to locate the building at a new site towards the central zone of the polytechnic campus.

In applying the CBA system to make a choice within F1, eight factors, with corresponding criteria, were collectively identified and agreed by stakeholders. The determination of the factors to distinguish the alternatives was guided by the established project requirements (Table 5.1). The attributes, respective to each factor were then defined and the corresponding advantages established. The advantages were ranked according to their importance.

Table 5.1: CBA data for decision-making frame 1 (siting project)

Factor / Criterion	Location at current site (Retrofitting)	Relocation to a new site

1. Potential as iconic attraction of public to the polytechnic	*Attribute*: overlooks the Kumasi-Sunyani highway and is, therefore, within sight of the general public	*Attribute:* Not close to any major highway and is therefore out of sight of the general public
Criterion: higher is better	*Adv.:* higher potential to attract general public Imp: 30	*Adv.:* Imp:
2. Accessibility to other parts of the campus	*Attribute*: positioned at the extreme northern end of the campus and is therefore very far from the southern part of the campus	*Attribute:* positioned close to the central part of the campus and is therefore not extremely far from any part
Criterion: more is better	*Adv.:* Imp:	*Adv.:* generally more accessible to other parts of the campus Imp: 80
3. Noise from vehicular traffic	*Attribute*: very close to a major highway with heavy vehicular traffic	*Attribute:* Away from a major highway with heavy vehicular traffic
Criterion: less is better	*Adv.:* Imp:	*Adv.:* less noise from vehicular traffic Imp: 10
4. Generation of construction waste	*Attribute*: will involve a lot of demolition of existing structure	*Attribute*: will not involve any demolition of existing structure
Criterion: less is better	*Adv.:* Imp:	*Adv.:* less generation of construction waste Imp: 80
5. inconvenience of temporary relocation of administrative activities	*Attribute*: will involve the relocation of current administrative activities to a temporary location	*Attribute*: there is no need for relocation of current administrative activities to a temporary location.
Criterion: less is better	*Adv.:* Imp:	*Adv.:* less inconvenience from temporary relocation Imp: 60
6. flexibility for innovation in design	*Attribute*: design will be largely confined to the limits of the existing block and surrounding built environment	*Attribute*: the largely undeveloped site offers less restrictions to design
Criterion: more is better	*Adv.:* Imp:	*Adv.:* more flexible for design Imp: 100
7. encroachment on vegetative cover	*Attribute*: construction will be largely confined within existing structure with less destruction on vegetative cover	*Attribute*: construction will largely involve clearing and destruction of vegetative cover
Criterion: less is better	*Adv.:* less encroachment on vegetative cover Imp: 30	*Adv.:* Imp:
8. accessibility to general public	*Attribute*: close to the existing main entrance of the campus	*Attribute*: away from the existing main entrance of the campus
Criterion: more is better	*Adv.:* more accessible to general public Imp: 75	*Adv.:* Imp:
Total IoA	**135**	**250**

The overwhelming total IoA for relocation to a new site compared to location at the current site resulted in stakeholders' preference for siting the project at the new location. If the target cost for this frame had been established, the cost of locating the project at each of the locations (especially with respect to cost of site preparation and temporary relocation of staff) would have been compared to this target cost to determine if it's within the target budget. This notwithstanding, it was estimated that it would cost more to locate the project at the current site especially due to cost of demolitions and temporarily relocating administrative staff. The consensus was, thus, to locate the project at the new site. The A3 report for this frame is in Appendix I.

Frame 2

The enforcement of the second decision-making frame, F2, was based on the outcome of the first decision-making frame, F1. It involved the design of a conceptual block for the project at the chosen site (Figure 5.5).

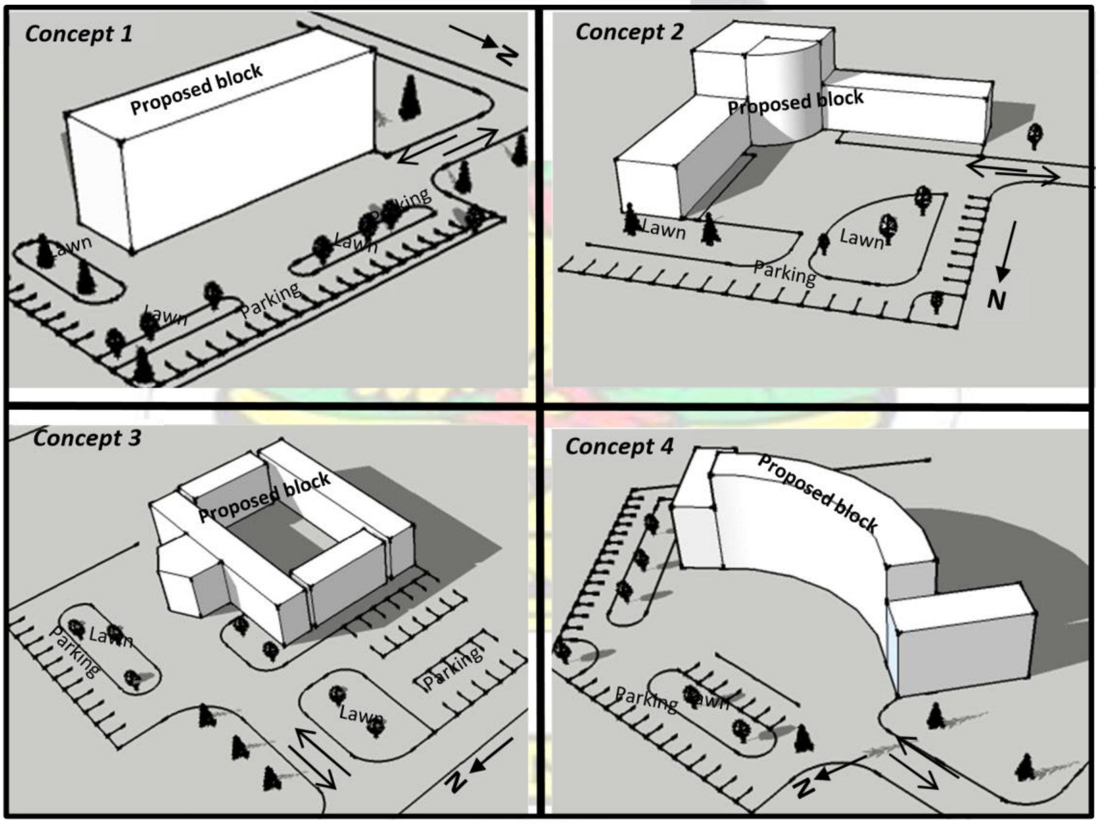


Figure 5.5: Proposed options of conceptual block

Details of the CBA data for this frame are shown in Table 5.2

Table 5.2: CBA data for decision-making frame 2 (Choice of conceptual blocks)

Factor / Criteria	Concept 1	Concept 2	Concept 3	Concept 4

1. exposure to solar path *less is better*	*Attribute*: The longer façade of the block faces N- S	*Attribute:* The longer facades of block the face both N-S and E-W	*Attribute:* The longer facades of the block face both N-S and E-W	*Attribute:* The longer façade of the block faces N- S
	Adv.: much less exposure Imp: 100	***Adv.:*** less exposure Imp: 50	***Adv.:*** Imp:	*Adv.:* much less exposure Imp: 100
2. ventilation across block	*Attribute*: orientation and shape of block is across the prevailing wind/breeze direction	*Attribute:* one wing of the block is across the prevailing wind direction; the other wing is not.	*Attribute:* The southern and northern wings are oriented across prevailing wind direction. The other wings re not	*Attribute:* orientation and shape of block is across the prevailing wind/breeze direction
more is better	*Adv.:* much more ventilation Imp: 45	*Adv.:* more ventilation Imp: 35	***Adv.:*** Imp:	*Adv.:* much more ventilation Imp: 45
3.compactness *more is better*	*Attribute*: all spaces are condensed within one block	*Attribute:* spaces are contained in two wings joined at right angle	*Attribute:* spaces are contained in four blocks arranged around a courtyard	*Attribute:* all spaces condensed in one block with perpendicular projections at the ends
	Adv.: much more compact Imp: 70	*Adv.:* more compact Imp: 55	***Adv.:*** Imp:	*Adv.:* much more compact Imp: 70
4.functional relationship *more is better*	*Attribute*: units of spaces are arranged along a linear path starting at one end and ending at an opposite end	*Attribute*: units of spaces are arranged along two perpendicular linear path starting at one end and ending at an opposite end	*Attribute:* units of spaces are arranged along a closed loop, starting and ending at the same point.	*Attribute:* units of spaces are arranged along a curvilinear path starting at one end and ending at an opposite end
	Adv.: Imp:	*Adv.:* more functionally related spaces Imp: 60	***Adv.:*** much more functionally related spaces Imp: 65	*Adv.:* Imp:
5. Ease of modular constructio n *higher is better*	*Attribute*: shaped like a regular cuboid and could easily become a multiple of a basic module	*Attribute*: two cuboids are fundamentally joined at 90^{o} by a rising cuboid with a filleted corner	*Attribute:* configuration of four cuboids around an open court with a polygonal prism attachment on one side	*Attribute:* an arc shaped prism with identical cuboids attached to each end
	Adv.: much easier Imp: 35	*Adv.:* easier Imp: 30	***Adv.:*** easier Imp: 30	*Adv.:* Imp:
6.enhancement of team cohesion *more is better*	*Attribute*: a single block of office units arranged linearly at each floor without any face-toface interaction orientation	*Attribute*: two blocks of office units with diagonal face-to-face office interaction of offices across the blocks	*Attribute:* Four blocks of office units radiating from a central court with perpendicular and diagonal interaction of offices across the blocks	*Attribute:* a single block of office units arranged curvilinearly without a face-to-face interaction
	Adv.: Imp:	*Adv.:* more potential Imp: 50	***Adv.:*** much more potential Imp: 60	*Adv.:* Imp:
7. prominence of form *more is better*	*Attribute*: a regular shape similar to most buildings inside and outside campus	*Attribute*: an L-shaped form with a rising prism at the corner which doesn't appear too common	*Attribute:* a regular concept of form commonly associated with traditional domestic layout but rare on the campus	*Attribute:* aear curvilin forms which appea side rare within and out campus
	Adv.: Imp:	*Adv.:* more prominent Imp: 35	*Adv.:* Imp:	*Adv.:* much more prominent Imp: 40
Total IoA	**225**	**295**	**155**	**255**

Four main conceptual blocks were agreed by the team for consideration (concepts 1, 2, 3 and 4). The CBA application process to decide among the options was similar that of F1. If the target cost for this frame had been established, the cost of each concept would have been compared to the target cost to determine if it's within the target budget. The A3 report for this frame is shown in appendix II.

Frame 3

In enforcing the third decision-making frame, the stakeholders had to decide on a façade system to the building. The façade system was recognised to be very crucial in fulfilling the project requirements of providing a serene working environment for management and administrative staff, as well as enhancing the aesthetic appeal of the administration building to fulfil its iconic attraction requirement . The team, upon reflecting on the project requirements, agreed on three options as possible façade systems for the project. These included: "rendering and painting on sandcrete block wall", "curtain walling", "alucobond cladding on block wall" and tiling on block wall (Figure 5.6). Each of these options was expected to incorporate glazed openings.

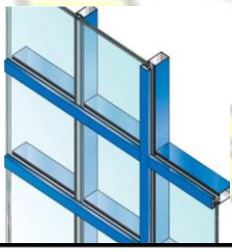
Curtain walling	Alucobond on blockwork	Rendering and painting on blockwork	Tiling on blockwork
			

Figure 5.6: Alternative façade systems

A summary of the CBA decision data for this decision-making frame is shown in Table 5.3.

Table 5.3 CBA data for decision frame 3 (choice of façade system)

Factor / Criterion	Curtain walling	Alucobond on blockwork	Rendering and painting on blockwork	Tiling on blockwork
1. self-load	*Attribute*: about 63.47kg/m^2	*Attribute:* about 228.00kg/m^2	*Attribute:* about 317.00 kg/m^2	*Attribute:* about 317.00 kg/m^2
less is better	*Adv.:* 253.53 Imp: kg/m^2 less 80	*Adv.:* 89.00 Imp: kg/m^2 less 25	*Adv.:* Imp:	*Adv.:* Imp:
2. acoustic insulation	*Attribute*: lightweight, smooth surface with a sound diffusive core	*Attribute:* a dense solid barrier with a smooth surface finish	*Attribute:* a dense solid barrier with a smooth surface finish	*Attribute:* a dense solid barrier with a smooth surface finish
more is better	*Adv.:* Imp:	*Adv.:* much more insulative Imp: 35	*Adv.:* more insulative Imp: 30	*Adv.:* more insulative Imp: 30
3. thermal mass	*Attribute*: lightweight barrier	*Attribute:* a dense solid barrier	*Attribute:* dense solid barrier	*Attribute:* a dense solid barrier
more is better	*Adv.:* Imp:	*Adv.:* more thermal mass Imp: 100	*Adv.:* more thermal mass Imp: 100	*Adv.:* more thermal mass Imp: 100
4. speed of construction	*Attribute*: involves assembly of prefabricated panels	*Attribute*: assembly of prefab panels as a finish to an in-situ constructed wall	*Attribute:* in-situ constructed wall a finish d	*Attribute:* in-situ constructed wall a finish d
more is better	*Adv.:* much faster to install entire system Imp: 75	*Adv.:* faster to apply finish layer Imp: 30	*Adv.:* Imp:	*Adv.:* Imp:
5. reusability	*Attribute*: panels and frames can easily be dismantled and reused	*Attribute*: while difficult for the structural wall, finish can easily be dismantled and reused	*Attribute:* it is very difficult to dismantle the wall and use the elements	*Attribute:* it is very difficult to dismantle the wall and use the elements
higher is better	*Adv.:* much higher reusability Imp: 75	*Adv.:* higher reusability Imp: 20	*Adv.:* Imp:	*Adv.:* Imp:
6. flexibility in altering outer colour	*Attribute*: colour is permanently embed to the panels and is difficult to alter	*Attribute*: colour of the finish is permanently fixed on the panel and is difficult to change	*Attribute:* colour can easily be altered by repainting	*Attribute:* colour of the finish is embed on the tiles making it difficult to change
more is better	*Adv.:* Imp:	*Adv.:* Imp:	*Adv.:* more flexible to alter outer colour Imp: 10	*Adv.:* Imp:
7. impact resistance	*Attribute*: less dense and thick, making it more susceptible to fracturing at some level of impact	*Attribute*: A very dense and thick wall construction. The finish is however prone to denting on impact	*Attribute:* A very dense and thick wall construction with a resilient surface rendering	*Attribute:* A very dense and thick wall construction with a resilient surface rendering
more is better	*Adv.:* Imp:	*Adv.:* more impact resistant Imp: 35	*Adv.:* much more impact resistant Imp: 50	*Adv.:* much more impact resistant Imp: 50
8. regularity in finishing *more is better*	*Attribute*: largely factory made with high level of precision and regularity	*Attribute*: finish is largely factory made with precision but possible irregularity of block work could affect regularity	*Attribute*: the entire is executed on site with a tendency to reduce regularity	*Attribute*: finish is largely factory made with precision but possible irregularity of block work could affect regularity
	Adv.: much more regular finish Imp: 55	*Adv.:* more regular finish Imp: 45	*Adv.:* Imp:	*Adv.:* more regular finish Imp: 45
9. ease of maintenance	*Attribute*: requires highly skilled labour for regular maintenance to ensure water and air tightness.	*Attribute*: specialized skill is required for cleaning and replacement of panels	*Attribute*: regular maintenance largely involves repainting for which skilled labour is common	*Attribute:* regular maintenance will largely involve surface regeneration by ordinary cleaning or washing.

higher is better	*Adv.:*	Imp:	*Adv.:*	Imp:	*Adv.:* easier to maintain	Imp: 30	*Adv.:* much easier to maintain	Imp: 40
Total IoA		285		290		220		265

The CBA process led to the establishment of "alucobond on blockwork" as the option with the highest total IoA. The closeness of the total IoA of "curtain walling" to that of "alucobond on blockwork" resulted in a consideration of a possible composite facade system involving "alucobond on blockwork" and "curtain walling" for the project. In line with TVD, the final decision would have been taken relative to a defined target cost. The A3 report is in Appendix III.

Frame 4

This frame involved the specification of a window system for the building. A window system was identified to also play a crucial role in meeting the project value, especially with respect to ensuring heat and acoustic insulation, as well as adequate ventilation, to create a comfortable working environment. Similar to case 2, five options of window systems were agreed and considered by the stakeholders: casement, sliding, louvered, and pivoted and awning (Figure 4.6).

The factors in case 2 were agreed as being also relevant for this decision frame. There were however changes in the definition of some factors to make them clearer (Table 5.4). "Ventilation area" as a factor was, for instance, redefined as "area openable for ventilation" to make it clearer to stakeholders. Some of the attributes were also redefined by stakeholders. One of the attribute of louvers in case 2, (i.e. "It doesn't project into any adjoining space beyond the thickness of the wall when opened") was redefined in this frame (i.e. "It could project a bit into the interior space beyond the thickness of the wall when opened") resulting in a change in the advantage of louvers with respect to the factor obstruction of surrounding space.

Table 5.4: CBA data for decision-making frame 4 (choice of a window system)

Factor/Criterion	Sliding window	Pivoted window	Awning window	Louvered window	Casement window
1. Opening / closing flexibility	*Attribute*: allows for infinite degree of slides to open up to about 50% of the total area of the window.	*Attribute:* allows for infinite degree of rotation of sash to open up to the total window area less the area of the edge of the sash.	*Attribute:* allows for infinite degree of tilt to open up to the allowable angle of tilt of the sash.	*Attribute:* allows for infinite degree of tilt of louver blades to open up to about 90% of window area.	*Attribute:* Allows for infinite degree of swing of sash up to about 100% of window area.
Criterion: higher is better	*Adv.:* Imp: 0	*Adv.:* **allows for higher flexibility** Imp: 20	*Adv.:* **allows for higher flexibility** Imp:20	*Adv.:* **allows for much higher flexibility** Imp: 25	*Adv.:* **allows for higher flexibility** Imp:20
2. Familiarity to users	*Attribute*: It has become popular in the past few years as a more contemporary system especially in the urban areas of Ghana.	*Attribute:* The use of this system is rare in Ghana and some of the users have not seen or had any experience with its use.	*Attribute:* It is an emergent system and is typically common with curtain wall systems in Ghana.	*Attribute:* It is the commonest glazing system for windows for various kinds of buildings in Ghana with almost all users having had experience with its use.	*Attribute:* It is very common with colonial buildings and rural architecture but is rare in contemporary buildings even though seem to be re-emerging.
Criterion: more is better	*Adv.:* **more familiar** Imp: 15	*Adv.:* Imp: 0	*Adv.:* Imp: 0	*Adv.:* **much more familiar** Imp:20	*Adv.:* **more familiar** Imp:15
3. Ease of cleaning	*Attribute*: A generally wider pane of glass for each sash provides for a firmer surface but is however quite difficult to access the surface facing the exterior from the interior to clean.	*Attribute:* A generally wider pane of glass for a sash provides a firmer surface for cleaning while the mode of operation allows for easy access to both sides of sash to clean when cleaning from the interior space.	*Attribute:* A generally wider pane of glass for a sash provides a firmer surface for cleaning but however presents great difficulty in cleaning the surfaces facing outside from the interior space.	*Attribute:* The louvre blades are narrower panes of glass that are flexible and could break easily when cleaning but however offers better access to all surfaces of the louvre blades to clean.	*Attribute:* A generally wide pane of glass for each sash which could provide a firmer surface for cleaning but could pose a difficulty in accessing the exterior surface from inside to clean.
Criterion: higher is better	*Adv.:* **easier to clean** Imp: 30	*Adv.:* **much easier to clean** Imp: 50	*Adv.:* Imp: 0	*Adv.:* **easier to clean** Imp: 30	*Adv.:* Imp: 0
4. Area openable for ventilation	*Attribute*: Maximum area openable for ventilation is about 50% of window area.	*Attribute*: allows for up to about 95% of winc opened for ventilation	*Attribute:* allows for up to about 90% of window area to be opened for ventilation	*Attribute:* allows for up to about 90% of window area to be opened for ventilation	*Attribute:* allows for up to about 95% of window area to be opened for ventilation
Criterion: more is better	*Adv.:* Imp: 0	*Adv.:* **45% more open area** Imp: 100	*Adv.:* **40% more open area** Imp: 90	*Adv.:* **40% more open area** Imp: 90	*Adv.:* **45% more open area** Imp: 100
5. Obstruction of surrounding space	*Attribute*: It doesn't project into any adjoining space beyond the thickness of the wall when opened.	*Attribute*: It projects up to about ½ the width of the sash simultaneously towards the interior and exterior adjoining spaces when fully opened.	*Attribute*: It projects up to about the full length of the window sash into the exterior adjoining space when fully opened.	*Attribute*: It could project a bit into the interior space beyond the thickness of the wall when opened.	*Attribute*: It projects up to about the full length of the window sash into the exterior adjoining space when fully opened.
Criterion: less is better	*Adv.:* **zero obstruction of adjoining space** Imp: 70	*Adv.:* **less obstruction of adjoining spaces** Imp: 40	*Adv.:* Imp: 0	*Adv.:* **very less obstruction of adjoining space** Imp: 67	*Adv.:* Imp: 0
6. Adjustment of air flow direction	*Attribute*: sashes slide to create uninterrupted entry for air.	*Attribute*: some level of interruption of air flow direction could be achieved by adjusting angle of rotation of sash.	*Attribute:* varying degree of tilt of sash could have varying level of interruption of air flow direction.	*Attribute:* capable influencing air flow direction by tilting louver blades at various angles.	*Attribute:* varying degree of rotation of sash could have varying level of interruption of air flow direction.
Criterion: more is better	*Adv.:* Imp: **0**	*Adv.:* **more control of air flow direction** Imp: 20	*Adv.:* **more control of air flow direction** Imp: 20	*Adv.:* **much more control of air flow direction** Imp: 30	*Adv.:* **more control of air flow direction** Imp: 20
7. Seamlessness in closed position	*Attribute*: closed position depicts a vertical overlap at the edges of two sashes of continuous pane of glass in profiles.	*Attribute*: closed position depicts a sash of continuous pane of glass in a profile.	*Attribute:* closed position depicts a sash of continuous pane of glass in a profile.	*Attribute:* a series of louver blades overlap horizontally in closed position	*Attribute:* closed position depicts a sash of continuous pane of glass in a profile
Criterion: more is better	*Adv.:* **more seamless** Imp: 50	*Adv.:* **more seamless** Imp: 50	*Adv.:* **more seamless** Imp:50	*Adv.:* Imp: 0	*Adv.:* **more seamless** Imp: 50
8. exclusion of rain when open	*Attribute*: window sash slides to open and do not provide any protection to the opening against the ingress of moisture during rainfall.	*Attribute*: window sash rotates horizontally about a pivot to open and do not provide any protection to the opening against the ingress of moisture during rainfall.	*Attribute*: window sash projects over the opening when opened and therefore provides some protection for the opening against moisture ingress during rainfall.	*Attribute*: louver blades project over the opening when opened and therefore provides some protection to the opening against the ingress of moisture during rainfall.	*Attribute*: window sash swing horizontally about the side to open and do not offer any protection to the opening against the ingress of moisture during rainfall.
Criterion: higher is better	*Adv.:* Imp: 0	*Adv.:* Imp: 0	*Adv.:* **more protection** Imp: 20	*Adv.:* **more protection** Imp:20	*Adv.:* Imp:0
9. Ease of replacement	*Attribute*: requires the replacement of entire pane within a sash when broken.	*Attribute*: requires the replacement of entire pane within a sash when broken.	*Attribute*: requires the replacement of entire pane within a sash when broken.	*Attribute*: requires the replacement of individual louver blades when they are broken.	*Attribute*: requires the replacement of entire pane within a sash when broken.
Criterion: higher is better	*Adv.:* Imp: 0	*Adv.:* Imp: 0	*Adv.:* Imp: 0	*Adv.:* **Easier to replace** Imp: 50	*Adv.:* Imp: 0
Total IoA	**165**	**280**	**200**	**332**	**205**

Even though louvered windows turned out to be the option with the highest importance, similar to case 2, there were some changes to the IoAs of some of the options. The generated A3 report for this frame is in Appendix IV.

5.3.3 Evaluation

Evaluation, according to March and Smith (1995), is the formulation of a set of performance metrics in the form of criteria and the assessment of the construct against those performance metrics. A construct is generally evaluated based on the following criteria: completeness, simplicity, elegance, understandability, and ease of use (Ander Lia and Ringerike, 2014; Hevner et al., 2004). However since CBAUF is essentially made up of a set of episodes to perform goal-oriented activities, it is additionally evaluated in terms of operationality, efficiency and generality (Lia and Ringerike, 2014).

Completeness

A construct is said to be complete and effective if it fulfills the requirements and confines of the problem it was meant to solve (Hevner et al., 2004). The fundamental objective of CBAUF was to solve the problem of setting a stage to improve collaboration between designers and users towards discovering and meeting project values during the design process. In doing so, CBAUF was required to incorporate a participative decision-making system in order to stimulate an atmosphere of trust, transparency, respect and learning for effective user participation in design process. The prevalence of the problem of lack of effective strategies for stakeholder engagement in design process resulting in the need for a solution, such as CBAUF, has been amply demonstrated in the literature review, as well as the exploratory and evaluation case studies.

The outcome of the evaluation case study and knowledge base of relevant literature (especially on 4D, 5D and 6D BIM applications) presents CBAUF, with its six performance episodes, as fundamentally creating a space for effective designer – user interaction towards *discovering*, *generating* and *validating* project value at the design stage of the construction project delivery process. This, arguably, is essentially a complete solution to the problem. The first and second performance episodes (i.e. team composition and project value definition) were very significant in discovering the value of the future administration building. The composition of a knowledgeable team mainly made up of user representatives and the design team, as well as the creation of a platform for the team members to contribute to establishing the project requirements, contributed immensely to the project value discovery process.

Based on inputs from the first and second performance episodes, the third and fourth performance episodes (i.e. identification / anticipation and enforcement of decision making frames) were where the discovered value of the proposed building was generated. Even though the design process was associated with an endless number of decisions, the four decision frames, based on which CBA was applied, was collectively identified and agreed by the stakeholders as being very instrumental in generating the discovered value for the project. The stimulation of an atmosphere of transparency, respect and learning, among stakeholders, in the CBA application across the four decision-making frames, in the evaluation case study, was a further corroboration of what was observed in the exploratory case studies.

The outcome of the decision-making frames which were expected to embody the project requirements would have been subjected to validation in performance episodes 5 and 6. Even though this was not carried out in the evaluation case study, the value validation process (using 4D, 5D, and 6D BIM applications), in the view of the participants, would have provided feedback on the ability of the outcome of each decision frame to meet expected project requirements. Besides, the participants indicated that BIM would have also provided more concrete insight especially with respect to the technical attributes and advantages of the alternatives within each decision-making frame. For example, attributes on speed of installation of façade system (in frame 3) and area openable for ventilation (in frame 4) would have been better demonstrated to stakeholders through the application of BIM.

Even though CBAUF exhibits elements of comprehensiveness towards solving the identified problem, its completeness is challenged, as an artifact of design, by the phenomenon of wicked problems associated with the design sciences (Rittel & Webber, 1973; Farrell & Hooker, 2013). The conditions of finitude, complexity and normativity associated with the wicked problems of design are indispensible limitations to an attempt at optimal completeness of a designed construct such as CBAUF. Owing to the inexhaustive and expandable nature of decisions in design process, the limitation of the decision-making frames to a particular number as suggested in CBAUF (though a rational approach in practical design settings), for instance, tends to be adversarial to optimal completeness of the framework. Even though the four decision-making frames that were enforced in the case study were expected to contribute significantly to meeting project requirements, realization of the entire project value could not be said to be exclusive to the enforcement of only the four decision-making frames. The focus of CBAUF on creating an atmosphere of respect, transparency and learning, towards building consensus among stakeholders, should however contribute to dampening the effect of this challenge.

Simplicity

The need for simplicity identifies with the philosophy of parsimony or Occam's razor, which suggests that "keeping methods simpler is better" (Baker 2013). Even though the design process is typically complex, there has been an attempt to reduce this complexity with a simplification of the proposed framework. The framework is composed of six distinct performance episodes each of which is explicit with a measurable attainability. In the case application of CBAUF, the clarity of role assignment and specificity of activities to be carried out, within each performance episode, contributed to its simplicity.

The reducibility of all the various components of CBAUF into a unit scheme (see Figure 5.1) containable on an A4 size sheet is a further illustration of its simplicity. Even though for academic purposes the unit scheme of CBAUF is expandable to more textual description with theoretical connotations, in practice its application could be adequately explained to stakeholders with a reference to only the unit scheme. In the case study, it did not require more than the unit scheme of CBAUF on a single page/slide for the framework to be introduced to the understanding of all participants in the case study.

One of the rigorous episodes, in CBAUF implementation, was the enforcement of the decision-making frames involving CBA application to reach consensus on decisions.

However the explicit nature of the CBA application process as observed from both the exploratory and evaluation case studies, and corroborated in literature (Arroyo et al., 2015; Arroyo et al., 2013; Mossman, 2012) tend to enhance its simplicity compared to traditional decision processes in the AEC sector such as AHP and WRC which may involve more laborious high order abstractions. A number of instances were observed in the case studies when some participants, without any prior introduction to the CBA process easily got acquainted with the process and are able to offer effective contributions.

It is however worth noting that the observed simplicity of CBAUF could be challenged by the reciprocal loops among the various performance episodes. Therefore rather than being a straight forward linear progression, there is a back and forth progress among the performance episodes in the application of CBAUF. The incidence of team regeneration was one manifestation of the non-linear progress, whereby during the enforcement of frames 3 and 4, in performance episode 4, it occasioned a reverse to performance episode 1 to reconstitute the team to allow for the input of a façade and window installation specialist in the CBA application process (especially during the generation of alternatives and definition of attributes).

Understandability

Understandability, which is closely related to simplicity, refers to how easily the construct is understood (Lia and Ringerike, 2014). The demonstrated simplicity of CBAUF is one of the key drivers of getting it easily understood. The condensation of the entire framework into a graphical scheme has also been observed to facilitate its understanding. The reciprocal links among the performance episodes may however create a picture of complexity.

Ease of use

The ease of use of the framework is also linked to its demonstrated simplicity and understandability. Generally a construct that is simple to understand and implement tends to have its use being eased. In the case studies there was virtually a representation of the required experience and expertise to undertake the roles and responsibilities in implementing episodes 1, 2, 3 and 4. Even though there was, however, some difficulty in implementing episodes 5 and 6, due to constraints in expertise and experience of BIM implementation, the continuing spread of BIM across the AEC sector should eventually ease the implementation of this component of CBAUF.

Operationality

This criterion is in relation to stakeholders' ability to effectively use the construct. There is a strong linkage between operationality and ease of use. The simplicity and ease of use of CBAUF tends to ensure a proper understanding of its implementation to achieve the desired outcome. The framework has also been structured around the IMOI model of team process to enhance its operationality especially in respect of the reciprocal dependency tendencies in design process.

Beyond the client, users and design team, the operation of CBAUF may require the early involvement of other stakeholders such as contractors, subcontractors and specialists in the construction project delivery process. This requires, especially for public projects, a procurement regulatory system that accommodates this arrangement. In Ghana, as observed by participants, the two stage tendering method provided for in the public procurement Act (Act 663) could be exploited to allow for an early input of contractors' contribution to the design process.

Efficiency

Efficiency is related to the commensuration of the output of the framework compared with the input during its application. One area where CBAUF draws its efficiency, as observed from the case study and corroborated by participants, is its composition of a set of simple and unambiguous steps which are specifically directed towards enhancing collaboration for value generation in participatory design. The efforts, in respect of time and resources, that were put into the various performance episodes yielded outcomes which ultimately led to consensus among stakeholders on a series of value generating design decisions.

In the CBA application process in performance episode 4, the rigorous process of generating design alternatives, through to defining attributes and establishing importance of advantages, required a lot of effort and time, but resulted in design solutions that were largely agreed by stakeholders as capable of meeting the project requirements. The use of boundary objects such as drawings and models facilitated a shared understanding (especially on the attributes of alternatives) among the stakeholders leading to a smooth progress of the process and enhancing efficiency. Performance episodes 5 and 6 would have required more time and resources to implement but would have also led to the creation of more shared understanding, among stakeholders, on the outcome of the decisions.

Elegance

Design, in its various representations (e.g. architecture, engineering, music etc.) is defined by style (Hevner et al., 2004). It is argued that, due to the fact that there is some level of flexibility in which a construct can be built to meet the requirements of researchers and users, elegance or style should form one of the components of evaluation (Hevner et al., 2004). The subjective perception of elegance however makes its measurement inevitably complex (Lia and Ringerike, 2014). Nevertheless style is described as the unification of power and simplicity (Gelernter, 1998). This implies that a construct is elegant if it is simple and efficient. Some elements of simplicity and efficiency of CBAUF have already been illustrated, therefor demonstrating its potential of elegance.

Generality

Evaluating the generality of a construct is one of the main elements of the design of constructive research, because, apart from devising a workable solution to improve the performance of the case studied, another objective of the research (objective v) was to contribute to the theory on which the research was based. Lukka (2003) suggests four key alternatives of linking any study to its theoretical contribution: creation of new theory; refinement of existing theory; testing of existing theory and illustration of existing theory. Refinement of theory, Lukka further observes, is perhaps the most expected theoretical outcome of a constructive research. The argument is that the constructive research method presents a basis for the modification of prior beliefs (i.e. means – ends or process relationships) which were held before the conduct of the research.

One element of theory refinement, in this research, is in relation to the theory of CBA application across the entire spectrum of design process. The specific enhancement of this theory is the reliance on the concept of reflective practice in design process to compartmentalise the design process into various decision-making frames corresponding to respective episodes of design activity within which the CBA process can then be applied. This refinement of the theory of CBA application recognises the fact that the design process is characterised by expandable and inexhaustive decision points, hence the need to operationalize CBA application, across the design process spectrum, by concentrating on certain identified decisions.

Conversely, the concept of decision-making frames in design process management has received some theoretical refinement especially in the context of enforcing collaborative design within the decision-making frames through CBA application. The episodes of design activities, contained within each frame, has been given further enhancement in implementation as fundamentally comprised of generating options of design solutions or specification, and going through the rest of the CBA steps of identifying factors, through to assigning importance to advantages before a final decision is reached within each frame. Another enhancement of the theory of decision-making frames, especially with respect to TVD in CBAUF implementation, is the proposal to align subdivisions of the overall target value and cost to the respective decision-making frames.

The elaboration, in CBAUF, of the significance of BIM models, functioning as boundary objects, to create a shared understanding, among stakeholders, of the attributes and advantages of design alternatives, and provide early feedback on the consequences of CBA decisions is a further refinement of the CBA application theory. BIM should therefore become an integral part of the CBA process when users and other stakeholders are involved in design decisions. This will eventually facilitate efficiency and consensus building in the CBA process.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter presents the conclusion of the research. It contains summary of the research outcomes, contributions to knowledge, recommendations for further research and some concluding remarks.

6.2 Summary of Research Outcomes

The significance of the involvement of stakeholders, such as users, in design process, towards generating value and minimizing waste, in the construction project delivery process, has been demonstrated in literature. There is also ample evidence, in literature, on the need to make the participation of stakeholders, such as users, effective by creating a collaborative environment where designers and users can meet, interact, share and discuss values, needs and concerns. The researcher further demonstrated, through literature review, the need to employ a collaborative multicriteria decision-making system in a framework to create and sustain collaboration between designers and users in participatory design. The CBA decision system which has been identified in literature as having the potential of enhancing collaboration in group decision-making process was considered.

6.2.1 Collaborative Potential of CBA

Through the application of the CBA decision system, in three exploratory case studies, the potential of CBA in fostering collaboration, between designers and users, in design process, was empirically confirmed. The case studies revealed that the CBA decision system facilitates collaboration in design decision-making process by stimulating an atmosphere of respect, transparency and knowledge sharing among stakeholders. The explicit and simple nature of the CBA application process was found to be instrumental in building consensus on design decisions by enhancing participation and conversation among stakeholders.

6.2.2 Strategies for Incorporating CBA in a User-involvement Framework

Apart from establishing the collaborative potential of the CBA decision system, one other significant objective of the exploratory case studies was to acquire knowledge on strategies for incorporating CBA in user-involvement framework. One of the lessons from the exploratory case studies was the strong linkage between CBA application in design process and pre-design activities such as team composition and project value definition. A CBA-based user-involvement framework should therefore have team composition and project value definition as key and explicit activities.

It was also learnt that the number of design decisions to involve users is inexhaustive and expandable. There is, therefore, the need to identify and anticipate specific decision-making frames to apply CBA when involving users. These decision-making frames should correspond to respective episodes of design activities. Considerations such as level of user stake in decision and possible impact of decision on project budget could guide the identification of the decision-making frames.

The effectiveness of employing CBA in user-involved design is enhanced by combining the application of CBA with other lean tools such as TVD, SBD and BIM. TVD provides a more explicit definition of value and budgetary boundaries to guide CBA application. SBD encourages the generation of design alternatives as well as postponement of commitment to a single design solution until the rigorous CBA process is applied to decide on a solution at the last responsible moment. BIM provides boundary objects in the form of nD computer imagery models to create a shared understanding, among stakeholders, on the attributes and advantages of design alternatives.

6.2.3 Limitations in the Application of CBA in User-involved Design

Notwithstanding the successful application of CBA to involve users in some key design decisions in the exploratory case studies, some limitations were observed.

One of the limitations was the fact time and resource constraints may not allow for CBA application for all projects and on all design decisions. Another limitation was the difficulty in representing the attributes of alternatives in qualitative terms, with certainty, compared to quantitative terms. The number of possible design alternatives is inexhaustive and as the number of alternatives increases there is more difficulty in applying CBA.

6.2.4 CBA incorporated User-involvement Framework (CBAUF)

The ultimate outcome of this research in fulfillment of the research aim was the design of CBAUF based on knowledge from the exploratory case studies and literature review. CBAUF is a construct whose application is expected to enhance collaboration between designers and users towards value generation in design process. Operationalizing CBAUF involves six performance episodes: compose a team; define project value; identify and anticipate decision-making frames; enforce decision-making frames (apply CBA); implement decisions (deliver virtual value); run product (experience virtual value). These performance episodes are linked by reciprocal dependency loops.

Based on an evaluation case study, the completeness, simplicity, ease of use, operationality, efficiency, elegance and generality of CBAUF have been verified. Even though findings from the evaluation case study generally illustrate the workability of CBAUF, with respect these criteria, the process of its design was within a typical setting of wicked problem conditions (finitude, complexity, normativity), therefore posing a limitation to it as an optimum solution to the problem for which it was constructed. With respect to its generality it was established that the design of CBAUF has led to the refinement of theories on CBA application, lean design, design process management, and stakeholder participation.

6.3 Contributions to Knowledge

The research contributes to knowledge by providing:

i) A theoretical rationale for incorporating the CBA decision system in a user-involvement framework. Section 2.1.4 demonstrates the need for a lean decision system such as CBA to create, sustain and optimize the collaborative realm for participatory design (Kpamma et al., 2014a & 2014b).

ii) An empirical evaluation of the collaborative attributes of the CBA decision system (chapter 4). Some highlights in the case studies presented in this chapter include the use of CBA to manage user preferences and as a user engagement tool in participatory design (Kpamma et al., 2016a & 2016b).

iii) An analysis of the functioning of the CBA decision system in the context of the wicked problems in participatory design. Section 4.4.1 presents how some elements of the application of the CBA decisions system could be exploited to manage wicked problems in participatory design.

iv) An analysis of strategies that can be employed to incorporate CBA in a user-involvement framework. Section 4.4.2 presents various strategies for employing CBA in the design of a user-involvement framework.

v) A design and evaluation of a CBA incorporated user-involvement framework (CBAUF) to enhance the participation of users in design process (Chapter 5). The research provides a method, with an explicit decision system, for involving users in design process towards value generation.

vi) An insight into how CBA could be combined with other lean design tools such as TVD, SBD, A3 and BIM to enhance collaboration between designers and users for project value generation (Chapter 4 and 5).

vii) A direction on implementing design management at the process level (Chapter 4 and 5).

6.4 Recommended Further Research

The outcome of this research provides a basis for future studies:

- Reducing the effect of subjective sentiments on collaboration among stakeholders especially at the stage of deciding IoAs in CBA application.
  - What specific measures can be taken to improve consensus building among stakeholders on IoAs?

- Implementing lean design.
  - What other tools, apart from TVD, A3, SBD can be incorporated in CBAUF towards a holistic lean design practice?
  - How can lean tools such as LPS, DSM and ADepT be effectively applied in planning and controlling the process of user-involved design involving the application of CBAUF?
  - Does the compartmentalization of the design process into decisionmaking frames offer a potential for effectively planning and controlling the implementation of CBAUF using LPS, DSM or ADepT? For example can the design activities within the identified and anticipated decision-making frames form the basis for planning the controlling the CBAUF application process?
- Enhancing involvement among stakeholders who are apart.
  - What are the major challenges involved in applying CBAUF where stakeholders are located apart?
  - What strategies can be adopted to make the application of CBAUF be effective when stakeholders cannot be brought to the same location? For example, can the stage of deciding IoAs, in the CBA application, which may require face-to-face dialogue, be made effective through other means of communication and information sharing?
- Contextualizing CBAUF for the construction phase of project delivery.
  - How can CBAUF which has been designed to fundamentally enhance user-designer collaboration at the design stage be modified to enhance collaboration among actors at the construction stage of project delivery?

- How can the concept of decision-making framing be contextualized for applying CBA at the construction stage of project delivery?

- Employing BIM to enhance the CBA process.
    - What are the specific areas of synergy between CBA and BIM towards enhancing stakeholder collaboration for value generation in design?
    - What are the challenges involved in the application of BIM to involve users in design process?

- Collaborative designing for sustainability ○ What are the significant areas of focus when identifying and anticipating decision-making frames in the application of CBAUF towards sustainable design and construction?

6.5 Concluding Remarks

This research explained the significance of involving stakeholders, such as users, towards value generation at the design stage, and how the CBA decision system could be employed to enhance collaboration among stakeholders during design process. Through the constructive research approach, a user-involvement framework, CBAUF, has been presented to enhance the participation of users in design process for value generation. The design of CBAUF was a culmination of knowledge from theoretical and empirical studies. Theoretical knowledge was mainly formed from reviewing literature on participatory design, CBA application process, design process management, team process and lead design. The empirical studies involved case studies on CBA application on selected projects.

CBAUF is made up of six performance episodes connected by reciprocal dependency loops. The workability of CBAUF with respect to criteria, such as its completeness, efficiency, simplicity and generality has been demonstrated in an evaluation case study. The contribution of the framework to the theoretical knowledge, based on which it was constructed, has also been established. Knowledge in CBA application process, participatory design, design process management and lean design has been advanced through the design of CBAUF.

In the implementation of CBAUF in design process management, the fundamental recommendation is to compartmentalize the design process into key decisionmaking frames within which CBA is employed to involve users in design decisions. The identification of the decision-making frames should be aligned to the project value defined at the pre-design phase, and guided by such factors as the level of user stake in the decision frame. Lean design tools such as TVD, SBD A3 and BIM should be employed to complement the application of CBA within each decisionmaking frame.

A further study on CBAUF is recommended to understand how it can be enhanced for a holistic implementation of lean design beyond a focus on value generation to waste minimization. The synergistic benefit of incorporating other lean tools, such as LPS, DSM and ADepT, in CBAUF, to enhance design schedule predictability and improve progress stability needs to be explored.

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APPENDIX I
A3 Report for decision frame 1

Choice of Site for a Future Administration Block for Sunyani Polytechnic

1. Background

-There has been an increase in the complexity and size of the administrative and management structure of the polytechnic

- A need has therefore has arisen for the construction of a new administration block for the Sunyani Polytechnic.

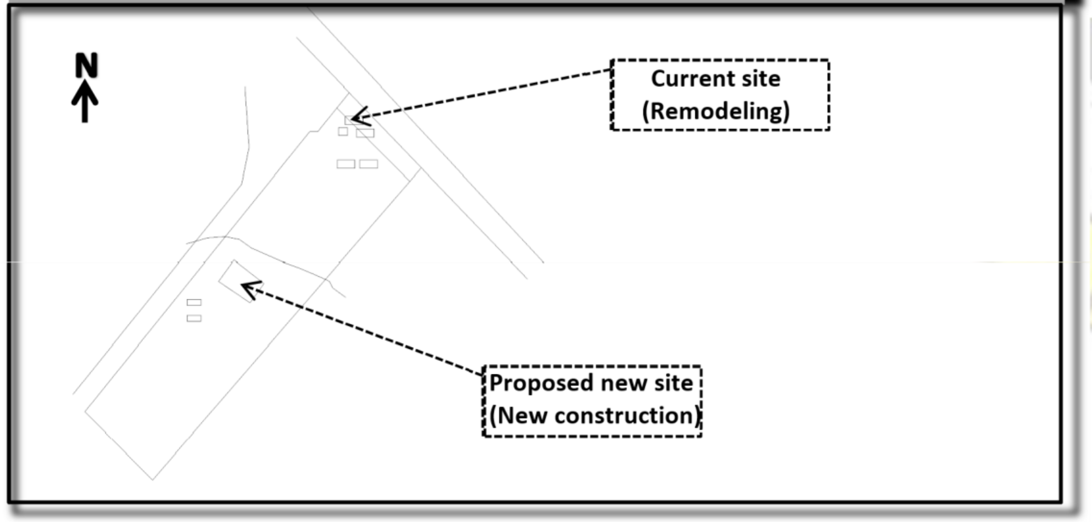
- An appropriate location is required for the construction of the new block to fulfill established project requirements

-Decision participants included the design team, user representatives and the facilitator

2. Alternative Locations

i) Location at current site: this involves remodeling the existing administration building to meet the new requirements.

ii) Location at a new site: this involves siting the project a new towards the central zone of the campus.



3. Summary of Advantages with Corresponding Importance

i) Location at current site		*ii) Relocation to a new site*	
Adv.: higher potential to attract general public	**30**	*Adv.:*	
Adv.:		*Adv.:* generally more accessible to other parts of the campus	**80**
Adv.:		*Adv.:* less noise from vehicular traffic	**10**
Ad		*Adv.:* less generation of construction was	**80**
Adv		*Adv.:* less inconvenience from temporary relocation	**60**
Adv.		*Adv.:* more flexible for design	**100**
Adv.: less encroachment on vegetative cover	**30**	*Adv.:*	
Adv.: more accessible to general public	75	*Adv.:*	
	135		**250**

4. Selected Alternative

- The option of locating the project at a new site had a far higher

5.

Facilitator……………………………….. *Date……………………..*

Director of works …………………….. *Date……………………………*

APPENDIX II

A3 Report for decision frame 2

Choice of a Conceptual Layout for a Future Administration Block for Sunyani Polytechnic

1. Background

- A need has arisen for the construction of a new administration building for the Sunyani Polytechnic.

- Among others, the building is expected to provide a serene work environment and become the beacon of academic excellence

-Decision participants included the design team, user representatives and the facilitator

Concept 1	***Concept 2***	***C***
Adv.: much less exposure to solar **100**	*Adv.:* less exposure to solar **50**	
Adv.: much more ventilation **45**	*Adv.:* more ventilation **35**	
Adv.: much more compact **70**	*Adv.:* more compact **55**	

3. Summary of Advantages with Corresponding Importa A

A

APPENDIX III

Adv.:	*Adv.:* more prominent

APPENDIX IV

A

35

250 295

Adv.: *Adv.:* more functionally related spaces *A* fu

60

Adv.: much easier for *Adv.:* easier for modular *A* modular const. const. m

35 **30**

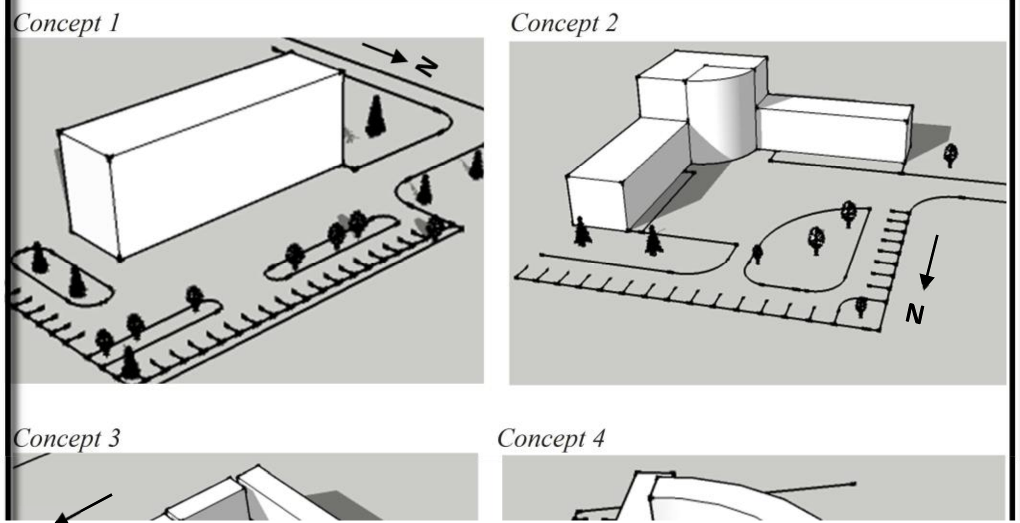
Adv.: *Adv.:* more potential for *A* team cohesion p

50

A

s

2. Alternative Concepts



A3 Report for decision frame 3

Choice of a Façade System for a Future Administration Block for Sunyani Polytechnic

c

4. Selected Alternative

APPENDIX V

1. Background

- One of the key components in meeting the requirements of the future administration block is the envelope.

- The façade system should, thus, play a critical role of screening the element s of the climate to create indoor comfort.

-Decision participants include the design team, user representatives and the facilitator

3. Summary of Advantages with Corresponding Importance

APPENDIX VI

Curtain walling	***Alucobond on blockwork***	***Pa blo***
*Adv.:*253.53 kg/m^2 less **80**	*Adv.:* 89.00 kg/m^2 less **25**	*Ad*
Adv.:	*Adv.:* much more acoustic insulation **35**	*Ad* ins
Adv.:	*Adv.:* more thermal mass **100**	*Ad* ma
Adv.: much faster to install **75**	*Adv.:* faster to install **30**	*Ad*
Adv.: much more regular finish **55**	*Adv.:* more regular fi ish **45**	*Ad*

APPENDIX VII

Adv.: much higher *Adv.:* higher reusability *Ad* reusability

Adv.: *Adv.:* *Ad*
ma

285 **290**

75 **20**

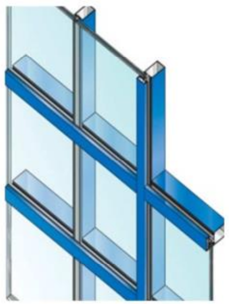
Adv.: *Adv.:* *A*

Adv.: *Adv.:* more impact *Ad* resistant imp

35

A3 Report for decision frame 4

2. Alternative Façade Systems



Curtain walling

Alucobond on blockwork

APPENDIX VIII

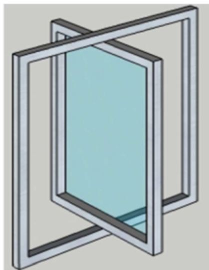
Choice of a Window System for a Future Administration Block for Sunyani Polytechnic (Decision Frame 4)

1. Background

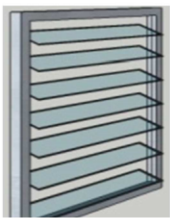
- Windows form an integral part of the façade of a building.
- Windows fundamentally close and open to allow for ventilation, acoustic insulation, heat insulation and daylighting.
- Decision participants include the design team, user representatives and the facilitator

2. Alternative Window Systems

Sliding



Pivoted



3. Summary of Advantages with Corresponding Importance

Sliding window	***Pivoted window***	***Awning window***
Adv.	*Adv.*: allows for higher flexibility **20**	*Adv.*: allows for higher flexibility **20**
Adv.: more familiar to users **15**	*Adv.:*	*Adv.:*
Adv.: easier to clean **30**	*Adv.:* much easier to clean **50**	*Adv.:*
Adv.:	Adv.: 45% more openable area **100**	Adv.: 40% more openable area **90**
Adv.: zero obstruction of adjoining space **70**	*Adv.:* less obstruction of adjoining space **40**	*Adv.:*
Adv.:	*Adv.:* more control of air flow direction **20**	*Adv.:* more control of air flow direction **20**
Adv.: more seamless **50**	*Adv.:* more seamless **50**	*Adv.:* more seamless **50**
Adv.:		*Adv.:* more protection form rain **20**
Adv.:		*Adv.:*
165	**280**	**200**

APPENDIX IX