IDENTIFICATION AND ELIMINATION OF FACTORS CAUSING DESIGN ERROR IN BUILDING DESIGN PROCESS

By

MUHAMMAD KAMRAN GHAZI

2017-NUST-MS-CE&M-09

A synopsis submitted in partial fulfillment of

the requirements for the degree of

Masters of Science

In

Construction Engineering and Management

Department of Construction Engineering and Management

National Institute of Transportation (NIT)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST),

Islamabad, Pakistan

(2021)

IDENTIFICATION AND ELIMINATION OF FACTORS CAUSING DESIGN ERROR IN BUILDING DESIGN PROCESS

Submitted by

MUHAMMAD KAMRAN GHAZI

(NUST2017MSCE&M0900000206327)

has been accepted towards the partial fulfilment
of the requirements for the degree of
Masters of Science in Construction Engineering and Management

____

Dr. Khurram Iqbal Ahmad Khan
Supervisor
Department of Construction Engineering and Management
National Institute of Transportation, SCEE, NUST, Islamabad

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS thesis written by Muhammad Kamran Ghazi (Registration No. NUST2017MSCE&M00000206379), of PG Wing – SCEE has been vetted by undersigned, found complete in all respects as per NUST Statutes / Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

Signature: ____________________________________

Name of Supervisor: Dr. Khurram Iqbal Ahmad Khan

Date: ____

Signature (HOD):______________________________

Date: ____

Signature (Dean/Principal):______________________

Date: _______________________________________

DEDICATED

TO

MY PARENTS, BROTHERS, SISTERS AND SUPERVISOR

ACKNOWLEDGMENTS

I, Muhammad Kamran Ghazi, am thankful to Allah Almighty for HIS blessing to conduct this research work. Further, I am highly obliged to my Supervisor for this program, Dr. Khurram Iqbal Ahmad Khan, for his selfless support, guidance, valuable time, and encouragement. At this moment, I can't forget effort made by my late father, who was mentor for me during my education life and stood with me at hour of need. I also owe acknowledgments to family members for their support which has helped me stay steadfast throughout my life.

I am highly grateful to Ms. Sidra muzaffar, who has been a massive help in the performance and authentication of this study. I am thankful to all the field experts who were important to completion of this research work. I pay gratitude to the respected GEC members for their sincere and constant. I am grateful to the esteemed faculty and administration of the Department of Construction Engineering and Management (CE&M) of National University of Sciences and Technology (NUST), Pakistan, for giving the much-needed technical inputs, assistance, and resources for the thesis work.

TABLE OF CONTENT

List of Tables

List of Figures

LIST OF ABBREVIATIONS

Building Design Process	BDP
Change Order	C/O
Design Error	DE
Design Management	DM
Design Process	DP
Gross Domestic Product	GDP
Gross National Product	GNP
Integrated Concurrent Engineering	ICE
Key Performance Indicators	KPIs
National Aeronautics and Space Administration	NASA
National Office for Economic Development	NEDO
Royal Institute of British Architects	RIBA
The Building Research Establishment	BRE
United Kingdom	UK
United States of America	US or USA

ABSTRACT

Building construction is one of the most complex sector, in construction industry. Among many other, this sector has a major challenge of DM for a long. Although BIM has helped to solve some of the problems, but there are some challenges that needed to be addressed for effective DM. Though DP has improved but number of unprofessional stakeholder and evolution in material science is making it a complex system. A research was conducted to identify and value, role of DE in building construction. Research has revealed that projects are suffering due to DE in term of budget creep, and it is valued 7.92%. A major factor for DE, is 'lack of coordination' and followed by 'unrealistic design schedule'. In advancement in building construction for developing countries there is need of a standard protocol for building design and approval process. A framework is therefore proposed to improve coordination process and figure out a DP which shall help industry stakeholder to properly understand DP and develop a realistic design schedule to minimize challenges to project design.

Chapter 1

INTRODUCTION

1.1 General

Construction industry is regarded as one of the strongest and most responsive sectors in the industry. It has a significant impact and stimulates a significant amount of economic growth through the interpectoral link between construction and other sectors, making the construction sector economically viable (Giang and Pheng, 2011). The difficulty factor of the project, the number of designers and other stakeholders involved in its concept development and execution, and the difficulty in tendering and service value, contribute to the potential for'atrogenic 'deformities. Further, some problems such as lack of reviews, verification, quality assurance procedure, reuse of design data, irrational schedules, unskilled and unprofessional staff, and absence of project management (Love et al., 2010b). Furthermore, the technical advancement associated with the modernization of design tools such as Building Information modeling and others are enriched with potential to develop error, as all solution value to possible interactions between these interventions. As a result, this offers an abundant base for potential errors.

Further, changes in construction are common in during course of project design development (Ibrahim Mohamad et al., 2012). It severely impact cost and schedule management (Adisa Olawale and Sun, 2010) leading to time delays and increased cost (Le-Hoai et al., 2008 and Hanif et al., 2016). Cost increases due to project design change varies between 10 - 15% of the project value and time increases from 10 - 15% of the project defined timeline (Yap et al., 2017b) exceeding the acceptable limit of 5 percent (Caffieri et al. , 2017). The change in design is also a foremost cause of non-existent value addition at the time of execution that effects project health. (Adam et al., 2017). In construction industry, successful mitigation of changes in project design, therefore, it is essential for management of project (Abdul-Rahman et al., 2017).

The design error is defined as an shortcoming in the design on which it is built or constructed but required retro repairs and / or installation of additional components in order to correct the error (Gashi, 2018).

As the high value of the fund is associated with construction projects so any error in construction leads to a loss of high value during cost and growth schedule. The exact cost associated with reworks for a project is significant and is reported to be more than 15% of the project cost (Barber et al., 2000). Josephson and Hammarlund (1999) identified this value for residential, commercial and other building related projects that varies from 2 percent – 6 percent of the project contracted value.

In design and execution there is very little attention being given to errors and discrepancies or possible failures by many designer as well construction firms. (Rounce, 1998, Robinson Fayek, 2019, Love et al., 2009, Love et al., 2010b).

Love and Li (2000b) in a research for the cost of repair and reworks in housing and industrial sector found the repair and rectification costs up to 3.15 percent and 2.40 percent of the project cost, respectively. Further, addition to this, Love and Li (2000a) revealed for the case of a contractor firm where they uses a quality control system in aggregation with an efficient development strategy, the cost of replacement is less than 1% of the project cost; there, a large portion ~ 76%! quality failures are caused by design-generated problems, i.e. incorrect documentation and lack of communication plan between project stakeholder.

Love and Li (2000b) indicated that the recurring costs for their case studies were 2.40 and 3.15% of the project cost of their project. Changes originated by the owner and the end user combined with omission and errors in the agreement were found to be the primary source for of rework. A study by Cnuddle (1991) indicated the cost of construction failure by evaluating the amount of non-compliance with site activity. Cnuddle (1991) found in research for the cost of non-compliance where it ranges 10% - 20% of the total project value. Further, it was determined that 46% of all change order cost were incurred during the design, compared to 22% of construction deviations. BRE in the UK (BRE, 1981) found that structural defects have fifty percent of their derivation in initial stage of design development and around forty percent in the construction phase. In 1987 the National Office for Economic Development performed a study (NEDO, 1987) that targeted to find ways to improve quality control in construction projects. It was discovered that key components affecting quality are due to design (e.g. another study conducted by NEDO in 1988, and these outcomes were very similar to earlier research.

Lawson (2006) describes design solutions and design problems as dependent on others. Construction challenges can neither be stated logically, also a credible solutions to construction problems is not defined so far, whereas design solutions are un-limited in number. Therefore, there is a need to regulate the DP, that is also a major challenge. The DP can be regarded as a continuous process of retaliation compared to the traditional manufacturing process of construction is considered a strict sequential process.

Previous studies have repeatedly pointed to structural changes as important causes of global project failure (Abdullah et al., 2010; Kaming et al., 1997; Le Hoai et al., 2008; Bagaya and Ngoma, 2016, Adisa Olawale and Sun, 2010,). Despite negative effects of repeated design changes on project accomplishment, documentation on the cause of design modifications during development is still inadequate (Yap et al., 2017a). Although major contributors to changes in the construction of buildings, especially clients, coordinators, contractors, project or outsiders (Ibrahim Mohamad et al., 2012; Iliyas J. Suleiman, 2016, Yana et al., 2015), negatively affect cost, time, fabrication and risk (Sun and Meng, 2009). Therefore it is important to earn a better insight of the causes.

Latham (1994) has played an important role for clients in promoting good construction in order to provide worth for money in respect of cost and value in use. A fundamental shortcoming in the industry is the fragmentation of the project and the project process that results in the efficient operation of buildings according to the conditions in use, operation and cost savings and sustainability. Designers should work in a close relation with other stakeholders in project process and design for lifetime costs. However, similar problems can still be seen today, more than 10 years after the publication of those two reports (Latham, 1994, Egan, 1998).

Abdul-Rahman et al. (2017) makes integration of documentation with well-defined design changes as ‘standard superfluities, oversights and alterations in both concept development and execution of work for a project that is started immediately contract award affecting agreement terms and work situations that make construction stronger and more stable’. Ibrahim Mohamad et al. (2012) Collective discussions, case studies and questionnaires uncover that engineering-based changes are common occurrences in the execution of reinforced concrete structures and often lead to overcrowding and conflict.

A collection of research work was performed across the globe to examine the inherent causes and nature of modifications in engineering projects. It is pertinent to mention that many researches i.e. (Assaf and Al-Hejji, 2006, Kikwasi, 2013, Oyewobi et al., 2016) have implemented the classification of factors from cost overruns and schedule delays within construction and design management. For reference, Sun and Meng (2009) appraised sixty-one project where it was found that change occurred and settled a taxonomy for these change which incorporate outward causes (social, economic, political, technical factors, environmental), organizational causes (system, resource and information technology related) and internal causes (owner, designer, project manager, consultant, contractor and subcontractor and others).

A current study by Yap et al. (2017a) in Malaysia collected the reasons of project design change in construction into owner, design oriented, site condition, contractor exposure and external-related causes. Similarly, Iliyas J. Suleiman (2016), a researcher in Tanzania, focuses on these internal and external causes. Internal comprise of the owner, designer, contractor, consultant and management of causes caused by the consultant while external comprises environmental, political and economic related factors and third parties. In a separate study, Yana et al. (2015) used PLS to obtain loading materials for client, supervision consultant, building managers, political and economic, environmental, contractor, third party and development of technological variables. Chang et al. (2011) categorized the reasons into three categories: under the control of the owner, under the control of the designer and out of control. All of the above research work presume that client and exhibitors have a major impact on design transformation in construction projects.

1.2 Problem Study

Design Error (DE) are inevitable in building construction projects where they commonly adversely affect project budget, schedule and safety of the project. Further, issuance of multiple types of design drawings from different discipline may cause various DE owing to several factors such as uncertain overview of the project designs, lack of coordination plan, and human errors. Different type of projects may have different level of DE. It is therefore required to identify these errors and analyze their impact and propose a framework to control these errors.

1.3 Research Objectives

- To identify factor causing design errors in building construction projects.
- To evaluate a cost overrun, subjected to design error.

- To develop a framework for improvement of building design process.

Chapter 2

LITERATURE REVIEW

2.1 Background

This chapter confers the previous work completed, related to the research intended to carried out. It also comprises the study entailing problems of construction industry pertaining to DM. Challenges to designer, their impact on project design and construction work, in term of project performance indicator i.e. project budget, quality of work, duration of project and safety aspects of the project. Construction is a broader term includes different nature of works including town planning, road network, bridges, dams and barrages, airport, seaports housing and Highrise building structure. Research work on all type of construction projects is being discussed further research on building DM is deeply explored to understand challenges to building design work.

Further, associating the concerned literature for research, this chapter also enhances the understanding about causes and origin of DE in construction business. The focus of this work is to examine the causes of DE in construction industry of developing countries and impact of these DE on project cost. Research objective are to develop a framework to improve BDP, therefore there in need to identify factors causing design challenges to construction industry and their role in BDP.

2.2 Role of Construction in economy.

The contribution of the construction sector to country's economy and its contribution to social and economic development has been addressed by various authors and international organizations, and many of them focus on developing countries. One factor is the creation of a dual economic sector that doubles in the national accounts of any country: as a major component of fixed income generation and as a sector that contributes to gross domestic product (GDP) (Hillebrandt, 2000).

Every so often, the question that appears is the influence made by the construction industry to economic growth, and how does it impact to growth? It is the inclusion in the production process or the effects of economic growth? It can contribute to the growth of output in two ways. Whenever construction work is in its final state, it can simply be taken out of output and assets (in the sense of accounting); otherwise, it may assist in an additional production process, which has led to improved outcomes. At lowest level, it increases revenue and expenditure by boosting engagement of resources. However, if not used in the production and is in its last stage, it is therefore considered a final result.

Leamer's analysis (2007) and given the latest information on the subprime crisis in the US, is appropriate in that the housing group is widely recognized as a business activity in the US economic context and plays an important role. It is a tangible and long-lasting property for domestic buyers, builders and financers. With the awarding of this honor, financial institutions have provided consumers with speculative loans against secured securities (real estate), which were able to pay interest rates with the principal. This has led to increased spending on home buyers by financial institutions, enabling buyers to improve their greater need for housing. Home builders are also accumulating more and more homes during this time. The amount of housing that has already accumulated was more than the rising number of houses, which decreased the market worth of the property and thus expanded the mortgage rate to the value of the property. Home buyers have not been able to repay a mortgage loan due to excessive repayment of real estate. The successful state of non-payment of loans has forced financial institutions to acquire property from homeowners. Banks have been unable to repay their loans because of the sharp decline in commodity prices and higher interest value. Leamer's (2007)

A study by Rameezdeen, 2008, found the share of the country's GDP and national income is considered low in Sri Lanka compared with developed countries. Where, the GNP's performance budget has declined while service delivery has risen with economic development. The reverse connection index is ranges 0.364 - 0.457 during the 1970-2000 while the repetition output from 1.496 and 1.641 indicates a ‘pull effect’.

The construction industry has performed an important role in China's economic expansion (Han, 2000). China's construction industry is huge. China's swift economic growth (growth rate of 11.6%, became the swiftest growing global economy in 1991-1996 (Zhao, 1999)) that generated the largest number of construction jobs (Chen, JJ, 1998, p. (711) Total financing in construction touched US dollar 188,000 million in year of 1997 (US dollar 182,000 million in year of 1996). US $ 68,000 million in 1998 (Zhao, 1999) The role of economic growth has been increasing: the value of GDP growth almost doubled in 1978-1994. Employment in 1997 was 35 million (compared to millions) (24, 1990) (Zhou, 1999) In many central provinces and western of China, without which low levels, or shortages, in other economic sectors such as productivity and basic services could lead to much lower growth.

2.3 Construction Industry Problems

It is been extensive dissatisfaction from government and owners over the construction industry due to its failure to revolutionize and complete projects following timline and budget (Waldron, 2006). One essential and well-known issue that continues to curse construction projects and causes for growth in budget creep and schedule growth is changes in design and errors (Love et al., 2009; Love and Edwards, 2004, Love et al., 2010b, Love et al., 2010a). A foremost contributing factor to cost increment and delay in time is rework (Love Peter, 2002). Rework in a construction project referred as remodeling work that is been done with the ultimate goal of satisfying the operational need of the project. It is a foremost problem in construction and engineering projects (Hwang et al., 2009; Love et al., 2010b, Palaneeswaran et al., 2008; Love et al., 2009) and greatly impacts project success because it creates challenges, such as overhead costs and time delays . Feature analysis identified 11 basic causes of these factors, related to DM, stakeholder management, field management, scope management, project process management, active remediation, change control, contract management, owner capacity, and external technology environment. (Ye et al., 2014)

In many public works, construction changes have caused to a major reason of construction delays and high costs. Modifications in the design also expose other adverse effects, such as poor morals, quality differences, and legal challenges. Depending on the literature and the practical experience, the causes of change orders vary widely, making the task of change management more difficult for many customers. Limited research of the effects of change has emphasized the need to deal with change orders. Due to a variety of factors, the overall design is unreasonable, so design changes are unavoidable. In cases wherever design change is required, act in response to environmental changes or project requirements requires the issuance of a change order (C / O). While the reasons of systematic change are not related to general knowledge in the field, the efficient management of the change order is less noticeable, especially in a large project.

2.4 Building Design Management

The Architecture, Construction and Engineering industry has the ability to increase productivity and enhance the number of projects (Knotten et al., 2015). There is a common fear that the full functioning of the Architecture, Construction and Engineering sector has not changed along with other and resulting there many quality errors, that are leading to reuse/rework (Love et al., 2003). The finger has been identified in architecture as a most important factor in low performing (Ballard and Koskela, 1998). In particular, the mistreatment of the initial stages of construction has established to be the source of the lack of documentation and rework (El. Reifi and Emmitt, 2013a, Tilley, 2005a). In addition, it has been proven that these problems have an impact on construction projects completely in terms of additional budget or reduced productivity (Baldwin et al., 1999a). Likewise the failure to understand customer needs and value affects of properties in a way that customers do not get what they need and what they really want (Thyssen et al., 2010).

The term value is disputed by several definitions (Salvatierra-Garrido et al., 2012), but here is considered in the perspective of client, owners and end user. Value can be considered as a development factor, either as a successful process or a final product (Eikeland, 1999). It is in the initial stages of the design where stakeholder impacts are greatest and the cost of change is very low, making this an excellent phase of value information. This stage is very difficult to appreciate, implement and manage.

Various projects fail to recognize their capability, and this is said due to management challenges in the design (Hamzeh et al., 2009; Hansen and Olsson, 2011). While defining the reason, one for this is the complication of the design phase, and particularly the first stage of design in which things are done is important in value building (Ballard, 2000). The factory production of bulk production can always be arranged in order, where task A has to be completed before the start of work B. This is not uncommon in project management, where you want several duplicates to produce value, as a result of which the first phase of the design is a complex management process (Knotten et al. , 2015).

In comparison to management of projects, only a few papers written on building design that describe explicit challenges in project management (Blyth and Worthington, 2010, Emmitt and Ruikar, 2013). There is a common fear that the full functioning of the AEC [Building Builder, Engineer and Construction Industry] industry is not emerged with other industries and that still there are too many quality errors, lead to reuse (Love et al., 2003, Love and Li, 2000b). The mistreatment of the early construction phase has proven to the cause of the lack of documentation and redesign (El. Reifi and Emmitt, 2013b, Tilley, 2005b). In addition, it has been proven that these problems have an impact on overall construction projects in terms of additional costs or reduced productivity (Baldwin et al., 1999b). Similarly, failure to develop an understanding of customer needs and its worth, the value of properties in a way that customers do not get what they really need and want (Thyssen et al., 2010).

2.4.1 The Building Design Process

In order to understand the complexities of project management one is required to understand the process of project design. The DP is usually distributed into a number of stages. For example the RIBA project plan that separated the construction process into 07 phases where phase 1 - 4 incorporates design (RIBA, 2013). Information flow, focus points, management and planning vary in these categories. A streamlined definition to say that project management is about managing people and knowledge (Emmitt and Ruikar, 2013). People in this situation are part in a construction project and information is floated among these stakeholders. The final part of the delivery i.e. drawings, models etc. are sound enough and is also easier to handle than for example the changing ideas or concepts arising from the creative ideas of artists. “DM is a complex social environment as value can be something that is built for the public and decision-making in that way can be expected naturally” (Kestle and London, 2002).

The short phases and the impact this can have on the project draws increasing focus which is why it provides ideas for the entire construction process (Blyth and Worthington, 2010, El. Reifi and Emmitt, 2013a, Gilbertson, 2006). But this is important and under investigation. Awareness time is also a complex phase of management. If at the time of management managers are not properly managed, it shall be likely to miss opportunities over time in the DP (Tilley, 2005a). Apart from this, (Ali and Au - Yong, 2013) say that virtuous designers can improve client briefs.

Information section usually ends with information letters, where the project is based. For some of the projects, the process is considered short and usually comprises only of the owner and the architect. At that point, a great work of important outcomes are made. (Gilbertson, 2006) states that the cost of design is considered twenty percent compared with the cost of construction, but the cost of operations and maintenance is five times the cost of construction and the cost fot business can be valued two hundred times more than the cost of construction. A study by (El Reifi et al., 2013) uncovered issues related to brief of the project for approximately 30% to the rework. Therefore, they also found that owner developed brief was one of the largest barrier to design value and accountable for more than 60%. This emphasizes the standing of the information section.

At initial stage of project design, i.e. preparation, project brief, conceptual development etc. These activities such as solutions, ideas and ideas communicated between participants. These activities need to be opened up and given the best solution to arrive (Hansen and Olsson, 2011). This actvity has a repetition form and each iteration in the hope that it will contribute to the end of the project (Kalsaas and Sacks, 2011).

Research by Lawson, (1997) describes design problems and solutions as dependent on others. Problems related to design cannot be specified logically and plausible solutions to these problems is not found there, however design solutions are regarded as un-limited in their number. Therefore, it is need to regulate the DP, but also a major challenge. The DP can be regarded as a continuous process of retaliation compared to the traditional manufacturing process of building construction that is considered a strict a process in sequence.

In a research by Bølviken et al.,(2010) introduced the research of Thompson (1967) to explain the various activities in designing and dependence on others. There is a combined dependence, a subsequent dependence and a reconciliation dependence. Procedures occur at various times and at the equivalent time in the designing phase. This requires an integration form, that is defined as integration by standardization, planning and collaborative correction. "Decision making while design stage is often negotiated between groups and groups, it is regarded as a repetitive process" (Kestle and London, 2002). That was shadowed by (Andersen, 2011) and (Kalsaas and Sacks, 2011) who use the same model in case studies to describe the process of designing a hospital project.

2.4.2 Managing the building design

The most common method for management of project is to obtain control over process in terms of quality, cost and time (Eynon, 2013). In a series of planned procedures, it is possible to see how the agreed drawing is delivered on time and how many hours spent. Quality is regarded as more challenging This method allows to protect the scope of a design individuals but may not certainly deliver the most optimal amount for an owner. This is consistent with many arguments for the value of project design design (Emmitt et al., 2005 and Thyssen et al., 2008, and Emmitt and Ruikar, 2013). Waste and value are essential for project as well designing of the project. Similarly, decision and processes are important in view of their impact on value creation (Koskela et al., 2013) that is important.

If the process of building a structure consists of integrated, sequential, repetitive and dynamic processes, process management is complex. A standard project management approach can help you accomplish integrated and dynamic procedures, however not an effective tool for managing a coherent or dynamic method. (Mintzberg, 1993) describes processes that can be reduced and depend largely as compliments. Adhocracy consists of a natural structure with low morale, high-performance performance established on recognized training and expertise in working groups, which means a multi-sectoral construction team. Management includes chaos and the unexpected. Project planning by appointment of various consultants makes it appropriate to compare issues with designing firms with visible teams (Bell and Kozlowski, 2002). Project culture, clear commitments, real-time details and transparency are becoming more when there is certain rise in level of complexity in projects. (Morgan, 2011) further recommends that we reconsider how we plan when we are on the brink of anarchy. "Supervisors need to flow along with the change rather than try to reorganize and control in a conventional way."

From the management's point of view, planning and implementation are discussed. Numerous have agreed design phase shall not be directly compared with to the execution phases and therefore, one cannot use the same managing instruments (El Reifi et al., 2013; Bølviken et al., 2010; Hansen and Olsson, 2011). Lean Construction's methodology for development of the Last Planner as a strategic goal in architecture management has also been discussed. (Hamzeh et al., 2009) and (Rosas, 2013) oppose the application of the latter system. (Hamzeh et al., 2009) reported on the implementation of the Final Plan at Crohedral Hill Hospital (CHH) where disputed the circumstance that collective planning and reorganization were key elements of the CHH planning process at a time when design was ubiquitous, complex and dependent, and challenges they need to be removed during operation ". Therefore, the plan of designing a complex building structure is an ongoing process and can somehow be used to plan and carry out design task. (Hansen and Olsson, 2011) claim for a concentrated process, in which the Degree of Detail in planning should adapt to the various information for demand of projects. (Bølviken et al., 2010) criticized the deficiencies of the Final Planning Process used in designing. How to use LPS in construction is categorized Collaborative DM (CDM). The CDM express at planning, teamwork, networking and issues. A study by (Fundli and Drevland, 2014) states that "CDM allows constructive changes in the designing process when compared to other conventional methods". There have been some efforts to make the planning processes modification. Rosas (Rosas) is trying to combine the Design Structure matrix with the Last Planner in building structures. Senescu et al. (2014) introduced the Communication Method of the DP. Cheng et al. (Cheng et al.) Controversy over modeling resource management in building the construction process.

Collaboration between project stakeholders is crucial. The main objective of the design phase is the interchange of information and the conversion of these information to ideas then solutions to be submitted to others. This process is difficult to organize and track, and difficult to see the potential dependence on each exchange. (Ali and Au - Yong, 2013) state that “assembling needs to be done by a designer”. Therefore, the method we use to transmit is important. (Den Otter and Emmitt, 2008) illustrate two modes of communication, namely synchronous and asynchronous. Asynchronous communication is defined as the flow of information multiple device directly used to hear, see and speak (e.g., meetings, telephone, etc.). Asynchronous mothos is a distant, indirect flow of information (e.g. emails, drawings, models). Increase in complexity level of the process, there is higher need of consistent communication. (Flager et al., 2009) have spent that most of the time is on data handling in the project design. With more efficient data handling, some of time can be saved and used for value-creation.

Synchronous communication is a well-defined design instrument. This is supported by simultaneous Engineering (Rounce) and Integrated Concurrent Engineering (ICE) methods. Excessive co-operation by NASA (Mark, 2001) has designed opportunities for faster and complex design in the project desing industry (Chachere et al., 2004). Whenever try to manage a retaliatory or incentive process, ICE is a effective tool. It requires assurance among key participants to make the necessary determinations to keep the designing flexible and efficient.

For last few years, the use of the Building Information Model (BIM) in the engineering works is grownup and it is considered as a powerful tool for asynchronous communication, also as a device that can be used equally in in synchronous communications such as ICE. (Moum, 2008) expressed the usage of a collaborative design and further demonstration of participants on how BIM can alleviate the difficulty of understanding complex challenges and their solutions. The reimbursements of communication are good and opportunities to enhance quality through early detection can save a lot of money on projects (Clemente and Cachadinha, 2013; Khanzode et al., 2007).

To effectively manage the DP, it is essential to define the process metrics. (Drucker, 2008) debates about the importance of balancing work in organizations and further elaborates that you are in need of “controls” (various scales) to develop control over the process. Research identifies 14 performance indicators (KPIs) required to control construction processes (Kristensen, 2013).

All of these KPIs are categorized into three of categories operational metrics, strategies, and tactical. In addition to the cost over time and their quality these metrics include e.g. information request, participation and evaluation. The demand for metrics to get better DP is also discussed (Leong and Tilley, and 2008Carvalho et al., 2008). While it is significant to evaluate the project's impact on duration and budget, it is also vital to set metrics that manage the quality of the engineering work and exchange of information. Metrics are used to track efficiency and quality, e.g. in ICE times, it is valuable to expand the project design sequence. (Knotten et al., 2014). The necessary decisions to keep the DP flexible and efficient with ad-hocracy.

Keeping the concept of value in mind, some of the ways of organizing and defining the early phase of the design development can be well-thought-out. Comparisons of design and product design provide alternative approaches to structural design improvement, e.g. Innovation Diamond (Best, 2006).

Construction projects are often not fully considered but are categorized by specialized materials that require special skills (planning, architecture, equipment, equipment, and finishing) with minimal supervised or non-existent integration in the construction process. Indeed, it often happens that individual features are simply overused by a scheme or, as in the case of programming machines, or are considered a posteriori, sometimes designed only to correct design flaws (e.g. structural design, fragmentation, and thermal inertia). (Sassu, 2014 # 54)

2.5 Design Error in Building Design

2.5.1 Definition of Design Error

The design error is termed as an error in the construction on which it is built or constructed but required improvement and / or installation of a components to correct the error (Gashi, 2018).

However, some researcher defined error as:

1. Busby (2001, p. 237) "Unexpected and unforeseen events could not have happened by accident or circumstance only"
2. Kaminetzky (1991) “Deviation from the right direction, no accuracy, discrepanices in dimensions owing to a lack of mechanical and human limition”
3. Reason and Hobbs (2003) defines “Whenever planned action failed to achieve their intended purpose, and it happens in absense of any unexpected or accidental intervention”
4. Hagan and Mays (1981) defines “Whever a task in missed to perform on pre defined time, sequence or order”

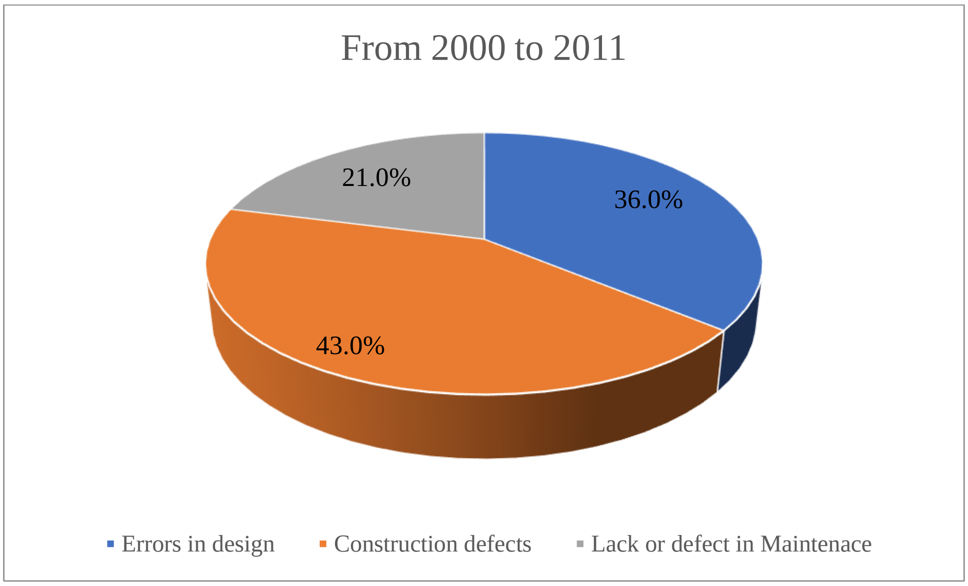
2.5.2 Design Error Role in Construction

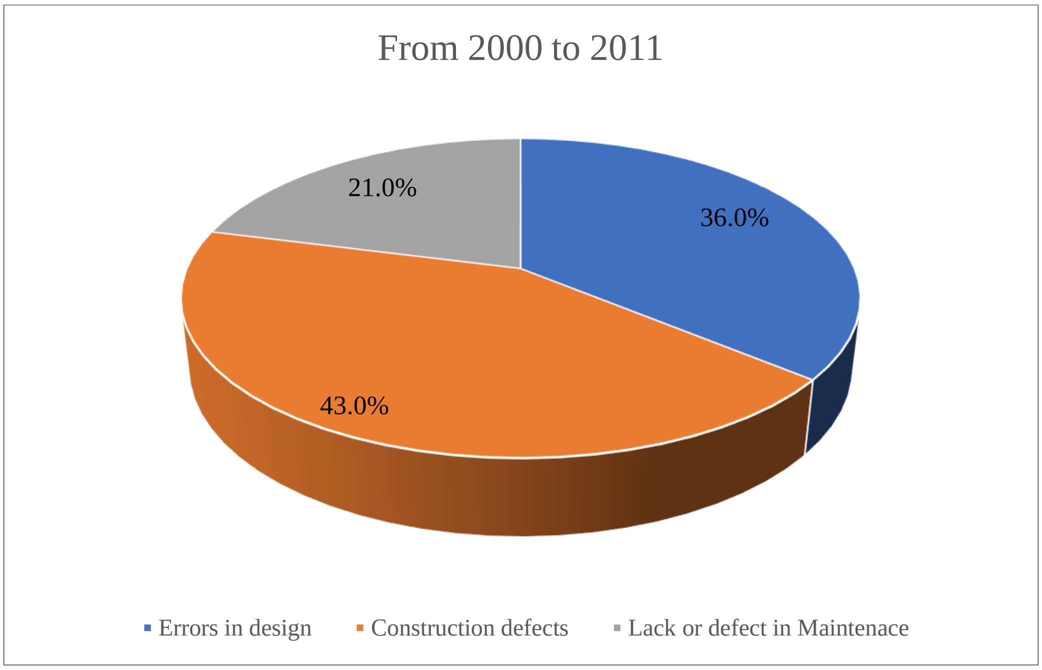
A study by Lopez and Love Peter (2012) found the cost of DE from 139 projects and found that the costs of direct and indirect DE were figured out to 6.9 percent and 7.4 percent of the project project cost, respectively.

Similarly, Burroughs (1993) identified for a major Australian contractor who incurred the repetitive costs of 5 percent of the project cost due to DE. At this very moment, a wise way to find the weight of the factors that cause the error in the construction process.

In addition, in a study conducted by (Sassu, 2014 # 54) they identified design error as one of the causes of financial losses in a construction project. Mistakes made during structural pregnancy (Gucci, 1997 # 55) were responsible for damage in approximately 36% of cases and affected both structural and structural aspects. In a study conducted on itlay (Sassu, 2014 # 54), he also pointed out that in combination with DE, errors made, occurring in approximately 43% of cases, were the source of many construction errors encountered. Indeed, DE and construction errors often occur in combination. Compared to evolution during the Twelve Years, it would have meant that the types of disabilities and their occurrence percentages have remained remarkably similar over the past 20 years, especially in terms of the most common categories of problems: water damage, fractures, and congestion. Their discovery leads to the conclusion that although much progress has been made in construction technology and scientific knowledge over the past two decades, their use has not been well distributed. Most engineers, architects, and builders choose to continue with their construction practices over time and change their construction method when new regulations are issued (such as earthquake codes).

One intresting finding in research by (Sassu, 2014 #54) explored increase in DE in building construction from 1990-1991 to 2001-2010. But research was conducted in a certain area of Italy therefore can't be refered as representaton of a large scale area.





DE are resulting major impact on projects, in some cases researches found complete change in project desing due to errors. This litrature review identifies some major DE impact on construction project, that is tabulated below;

Impact of DE	**Reference**
Illogical Design	Lee, G., Park, H.K. Won, J., 2012
Discrepancies	Yana, A.G.A., Rusdhi, H.A. and Wibowo, M.A., 2015 Rounce, G., 1998 Assaf, S.A. and Al-Hejji, S., 2006
Missing Items	Yana, A.G.A., Rusdhi, H.A. and Wibowo, M.A., 2015 Rounce, G., 1998 Wu, C.H., Hsieh, T.Y., Cheng, W.L. and Lu, S.T., 2004 Andersen, B., Olsson, N.O., Onsøyen, L.E. and Spjelkavik, I., 2011 Cox, I.D., Morris, J.P., Rogerson, J.H. and Jared, G.E., 1999 Wu, C.H., Hsieh, T.Y. and Cheng, W.L., 2005 Rosenfeld, Y., 2014 Akinsola, A.O., Potts, K.F., Ndekugri, I. and Harris, F.C., 1997 Lee, G., Park, H.K. and Won, J., 2012
Rework-Related - May Lead To Demolition	Han, S., Love, P. and Peña-Mora, F., 2013 Park, M. and Peña-Mora, F., 2003 Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
Delay-Related - Likely To Prolong	Han, S., Love, P. and Peña-Mora, F., 2013 Park, M. and Peña-Mora, F., 2003
Leading Design Changes	Han, S., Love, P. and Peña-Mora, F., 2013 Han, S., Lee, S. and Pena-Mora, F., 2012 Love, P.E., Lopez, R. and Kim, J.T., 2014 Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
DE Leading Schedule Delays	Han, S., Love, P. and Peña-Mora, F., 2013 Han, S., Lee, S. and Pena-Mora, F., 2012 Love, P.E., Lopez, R. and Kim, J.T., 2014 Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
DE Leading Cost Overruns	Love, P.E., Lopez, R. and Kim, J.T., 2014
DE Leading Safety Concerns	Han, S., Love, P. and Peña-Mora, F., 2013 Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
Design Error Leading Scope Changes	Han, S., Love, P. and Peña-Mora, F., 2013 Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011

Unclear And Inadequate Details In Drawings	Assaf, S.A. and Al-Hejji, S., 2006 Akinsola, A.O., Potts, K.F., Ndekugri, I. and Harris, F.C., 1997
Expensive Design	Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012 Rosenfeld, Y., 2014
Non Compliance With Quality Standards	Love, P.E., 2002
Non Compliance With Authority Standards	Wu, C.H., Hsieh, T.Y. and Cheng, W.L., 2005

2.5.3 Causes of Design Error

(Sassu, 2014) in his research explored design flaws created by, in some cases, inadequate procedures in determining the details of composition and lack of quality control in technical drawings can lead to collapse. DE are common in construction projects. Unfortunately, regardless of a person's ability, project exposure, or level of skills, mistakes may encounter at any time because of a person's physical and mental limitations. In addition, contractor and designers do not record the number of errors generated at their end and, in particular, they do not make well versed design updates, validations and quality check.

Significantly, the engineering firms and organization in Western Australia is now a days facing a skills shortage that is leading to more workers working for a long duration (Love et al., 2010b). Real estate firms must organize and see that they have the necessary resources to carry out the projects they are committed to. Having dedicated staff assigned to specific projects will reduce workloads, which will reduce the chances of job losses and give employees the ability to better deal with disruptions. Planning and resources are also linked to a lot of work. Increased workload, or a decrease in available time to perform required tasks, may result in employees taking shortcuts and re-using non-work-related information and specifications. Having time to think and think about the problem at hand will ensure that an appropriate construction solution is found. Finally, a reduction in the number and size of errors will be reduced during audits, reviews and verifications.

The design coordinator has eight features that include the unavailability of an engineering license; unreasonable design time; lack of the designer to present required information and clear understanding in the procurement documents; omissions and errors of moderators; modification made at the request of the consultant; contractors unfamiliar with laws and building permits; low cost of consultation and poor linking of construction team members and owner. In addition, some of the factors that change the structure of a project are the owner's instructions for modifying project design; the client's failure to communicate his/her decisions or to share feedback on documents in a timely manner; change of financing system from client; and the project bried shared by the client is whether incomplete or incorrect (to understand the size of the project). There are certain external factors that may influence the will of the project are political and economic issues, environment, technological development and third parties.

In a work conducted by Sadi A. Assaf (2005) for a specific project challenge due to a team that makes mistakes and errors in construction documents, delays in the production of building documents, ambiguities and insufficient details in drawings, complex project design, data collection and adequate pre-design, Non-use of state-of-the-art engineering software. Linking to one other cause of design problem is not enough data completion during the initial evaluation of a project proposal. In addition, other external factors attributing to the formation of a project are changes in law, politics or policy base, adverse weather conditions, non-ground conditions. Lack of communication plan and working without well defined project desing data have been presented as other causes in the literature (McDermott and Dodd, 1984; Lutz, Hancher and East, 1990)

SR. NO	FACTOR CAUSING DE	REFERENCE
1	Design Reviews, Checks And Verifications	Han, S., Love, P. and Peña-Mora, F., 2013
		Love, P.E., Lopez, R., Edwards, D.J. and Goh, Y.M., 2012
2	Re-Use Of Specification And Details	Han, S., Love, P. and Peña-Mora, F., 2013
		Love, P.E., Lopez, R., Edwards, D.J. and Goh, Y.M., 2012
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
3	Understaffing	Han, S., Love, P. and Peña-Mora, F., 2013
		Love, P.E., Lopez, R., Edwards, D.J. and Goh, Y.M., 2012
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
4	Unrealistic Design Schedules	Han, S., Love, P. and Peña-Mora, F., 2013
		Love, P.E., Lopez, R., Edwards, D.J. and Goh, Y.M., 2012
		Yana, A.G.A., Rusdhi, H.A. and Wibowo, M.A., 2015

		Akinsola, A.O., Potts, K.F., Ndekugri, I. and Harris, F.C., 1997
		Lopez, R. and Love, P.E., 2012
		Love, P.E., Lopez, R. and Kim, J.T., 2014
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
5	Low Design Cost	Yana, A.G.A., Rusdhi, H.A. and Wibowo, M.A., 2015
		Lopez, R. and Love, P.E., 2012
		Love, P.E., Lopez, R. and Kim, J.T., 2014
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
6	Poor Coordination/Integration Of Stakeholder	Yana, A.G.A., Rusdhi, H.A. and Wibowo, M.A., 2015
7	Client Late Decision	Yana, A.G.A., Rusdhi, H.A. and Wibowo, M.A., 2015
8	Complexity Of Project	Assaf, S.A. and Al-Hejji, S., 2006
		Love, P.E., Lopez, R. and Kim, J.T., 2014
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
9	Insufficient Data Collection And Survey Before Design	Assaf, S.A. and Al-Hejji, S., 2006
		Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
		Nekooie, Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
		Al-Harthy, A.B.S. and Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
		Wu, C.H., Hsieh, T.Y., Cheng, W.L. and Lu, S.T., 2004
		Wu, C.H., Hsieh, T.Y. and Cheng, W.L., 2005
		Rosenfeld, Y., 2014
10	Misunderstanding Of Owner'S Requirements	Assaf, S.A. and Al-Hejji, S., 2006Rounce, G., 1998Rosenfeld, Y., 2014
11	Inadequate Design-Team Experience	Assaf, S.A. and Al-Hejji, S., 2006
12	Un-Use Of Advanced Design Software	Assaf, S.A. and Al-Hejji, S., 2006
		Wu, C.H., Hsieh, T.Y. and Cheng, W.L., 2005
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
13	Lack Of Coordination Among Various Professional	Wu, C.H., Hsieh, T.Y. and Cheng, W.L., 2005Love, P.E., 2002
14	Modification To Design (Improvement)	Rounce, G., 1998
		Cox, I.D., Morris, J.P., Rogerson, J.H. and Jared, G.E., 1999
		Love, P.E., 2002
15	Constructability Ignored In DP	Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
		Love, P.E., 2002
		Rosenfeld, Y., 2014
16	New Design Standards	Love, P.E., 2002
17	Client - Lake Of Construction Experience	Akinsola, A.O., Potts, K.F., Ndekugri, I. and Harris, F.C., 1997

18	Unclear Initial Design Brief	Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
		Nekooie, Mohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
		Al-Harthy, A.B.S. and AMohamad, M.I., Nekooie, M.A., Al-Harthy, A.B.S. and Amur, B., 2012
19	Loss Of Biorhythm	Lopez, R., Love, P.E., Edwards, D.J. and Davis, P.R., 2010.
20	Adverse Behavior	Lopez, R., Love, P.E., Edwards, D.J. and Davis, P.R., 2010.
21	Inadequate Quality Assurance	Lopez, R., Love, P.E., Edwards, D.J. and Davis, P.R., 2010
		Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011
22	Physiological And Psychological Limitations Of Humans	Love, P.E., Edwards, D.J., Han, S. and Goh, Y.M., 2011

Chapter 3

RESEARCH METHODOLOGY

This research intends to follow a certain sequence of steps, techniques and procedure required to accomplish the above mentioned objectives in Chapter 1. Literature review, Content analysis, preliminary field survey, analysis of primilinary data and corelation with litrature review, detailed field survey, data analysis, and then development of framework for improvement of BDP.

A four stage research methodology as shown in Fig 3.1 below has been developed. The details will be discussed in the subsequent section:

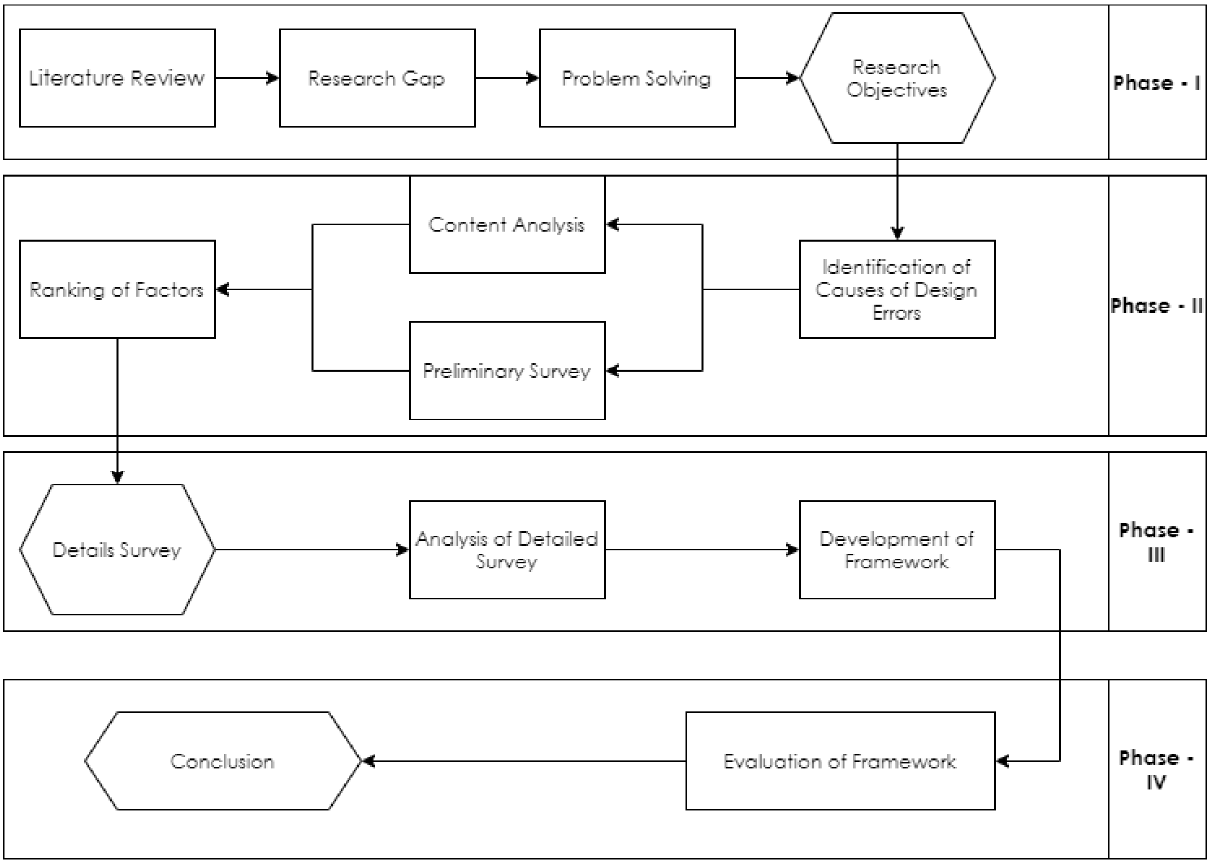


Figure 3. 1 Research Methodology

3.1 Research Gap Analysis:

Search for the research gap started by scrolling through the research articles that appeared in recent publication year. Going through the background of DM, it was realized that despite the extensive work in DM, area of design error is still under research and area of challange for building designers. A number of design professional from different decipline working for a project, therefore DP is a little challanging and previous research highlighted coordination challanges in DP. Further, some researcher highlighted unrealistic design schedule in design managenet effecting project design. Therefore, it is required to develpe a standard protocol for DM so that challanges to industary may be addressed.

3.2 Literature Review

Construction industary is prone with errors and leading to cost and schedule growth. There are mutiple factors for these errors, unexperienced client, poor DM, unprofessional contractor, role of external stakeholder. All these factors may effect health of the project. One of the main cause experiened during construcion work was found to be design challanges, therefore, an extensive literature review was conducted to identify factors causing DE in building construction. Content analysis was piloted to observe the researchers' data in an organized and structured form (Antwi-afari et al., 2018) which used contextual importance (qualitative scores) and frequency of appearance (quantitative scores) as a basis for computations of results. Normalized scores for literature were then determined to rank the identified factors.

3.3 Preliminary Field Survey

An appropriate literature review technique was adopted along with the participation of experts from the field (Ullah, 2016; Ahmad, 2018). A mandatory approach was implied that promoted the participation of field experts in the form of online questionnaire survey form aimed to evaluate role of factors causing DE in construction. The questionnaire survey form was generated through GoogleTM docs and was sent to the targeted respondents nationaly and internationaly to determine the importance of each factor in field. Multiple fourms were used to share survey with participants i.e. Linkein, WhatsApp, Facebook, Email and others.

3.4 Data Analysis:

After getting a reasonable number of responses from the field survey, results were compiled and tested for further analysis. Statistical Package for Social Sciences was used for testing the reliability of responses and the extent of agreement of respondents(Bonett and

Wright, 2015). Cronbach's alpha reliability analysis and Concordance analysis tests were done respectively.

The statistical verified data was then put forward for factor analysis that helped to deduce the most important factors. Ranking and shortlisting of factors was done by taking collective scores of respondents and literature giving the weightage of 60 and 40 respectively with the combined significance of 50 percent (Nazia et al., 2019).

3.5 Detailed Field Survey:

To determine the cost impact of associated with DE, a detailed survey on Google forms was conducted to validate priliminary results and further evaluated cost impact on projects. Survey was shared with industary professioanl in developing countries for feeback on their the basis of their experience on projects.

3.6 Framework Development:

The last objective of research is to deveope a framework for DP improvement on the basis of results obtained from research. This framework was developed keeping in view leading factor causing design error.

Chapter 4

RESULT AND DISCUSSION

4.1 Content Analysis:

First most step was the identification of factors via extensive relevant literature review. For the required purpose, Emerald Insight, Science Direct, Wiley, Google Scholar and various online libraries forums were frequently used. Total of 50 papers were studied from which 38 factors were extracted. Owing to the similar meanings and context, many factors were synonymously used in place of others or were merged respectively. The number of overall factors was decreased to 24. Semi qualitative analysis was then done to analyze the literature associated importance of each factors. Frequency of appearance of factor in the research article as quantitative score was simply noted as “one” in the spreadsheet for each associated research article and contextual importance used as qualitative score were assessed using a 3-point Likert(5 as High, 3 as medium, 1 as Low). Qualitative and quantitative scores were then multiplied to elicit the literature score. This score was further normalized to scale the data for factor analysis in the next step. Literature studies tell about the research trends carried out in the past. It is considered to be a secondary data. This is the reason why it is deemed necessary to collect primary data that is done through preliminary field survey in the study.

4.2 Preliminary Questionnaire Survey:

This research has two staged data collections: Preliminary field survey that is considered to be the part of pilot study and the detailed questionnaire survey that helped in developing framework for design improvement. Thus to get primary data, it was deemed necessary to carry out an international survey. For this purpose, GoogleTM Docs was used that was divided into two sections.(Shen, Zhang and Long, 2017)

- First section comprises of demographic and professional information about the respondents: qualification, field of experience, job description, professional experience, country of origin and details about prioritization of design error chance.
- Second section consists of multiple choice grid, that inquired respondents according to their knowledge, approximately how much the causes of design have contributed towards the construction waste. It was recorded on the 5 points ordinal Likert scale data.

Online professional forums like Linkedin and ResearchGate were used to disseminate the survey form to targeted respondents. The main focal area was the developing countries. This is the limitation of this research. It took three to four months to collect the data. A total of 30 samples were collected from 8 different developing countries as shown below in table. Almost half of the survey was filled by the experts having experience in between of 6 to 15 year. Following the rules that are accepeted globaly, compraising a sample size of thirty or above, defined central limit theorem holds true(Albert Ping Chuen Chan, 2015). Most of the responses were from the professional experience of 06 to 15 years that further proves the validation of the research.

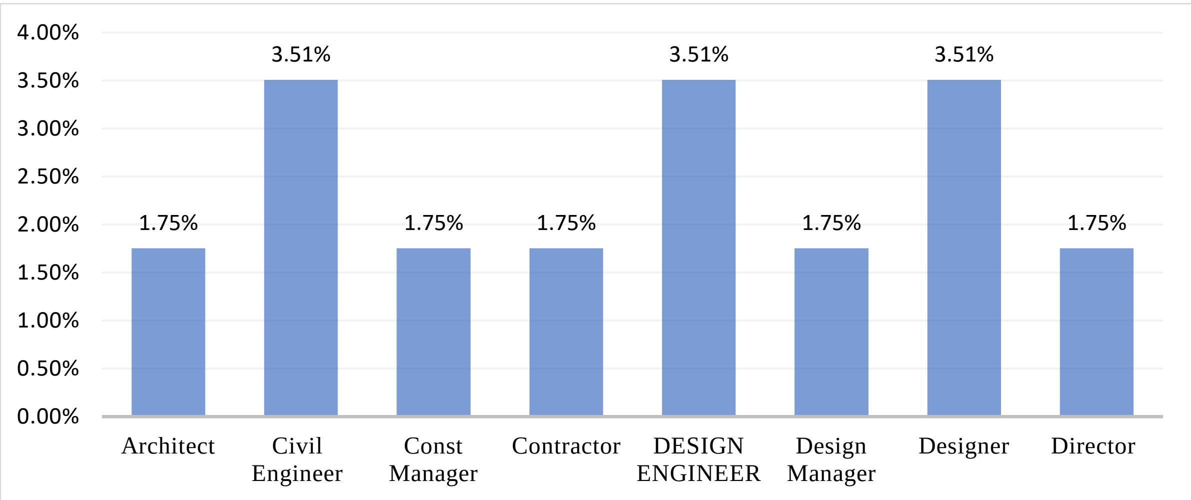
Table 4. 1 - Respondents' Experience

Professional experience			
S. No.	**Experience**	**Number**	**Percentage**
1	0 to 1	0	0%
2	2 to 5	12	40%
3	6 to 10	12	40%
4	11 to 15	5	16.6%
5	16 and above	1	3.3%
Total		30	100.00%

Table 4.2 - Respondents' Organizations

2) Organization type			
Sr.	**Organization type**	**Number**	**Percentage**
1	Client	2	6.66%
2	Contractor	20	66.66%
3	Consultant	06	20%
4	Specialty Contractor	1	3.33%
5	IT Industry	1	3.33%

Figure 4. 1 - Respondents' Professional Background



4.3 Data Analysis:

Measurement level of responses recorded in a 5 point Likert scale is ordinal. Parametric statistics would not yield meaningful result unless and until they are normalized (Bishop and Herron, 2015). Tending to the nature of this data type, some of the non-parametric tests were implied(Golparvar-fard et al., 2006) using the Statistical Package for Social Sciences(SPSS) in the beginning to see the consistency among the data recorded and agreement between the respondents regarding variables.

4.3.1 ANOVA Result:

The results of the weighting criteria were then tested using ANOVA. The data tested through ANOVA is now a scale data hence it is appropriate for parametric tests (Mircioiu and Atkinson, 2017). The P-value/Sigma value was 1 that signifies the null hypothesis exists and the difference between the means of the data is not significant.

Table 4. 3 - ANOVA Results

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
80/20	22	1	0.045454545	0.00012
70/30	22	1	0.045454545	0.000166
60/40	22	1	0.045454545	0.000234
50/50	22	1	0.045454545	0.000323
40/60	22	1	0.045454545	0.000435
30/70	22	1	0.045454545	0.000569
20/80	22	1	0.045454545	0.000724

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.93889E-18	6	1.15648E-18	3.15E-15	1	2.160777574
Within Groups	0.053980536	147	0.000367215			
Total	0.053980536	153				

4.3.2 Shortlisted Factors:

Decision of 60/40 ratio finally posited 9 most important factors ranked in order with the cumulative impact of 50 percent to encompass maximum influence(Nazia et al., 2019). 60/40 weight criterion was selected as to allow a balanced amalgamation between field respondents and literature score. Pertaining due importance to the recent data, primary data was specified more weight than the secondary(Nazia et al., 2019).

Table 4. 4 - Shortlisted Factors

Sr. No	Code	Factor	Weightage (60/40)	Cumulative Weight
1	F22	Unrealistic design schedules	0.088	0.088
2	F9	Insufficient data collection and survey before design	0.080	0.169
3	F14	Misunderstanding of owner's requirements	0.056	0.225
4	F10	Lack of coordination among various professionals	0.056	0.280
5	F13	Low design cost	0.048	0.329
6	F5	Complexity of project	0.048	0.377
7	F6	Constructability ignored in DP	0.048	0.425
8	F15	Modification to design (Improvement)	0.048	0.473
9	F19	Re-use of specification and details	0.048	0.521

4.4 Detailed Field Survey:

An international detailed questionnaire survey was carried out in order to determine cost associated with DE, role of factors towards budget creep.. The survey comprised of three parts: In first section, respondents were asked about cost creep owing to DE. However, in second part respondents were asked to rank these factors as cause of DE. In the end, respondents were provided space to rate these factor for their impact on project cost. This survey was supposed to develop an undestanding for development of framework to eliminated desgin errors in BDP.

4.4.1 Data Collection

In order to collect data, survey foram was distributed among professionals from various developing countries. Professional Online forums like LinkedIn and Research gate and social networks like Facebook were made into use for this purpose. The survey conducted was held in bidirectional flow to cover every perspective in order to achieve the most meaningful relationships. The data collected, covered 08 developing countries. Most of the respondents were with the experience of more than 5 years. The respondents' data is represented below:

Table 4. 5 - Respondent's Experience

1) Professional experience			
S. No.	**Experience**	**Number**	**Percentage**
1	0 to 5	21	35%
2	6 to 10	20	23%
3	11 to 15	15	25%
4	16 and above	4	7%

Figure 4. 2 - Organization Type

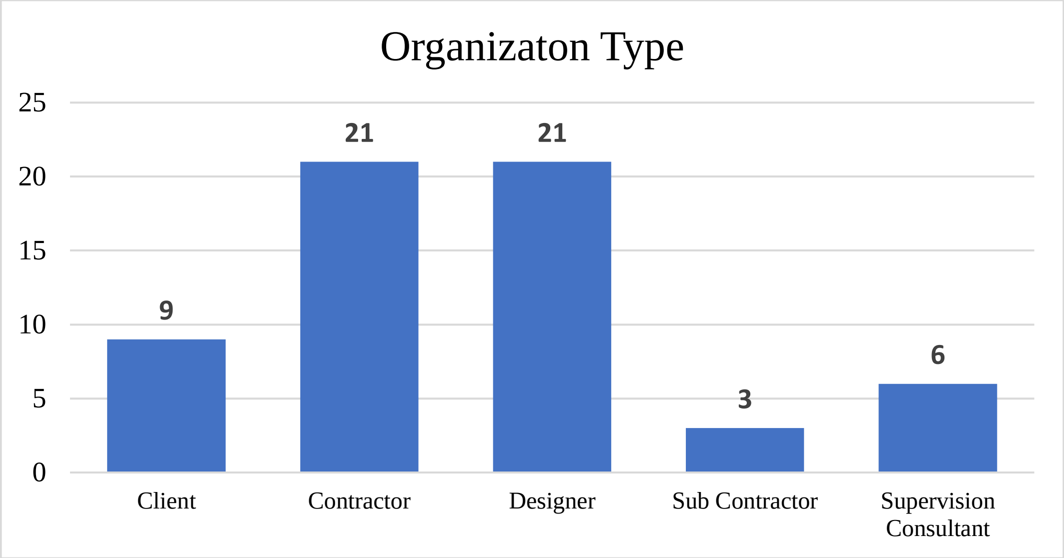
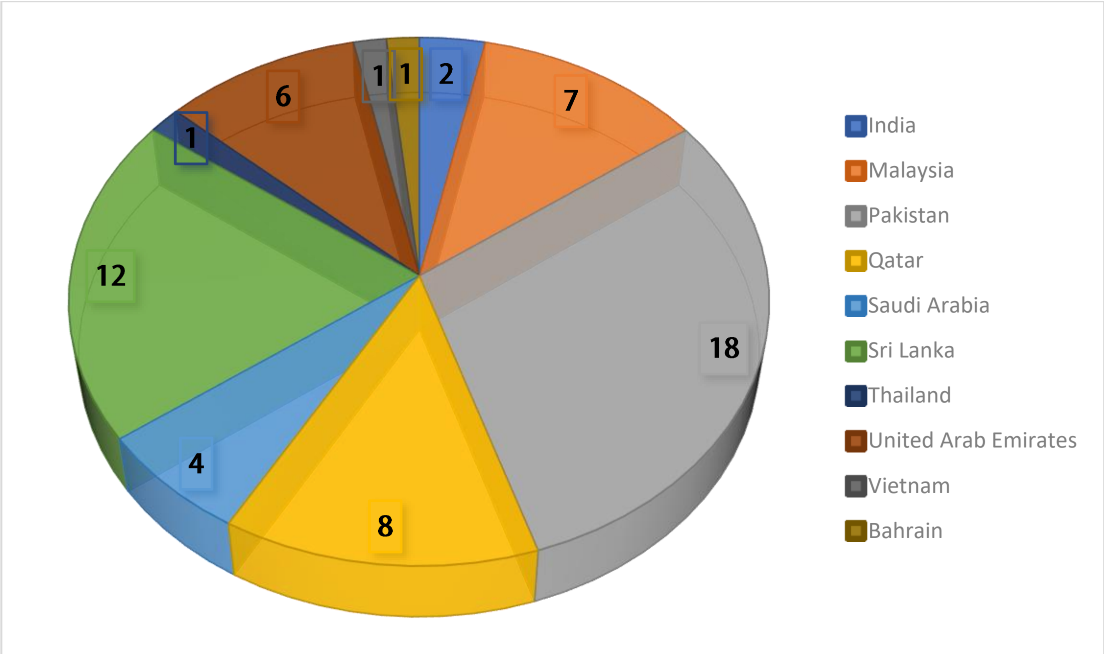


Figure 4. 3 - Origin of Responses



4.4.2 Detailed Data Analysis

After the collection of 60 responses from 09 different developing countries, the data was compiled and statistically analysis was performed.

Result of cost creep is more than expectation, mean value of data is 7.92% however, standard deviation of data of data is 5.98.

In second part of survey responded were asked to rank further highlighted factors in primilimary survey as causation of DE. Results indicated building DM has major factor arrising errors is lack of coordination. Summary of analysis is as follow;

Table 4. 6 - Factors Ranking - Causation

Factor	Sum	Field Score	Normalized Field score
Lack of coordination among various professionals	230	0.767	0.125
Insufficient data collection and survey before design	227	0.757	0.123
Unrealistic design schedules	216	0.720	0.117
Constructability ignored in DP	216	0.720	0.117
Misunderstanding of owner's requirements	200	0.667	0.109
Modification to design (Improvement)	200	0.667	0.109
Re-use of specification and details	193	0.643	0.105
Low design cost	184	0.613	0.100
Complexity of project	175	0.583	0.095

Last part of survey defines weightage of factor in budget creep. Results has revaled unrealistic design schedule as major factor responsible in project budget creep. A complete ranking of factors is as follow;

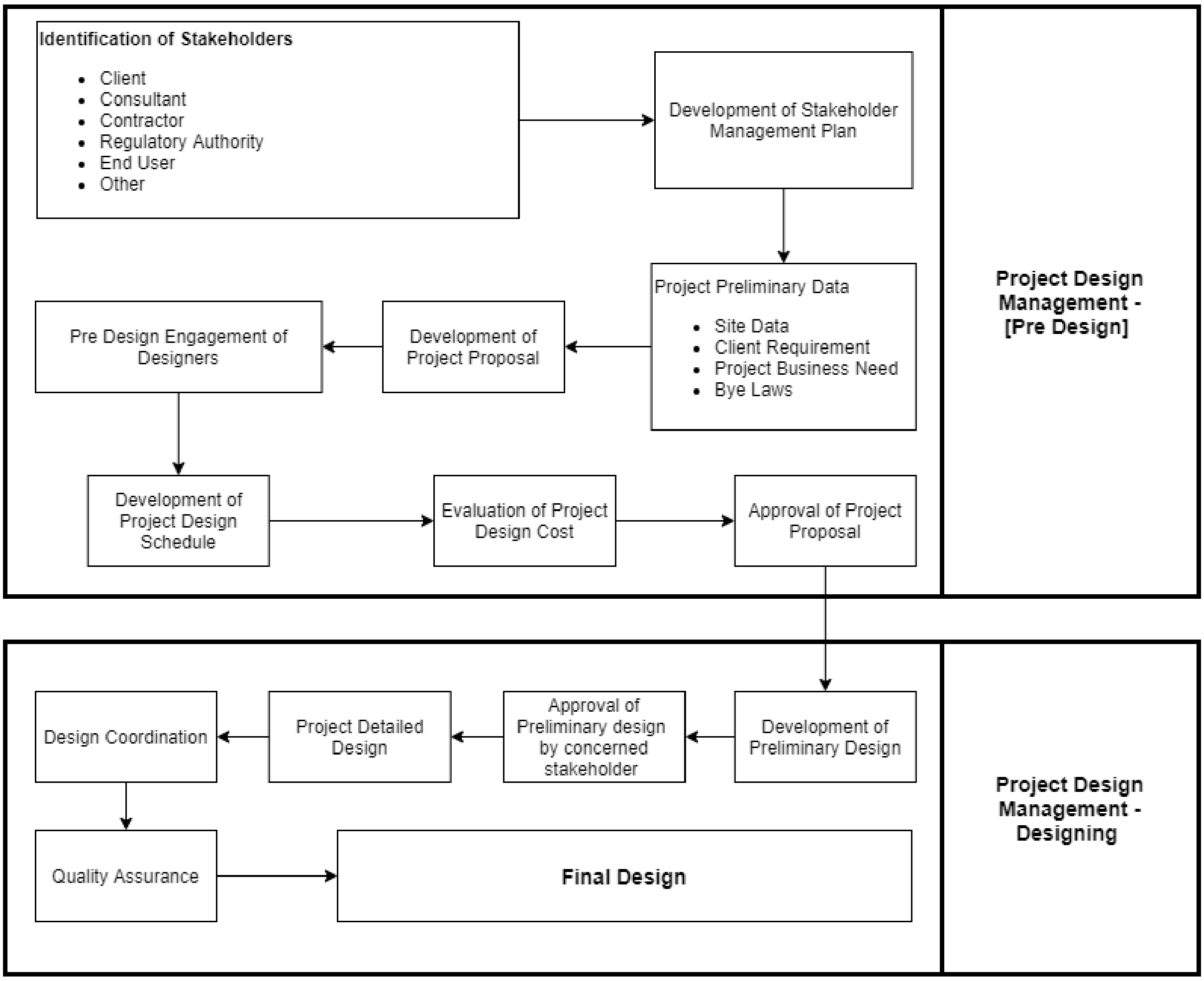
Table 4. 7 - Factors Ranking – Budget Creep

Factor	Sum	Field Score	Normalized Field score
Insufficient data collection and survey before design	224	0.747	0.122
Constructability ignored in DP	213	0.710	0.116
Misunderstanding of owner's requirements	212	0.707	0.115
Lack of coordination among various professionals	208	0.693	0.113
Unrealistic design schedules	206	0.687	0.112
Modification to design (Improvement)	205	0.683	0.111
Complexity of project	194	0.647	0.105
Low design cost	190	0.633	0.103
Re-use of specification and details	190	0.633	0.103

4.4.3 Framework development

Considering role of factors and there survey score, a major challange for building design managemet is still lack of coordination, although BIM has started its role to minimize challanges of coordination still some area are there that can't be addressed with BIM so far. To address factors causing DE, discussion was made with industary professional to understand standard practice of DP. Keeping in view existing process and factors contributing DE a framework was developed to eliminate causation of DE.

Figure 4. 4 – Initial Framework



This framework addresses factors causing design erros, a well defined DM system shall help to manage these factors, lead to improved desing process, that shall further reduce disputes, claim and litigation.

4.4.4 Feedback on framework

Framework was shared with industary professional for their reviews and asked to share their suggestion for any improvement whereever required. This framework was shared with twenty professionals, out of which thirteen replied throught email. Summary of feedback is as follows;

Table 4. 8 - Feedback on Framework

Expert	Comments
Azhar Islam	It is necessary to add up an observation phase to identify these factors at stage before final design. Well-set scope of design, documents must be materialized after project proposal stage before any involvement of design stakeholders will help to improve design
Azhar Abbasi	Flow chart is organised with orderly steps limiting some vital steps envisaged standards, single & 3D view-and missing information of scope of work amd technical specification.
Junaid Rahim	Proposed framework is practical and addressing all factors mentioned in email.
Ammar Rafiq	Explore a detailed DP for coordination of multiple designers
Mehtab Irshad	Constraint of minimum time requirement based on cost or project execution duration must be incorporated
Roaid Mumtaz	1. Project feasibility i.e covered area cost , Clientage force sale value of the property where project is proposed. Feasibility has a tremendous effect on design considerations. 2. 3D drawings by the architects to avoid aesthetic malfunction. 3. Idea of overlapping Drawings of MEP elements
Dr. Shamshair Sadiq	Proposed framework will definitely improve the current state of DP since your framework integrates well among stakeholders, project metadata and required coordination.
Mudassar Kamal	Identification of stakeholders at very early stage shall help to engage them on right time
Muhammad Rameez	**Vetting should be added in frame work**
Syed Jawad Agha	Your plan of action is sound and should be implemented for proper construction management and stakeholders satisfaction.
Fakhere Aleem	**After completion of both the stages if a 3rd stage should be added which can be the "Experts Reviews".**
Engr. Fayaz Rashid	Framework for BDP covered almost all aspects required during the process.
Khurram Azad	Satisfied

After review of experts, it was observed framework is improving DP and helps to eliminate factors causing DE, however a process of design vetting is required to be added as suggested by two experts. Vetting is being done after completion of preliminary design to have review by an expert, if it is taken after final design and design required any modification that shall impact financial as well loss of time, therefore while developing stakeholder management plan there should clear role of vetting designer for his expert opinion at project preliminary design.

4.4.5 Discussion on Framework

The framework is divided into two phases i.e. Pre-Design and designing. Some of the factors that causing desing errors are arisen in pre desing phase, i.e. Unrealistic timeline to design, Insufficient data collection and survey before design, misunderstanding of owner's requirements, lack of coordination among various professionals, low design cost.

4.4.5.1 Management of Project Stakeholders

It was observed, lack of coordination is owing to lack of identification of project stakeholders. It is very important to figureout there individuals and get a close contact at very early stage. There are two types of stakeholders, internal and external stakeholders. A proper stakeholder management plan shall define role of stakeholder and time of engagment. Some of the stakeholders are required to be in touch at every stage of project DP i.e. Owner, Supervision consultant, building designers, services designers, governament agencies to defince applicable regulations. For building construction projects in developing countries, usually client administer DP and take on board stakeholder at very later stages. In absence of professional consultant for design developmnet, some vital steps are being missed further at many cases, client is uneducated to share his/her requirement to project designer. Client is required to get services of expert to draft his requirement.

4.4.5.2 Project Priliminary Data

Owner/Client is required to develop buisness need of the project therefore required site data. Location, dimension, topograph of the project site. Further, it is required to understand socio-economic condition of the project area to develope a relistic buisness need. Once site data is collected to develop buisness need following regulations of authorities, it shall help to draft project design requirements.

4.4.5.3 Project Proposal

Best project proposal can be developed considering requirements of clients/project brief, keeping in loop all designer, i.e. Structural Designer, Electrical services designer, mechanical designers and others. For some of building that are deemed to be use for commercial purpose and planned to be managed by facility manager are required to be reviewed by facility manager. One can't forget role of financer of the project at approval of project proposal. Project proposal draft must be reviewed by all stakeholders, client may share financial statistics with concerned however project design must be shared with all to avoid modification during design phase.

4.4.5.4 Project Design

Design phase should be started after approval of project proposal. A preliminary design is developed to get understanding of project design, at this stage preliminary design is needed to be developed by all designers. Architectural plan is required to provide space for all services i.e. Utility service, facility management service and other. Also, it is required to review preliminary survey and develop a synchronization plan with infrastructure of locality. Further, a project budget is required to be developed at this stage to strengthen project proposal. At all design stages, designers are required to keep in touch with construction manger to ensure constructability of project.

Detailed design elaborates preliminary design, it should be coordinated very well. While developing detailed design there should be quality assurance to ensure design is developed up to the mark. BIM models shall help designer for coordination of multiple designer.

Chapter 5

RESULT AND DISCUSSION

5.1 Conclusion

The construction industry has proved to have major desing issues and results on project deliverables i.e. Cost, quality and time. Once design is effected no one assured about time for completion and there is a major cost for recovery schedule. In construction industary, building design is referred as most critical and complex process. Research has revailed number of factors accountable for chance of error in DP.

This study targets the identification of causative factors of DE, their cost on project and find a way to eliminated these errors. The system thinking approach assisted in widening the perspective on complex issues combining long-term effects as well as side effect. In return, this will enable decision makers to propose sustainable solutions to the problems (Beck, et al. 2012).

Initially an extensive literature review was conducted to identify factors causing DE. A total of 22 factors were extracted. A pilot study was conducted in which the respondents were allowed to rank the 22 factors on the basis of their contribution towards DE on Likert scale (1 to 5). Factor analysis was done by taking combined scores of respondent and literature giving the weightage of 60 and 40 respectively to deduce the most important factors encompassing the cumulative impact of 50 percent (Nazia et al., 2019).

Secondly the statistical verified data was then put forward for factor analysis that helped to deduce the most important factors. Ranking and shortlisting of factors was done by taking collective scores of respondents and literature giving the weightage of 60 and 40 respectively with the combined significance of 50 percent (Nazia et al., 2019). 9 most important factors were shortlisted through this analysis.

Then, a detailed questionnaire survey was circulated to the targeted field respondent in order to find the cost associated with DE, role of factos in DE, their significance and impact on project cost..

After the collection of 60 responses from 09 different developing countries, the data was compiled and statistically analysis was performed.Result of cost creep is more than expectation, mean value of data is 7.92% however, standard deviation of data is 5.98.

Conclusion is that, in BDP involved number of stakeholder i.e Project Sponser, Architecture , Structural Engineer, MEP Engineer, Project Manager, Regulatory Authority, Vendors, End Users/Customers etc. Hence, coordination is major challange for valueble design for a project. This sholud be properly defined and follwed to minimize risk of design error. According to above stated procedure a mature DP shall fullfill the requirements of all the stakeholders.

Moreover, it is required to follow the process flow diagram to eliminate the unrealistic design schedule as well mitigate the design challanges and develope a confidence of stakeholdrs.

5.2 Recommendations

Recommendation is that, framework was develped on the basis of survey and evaluated by industry professionals, further recommended to validate for real projects. It is also recommended to extend some research work in detailed design and define role of BIM to manage coordination challenges.

REFERENCE

Abdul-Rahman, H., Wang, C. & Yap, J. 2017. *Impacts of design changes on construction project performance: Insights from literature review*.
Abdullah, M., Abdul Rahman, I., Asmi, A. & Azis, A. 2010. *Causes of Delay in MARA Management Procurement Construction Projects*.
Adam, A., Josephson, P.-E. B. & Lindahl, G. 2017. Aggregation of factors causing cost overruns and time delays in large public construction projects: Trends and implications. *Engineering, Construction and Architectural Management,* 24**,** 393-406.
Adisa Olawale, Y. & Sun, M. 2010. *Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice*.
Ali, A. S. & Au-Yong, C. P. 2013. The designer in refurbishment projects: implications to the compatibility of design. *Structural Survey*.
Andersen, L. 2011. Virtual Design and Construction, St. *Olavs Hospital Kunnskapssenteret. Trondheim, NTNU Samfunnsforskning AS,* 45.
Assaf, S. A. & Al-Hejji, S. 2006. Causes of delay in large construction projects. *International Journal of Project Management,* 24**,** 349-357.
Bagaya, O. & Song, J. 2016. Empirical Study of Factors Influencing Schedule Delays of Public Construction Projects in Burkina Faso. *Journal of Management in Engineering,* 32**,** 05016014.
Baldwin, A., Austin, S., Hassan, T. & Thorpe, A. 1999a. Modelling information flow during the conceptual and schematic stages of building design. *Construction management & economics,* 17**,** 155-167.
Baldwin, A. N., Austin, S. A., Hassan, T. M. & Thorpe, A. 1999b. Modelling information flow during the conceptual and schematic stages of building design. *Construction Management and Economics,* 17**,** 155-167.
Ballard, G. Positive vs negative iteration in design. Proceedings Eighth Annual Conference of the International Group for Lean Construction, IGLC-6, Brighton, UK, 2000. 17-19.
Ballard, G. & Koskela, L. On the agenda of DM research. Proceedings IGLC, 1998. 52-69.
Barber, P., Graves, A., Hall, M., Sheath, D. & Tomkins, C. 2000. *Quality failure costs in civil engineering projects*.
Bell, B. S. & Kozlowski, S. W. 2002. A typology of virtual teams: Implications for effective leadership. *Group & organization management,* 27**,** 14-49.
Best, K. 2006. *DM: managing design strategy, process and implementation*, AVA publishing.
Blyth, A. & Worthington, J. 2010. *Managing the brief for better design*, Routledge.
Bølviken, T., Gullbrekken, B. & Nyseth, K. Collaborative DM. Proceedings of the 18th annual conference of the International Group for Lean Construction, Haifa, Israel, 2010.
Caffieri, J., Love, P., Ahiaga-Dagbui, D. & Whyte, A. 2017. *Planning for Production in Construction: Controlling Costs in Major Capital Projects*.
Carvalho, J., Mangin, J. & Sauce, G. 2008. Quality Management in Buildings Design Phase.
Chachere, J., Kunz, J. & Levitt, R. 2004. Observation, Theory, and Simulation of Integrated Concurrent Engineering: Risk analysis using formal models of radical project acceleration. *available as Center for Integrated Facility Engineering Working Paper WP088, Stanford University, Stanford, CA*.
Chang, A., S. Shih, J. & S. Choo, Y. 2011. *Reasons and costs for design change during production*.
Cheng, F., Li, H., Wang, Y.-W., Skitmore, M. & Forsythe, P. 2013. Modeling resource management in the BDP by information constraint Petri nets. *Automation in Construction,* 29**,** 92-99.
Clemente, J. & Cachadinha, N. 2013. Bim-Lean synergies in the management on mep works in public facilities of intensive use–A case study. *IGLC 21***,** 751-759.
Cnuddle 1991. Lack of quality in construction – economic losses. *Management, Quality and Economics in Building***,** 8.
Den Otter, A. & Emmitt, S. 2008. Design team communication and design task complexity: The preference for dialogues. *Architectural Engineering and DM,* 4**,** 121-129.
Drucker, P. F. 2008. *Management rev ed*, Zondervan.

Egan, J. 1998. Rethinking construction, construction task force report. *Department of theEnvironment,Transport and theRegions,London*.
Eikeland, P. 1999. Samspillet i byggeprosessen. *Teoretisk analyse av byggeprosesser*.
El Reifi, M., Emmitt, S. & Ruikar, K. Developing a conceptual lean briefing process model for lean DM. 21st Annual Conference of the International Group for Lean Construction 2013, IGLC 2013, 2013. 325-334.
El. Reifi, M. & Emmitt, S. 2013a. Perceptions of lean DM. *Architectural Engineering and DM,* 9**,** 195-208.
El. Reifi, M. H. & Emmitt, S. 2013b. Perceptions of lean DM. *Architectural Engineering and DM,* 9**,** 195-208.
Emmitt, S. & Ruikar, K. 2013. *Collaborative DM*, Routledge.
Emmitt, S., Sander, D. & Christoffersen, A. K. The value universe: defining a value based approach to lean construction. Proceedings IGLC, 2005. Citeseer, 57-64.
Eynon, J. 2013. *The design manager's handbook*, John Wiley & Sons.
Flager, F., Welle, B., Bansal, P., Soremekun, G. & Haymaker, J. 2009. Multidisciplinary process integration and design optimization of a classroom building. *Journal of Information Technology in Construction (ITcon),* 14**,** 595-612.
Fundli, I. S. & Drevland, F. Collaborative DM–a case study. Proc. 22nd Ann. Conf. of the Int'l Group for Lean Construction. Oslo, Norway, 2014. 627-638.
Gashi, E. 2018. *Management of defective works in infrastructure projects*.
Giang, D. T. & Pheng, L. S. 2011. Role of construction in economic development: Review of key concepts in the past 40 years. *Habitat international,* 35**,** 118-125.
Gilbertson, A. L. Briefing: measuring the value of design. Proceedings of the Institution of Civil Engineers-Municipal Engineer, 2006. Thomas Telford Ltd, 125-128.
Hamzeh, F. R., Ballard, G. & Tommelein, I. D. Is the Last Planner System applicable to design?—A case study. Proceedings of the 17th Annual Conference of the International Group for Lean Construction, 2009. IGLC Taipei, 13-19.
Hanif, H., Khurshid, M., Lindhard, S. & Aslam, Z. 2016. *Impact of Variation Orders on Time and Cost in Mega Hydropower Projects of Pakistan*.
Hansen, G. K. & Olsson, N. O. 2011. Layered project–layered process: Lean thinking and flexible solutions. *Architectural Engineering and DM,* 7**,** 70-84.
Hwang, B.-G., Thomas Stephen, R., Haas Carl, T. & Caldas Carlos, H. 2009. Measuring the Impact of Rework on Construction Cost Performance. *Journal of Construction Engineering and Management,* 135**,** 187-198.
Ibrahim Mohamad, M., Nekooie, M. A., B Salim Al-Harthy, A. & Amur, B. 2012. *Design Changes in Residential Reinforced Concrete Buildings: The Causes, Sources, Impacts and Preventive Measures*.
Iliyas J. Suleiman, V. G. M. L. 2016. Factors Influencing Change of Design of Building Projects during Construction Stage in Dar-es- Salaam Tanzania. *International Journal of Construction Engineering and Management,* 5 (4)**,** 93-101.
Josephson, P. E. & Hammarlund, Y. 1999. *The causes and costs of defects in construction: A study of seven building projects*.
Kalsaas, B. T. & Sacks, R. 2011. Conceptualization of interdependency and coordination between construction tasks. *Proceedings of the IGLC-19. Lima, Peru*.
Kaming, P., O. Olomolaiye, P., D. Holt, G. & C. Harris, F. 1997. *Factors influencing construction time and cost overruns on high-rise projects in Indonesia*.
Kestle, L. & London, K. Towards the development of a conceptual DM model for remote sites. IGLC 2002: proceedings: 10th Conference of the International Group for Lean Construction, 2002. International Group on Lean Construction, 1-14.
Khanzode, A., Fisher, M. & Reed, D. Challenges and benefits of implementing virtual design and construction technologies for coordination of mechanical, electrical, and plumbing systems on large healthcare project. Proceedings of CIB 24th W78 Conference, 2007. 205-212.
Kikwasi, G. 2013. *Causes and Effects of Delays and Disruptions in Construction Projects in Tanzania*.

Knotten, V., Svalestuen, F., Aslesen, S. & Dammerud, H. Integrated methodology for DM–A research project to improve DM for the AEC industry in Norway. Proceedings of the 22nd Annual Conference of the International Group for Lean Construction, 2014. 1391-1400.
Knotten, V., Svalestuen, F., Hansen, G. & Lædre, O. 2015. DM in the Building Process - A Review of Current Literature. *Procedia Economics and Finance*, 21.
Koskela, L., Bølviken, T. & Rooke, J. 2013. Which are the wastes of construction?
Kristensen, K. H. 2013. Building DM: Management of the cooperative design and its interdisciplinary functions.
Latham, M. 1994. Constructing the team: Joint review of procurement and contractual arrangements in the UK construction industry. *Department of the Environment, UK*.
LAWSON, B. 1997. How designers think–the DP demystified. rev. e amp. Oxford: Architectural Press/Butterworth-Heinemann.
Lawson, B. 2006. *How Designers Think – The DP Demystified*.
Le-Hoai, L., Dai Lee, Y. & Lee, J.-Y. 2008. *Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries*.
Leong, M. S. & Tilley, P. A lean strategy to performance measurement–reducing waste by measuring'next'customer needs. Proceedings for the 16th Annual Conference of the International Group for Lean Construction Safety, Quality and the Environment, 2008. University of Salford, 757-768.
Love, P., Davis, P., Ellis, J. & Cheung, S. 2010a. *Dispute causation: Identification of pathogenic influences in construction*.
Love, P., Edwards, D., Smith, J. & Walker, D. 2009. *Divergence or congruence? A path model of rework for building and civil engineering projects*.
Love, P., Edwards, D., Watson, H. & Davis, P. 2010b. *Rework in civil infrastructure projects: determination of cost predictors*.
Love, P. E. D. & Edwards, D. J. 2004. Forensic project management: The underlying causes of rework in construction projects. *Civil Engineering and Environmental Systems,* 21**,** 207-228.
Love, P. E. D., Irani, Z. & Edwards, D. J. 2003. Learning to Reduce Rework in Projects: Analysis of Firm's Organizational Learning and Quality Practices. *Project Management Journal,* 34**,** 13-25.
Love, P. E. D. & Li, H. 2000a. Overcoming the problems associated with quality certification. *Construction Management and Economics,* 18**,** 139-149.
Love, P. E. D. & Li, H. 2000b. Quantifying the causes and costs of rework in construction. *Construction Management and Economics,* 18**,** 479-490.
Love Peter, E. D. 2002. Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects. *Journal of Construction Engineering and Management,* 128**,** 18-29.
Mark, G. 2001. Extreme Collaboration. Forthcoming in Communications of the ACM.
Mintzberg, H. 1993. *Structure in fives: Designing effective organizations,* Prentice-Hall, Inc.
Morgan, G. 2011. Reflections on images of organization and its implications for organization and environment. *Organization & Environment,* 24**,** 459-478.
Moum, A. 2008. *Exploring relations between the architectural DP and ICT: learning from practitioners' stories*, Fakultet for arkitektur og billedkunst.
Oyewobi, L., Abiola-Falemu, O. & Timothy Ibironke, O. 2016. *The impact of rework and organisational culture on project delivery*.
Palaneeswaran, E., Love, P. E. D., Kumaraswamy, M. M. & Ng, T. S. T. 2008. Mapping rework causes and effects using artificial neural networks. *Building Research & Information,* 36**,** 450-465.
RIBA 2013. Handbook of Practice Management. *RIBA Publishing, London*.
Robinson Fayek, A. 2019. *Measuring and Classifying Construction Field Rework: A Pilot Study*.
Rosas, E. Integrating the design structure matrix and the last planner system into building design. 21th Annual Conference of the International Group for Lean Construction, Fortaleza, Brazil, 2013. 389-398.
Rounce, G. 1998. Quality, waste and cost considerations in architectural building DM. *International Journal of Project Management,* 16**,** 123-127.

Salvatierra-Garrido, J., Pasquire, C. & Miron, L. Exploring value concept through the iglc community: Nineteen years of experience. Proceedings for the 20th Annual Conference of the International Group for Lean Construction, San Diego, CA, 2012. Citeseer.

Sun, M. & Meng, X. 2009. Taxonomy for change causes and effects in construction projects. *International Journal of Project Management,* 27**,** 560-572.

Thompson, J. D. 1967. *Organizations in action: social science bases of administrative theory*, McGraw-Hill.

Thyssen, M. H., Emmitt, S., Bonke, S. & Kirk-Christoffersen, A. The Toyota product development system applied to a DM workshop model. 16th Annual Conference of the International Group for Lean Construction, IGLC16, Manchester, 2008.

Thyssen, M. H., Emmitt, S., Bonke, S. & Kirk-Christoffersen, A. 2010. Facilitating client value creation in the conceptual design phase of construction projects: a workshop approach. *Architectural Engineering and DM*, 6**,** 18-30.

Tilley, P. A. Lean DM: a new paradigm for managing the design and documentation process to improve quality? 13th International Group for Lean Construction Conference: Proceedings, 2005a. International Group on Lean Construction, 283.

Tilley, P. A. 2005b. Lean Design Managment- A New Paradigm for Managing the Design and Documentation Process to Improve Quality? *Proceedings of the IGLC-13. Sydney, Australia*.

Waldron, B. D. 2006. Scope for improvement: A survey of pressure points in Australian construction and infrastructure projects. *Rep. Prepared for the Australian Constructors Association*.

Yana, A. A. G. A., Rusdhi, H. A. & Wibowo, M. A. 2015. Analysis of Factors Affecting Design Changes in Construction Project with Partial Least Square (PLS). *Procedia Engineering,* 125**,** 40-45.

Yap, J., Abdul-Rahman, H. & Wang, C. 2017a. *Design Change Dynamics in Building Project: From Literature Review to A Conceptual Framework Formulation*.

Yap, J. B. H., Abdul-Rahman, H. & Chen, W. 2017b. Collaborative model: Managing design changes with reusable project experiences through project learning and effective communication. *International Journal of Project Management,* 35**,** 1253-1271.

Ye, G., Jin, Z. & Skitmore, M. 2014. Analyzing Causes for Reworks in Construction Projects in China. *Journal of Management in Engineering,* 31.

APPENDIX-A

Preliminary Survey draft to identify role of factors causing Design Error.

Questionnaire Survey Form

Dear Respondent,

This survey is being carried out as part of Masters' Research on subject of "Identification of root causes of building design errors". The aim of this study is to assess the origin of design errors in the building construction industry in developing countries.

Design errors are one of the major risk factors causing schedule and cost overrun, therefore affecting project success and quality. While design errors are deemed prevalent, most designer and contractors do not measure the number of errors they create, thereby having limited knowledge regarding their mechanism to undermine project performance.

Note: Please be assured that the data will only be used for study purpose and no personal information will be disclosed at any forum/level.

Muhammad Kamran Ghazi
Post Graduate Student
Dept. of Construction Engineering & Management,
School of Civil & Environmental Engineering (SCEE),
National University of Sciences & Technology (NUST),
Islamabad, Pakistan
Email: kamranghazi@outlook.com

* Required

1. Email *

____

SECTION A: Demographic Information

2. Full Name *

____

3. Country *

____

4. Organization/Institute *

Mark only one oval.

- ( ) Client
- ( ) Consultant
- ( ) Contractor
- ( ) Subcontractor
- ( ) Supplier
- ( ) Other: ____________

5. Job title/Position in organization *

____

6. Please indicate years of experience *

Mark only one oval.

- ( ) 0-5
- ( ) 6-10
- ( ) 11-15
- ( ) 16-20
- ( ) More than 20

SECTION B: Causes of building design error.

Research carried by Lopez and Love Peter (2012) obtained design errors costs from 139 projects and found mean direct and indirect design error costs were found to 6.9% and 7.4% of a project's contract value, respectively. Similarly, Burroughs (1993) reported that a major Australian contractor had experienced rework costs of 5% of contract value due to design errors. In this very moment, the prudent approach is to figure out weightage to factors causing error in building design process

Some causes of design errors are identified from literature review. Kindly rank these causes based on your experience/knowledge considering how much these causes contribute towards the building design errors.

Your response will be highly appreciated.

7. Adverse behaviour of design team *

Mark only one oval.

	1	2	3	4	5	
Low	⬭	⬭	⬭	⬭	⬭	High

8. Client - Lack of construction experience *

Mark only one oval.

	1	2	3	4	5	
Low	⬭	⬭	⬭	⬭	⬭	High

9. Client - Late decision *

Mark only one oval.

	1	2	3	4	5	
Low	⬭	⬭	⬭	⬭	⬭	High

10. Complexity of project *

Mark only one oval.

	1	2	3	4	5	
Low	⬭	⬭	⬭	⬭	⬭	High

11. Constructability ignored in design process *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

12. Lack of design reviews, checks and verification *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

13. Inadequate design-team experience *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

14. Inadequate quality assurance *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

15. Insufficient data collection and survey before design *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

16. Lack of coordination among various professionals *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

17. Loss of Biorhythm *

Individuals have a biorhythm, which involves their physical, emotional and intellectual mental states. An individual's biorhythm is influenced by their on-and off the job experiences, which influences their ability to deal with work demands.

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

18. Low design cost *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

19. Misunderstanding of owner's requirements *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

20. Modification to design (Improvement) *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

21. New design standards *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

22. Physiological and psychological limitations of human *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

23. Re-use of specification and details *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

24. Poor coordination/ integration of stakeholders *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

25. Unclear initial design brief *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

26. Understaffing *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

27. Unrealistic design schedules *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

28. Advanced design software *

Mark only one oval.

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

29. Any other factor, if encountered during professional career.

____

APPENDIX-B

Final Survey draft to evaluate project budget creep due to design erros and identify role of factors causing DE and impact.

Survey Form

Dear Respondent,

This survey is being carried out as part of Masters' Research on subject of "Identification of root causes of building design errors". The aim of this study is to assess the origin of design errors in the building construction industry in developing countries. Design errors are one of the major risk factors causing schedule and cost overrun especially in building construction, therefore affecting project success and quality. While design errors are deemed prevalent, most designer and contractors do not measure the number of errors they create, thereby having limited knowledge regarding their mechanism to undermine project performance. This research is being conducted to evaluate these causes and impact on project cost.

Note: Please be assured that the data will only be used for study purpose and no personal information will be disclosed at any forum/level.

Muhammad Kamran Ghazi
Post Graduate Student
Dept. of Construction Engineering & Management,
School of Civil & Environmental Engineering (SCEE),
National University of Sciences & Technology (NUST),
Islamabad, Pakistan
Email: m.kamran.ghazi@gmail.com

* Required

1. Email *

____

2. Full Name *

____

3. Employer Background *

Mark only one oval.

- ( ) Client
- ( ) Designer
- ( ) Supervision Consultant
- ( ) Contractor
- ( ) Sub Contractor
- ( ) Other: ____________________

4. Job Title/Position *

____

5. Professional Experience in Years *

Mark only one oval.

- ( ) 0 to 1
- ( ) 2 to 5
- ( ) 6 to 10
- ( ) 11 to 15
- ( ) 16 and above

6. Please indicate your country (country of working experience) *

____

Analyzing the causes of design errors and their cost impact

A total of 9 design based factors were identified that contribute to building design error. The aim of this questionnaire survey is to evaluate their impact on project cost.

7. Please mention project budget creep [going over budget within defined scope of work], in percentage, subjected to design error. *

____

8. Some of the causes to generate design errors are listed below. Kindly rank these causes based on your experience/knowledge considering how much these causes contribute towards the building design errors. (1 for Low, 5 for High) *

Check all that apply.

	1	2	3	4	5
Unrealistic design schedules	☐	☐	☐	☐	☐
Insufficient data collection and survey before design	☐	☐	☐	☐	☐
Misunderstanding of owner’s requirements	☐	☐	☐	☐	☐
Lack of coordination among various professionals	☐	☐	☐	☐	☐
Low design cost	☐	☐	☐	☐	☐
Complexity of project	☐	☐	☐	☐	☐
Constructability ignored in design process	☐	☐	☐	☐	☐
Modification to design (Improvement)	☐	☐	☐	☐	☐
Re-use of specification and details	☐	☐	☐	☐	☐

9. On the basis of your experience, please rate these factor to identify contribution towards project budget creep.[going over budget within defined scope of work] (1 for Low, 5 for High) *

Check all that apply.

	1	2	3	4	5
Unrealistic design schedules	☐	☐	☐	☐	☐
Insufficient data collection and survey before design	☐	☐	☐	☐	☐
Misunderstanding of owner’s requirements	☐	☐	☐	☐	☐
Lack of coordination among various professionals	☐	☐	☐	☐	☐
Low design cost	☐	☐	☐	☐	☐
Complexity of project	☐	☐	☐	☐	☐
Constructability ignored in design process	☐	☐	☐	☐	☐
Modification to design (Improvement)	☐	☐	☐	☐	☐
Re-use of specification and details	☐	☐	☐	☐	☐