DESIGN DOCUMENT DEFICIENCY TYPES, CAUSES, EFFECTS, AND PREVENTION

BY

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DEDICATION

I dedicate this work to my parents, sister, brother, extended family, friends

and both my beloved late grandmothers

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In the name of Allah, Most Gracious, Most Merciful

I would first like to extend my sincere gratitude to my thesis advisor, Dr. Sadi Assaf, for his unwavering support, guidance, and immense kindness. Had it not been for him I would not have found the patience to endure this journey. Thanks is also due to my thesis committee, Dr. Mohammad A. Hassanain and Dr. Ali A. Shash, who welcomed me with warm hands and also provided strong support and invaluable insight throughout my enrollment.

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THESIS ABSTRACT

Name of student:	ABDULLATIF SAID ABDALLAH
Title of the study:	Design Document Deficiency Types, Causes, Effects and Prevention
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This research addresses the growing problem of design document deficiency (DDD). In particular, four facets of DDD are analyzed within the setting of Saudi Arabia, namely, (1) frequent types of document deficiencies, (2) predominant factors that influence their occurrences, (3) adverse consequences that stem from them, and (4) list of best practices that may be adopted for preventing their occurrences. In all, 82 factors were identified from previous studies. Ultimately, the objective of the research was to (1) provide a better insight of DDD in the context of Saudi Arabia and (2) provide a list of the most effective preventive measures from the perspective of Saudi professionals. The approach utilized to achieve these objectives was a survey. The survey questionnaire incorporated a likert scale spanning from 0 to 5, where 0 represented least significant and 5 most significant.

A total of 71 respondents participated in the research of which 41 were consultants and 30 were contractors. The analysis of the deficiency types indicated that "nonconformance to building codes" was observed by the two parties to be the most pervasive form of deficiency encountered. As for the most profound cause of the deficiencies, both parties nominated "designer's experience" and "coordination of design team" as critical. For the effect of the deficiency, "impact on contractor" and "change order" were accepted as significant repercussions of deficient document. Finally, "quality management" was seen by both parties as the most effective means of either preventing the errors or diminishing the impacts of the errors. Both the parties displayed strong agreements with respect to the importance index of the factors in all the four identified aspects.

خلاصة الرسالة

اسم الطالب الكامل: عبد اللطيف عبد الله

عنوان الرسالة: مشكلة القصور في وثائق التصميم أنواع ، الأسباب ، الآثار، والوقاية

التخصص: هندسة البناء وإدارة

تاريخ الشهادة : محرم 1436ه

يتناول هذا البحث تنامي لمشكلة القصور في وثائق التصميم على وجه الخصوص، أربعة جوانب يتم تحليلها ضمن نطاق المملكة العربية السعودية، وهي كالتالي: (1) أنواع متكررة من القصور في الوثائق، (2) العوامل السائدة التي تؤدي إلى حدوث هذا القصور، (3) العوامل السلبية التي تنبع من هذ القصور، (4) قائمة بأفضل الممارسات التي يمكن اتخاذها للوقاية من هذا القصور. تم تحديد 82 عامل من هذه العوامل من خلال البحوث والدراسات السابقة. يهدف هذا البحث إلى التالي: (1) تقديم فهم أفضل لمشكلة القصور في وثائق التصميم في نطاق المملكة العربية السعودية، (2) تقديم قائمة من التدابير الوقائية الأكثر فعالية من وجهة نظر المهنيين السعوديين. النهج المستخدم لتحقيق هذه الاهداف كان عن طريق "استبيان". في هذا الاستبيان تم إدراج مقياس لايكرت من 0 إلى 5، بحيث تمثل 0 الأقل أهمية و تمثل 5 الأكثر أهمية.

شارك في هذا البحث ما مجموعه 71 مشارك منهم 41 استشاري و 30 مقاول. أشار تحليل أنواع القصور إلى أن "عدم المطابقة لقوانين البناء" هو الأكثر انتشارا حسب ملاحظة كلا الطرفين. بالنسبة لأعمق هذه العوامل، رشح كلا الطرفين بأن "خبرة المصمم" و "التنسيق بين فريق التصميم" هما الأكثر أهمية. بالنسبة لتأثير القصور، تم قبول "التأثير على المقاول" و "الأوامر التغييرية" كنتيجة هامة بسبب القصور في الوثائق. وأخيرا، لوحظ من قبل الطرفين أن "إدارة الجودة" تعتبر الوسيلة الأكثر فعالية للوقاية من الأخطاء أو التقليل من آثار هذه الأخطاء. كلا الطرفين عرضا اتفاقا قويا فيما يتعلق بأهمية هذه العوامل في جميع الجوانب الأربعة التي تم تحديدها.

CHAPTER ONE

INTRODUCTION

This chapter initiates with an overview of the research followed by a problem statement. Next, it delineates the objective and importance of the performing the study. To reinforce the significance of the study, a list justifying why tackling the problem is of relevance to the construction industry is presented. The scope of the research is then stated. Finally, the chapter ends with an overview of the thesis's forthcoming chapters.

1.1 *Background*

Although there may be other targets, typically, cost, time, and quality are three aspects that are held sacrosanct by all stakeholders partaking a construction project (Chua et al., 1999). They are the key determinants of a project's realization. Unfortunately, despite the prominence of these factors to the construction industry, a great many projects invariably incur time overruns and consequently other detrimental attributes such as added costs, and a compromise to quality and safety (Assaf & Al-Hejji, 2006; Mahamid et al., 2012). A pivotal factor that may be attributed to this epidemic is the issue of design document deficiency (DDD). Thus, this research endeavors to analyze the problem of design document deficiency.

The construction industry in Saudi Arabia, unlike many other countries, is the main force providing economical growth. Forecasts show that this demand for construction does not seem to falter in the coming decade, with a continuing demand in the development of infrastructure, residential buildings, and social facilities. Based on the estimates issued by Central Department of Statistics and Information (CDSI), Saudi Arabia boasts a population of 29.2million as of 2012 and is undergoing population growth at a rate of 2.9% annually. Therefore, it can be inferred that the need for infrastructure will be highly demanded. In addition, Saudi Arabia from the year 2011 to 2012 underwent a gargantuan escalation in construction and infrastructure growth amounting to 177%. Merrill Lynch found that, in comparison to the rest of its Middle Eastern and North African counterparts, Saudi Arabia leads the pack with an approximated 46% share of the $448bn projects. Supporting this claim, the national commercial bank (NBC) observed a 50% rise in contracts awarded between 2011 and the first half of 2012 (The Report: Saudi Arabia 2013, 2013). Hence, due to the very costly nature of construction, any error, whether it be in either the design or construction stage, will result in the wastage of large sums of money that might be spent in other sectors such as education.

Indeed, the above passage gives a glimpse of the monumental scale of Saudi Arabia's construction industry. A matter of great concern, therefore, is of construction firms experiencing project duration and cost overruns, which as a consequence depletes profits, lowers reputation, introduces pressure and increases employee turnover. One cause pertaining to the aforementioned issue may be linked to their failure to develop a mechanism that allows them to learn from past design document deficiencies.

1.2 *Statement of problem*

Timeliness, low cost, and right quality, all interdependent traits, and all traits that construction organization strive to reach. Undoubtedly, these are the characteristics that classify a successful project. In reality, though, it may, in some instances, become very difficult to attain such ambitions. Why this may be so is largely due to the many variability encountered in projects. In particular, a construction project is an arduous endeavor fraught with various forms of impediments that emerge in the shape of issues that were not accounted for previously. In some cases, these issues may represent themselves as natural causes, the likes of bad weather condition, to name just one. Typically, in such cases, all the parties may agree to share the cost. On the other hand, some problems may arise due to lack of due diligence on the part of a particular party. Here, the accountable party invariably bears the full cost from its recklessness. Otherwise, a litigation ensues, which is never good for any involved party as it depletes time and profit. One form of the latter issue presents itself in the form of DDD.

What are DDD? DDD refer to errors that may found in the design documents. Thus, to begin with, the definition of error must be clarified. The word error has a negative connotation. It is what hinders the achievement of goals. According to the oxford dictionary the word error is defined as: *"thing done wrongly, the state of being wrong in belief or behavior, the amount of inaccuracy and the mistake in one's assessment of a situation."* Thus, an error can be thought of as a mistake. Accordingly, DDD, with respect to this thesis, represent any mistake, which divert the project away from the desired target, encountered in the design documents that have been formulated by the consultants. In addition, the documents fail to meet the quality requirements of the owner, contractor and the relevant codes/regulations (Andi, 2005). Consequently, they will have a direct bearing on a projects cost, time and quality. The errors may range from arithmetic mistakes, building's system conflict, inadequate structural design, to failure to account for client's needs. Figure 1.1 below summarizes the definition of DDD.

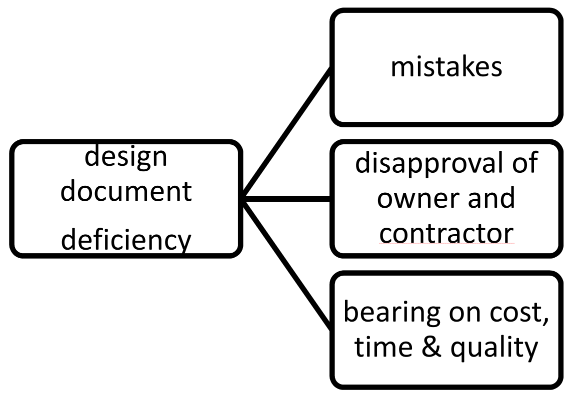

Figure 1.1: Definition of DDD

With that said, within the kingdom of Saudi Arabia, there is a strong conviction among the constructions practioners that the quality of architectural design documents are in a dire state. Moreover, the prevalence of claims between the parties (owner, contractors, and designers) involved in construction serves as another testament to this problem (Abolnour, 1994).

Design documents act as a communication medium for transferring the ideas of the clients to the contractors. In addition to this, they aid in the management of the construction work, allowing for a streamlined process that is accomplished within the specified duration, budget and quality (Mohammed, 2007). These design documents circumscribe the drawings, specifications, schedules, and B.O.Q (bills of quantities).

The initial decisions made during the kickoff stages of a project profoundly affect the future outcome of a project. In addition, recommendations made at this stage have influence that far outweigh those that may be made later, due to the inherent flexibility of this phase of the project. During this preliminary stage, goals with respect to time, cost, and quality may be easily devised. Contrary to this, once a project enters the construction period, implementing goals becomes an arduous task. This becomes the case due to the enormous prerequisite of modifying the already prepared construction documents (Mohammed, 2007).

Therefore, any error made in the design documents may spell disaster for a project. A majority of project underperformance can usually be connected to imprudent decisions made at the design stages. Errors and omissions contained in construction documents encourage time and cost overruns. Often, when an error is detected, entire site mayhem is inevitable (Mohammed, 2007). DDD are one of the most predominant factors that lead to cost overruns in construction projects. In general, they stem from a multitude of interconnected factors. They are the grass roots of many unwanted effects, such as the plummeting of productivity, coming from the need for unnecessary rework; added shift work and overtime; safety issues for both the workers and the people/client who will occupy the built facility; adversarial relation between the trades, owing from the financial loses; and costly litigations and claims (Andi & Minato, 2003). At the end, all the forgoing factors function only to add needless cost to the project. Additionally, if not identified and remedied at the outset, small problems can and will inevitably evolve into enormous proportions having far-reaching impacts.

A number of research, such as Andi and Minato (2003), have dealt with the issue of DDD across various countries, including a number in Saudi Arabia, like Mohammed (2007). The purpose of this research, therefore, is to reiterate these studies, and provide an updated status of the current trend of DDD specifically in the context of Saudi Arabia.

1.3 *Objectives of study*

The objective of this research are outlined below:

1. Gauge into the various types of design document errors found in Saudi Arabia and determine the most predominant errors
2. Identify the key factors that are responsible for their inception
3. Recognize what adverse effects these errors introduce into the project and the perils they expose them to
4. Derive possible preventative measures that may be undertaken to alleviate and, in the most idealistic scenario, prevent their occurrences in the first instance
5. Find the extent to which the contractors and consultants agree with each other on issues pertaining to DDD

6. Compare the findings in Saudi Arabia with that of other countries that had been previously studied

At the end, it is hoped that this research will provide a means of assessing and recognizing symptoms of DDD even before their inception, allowing the elimination of the root cause, thus, denying it the prospective of spreading and infecting the entire project. Subsequently, it is expected that by nullifying such errors, the problem of delays and costly overruns outlined at the beginning will be depleted.

Although all the parties (contractor, designer and clients) involved in the construction project will benefit, the consultant will stand to gain the most from this study. Specifically, an improved organizational reputation, higher profit and a more competitive edge (Sunday & Afolarin, 2013).

1.4 *Research scope and limitations*

Outlined below are the scope and limitations of the research:

1. The study is confined to the Eastern Province Region of Saudi Arabia.
2. Views are taken from consultants and contractors who have a ranking of at least grade 3.
3. The types of projects conducted by the participants ranged from building, infrastructure, industrial, to special purpose projects.

4. The frequency of the defective document factors were obtained on the basis of the consultants and contractors general experience in KSA and not on any particular project. Hence, neither the specific project size nor the particular procurement method utilized for the undertaken projects were considered. This aspect of the research is reflected in the research's questionnaire by their being no question that elicits information pertaining to these parameters.
5. The goal of the research was limited to derivation of the consultant and contractors perception on the current state of defective design documents in KSA. Information relating to the portion of the projects subjected to time and cost overruns together with the extent of these overruns as a result of the defective design documents were not taken into account.
6. The amount of deficiency encountered within any specific discipline, for instance, the electrical engineering drawings, were not obtained. In other words, the study provided a general overview of the deficiency of drawings and specifications irrespective of the discipline.

1.5 *Significance of study*

The impetus for performing this research comes from a multitude of real world problems faced by the construction industry. It is hoped that by assessing the problems relevant to DDD, the following targets will be attained:

1.5.1 Lowering cost

By decreasing the number of errors in the making of the design documents, the amount of errors in the entire project will to a proportionate degree decrease. This is supported by the findings of Darwish (2005) which demonstrated that inadequate design and documents resulted in an average of 9% exceeding of the project cost (Mohammed, 2007).

1.5.2 Improving performance

The construction industry is well known for its underperformance of projects. Design documents errors play a big role in the performance shortcomings. The construction sequence may be interrupted by temporary suspension as issues concerning missing information and contradictions within the documents are solved. This apparently momentary lost in time in fact derails the efficiency of work. Thus, finding what results in these errors and preventing them can go a long way towards ameliorating the performance of projects (Mohammed, 2007).

1.5.3 Requirements of contract

Contracts require that there be no flaws in the documents. In the instance that mistakes do occur, the designer is held liable and must fix problems under their own expense. Determining what breeds the errors may protect the designers from such claims(Mohammed, 2007).

1.5.4 Removal of high estimates

Owing to the construction industry's bad performance, it may be necessary to add room for contingency. For example, the contingency may say, "There is nothing absolute about construction prices". This is substantiated by the disparity between bid estimates of a project. By decreasing the quantity of errors contained in the construction documents not only will the efficiency of the project improve in terms of expense and duration, but the contingency amount will also reduce as a result of confidence in the construction documents (Mohammed, 2007).

1.5.5 Eradicating finance issues

Construction involves a considerable expenditure of money. Therefore, any unexpected rise in cost will be detrimental to the client. As result, a majority of clients request guarantees that ensures they receive their product at the cost and duration they have specified. Removing errors from documents ensures that the project does not exceed the cost bounds set by the owner. This benefits the owner and designer alike(Mohammed, 2007).

1.5.6 Preventing rework

Rework refers to the non-value added work of reiterating an activity that was poorly or wrongly performed the first time round. It is a recursive issue that has plagued the industry time and time again, and paves the way to time and cost increase. By reducing errors in the documents, not only will the design phase rework be reduced, but rework relating to the construction stage, a more substantive issue, will also be lessened. The end product is a more streamlined workflow (Mohammed, 2007).

1.5.7 Boosting consultant's reputation

Reputation is vital in any industry. Gaining a good image helps secure future jobs. Producing errors in documents creates an atmosphere of mistrust and unreliability. Referring to the results of Mohammed (2007)'s interview with clients, an association between the quantity of document errors and contractual relation discontinuation with the consultants was observed. In other words, the more errors found in the documents the less likely client will be willing to work with that particular consultant. Hence, producing flawless documents will help the consultant establish a firm basis in the industry (Mohammed, 2007).

1.6 *Thesis layout*

In order to achieve the objectives that have been laid out, this research is apportioned into 5 distinct chapters.

Chapter 1 The first section outlines what the thesis intends to do. It then highlights why the problem being tackled is of great relevance to the construction industry. Next, it provides a list of all the benefits the industry stands to gain from performing the research. Following is a section containing a passage stating the bounds of the research. At the end, it gives a detailed breakdown of the methodology employed to conclude the thesis.

Chapter 2 Takes the reader to the heart of the topic. This chapter starts of by discussing prior studies on the issue, expounding previous discoveries and statistical findings on the topic. The following section dissects the design stage, giving a general overview of what it involves and how it influences the entire project. The section that succeeds introduces the topic, DDD. It gives a definition and displays the classifications that are frequently applied to them. The chapter finally closes with a discussion of errors repeatedly found in the design documents.

Chapter 3 Explores the causes, effects and prevention methods for DDD. The first section introduces generic factors that are involved in the production of DDD. It then discusses the more specific factors in the context of the designer. Afterwards, the consequence of the errors are called to the reader's attention. On the final section, methods that may prevent the occurrences of DDD are shown.

Chapter 4 Disseminates the result and findings of (1) common types of DDD (2) most critical causes of DDD, (3) effect of DDD, and (4) the measure taken to prevent DDD. The findings are all displayed in statistical format.

Chapter 5 Concludes the research and provides recommendations for further studies.

CHAPTER TWO

LITERATURE REVIEW

There has been a significant number of papers addressing the issues relating to quality deviation in construction. Out of the vast list of issues found, DDD were found to be a key issue, requiring fair attention. A reason for this can be attributed to where the design process stands in the project phase, namely the initiation stage. The design phase serves as a blue print for the entire project life, from the tender, through construction, until the occupation of the final built building. Thus, with such profound implications, it is no wonder huge deficits in the profit may, and usually, occurs when errors arise at this stage.

2.1 *Previous studies*

This section explores the various findings of previous studies on DDD:

A study performed by Atkinson (2002) in which 40 managers were interviewed reported that, out of 220 errors analyzed, communication issues had by far the biggest contribution. This mainly included formal communications like poor specifications, drawings and written instructions.

According to a research, design errors, one of the identified deficiency in design documents, are the leading cause of failures, accounting for an enormous 80-90% of infrastructure failure (Love et al., 2012).

On the authority of Lopez et al. (2010), design errors have played a critical role in a number of disastrous accidents which have led to both the injury and death of subordinates and public members. He then goes further to discuss that design errors arise due to a variety of factors that may interact with each other. Finally, he concludes by stating that people and project management policies provide the greatest potential in reducing errors by the procedure of situated learning. An explanation for this is that the environmental condition provided by the organization and the method utilized to perform the project effects the subordinate's ability to perform tasks.

A case study of a school situated in Nepal implemented by Acharya et al. (2006) demonstrated to what extent deficiency in design documents, particularly design errors may extend and have an influence on a project after its construction. From the study, it was found that the shortcomings of the designer in terms of experience, coupled with other faults on the part of contractors, not only amounted to a twofold increase in the cost of work for the project office, but also lead to a tarnished image. To make matters worse, the users of the facility, teachers and students in this case, were also constantly disturbed by the flaw. Here, the primary cause of the error was the incompetency of the architect, but other factors served to exacerbate the situation.

Based on the study performed by Haydl and Nikiel (2000), DDD may go undetected in the design phase propagating into the construction phase. This ushers in negative repercussions for the entire project. A case study by the same researcher, where an ill-advised deduction was made by the designer, resulting in construction failure, which, in turn, amounted to a costly design change, substantiates this claim (Haydl & Nikiel, 2000). Additionally, the research displayed that designer err due to insufficient knowledge of fundamental engineering procedures and deficient generation of details. A case in point of poor knowledge was seen in an incident where structural members were incorrectly designed. More precisely, it was found that the designers placed redundant bracing. This not only escalated the cost but, contrary to the intention of the designer, also made the structure susceptible to failure.

According to Cusack (1992) errors in design documentation can materialize to 5% of the project's contractual value. Furthermore, if these contractual errors lead to engineering disasters, costs will substantially rise (Love et al., 2011; Love et al., 2012).

A research conducted in Australia discovered that a stunning 92% of the deviation in the construction industry could be traced to design documentation errors with the consultant having a 60% portion of this deviation (Dosumu & Iyagba, 2013)

Hancher et al. (1990) defined design deficiencies as ‘conflicts, omissions, or errors’ contained in the design documents that are overlooked during the design stage and make their way into the construction and/or operational stages where they can inflict damages. He characterized them as having one of the following three traits (Abolnour, 1994):

1. “Contract document conflict”: Contradiction among the drawings and specifications.
2. “Interdisciplinary coordination errors”: Clashes between various facilities’ systems, including structural, mechanical, and electrical systems.
3. “Technical compliance discrepancies”: Failing to comply with ‘design guidelines, technical specifications, and building codes.’

Moreover, a majority of design deficiency impact the owner or end-user by effecting at least one of the subsequent elements:

1. Satisfaction of the owner
2. Schedule of the project
3. Construction and operational outlay
4. Safety of the user
5. Morale of the user

With respect to the negative effects of design deficiencies, the resulting conflicts that ensue due to them, more often than not, harm the owner by prolonging the project duration and mounting the cost of construction. Total project cost is also vulnerable to increases in consequence of the contractors raising their bids to shield themselves against conflicts, or omissions within the contract documents. Time spent to administer the project may also be eroded owing to "negotiations, arbitrations, or litigations" between the contractors and designers as they attempt to seek for solutions to design deficiencies (Hancher et al., 1990).

Hancher et al. (1990) asserted that design deficiency accounted for nearly 50% of all construction contract amendments. In addition, they noted that there existed a proclivity that these errors will incur defects in the course of the project's operational life.

On the authority of Vlatas (1986), design deficiencies are key contributors to claims. According to him their proliferation are due to the intricacies of work, new and various design and construction associations between the experts, and the rush to complete projects.

Kirby et al. (1988) suggested that the introduction of design reviews in order to enhance constructability and quality had the potential to decrease project costs, the need for contract alterations, and litigations (Andi & Minato, 2003).

Abolnour (1994), who studied the connection between the fee structure in engineering offices and design deficiency in Saudi Arabia, concluded that design related problems had a non-linear inverse correlation with the design fee quantity. More specifically, project cost related to design issues plummeted with the increase in design fees until reaching a certain optimum fee amount, this fee being 3% of the total project cost. Abolnour (1994) then went further to explain that the two disciplines, residing in the design office, that had the strongest influence in regulating design deficiency were the architects and electrical engineers. Thus, he proposed that design deficiency cost may be quelled by enhancing these specialties by way of increasing personnel and experience. Finally, he identified four other factors that impacted design deficiency: (1) quantity of construction managers, (2) quantity of personnel within office, (3) chief structural engineer's experience, and (4) office's field experience. Likewise, McGeorge (1988) recognized a similar trend of escalating project cost as the design input was lowered below a certain threshold. Particularly, he performed his research by analyzing the design process as an integral portion of the entire project life cycle. The result of his findings illustrated that the design stage played a pivotal role in influencing the overall life cost, as well as other dimension of a projects success. Subsequently, he argues that since the design cost forms a small portion, falling in range of 2% to 10%, of the entire cost, it becomes advantageous to dramatically raise the effort of the design to realize a relatively minor lowering in the construction cost. The rationale being that the construction cost represents a big chunk of the total project cost. Thus, even a minute reduction in it will produce enormous savings. To support this view, he provides a hypothetical example where the design input, representing 5% of the total cost, is increased by 50%. As a result, the construction cost falls by 10% and the entire cost decreases by 7%, which signifies a saving of approximately 3 times the cost of the added design exertion. Unfortunately, in practice this view is shunned, which is evident by the established scheme of consultant payment and the lack of care of the owner in matters concerning design (Tilley & Barton, 1997).

Based on a research conducted by ‘The Building Research Establishment in the UK,’ 50% of building errors originated from the design phase, while 40% were from the construction phase. According to this, it can be seen that a large portion of errors originate from the design stage. Another study performed in 1987 by National Economic Development Office reported that one of the cardinal factors that impacted quality were related to inadequate workmanship and design, for instance, poor coordination of design, ambiguous and missing documents (Love et al., 2004).

A study performed by Andi and Minato (2003), relating to the quality of Japanese design documents, outlined that the problem of defective design is in fact complicated and deeply entrenched in a system. In addition, it was found that these design defects may stem from individuals, organizations, the construction industry, or may go all the way up to global or national extents. The implication being that defective design are intricate. Furthermore, drawing from the replies of the research’s survey, it was inferred that the drop in design fees in tandem with constrained time available for the design phase paved the way to the emergence of poor quality design documents. Referring to the design fee, according to Andi and Minato (2003) the clients in the process of decreasing fees to save money were, in fact, unbeknownst to them, doing harm to the project by cultivating an environment of errors. More precisely, the attempt to retain money by compromising the design may have an unfavorable impact equal to a ratio of 100 to 1on the project’s life cycle cost.

A study by Kartam and Kartam (2001) performed in Kuwait, which aimed to gain a contractor’s perspective of construction risks along with effective methods utilized for the management of these risks, demonstrated that defective design was ranked (4th out of 26 factors) amongst the top reasons for construction delays. The survey brought into light the fact that contractors were heavily hurt by lack of information and erroneous design information.

Another study in the USA run by Kangari (1995), with the purpose of understanding the attitude large U.S. construction firms had with respect to risks, established that defective design were considered to be among the most significant risk categories encountered in construction projects. This risk was deemed to be especially important to the contractor when performing the project under lump-sum or a unit-price contract.

Hong Kong, and Japan, all reported that DDD were ranked amongst the top causes of project schedule overruns (Andi & Minato, 2003).

DDD have been treated with great reverence due to their potentially deadly capabilities which, in some instances, if undetected, may incur a number of failures, including structural, civil and geotechnical. Such cases include West Gate Bridge and Tay Bridge (Love et al., 2008).

A study conducted by Burroughs (1993) found that a prominent Australian contractor underwent a rework expenditure that was equivalent to 5% of the contractual amount. When investigated it was found that the costs all pointed to the design consultant's poor documents. More disconcerting are the findings of Gardiner (1994) which approximated the cost related to rework at 20% of the designer's fees. He goes on to argue that the quantity of errors found in the design consultant's documents are overwhelmingly high and that it is imperative for them to enhance the manners in which they administer their work if this problem is to be averted (Love et al., 2004, p. 427).

Whether a project attains its planned goals or not is largely dependent on extermination of errors from the design documents. This claim is supported by a study undertaken by Kirby (1983) and Morgren (1986) who was able to illustrate that 56% of contractual alteration were needed to rectify design insufficiencies (Mohammed, 2007).

DDD and design changes play a major role in producing the need for rework. (Barber, 2000) discovered that when the indirect costs associated with rework are included, the overall cost can reach a staggering 23% of the contract value. Similarly, (love, 2002) demonstrated that the indirect cost associated with correcting rework can be many times more than the quantifiable direct cost of correcting the error (Love & Edwards, 2004).

In conclusion, it can be seen that DDD play an integral role in how a project ends.

2.2 *Design*

This section gives a brief introduction to what constitutes design, the definition of DDD and the various stages where they may be discovered.

2.2.1 What is design

It has been claimed that design is central to a project. The proper administration at this stage has a great influence to the success of any project. The functions of the design stage are listed below (Mohammed, 2007):

1. Explain the needs of the project
2. Form a design solution according to the accepted project needs
3. Once design solution is accepted by the client, documents pertaining to construction are formed
4. Aid the owner in soliciting proposals from contractors for the biding stage

The documents prepared by the designers are composed of the drawings, specifications, schedules, and the bills of quantities. The bill of quantities and schedules were omitted in this study. Figure 2.1 provides a schematic of these four documents. Following is a brief description of each of the two documents reviewed in this research(Mohammed, 2007).

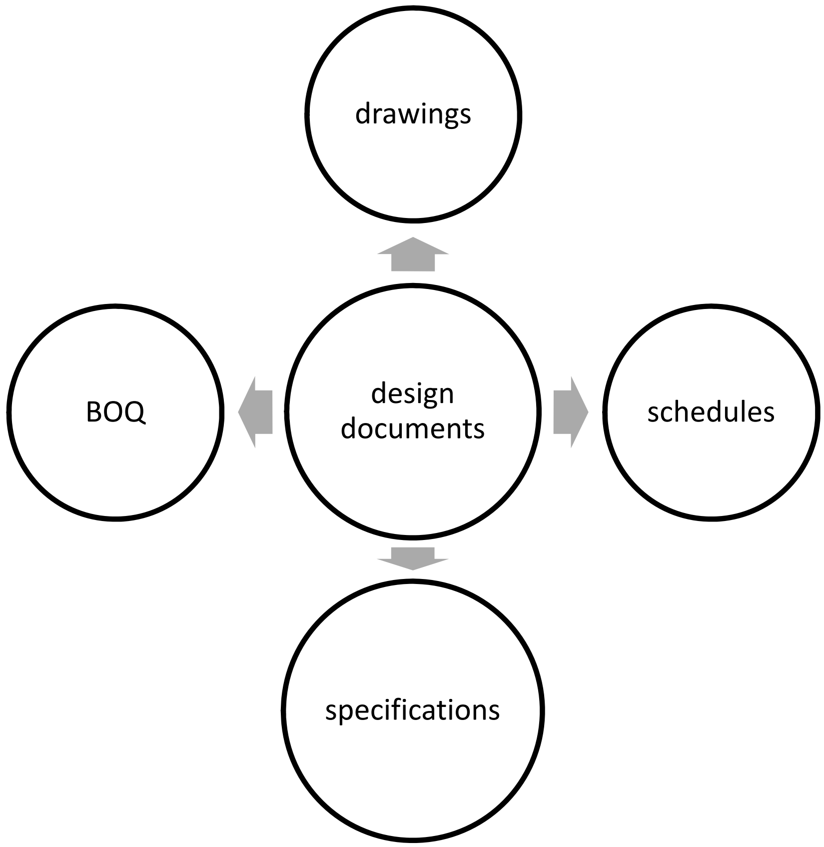

Figure 2.1: Design documents

Drawings: These consist of the structural, mechanical, electrical, architectural drawings. They are used to convey the work to be performed by both the contractor and subcontractor. They display this work graphically and quantitatively, illustrating the layouts, positions, interrelationships and measurements of the work. The types of drawings include the site and building plans, various elevations, sections, detailed drawings, and schedules.

<u>Specifications:</u> Act as a supplement to the drawings. They portray the required standards and qualities of the materials employed in the construction. In addition, they delineate the necessary level of service needed to accomplish the work.

The intended goal of the design documents are to (Mohammed, 2007):

1. Help inform the owner, with precision , the scope of the project
2. They outline the contractual responsibilities of the distinct parties involved in the project. Once construction commences, the documents may be used as a management tool in determining cash owed between the owner and contractor
3. In certain instances, they may be enlisted for gaining financial approval required for construction to take place
4. They enunciate everything required for the performance of work which will eventually lead to the project completion. This covers quantities, qualities, and layout of the work.

Any breach of the above mentioned points may be considered an error.

2.2.2 Design document deficiency

Rework has been recognized for being the predominant cause of project cost and schedule delays. Rework is manifested by a number of factors. These range from changes, damages, failures, all the way to errors that may materialize with in the course of a project (Love et al., 2004). Further, it has been suggested that the key cause of rework can be classified as being: (1) client related, (2) contractor related, or (3) designer related. With respect to the designer related category, previous research found that design related problems represented a big portion of rework. When design problems are further investigated, they are seen to develop through two means: (1) formed either by changes, initiated by various parties involved, or by (2) errors and omissions (Palaneeswaran, 2006). It is the latter of these factors that will be investigated in this research.

The term error has been used by a great number of practitioners to have various shades of meanings. This is evident from the wide disparity, in a number of papers, pertaining to the calculation of error costs in various projects (Love & Josephson, 2004) Therefore, before moving into the specifics of the types and causes of DDD, it is of great importance to have a clear understanding of the definition of an error that will be adopted in this research. The following definition summarizes the term: *"An error is a means by which a course of action committed by an individual strays away from its intended or planned goal resulting in unwanted outcomes"* (Love et al, 2012, pp. 101-102). An adequate design is capable of achieving its proposed goal and can be built with optimum cost savings and safety. Conversely, an inadequate design fails to adhere to the quality stipulated by the client, contractor, or applied codes. A defective design can recognized by two indicators. First, parties other than the designer expressing disapproval. Second, manifestation of undesirable incidents within the site, for instance, failures and accidents. Errors in the design documents embody omissions, miscalculations and many others (Andi & Minato, 2007). These errors have a direct bearing on the duration, expenditure and quality target of the project (Mohammed, 2007). Table 2.1 lists the attributes of a quintessential design document (Andi & Minato, 2003; Al-Far, 2005).

Table 2.1: Characteristics of ideal design document

Attribute	**Description**
Complete	Presents all necessary information for conducting the job
Clear	Documents can be read and understood with ease
Standardized	Documents utilize standard detail and specifications
Consistence	Documents have consistency
Accurate	Documents do not contain any errors or omission
Precise	Does not contain conflicts and contradictions with other construction documents
Coordinated	Coordinates between various design disciplines
Compliance	Complies with applicable standards and specifications
Representation	The design documents accurately portray the site conditions (geological (sub surface) and topographical conditions (surface)). In addition, it also displays existing utilities and structures

Errors may occur once, or, in some cases, reiterated without ever being noticed. Consequently, they vary in degree. When detected early, the damage they cause may be limited. On the other hand, if found at much later stages, these errors are afforded the chance to spread across the entire project, resulting in the introduction of damages that can be detrimental and in some cases, as mentioned previously, even catastrophic (Love et al., 2012). They are known to have a profound impact on safety issues related to the site and even the occupation of the final built facility long after its construction. In some extreme cases they have been known to result in deaths and injuries (Lopez et al., 2010). Furthermore, since these errors invariably lead to changes and rework, they are known to be the biggest contributors to late schedules and cost over runs (Love et al., 2011).

All errors initially stem from human shortcomings, resulting, in some cases, from the application of poor management practices. While it is well accepted that all errors are derived from human actions, it is, nonetheless, difficult to detect when they are first instigated due to the fact that they, after some period, become deeply embedded in the firm's process (also known as latent). Additionally, the role of late detection and change in location of the organization adds to the complexity of making such detections. Subsequently, it is these small initial errors that contribute to even more errors later on down the line, which, as a result, contribute to a majority of cost overruns that would have otherwise been avoided had these errors been discovered at their early stages (Love & Josephson, 2004).

Despite these errors being ubiquitous and introducing such adversarial issues, not a lot has been done to mitigate their recurrence, with innumerable projects experiencing cost and time overruns time and time again from similar errors. A paramount reason why this is the case is due to the slow learning pace of the construction industry. More precisely, the gathered data relating to the errors are not analyzed thoroughly to produce meaningful information in which the organization can learn from, hence, preventing the reiteration of these errors in the future. Consider, for instance, a designer who continuously produces erroneous drawings irrespective of the number of previously detected errors. Ultimately, the organization gains nothing from the gathered data. All this painstaking and non-value added work is due to the nature of the construction industry, where organizations are franticly flitting from one project to another seeking to produce profit (Love & Josephson, 2004). Another reason these errors continue to be an endemic can be traced to an individual's or organization's unwillingness to divulge their mistakes in fear of lowering their reputation. This again does nothing but hamper the learning process (Love et al., 2012).

2.2.3 Error discovery stages

Depending on what stage they are discovered, the errors in the design documents will vary in scale. This is owing to purpose of the documents at those stages and the people identifying the errors. The various stages at which the errors may be discovered are discussed in the succeeding subsections (Mohammed, 2007).

2.2.3.1 Quality assurance

Quality assurance (QA) can either be performed by the design team or by the client, provided that he has experience. The main drawback of this stage is that it may overlook certain errors and omitted items, especially when those responsible for conducting the review lack experience. QA mainly focuses on coordination issues and the layout of the drawings according to the office's technique.

2.2.3.2 Biding stages

This stage provides an easy means of estimating the cost of errors. The downside is that even though the errors might be noticed by the contractors, the contractor may resort to conceal the flaws in the hopes of gaining more profit by issuing change orders once construction commences. These errors pertain to those which effect the contractors in terms of cost and time.

2.2.3.3 Construction stage

Pertain to errors that surface once project construction commences. They may be detected by the contractor or supervision team. When discovered, they are documented in variation list so as to request for more time allowance or payment.

2.2.3.4 Operational stage

Pertain to the errors that are detected by the clients once the project is occupied. The errors are a byproduct of design errors, which, in turn, are a consequence of a designer's lack of knowledge or experience.

Noteworthy, as the project progresses through the various stages, the number of errors will decline while the severity of the errors increases, i.e. the cost of correcting the errors rises. Figure 2.2 shows a schematic of the stages.

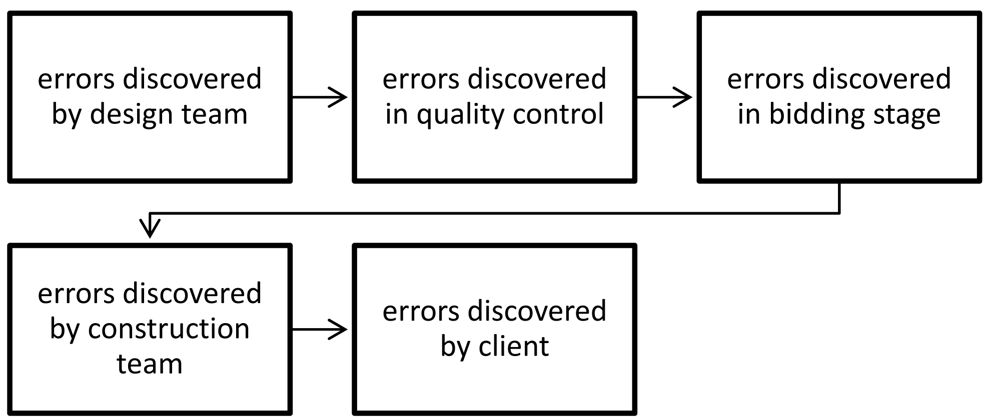

Figure 2.2: Stages of error detection

2.3 *Type of design document deficiency*

DDD strongly impacts a construction project. These problems usually surface either at the construction or occupation stages of a projects life. Top issues introduced by DDD circumscribe spreading of failure, escalation of costs, time overruns, claims and disputes, injuries, design-induced rework, and inconveniences (Sunday & Afolarin, 2013). Recalling Figure 2, it was seen that the documents that the designers develop are of 4 types: (1) drawings, (2) specifications, (3) bills of quantities, and (4) schedules (Sunday & Afolarin, 2013). The forthcoming sub-sections discuss the array of errors that one might encounter in the design documents.

2.3.1 Not complying with design parameters

2.3.1.1 Nonconformance to client's specification

When a project is first initiated, a document detailing the main requirements of the project is produced. Contained in this document are information regarding the ultimate objective of the project, the various activities that will be conducted and other information that will act as a road map for preparing additional construction documents. This document sets the stage for the project to begin, since the big picture of issues pertaining to facility requirement, project due date and costs are all set. The client influences this document by setting certain bounds relevant to the scale, quality, and budget. If there is any misunderstanding in the process of obtaining information from the client, such that there is a failure to meet what the client wants, it will be considered an error. Additionally, if indeed it can be substantiated that the documents feel short of meeting the client's constraints, the client is capable of ordering the designer to correct the error (Mohammed, 2007; Lopez et al., 2010).

2.3.1.2 Nonconformance to building code

Building codes provide guidelines that outline the minimum requirements of safety for a constructed building. Accordingly, since these codes provide the primary design requirements for a great quantity of design and construction detail, they act as a form of restriction for a building's design. Due to the fact that incompliance to the code inevitably leads to necessary change, subsequently, delaying the project, adherence to these codes is required of the designer. The severity of this error lies in its ability to go unnoticed until the period at which the building is occupied. By then, if any damage is incurred on the public, the designer may undergo legal liabilities and even a cancelation of practicing license. Another negative aspect of this error is that even if the owner authorized the negligence of the code or an official failed to find the code breach, blame will still lay on the shoulders of the designers (Mohammed, 2007).

Some examples of building codes are listed below:

2.3.1.2.1 Fire Protection

Imposes the parameters for the size and category of building that should incorporate sprinkler systems. The size of the building or occupied area that is bounded by outer walls, firewalls, or fire barriers are the factors that dictate the parameters. One code, known as the ICC, requires that every hospital, nursing homes, hotels, motels, and apartments embrace automatic sprinkler systems (Demkin, 2008).

2.3.1.2.2 Height and area

This code regulates the bounds for the height and area of the building. Many factors are linked to them, occupancy and if the building will be entirely protected with sprinklers being the most critical of these factors (Demkin, 2008).

2.3.1.2.3 Means of egress

Exiting, which is also referred to as egress, is amongst the main code conditions which has a direct bearing on the design of a building. Restrictions on the maximum distance that an occupant must move to access an exit in a specific occupancy (or occupancy category which the codes make mandatory to determine. For example, “group A-1 Occupancy” refers to occupants of a theater) are presented within this code(Demkin, 2008).

2.3.1.2.4 Water / plumbing codes

This code provides the specifications pertaining to a building’s water supply and plumbing fixtures (Demkin, 2008)

2.3.1.3 Incompatibility with vendors data

As a result of this error, a number of techniques have been devised, which include partnering and simultaneous engineering, among other techniques. The goal is to get suppliers involved in forming the documents. To optimally utilize a vendor's product it may be essential to acquire certain equipment, material, or follow some stipulation. The error arises due to conflict between equipment, obsolete specifications, and wrong materials. Due to the change orders, the byproducts of this error are completion date delay and a rise in cost. In order to combat such project impediment it may be necessary to have the clients accept vendors at the project's initial design stages (Andi & Minato, 2003; Mohammed, 2007).

2.3.1.4 Nonconformance to law

These errors represent those documents that do not adhere to the laws enforced on particular clients or projects. An instance of this is a law that makes it imperative for an organization working under the government to make use of local material and suppliers. Again, these errors, assuming discovery transpires at the construction stage, raise cost, if cost of local material is found to be higher than the materials already employed, and hinder progress (Andi & Minato, 2003; Mohammed, 2007).

2.3.2 Coordination

2.3.2.1 Coordination amongst drawings

Synchronization problems between drawings, elevations, sections, and detail drawings, conflict in drawings and calculations, and contradictions between drawings and specifications cover this document error. As with the prior error, if the errors are found belatedly during the construction stage claims will be raised (Andi & Minato, 2003; Mohammed, 2007).

2.3.2.2 Design team coordination

These errors embody omissions and errors in the drawings and specifications due to coordinating problems between the various design teams. This problem may present itself in the form of clash between structural, mechanical or architectural drawings. For instance, the HVAC system's ducts may cover windows, or an electrical room may not have enough space to fit an equipment. These errors arise due to insufficient consideration to detailed design, designers failing to coordinate, or due to the fast pace nature of construction projects. In the occasion that the errors are discover during the construction phase, the contractor has the privilege to prolong the duration and receive reimbursement for correcting the drawings (Kagan, 1985; Andi & Minato, 2003; Mohammed, 2007; Sunday & Afolarin, 2013).

2.3.3 Not following procedures

2.3.3.1 Errors in symbol and abbreviation

Symbols and abbreviations are utilized to add information to the various design documents. When these annotations are not consistent between the various design documents, confusion may quickly arise. Time will then be expended while waiting to receive clarifications from the designer. Contractors will then appeal for extra time (Mohammed, 2007; Sunday & Afolarin, 2013).

2.3.3.2 Errors in dimension

These errors cover issues related to dimensions not summing up, contradictions of dimensions between the drawings and schedules and missing dimensions. They prolong the project due to the time taken away as a result of the contractor being ideal while waiting to receive explanations concerning the dimensional problem from the designer (Andi & Minato, 2003; Mohammed, 2007; Sunday & Afolarin, 2013).

2.3.3.3 Failing to follow drafting standards

Document standards are utilized to reduce ambiguities, form a level of coherence amongst the various drawings and between projects. In addition, they can aid in producing the construction documents. They circumscribe aspects relating to:

1. Paper size, scale, arrangement
2. Thickness of lines, and font size
3. References contained in the documents
4. Notes and abbreviations
5. Dimensions

This error represents a problem since there is a propensity to confound the contractors when the task of estimating the project's cost comes into play. At the end, the designer's popularity with the contractor and owner will fall as a result of the fractured image (Mohammed, 2007).

2.3.4 Omission

2.3.4.1 Wrong or omitted callouts

Designers use callouts to further elaborate certain features in drawings. They may, for example, describe the thermal insulation to be used in walls. In some cases, callouts might be omitted in areas where they are compulsory, or the callouts might be ambiguous, calling for extra information. If the contractor wrongly interprets these unclear callouts, change in variation orders might be necessary (Mohammed, 2007).

2.3.4.2 Wrong or omitted notes

Text on drawings that are applied to explicitly state the intentions of the designer, or explain the drawing's contents are known as notes. Some of the errors that may be encountered in this taxonomy include placement of notes not relating to the drawings or details, the notes failing to explain the intent, or the need to have extra notes for the drawings to be comprehensible. In either of these cases, the byproduct will be claims to compensate for time and cost incurred (Andi & Minato, 2003; Mohammed, 2007).

2.3.5 Errors

2.3.5.1 Design errors

These errors encompass the technical issues of design. They are considered to be the most severe types of errors as they relate to mistakes made by the designer due to inadequate education, knowledge, or work experience. Missing items and failure to consider some important items in the design are the usual cases of design error. One instance of this category of error is a case where a designer failed to account for a suitable height of a mezzanine floor. Consequently, the floor was incapable of being utilized as a renting space. At best, added time and cost will be mandated in order to make the necessary corrections and amendments to the documents (Mohammed, 2007; Sunday & Afolarin, 2013). At worst, these errors may lead to injuries and even deaths. Some other more technical examples of design errors and their repercussions are presented in Table 2.2 (Minato & Andi, 2003; Lopez et al., 2010).

Table 2.2: Previous DDD and negative outcomes

Design error	Outcome
Inadequate design to a bridges bracing and fastenings exposing it gale forces	75 people killed
Errors in box-girder design of a bridge	35 people killed
Lack of proper structural design	33 people killed
Failure to consider design integrity of floor	5 people killed and 5 more hurt
Designer used wrong number to design conduit pipe	More than 5 million yen required for construction rework

2.3.5.2 Specification errors/incompleteness

Specifications are generally classified into two families. They can be either be design or performance specifications. Design specifications outline what is needed to achieve a design. Performance specifications, on the other hand, state the final requirement without going into the specifics of how to attain the desired outcome (Arditi et al., 2002). These specifications transcribe the needed requirements of equipment and materials. Furthermore, they enunciate the needed workmanship and product quality. The types of errors covered in this category include: Omitted items, items available in drawings but not included in specifications or contrariwise, and items that fail to meet the requirements of the client. These errors, in a similar vein to the other errors, when discovered at construction stages, will prompt claims (Mohammed, 2007; Sunday & Afolarin, 2013). Also, issues contained in specifications will hinder the consultant’s ability to implement constructability, a technique that greatly enhances the quality of design documents. According to Arditi et al. (2002), incomplete specifications ranked second amid the factors that prevented the application of constructability.

2.3.5.3 Insufficient detail

These deficiency are caused by the design documents not portraying adequate detail pertaining to connections or intersections. As an outcome, the contractor will request detail on the exact way of performing the construction. Once the explanation is received, the contractor might issues a claim, stating that the work that was expected was far less than what is required. In other cases, the designer may issue unsolicited information concerning details that were not precisely illustrated on the contract drawings. In this case, the contractor may file a change order, claiming that he anticipated less costly details (Kagan, 1985).

2.3.6 Other

2.3.6.1 Operational issues

This relates to the ease or difficulty in operating the final built project. Any inconvenience caused to the owner from poorly made design decisions, producing poor quality and high maintenance costs fall within this category of document error. The resulting side effect is a lost in the reputation of the design consultant (Mohammed, 2007).

2.3.6.2 Constructability

Constructability is concerned with the practicality of the design. More specifically, it relates to the level of agreement of the design to the site; materials used; method to construct; schedules; and construction. Furthermore, it can be described as the ideal employment of construction knowledge at various stages in construction to attain the project's goals. Much like operational issues, the chief problem faced when confronted with this error is its obscure nature. Typically, more experienced staff will be capable of detecting such flaws. This error may be ascribed to deficient knowledge or experience of the designer. Should this error be left to materialize at the construction stage, change orders may ensue, which, subsequently, may impact the project's budget or prolong the project's duration (Mohammed, 2007).

2.4 *Factors contributing to design document deficiency*

This chapter introduces the various factors that lead to DDD. It is divided into two main parts. The first section deals with the more broad factors that lead to the establishment of DDD. The half delves into the more specific issues contributing to DDD.

2.4.1 General factors

It may be argued that all errors are instigated by the actions/lack of actions of humans. That is to say, all errors owe their existence to humans. The three main types of human errors that incur deficient documents are listed below (Minato & Andi, 2003; Lopez et al., 2010):

1. **“Skill-/Performance-Based Errors”:** where the plan of performing a particular task is adequate but errors arise due to negligence on the part of the person performing the job. Hence, these types of errors are related to “lapse” (where one’s thinking is preoccupied by concerns not related to the job) and “slips” (where an individual’s work deviates from the work of the entire team). As a result, these types of errors can occur anytime during the “input, storage, or output stages”, and are regularly the result of distractions. Slips and lapses cover mistakes in typing, entering erroneous data, drawing incorrectly, failing

to read correctly (tables, outputs from computers, standards), erring in calculations (volume) and omission. For instance, an architect while working on a design may be interrupted by a phone call, regarding, for instance, clarification of a document. On returning to resume the design he/she may miss a point or incorrectly input data due to the prior distraction. The error here being a consequence of the disturbance of the train of thought.

2. **“Rule-/Knowledge-Based Errors”:** These errors can be more generally categorized as mistakes. The mistakes can be more specifically classified as either being “Rule-based” or “Knowledge-based”. “Rule-based” errors are misapplications of correct rules on the work at hand whereas “Knowledge-based” are applications of rules that are all together not suitable for a particular work (Love et al., 2011). Here error arises from, in contrast to the previously mentioned ‘skill based errors’, a plan that is not appropriate for performing a particular task. In this case the worker applies fixed rules to rote tasks. This is done since these rules may have been successful for past work. On occasions that the worker is overloaded with work, they may apply incorrect rules rendering the performed work erroneous (Atkinson, 1996). One such example of this category may be a worker who is not well acquainted with a particular strategy of work. Eventually, he applies actions that are unsuitable for the desired goal. What contributes to this form of mistake is knowledge that may

either be insufficient, not accurate or all together wrong. Another more specific example may be a subordinate who lacks familiarity of how a system works thereby causing conflicts to arise in design

3. **"Intentional Violations/Noncompliance":** where error occurs due to the non-compliance of standards set by the organization. A typical example of this error is a designer who chooses to forsake certain organizational policy, such as dismissing the design review.

Table 2.3 outlines the major distinctions between the foregoing discussion of "skilled" and "knowledge" based errors (Embrey, 2007).

Table 2.3: Variation of knowledge and skill based error

Type	**Knowledge**	**Skill**
Proficiency level	Unskilled	Skilled
Mindset	Conscious	Almost non conscious
Environment	New	Adapted
Pace	Gradual	Quick
Effort exerted	High	Low
Feedback	Significant	Small
Reasons for error	- Overburden - Inadequate knowledge - Unaware of repercussion	- Interruptions - Commonly used rule misapplied - Change in work condition that does not prompt change in applied rule

Table 2.4 portrays a general taxonomy of the causes of design errors. This includes people, organizational practices, and specific project. Stated another way, all these

categories may play a pivotal role in the formation of DDD. In addition, these groups are all interrelated in one way or another (Lopez et al., 2010).

Table 2.4: Error causation division

Level	Classification	Error category
People	Loss of biorhythm	Skill/performance-based
	Adverse behavior	Violation/noncompliance
Organizational	Poor teaching/no experience	Skill/performance-based
	Lack of proficiency in use of automation	Rule/knowledge-based
	Insufficient quality control	Rule/knowledge-based
	Competitive fees	Skill/performance-based
Project	Client problems	Violation/noncompliance
	Time period limitation	Skill-/performance-based
	poor coordination	Rule-/knowledge-based
	Lack of appropriate attention to constructability	Rule-/knowledge-based

Although it is has been popularly viewed that design defects relate to technical issues, leading to many researchers touting solutions such as the improvement of technology, risk analysis, and reliability theory, a number of research have suggested that human and organizational factor play a dominating role (Andi & Minato, 2007). In fact, due to the shortcoming of the former approach in expressing only a few information in order to acquire knowledge on the reasons for the defects, this approach of viewing errors as technical issues predisposes the system to repeated errors (Minato & Andi, 2003). To tackle this problem, Minato and Andi (2003) looked at, in addition to technological factors, systematic factors that encompass psychological, social and managerial aspects. Andi and Minato (2007) proposed a causal mechanism, based on human error, that lead to design errors being realized. The mechanism generally categorizes the error inducing factors into workplace and organizational factors and the types of failures that pave the way to defects being realized as either active failures or defenses failures. With respect to these failures, active failures pertain to erroneous actions performed by the people directly in contact with the system, presenting themselves in the form of slips, lapses, and violation, which were discussed previously. Defenses failures, on the other hand, denote the ineffectiveness of the design review to detect errors (Minato & Andi, 2003). The resultant error is classified as defective design. This mechanism is outlined as follows (Andi & Minato, 2007):

1. The occurrence of design errors are usually associated to the action/inaction of the designer (as a single individual or in a group). These actions (also known as "active failures") may occur at any stage during the design process and may be a result of the 3 categories of human errors (Skill-/Performance-Based Errors, Rule-/Knowledge-Based Errors, Intentional Violations/Noncompliance)
2. "Active failure" in combination with "failure of defense" (poor implementation of design review) expose the design error to other parties (owner, contractors, and others). These design errors are a consequence of "active failure" and the impact of workplace and cooperation factors
3. Designers do not work independently. Rather, they work dependently with other designers accompanied with a variety of limitations. These limitations

come from the individual condition of the designer, the organization, the clients, or the larger global environment. Thus, errors in design should be viewed as a result of either a single or a multitude of these factors acting together.

4. Defective design may be a product of "organizational factors" introduced by the choices made by the designer's client and management. Consequently, two failure paths may be spawned. On the one hand, an active failure path may be formed. What this means is that "organizational factors" work in an indirect manner to cause the defects by way of inducing certain conditions in the workplace (workplace factors), which encourage the designer or design team to make "active failures." On the other hand, a latent path may be formed. Here, the "organizational factors" directly work on the efficiency of the design review, rendering it less effective in detecting any deficiencies
5. Thus, for DDD to be removed, a management paradigm should tackle the system's primary factors ("influencing factors") responsible for encouraging error development rather than "active failures" which are difficult to forecast. Hence, preventive actions are taken on the basis that it is possible to alter the working environment but not the disposition of people (Minato & Andi, 2003).

Figure 2.3 and Figure 2.4 present a schematic of the causal mechanism and an illustration of the active and latent failure path way, respectively, both proposed by Minato and Andi (2003). A close inspection of Figure 2.3 shows that the mechanism is built on three main factors: (1) influencing factors divided into organizational and workplace factors, (2) direct failures composed of active and defenses failures, and (3) outcome (Minato & Andi, 2003).

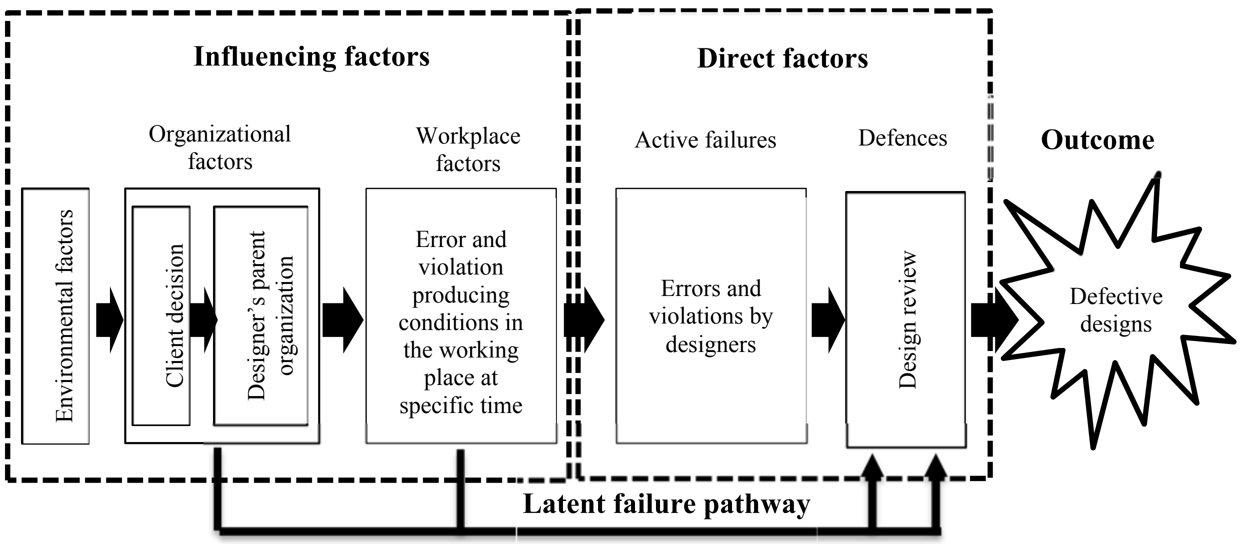

Figure 2.3: Defective designs causal mechanism (Minato & Andi, 2003)

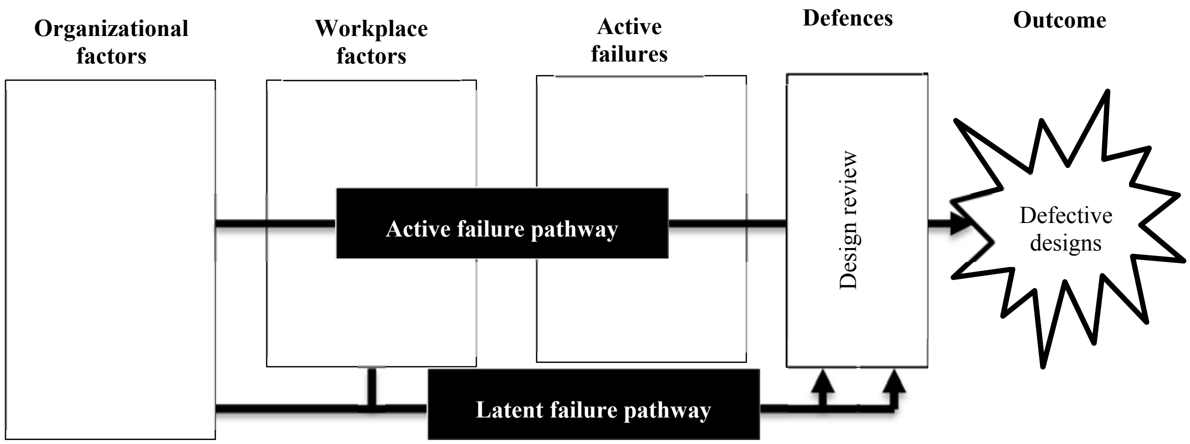

Figure 2.4: Active and latent failure pathway (Minato & Andi, 2003)

Workplace factors are related to the working conditions and encompass internal and external factors of the subordinate. Organizational factors are concerned with the designer organization's conditions. They, in an indirect manner, lead to the materialization of active failure by producing workplace factors (Minato & Andi, 2003). The paragraph below provides detailed definitions and examples of workplace and organizational factors (Minato & Andi, 2003; Andi & Minato, 2007):

Workplace factors: Conditions within the place of work that predispose designers to failures

1. Internal

   a) Psychological: Incentive, morale, attitude, trusting others

   b) Physiological: Pressure, exhaustion, work overload

   c) Knowledge, skill and ability: deficient knowledge

d) Informational

   i. Designer unware of variation in design information

e) Team work

   i. Poor team work with other disciplines

   ii. Conflict between individuals

   iii. Too much trust between groups

2. External

   a) Lack of time

   b) Lack of resources, such as equipment, manpower, or finance

   c) Insufficient atmosphere for working, such as noise, confined area, unhygienic, disorganized

Organizational factors: Conditions that indirectly result in active failure by means of producing workplace factors

1. Task management(lack of training and poor communication)

   a) Insufficiency in ensuring the correctness of the design input

   b) inappropriate duration for design

   c) insufficient site survey

2. Organizational

   a) lack of training and poor communication

3. Administrational
    a) Weak documentation system
4. Organization structure
    a) no one assigned responsibility for coordination review
5. Communication & coordination issues
    a) Insufficient cooperation among designers
    b) Insufficient interaction with outside parties

Ultimately, this research suggests that in order to achieve a reduction in errors, energy should also be focused on the client's and consultant's top management.

2.4.2 Specific factors

The preceding section demonstrated that errors arise from a multitude of factors. This section goes through the more specific factors that have been derived from the literature.

2.4.2.1 Poor training

As a result of the diminished profits generated, design consultants are unable to afford training their workforce. This can be attributed to the issue of the designers accepting work with low design fee (to be discussed in section 2.4.2.11). Consequently, the organization is incapable of providing training courses to further enhance its personnel (Tilley & Barton, 1997; Al-Far, 2005).

2.4.2.2 Designer's education

Another factor that influences the generation of errors in design documents is quantity and quality of education received by the design professional. A well-educated designer will have the needed knowledge to form the documents, find solutions to problems, and be able to communicate with the various construction disciplines (Mohammed, 2007).

2.4.2.3 Designer's experience

One of the constituents of DDD is incompetent personnel (undergraduates, fresh graduates or inexperienced part-time staff) who are simply incapable of conducting the task at hand. This incompetency, in the case of designers, leads to errors in the documentation process which can have a profound impact as time passes when they are discovered either by the contractors or sub-contractors. The lack of proficiency can be in the form of limited knowledge and capability in performing tasks. The reason why such practices are adopted is due to the presence of fierce competition which demands low fees. Thus, in a desperate attempt to produce more profit, the organization delegates work to inexperienced designers (Lopez et al., 2010). The amount of experience possessed by the designer will greatly shape the amount and types of errors in the design documents. Also, people who lack experience tend to consume more time in performing work and require more supervision when compared to their more experienced counterparts (Love et al., 1999; Andi & Minato, 2003; Al-Far, 2005;Love et al., 2006; Mohammed, 2007).

2.4.2.4 Design team cohesiveness

Refers to the compatibility of members in a team. I.e. The ability of the members in a design team to get along with each other. Since personalities differ, situations will exist where either cohesiveness or opposition will arise among individuals. Subsequently, teams may either be productive or unproductive. As a result, teams can be coordinated or uncoordinated. In the case where the team members are in conflict and disagree with each other, communication will suffer, dissemination of knowledge will be stifled, and errors in the documents run rampant (Andi & Minato, 2003; Mohammed, 2007).

2.4.2.5 Effective design team

An effective design team is characterized by the ensuing attributes (Mohammed, 2007):

1. Team members have a clear understanding of the roles and skills of one another
2. A sufficient mix of "functional/technical, problem solving, and interpersonal skills" between the individuals comprising the team
3. Particular set of team targets together with individual and organizational targets

4. Pragmatic targets that are unambiguous and of great significance to all the individuals within the team
5. All members feeling equally responsible

When such an effective team exist, issues pertaining to document's deficiency may be reduced. This is made possible since the entire team will leverage and improve the skills of the members who constitute the team, while at the same time altering and enhancing the work as time elapses (Mohammed, 2007).

2.4.2.6 Communication

The goal of a design team is to share knowledge and information so as to produce an optimized design. Thus, one of the prerequisites of working in a team is for the team participants to have the skill of communicating and collaborating. When there is a lack of communication among the team members, design quality suffers (Andi & Minato, 2003; Mohammed, 2007). The CNA insurance company reported that lack of communication was one reason why architects and engineers were producing errors (Brown, 2002).

2.4.2.7 Coordination of design team

At first, it might seem that the traditional (design bid build) approach is more susceptible to DDD, when compared to the nontraditional (design build) approach, due to the segregation of the design and construction team, but, contrary to this belief, the nontraditional approach may also undergo the same degree of errors. Granted, the nontraditional approach was established in order to tackle the problem of integration between these parties, but this has not deterred the quantity of error. Instead, the contributor to these errors lies not in the procurement method used, but rather on the way the organizations are managed. In this case, the problem may be attributed to the design organization implementing the same poor management technique of not bringing together the various teams. Additionally, in the nontraditional approach, the amount of concurrent work increases dramatically, subsequently forming a complex project whereby the entire process becomes more vulnerable to errors due to difficulty in coordinating and integrating the teams. Therefore, it is inferred that integration and coordination are factors that play a role in the degree of DDD. Simply put, the less coordination the more the DDD and vice versa (Andi & Minato, 2003; Lopez et al., 2010).

This lack of coordination is ascribed to the unavailability of individual/office who are designated the task of coordinating, comparing and deliberating details pertaining to the project with other disciplines to guarantee that the specifications and drawings are consistent (Tilley & Barton, 1997; Al-Far, 2005). In some instances the architectural consultant task may be confined to the responsibility of designing. Thus, they are not required to communicate with other disciplines. This also impedes the coordination (al-Far, 2005).

To illustrate this issue of coordination, a study conducted by Love et al. (2012) found that the failure of a designer to notice an omission of a storm water drain resulted in the contractor overlooking its inclusion in the bidding stage. This problem was then realized afterwards, rather belatedly, and proliferated to a cost of $100,000. What was the root cause of the problem? Poor design coordination. Noteworthy, intensive reviews were conducted but this was to no avial as the coordination was inadequate. Hence, this casestudy serves to demonstrate two lessons. First, how a seamingly minor mistake may evolve into an enormous issue. And, secondly, the significance of coordination.

Brown (2002) while conducting a project, reported that one-third of the change orders and one-forth of the time delayed were as a result of poor coordination among the disciplines. Based on his experience more than 50% of the errors and omission can be attributed to lack of discipline coordination.

Another parmount issue leading to poor coordination involves the designers working autonomously with out contemplating what influence their choices will have on the other disciplines. Again, this practice forms a barrier between the project teams, shuning any form of coordination. When information is received by the other teams furhter down the road, any error that may surface might be ignored. At other times, in order to complete their respective work, teams will have to work backwards to obtain the needed information, a time killing process (Love et al., 2012).

2.4.2.8 Improper use of CAD

With the advent of technology, it might be expected that designers would be less prone to errors, but, ironically, in practice this is not the case. Design firms fail to determine the practicality of the design produced by a software due to its automating capabilities. As a result, designers do not bother to recheck work for consistency. For example, a sectional view may illustrate something completely different from what is displayed in the plan view. This will pose a problem to the contractors who will be faced with a dilemma of what drawing to follow. Another problem concerning CAD is that of incompatibility of applications, meaning that designers are compelled to work with missing information (Tilley & Barton, 1997; Andi & Minato, 2003; Al-Far, 2005; Lopez et al., 2010;). Yet another issue with CAD is failure to keep files in sync. Specifically, lack of coordination (not clearly stating the alterations made) means that consultants are incapable of keeping changed files in line with the prime design firm. This effect is, of course, compounded with the passage of time as more changes are established by the prime firm (Brown, 2002).

2.4.2.9 Client

Issues pertaining to the clients that result in deficient design documents consist of (1) client experience, (2) lack of understanding and misinterpretation of the clients, and (3) unrealistic client demands. These are discussed more comprehensively below.

2.4.2.9.1 Client experience

The experience of the client has the ability to influence the quality of the design documents in terms of the document fulfilling the requirements of the client. This is due to the effect experience has on the level of communication between the client and designer (Love et al., 2008).

2.4.2.9.2 Misinterpretation of client on part of designer

A big issue in construction is the lack of contact and/or common understanding between the designers and client to attain an exact idea of what the client desires. This encourages omissions and errors in the documents. If not looked upon carefully, this issue can lead to major problems down the road. The inevitable outcome of this flaw is a series of change orders at the construction stage of the project. In particular, this problem stems from the absence of a common language amongst the designer and client. This is especially true considering that the client may not have any prior background on construction (Andi & Minato, 2003; Love et al., 2004; Lopez et al., 2010). In addition, the effectiveness of the communication is also influenced by type of client and their degree of experience. Typically, the client will tend to communicate with the designer indirectly. I.e. the message is altered through the politics of the organization. In some cases the client may delegate a representative to provide a means of communicating. Unfortunately, this further exacerbates the communication issue (Love et al., 2008). A study performed by Love et al.

(1999) which aimed to determine the main contributors to rework in projects, discovered that misinterpretation and inability to completely comprehend the clients requirements coupled with other shortcomings, such as lack of resources, were responsible for rework. By the same token, another study by Al-Far (2005) highlighted the need for the designer to expend sufficient time with the client such that a clear understanding of the project requirements is obtained. Similarly, Love et al. (2004) stated that inadequate communication among the design team and client fostered the fruition of document errors. Some of the factors, relating to the client and design team, that he identified as having a role in rework are:

1. Not enough finance allocated to the site investigation process
2. Insufficient time given to briefing
3. Deficient fees assigned to the design documentation process

2.4.2.9.3 Unrealistic client demand

Another problem originating from the clients relates to the unrealistic demands that they may impose upon the designers. These impractical expectations serve to add substantial stress on the consultants, especially when the process of choosing them is based on competitive tendering (Hanet al., 2011). The clients may enforce unrealistic demands in terms of fees, services and time (Tilley & Barton, 1997; Al-Far, 2005). With respect to time, clients may make it imperative for projects to be completed as early as possible leading to faulty and incomplete design documents (Love et al., 2004, p. 427). This is supported by Tilley and McFallen (2000), who demonstrated that the more the client expedited the project's completion, the more susceptible the designers were to forming contract documents that contained errors (Love et al., 2006). This issue was further echoed by Love et al. (1999) where architects and engineers asserted that they were provided insufficient time to form the contract documents. Furthermore, in a study performed by Laryea (2011) the contractors claimed that the time allowance for the design stage provided by the clients had markedly dropped. The consequence was substandard tender documents that in occasions resulted in as many as 100 queries.

2.4.2.10 Lack of quality assurance/management

Despite the importance of quality assurance, most designers choose to abandon this crucial activity. Added to this is the fact that individuals, as a result of great workloads, purposely do not allocate enough time to appraise their work for possible mistakes. More disturbing is that even design firms that employee a quality system, more often than not will eschew audits, checks, and verifications on the merit that it is seen an undertaking that is not only tedious, but also robs time and money. The design document's quality strongly sways the overall cost of the project together with the design firm's profit (Lopez et al., 2010). The Building Research Establishment (BRE) illustrated that utilizing quality management had the potential of fueling large cost benefits. Depicted in Figure 2.5 is the total construction cost saving that can be reaped if quality management is incorporated. With respect to the figure, it can be seen that the extra cost expended on the prevention (quality management) process produces a saving of 15% due to the removal of unnecessary future rework (Love & Edwards, 2004). Thus, the extra cost spent by the designers at early stages, say, on the coordination of the project's documents, will be repaid later in terms of

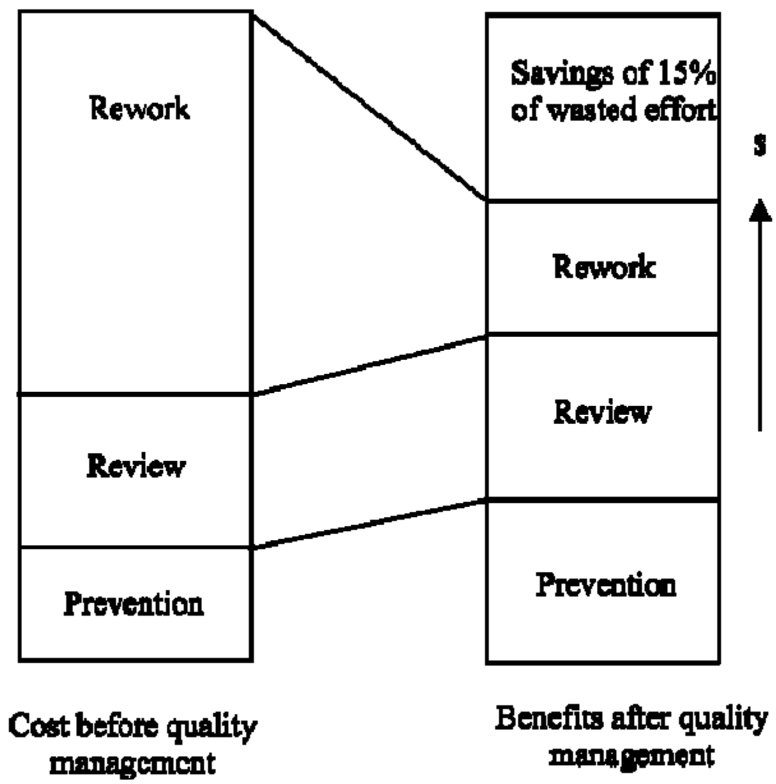

Figure 2.5: Cost and benefit of quality management (Love & Edwards, 2004)

lowered quality costs. This will consequently lead to an enhanced project performance (Love & Li, 2000).

The preceding paragraph illustrates the benefits of proper quality management, but it should be realized, though, that inspection has three profound limits. In the first case, inspections are by their very nature executed sporadically, meaning that there is a tendency to overlook certain errors. Secondly, those involved in the inspection process may themselves commit errors amounting to no gain in the added process. And, finally, the inspection process assumes that the error is conspicuous. In essence, inspection is not a foolproof method against errors (Mohammed, 2007).

2.4.2.11 Low designer fee

Often, it has been seen that a negative correlation exists between the quality of design and the cost of a project. This is understandable considering that all work will be based on the design. Usually, what results in poor design is the low fee offered. In an effort to produce profit, the designer resorts to the poor practice of excluding checks, revisions and quality assurance. Additionally, in some instances the designer may even employ inexperienced staff to meet the low fees offered. All these variables will have a profoundly negative impact on the quality of the documentations, which are the contractor's roadmaps (Love & Edwards, 2004).

According to Andi and Minato (2003) designers considered the practice in which the owners seek low design fees as a major issue influencing the quality of design documents.

In fact, the designers felt that the design fee provided by the public and private projects were inordinately low.

When design fees are raised, the amount of time available for producing the construction documents will also increase. Moreover, the consultant firm can afford to place more staff on the job. This added time and manpower will lower work pressure, thus, increasing communication and the ability to solve any problem that may arise (Mohammed, 2007). Several of the negative issues that poor fees introduce are listed in the subsequent sections.

2.4.2.11.1 Time boxing

A core issue resulting in poor design document is the fixed time, known as 'time boxing', assigned to the design process. Regardless of whether tasks are completed or not, the designer are obliged to submit the documents in the time allotted. In addition, imposing a limited time may mean that important tasks such as reviews, audits, and verifications are overlooked. This translates to the emergence of design errors during the construction phase (Love et al., 2004; Mohammed, 2007; Han et al., 2011). A research by Andi and Minato (2003) showed that the designers themselves considered the lack of time provided to be a paramount contributor to poor design document quality. This insufficient time may also be attributed to the improper planning undertaken by the management of the design team (Love

& Edwards, 2004). A list of several poor design management techniques are presented in section 2.4.2.18.

Mohammed (2007) argues that when designers are faced with limited time, the quantity of simultaneous activities undertaken rises. This diminishes the amount of coordination and communication, which will lower the amount of problems resolved. The final outcome will be construction documents having more errors.

Drawing from Love et al. (2012)'s research, insufficient fees and an impractical schedule to produce documents prompted a consultant to apply 'time boxing.' The justification for taking such an approach was to guarantee that the main components of the design were accomplished. As a result, adopting such a practice meant that the scope of work was decreased. At the end, discrepancies between the architectural and engineering drawings were discovered, leading to contractual variations.

Similarly, Al-Far (2005) and Tilley and Barton (1997) also reported that the lack of time available for the design is influential in the production of poor quality documents.

2.4.2.11.2 Design document reuse

A common trend employed by designers when faced with enormous job capacities is to reuse previous details and specifications from other projects, having no relation to the project at hand. This again lays the groundwork for errors. They do this as a means of cutting corners and having the work completed on time thus avoiding cost overruns (Love et al., 2012).

Love et al. (2011) stated that cutting corners by bypassing certain tasks and reprocessing previous specifications and “design solutions” encourages contractors to misconstrue the contract documents.

Al-Far (2005) concluded that one of the top factors (out of 39 overall factors) that contributed to poor design and documentation quality was that of copying and altering previous work so as to decrease time and cost. This breeds documents that are outdated and lack consistency.

Similarly, Busby and Hughes (2004) discovered that “pathogen oriented errors,”i.e. conditions that lay dormant within a system and play a role in the manifestation of errors, were contributed in large part by the subordinate’s “practices”, such as the reuse of design details, specifications, in conjunction with other contract documents while not considering the characteristics of the undertaken project in order to cut back on time and expenditure (Love et al., 2009).

Brown (2002) noticed that the quality of drawing’s details produced by CAD had plummeted. Frequently, the details were not even compatible with the proposed construction. According to him, the reuse and modification of details from different jobs or a manufacturer's readymade details could be blamed for the poor quality. In addition, new designers are denied the opportunity to learn how to form details.

2.4.2.11.3 Neglecting design review

Love et al. (2009) showed that cutthroat competition has meant that firms have adopted the practice of cutting corners and abandoning certain procedural tasks to accomplish the work given to them. For example, designers may regularly forsake design reviews to avoid incurring additional costs as a result of these tasks generally being precluded from the design fee (Love et al., 2011).

2.4.2.12 Lack of staff

The number of staff at hand with proper allocated time will have a bearing on the quantity of errors contained in documents. Adequate staff will lower the workload. This, in turn, will increase the distribution of knowledge and mitigate pressure amongst the staff. Finally, when knowledge is allowed to flourish, experience increase, which, ultimately, has the effect of thwarting errors (Mohammed, 2007).

2.4.2.13 Difficulty in finding good staff

This relates to the challenge in obtaining well qualified staff for writing specifications and construction details. One reason for this problem is professional have a tendency to seek better positions (Tilley & Barton, 1997; Andi & Minato, 2003; Al-Far, 2005).

2.4.2.14 Staff turnover

It has been recognized that human resource is a factor that may have the biggest influence on the failure of projects. Owing to the fact that humans are the ones who effectively perform relevant activities that lead to a project's materialization, they are taken to be the most significant risk. Aggarwal and Rezaee (1996) underscored this observation by noticing that in numerous occasions, management were forced to discontinue projects as a result of staff leaving. Why this factor has a profound effect on the project is as a result of the disturbance coupled with the gap of knowledge that follows when a senior staff member leaves an organization (Mohammed, 2007). Luth (2000) who briefly recounted the stages leading up to the disaster of the Hyatt regency offered several lessons gained from the tragic accident that claimed 114 lives. One of these lessons addressed the issue of disruption that emerges whenever there is an alteration in staff involved in a project. For this not to have a powerful impact, Luth (2000) proposed that "special precautions" have to be conducted to ensure that there is "smooth transition."

2.4.2.15 Simultaneous design work

As the number of concurrent work performed by the designers rises, the documents susceptibility to errors will correspondingly rise. This is because the preparation of drawings and specifications are expedited raising the likelihood of making mistakes and omitting items. However, some researchers have discovered that concurrency may in fact lower errors due to an increase in communication and coordination (discussed in section 2.4.2.7). But communication may well be hampered due to the resulting pressure (Mohammed, 2007).

2.4.2.16 Transfer of knowledge

It has been observed that an insufficient ability to receive criticism and learn from errors is amongst the largest contributors to poor design quality. The unavailability of a mechanism to transmit knowledge will mean that a task needs to restart from square one every time, meaning that errors that have been experienced in past projects are reiterated. In essence, not learning from past errors leads to future errors being realized (Mohammed, 2007).

2.4.2.17 Quantity of work allocated to designer

Organizations undertaking several projects will have limited resources to distribute to these various projects. Hence, the amount of errors produced will be effected by the capability of the design office to perform these projects. Stated differently, document errors will, to a certain extent, be dictated by the amount of resources at hand. Essentially, the less the resources, the more work overload experienced (Andi & Minato, 2003; Mohammed, 2007).

In a case study performed by Love et al. (1999), the architects and engineers of one of the reviewed projects accused lack of available resources, which meant that the scope of detecting errors was small, as the cause of incomplete documents.

2.4.2.18 Poor design management

The repetition of work in consultant firms have been attributed to a number of poor managerial practices. These are outlined below (Love et al., 2004):

1. Work to be performed not having estimated list of drawings so as to evaluate amount of work to be expected
2. Work failing to have design agendas according to the project's list of drawings. This means that particular design outputs cannot be recognized
3. Struggle to determine the status of the design

4. Doubt in informing other professionals (designers, contractors, clients) when information will be furnished
5. Hard time in vindicating resources needed according to actual amount of work

Lack of diligence directed to management leads to reductions in profit. Some examples of the specific types of non-value added rework that deteriorate the consultant's firm profit include (Love & Edwards, 2004):

1. Need to redo design due to insufficient briefing with client
2. Amendment requirements as a result of not checking documents
3. Need to re perform design as a result of improper drawing scale

To conclude, improved design management will automatically result in an enhanced plan of the work to be performed. Likewise, communication will also receive a boost (Mohammed, 2007).

2.5 *Consequence of errors*

Errors in documentation produced by the designers can pave the way to a vast array of problems during later stages of the project. Such problems may include, for instance, innumerable requests for information due to incomplete documentation. This, of course, will lead to loss in time which can only be recovered by more expenditure. Furthermore, another adverse outcome of errors is the claims and disputes that may arise as a result of confusions. Occasionally, the contractor may choose to interpret the information in their own way based on what is most convenient to them, but if this proves not to be the intended goal, the owner will mandate rework which will compel the contractor to file a claim in order to defend themselves from any financial lost (Lopez et al., 2010). Another major flaw that these errors introduce is that if and when the errors are discovered there would be pressure to rectify the error resulting in other types of errors.

2.5.1 Impact on project performance

DDD can have detrimental impacts on a project's productivity through the introduction of rework which entails the need for extra resources, time and costs. In addition, in the occasions where these errors are discovered at late stages during the construction process, even more resources will have to be expended, mandated by the need to demolish incorrectly built structures and reconstructing them once again. Occasionally, construction managers will try to circumvent these issues by amending the design and specification. However, if these revisions are not given great consideration, they may produce even bigger problems due to the change in sequence and needed resources (Han et al., 2011). Furthermore, the characteristics of DDD means that if a number of errors happen simultaneously on a particular work item, these errors will be additive in nature and produce a phenomenon known as "error traps" for the design firm (Love et al., 2012). Figure 2.6 below depicts the error detection cycle (Love et al., 2011). Additionally, DDD affect productivity by introducing non-value added time resulting from idleness, i.e. time in waiting and traveling (Love & Li, 2000).

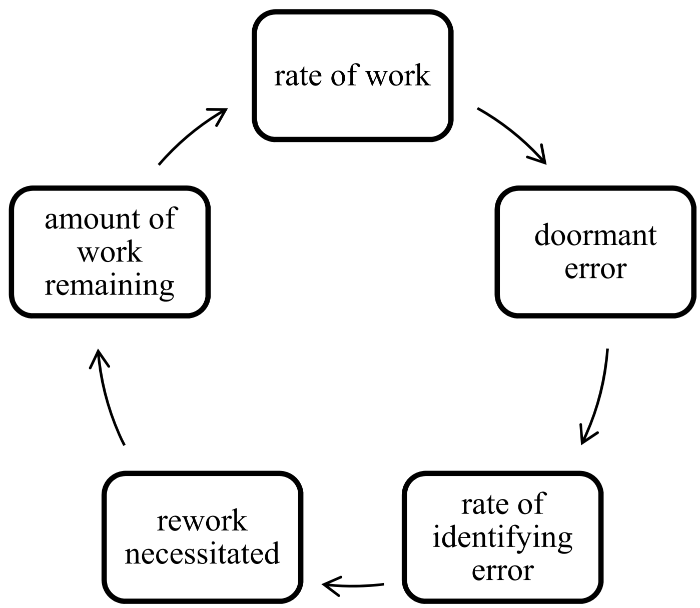

Figure 2.6: Error detection cycle (Love et al., 2011)

2.5.2 Impact on progress monitoring

In addition to introducing rework and design changes, DDD will also render the process of monitoring a project's progress useless. Thus, actions employed by project managers to reorient a project back on track after having fallen back becomes ineffective. Dormant rework increases the deviation between the actual and apparent progress and since the latter is the progress that the managers rely on when performing recovery actions, the impact of the recovery actions dwindles as the disparity between actual and apparent progress increases. Subsequently, the timely completion of a project becomes less likely (Han et al., 2011).

2.5.3 Raised estimates

Due to the possibility of errors in the design documents, designers prefer to add contingencies in their estimates so as not to be liable to potential cost overruns. This contingency is commonly concealed and will lead to the unproductive utilization of resources (Love & Edwards, 2004).

2.5.4 Impact on contractor

Deficient drawings and specifications foment additional work for the contractor required to rectify the generated deficiency. They consume the time of the contractors as they await for solutions from the owner. Furthermore, they interrupt the workflow of the contractors by coercing them to sequence their work such that the impacted region may be circumvented until the owner reaches a decision on the necessary actions (Long, 2013). Errors and omission in the contract documents may also necessitate the contractor and subcontractors to repeat certain work. The problem is further exacerbated when items such as supervision, scaffolds and crane are needed (Love et al., 2006).

A study conducted by Love et al. (1999) showed that site management had to expend between 30 to 35 hours a week for a stretch of 10 weeks inspecting architectural, structural and service drawings to make sure that dimensions and other items were consistent with each other. On discovering the errors the designer had to redo the design and reschedule the effected components.

2.5.5 Change orders

Deficiency in design documents beget change orders. For example, conflicts in coordination between the various drawings, such as architectural, structural, and mechanical, found at the construction stage will prompt the contractors to raise change orders for rectifying the discrepancies (Kagan, 1985). In some cases an unrealistic design due to the absence of constructability will result in change orders. In either case, the amount of change orders being issued have a strong ability to impact the time and cost of the project (Mohammed, 2007).

2.5.6 Error exploitation

A number of contractors have adopted the practice of seeking mistakes in the drawings and specifications. More precisely, when these errors are discovered, the contractors may leverage them to gain profit by way of change orders and claims (Brown, 2002).

A study conducted by Laryea (2011) made a similar observation. On conducting an interview with a contractor, the contractor stated that they would prefer to capitalize on errors found in the design documents rather than raise a tender query that would disclose "commercially advantageous information." Therefore, some of the approach used in pricing the project utilized errors.

Love et al. (2011) noted that when a situation which endangers an organization's profitability arises, "opportunism" follows. It was further observed that many times the contractor would leverage the contract as a means of securing extra money as a result of mistakes committed by the designers.

2.5.7 Rework

Rework has been recognized has a recurrent issue in the construction and engineering projects. Moreover, it is pivotal in the causation of delays and projects exceeding costs (Han et al., 2011). Love (2002) described rework as an unneeded work of repeating a task that was performed in an incorrect manner. Han et al. (2011) reported that typically rework plays a part in 52% of overall cost overrun, while also causing schedules to exceed by 22%.

In certain instances, errors may lay dormant with in a system and may become conspicuous after the passage of some time. At the time of their detection the issue of rework is realized. This sudden realization increases the amount of work needed to be performed by the subordinates. The extent of work to be performed is largely dependent on how long the error went unnoticed. Errors in dimension or space conflicts, for example, may only become visible once the construction of the project commences. If the error mandates a major alteration to be performed, all the previous apparent headway will be lost. Actions taken to alleviate the problem will result in added work for the subordinates and the probability of yet more errors being introduced (Love et al., 2009).DDD play a major role in producing the need for rework. Figure 2.7 portrays all the negative effects that DDD are capable of producing through rework (Love & Edwards, 2004; Love et al. 2006).

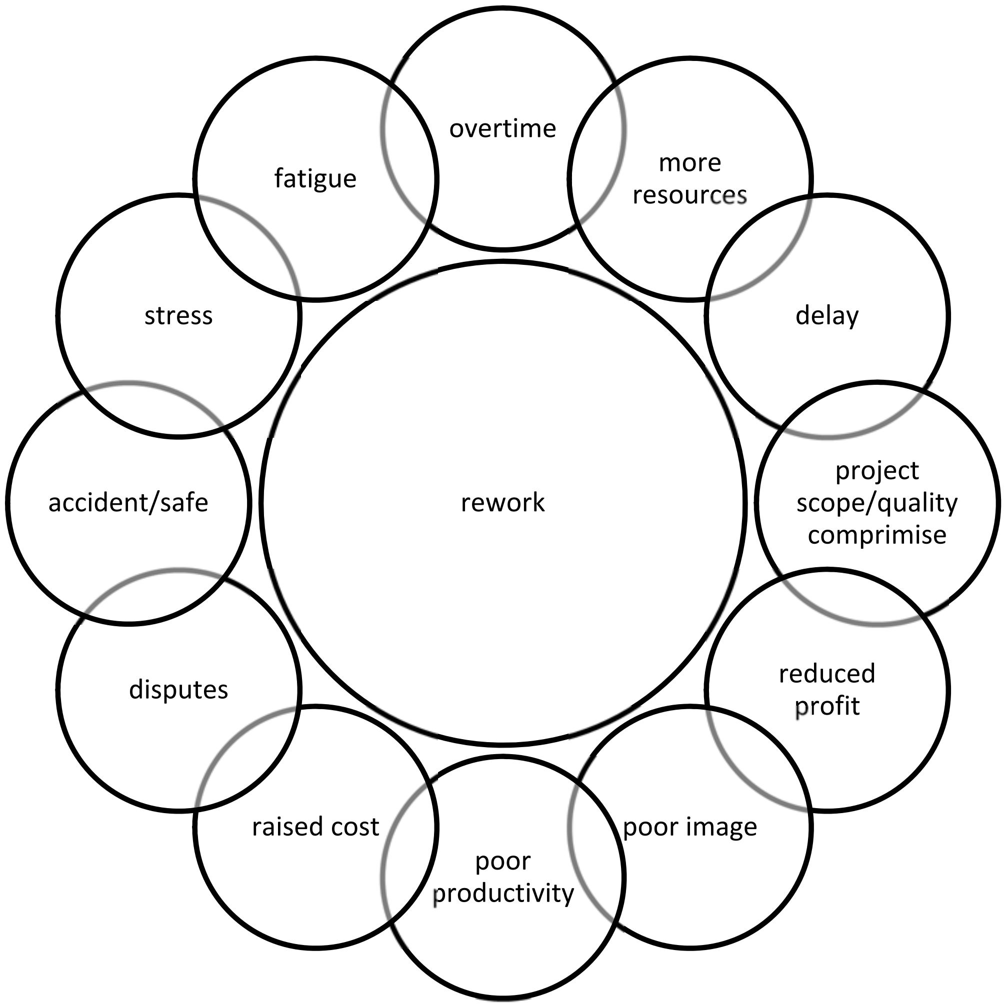

Figure 2.7: Consequence of design document deficiency

2.5.8 Consultant's profit

According to Stasiowski and Burstein (1994) consultants spend about 25-50% of man hours that should be dedicated to design in reiterating already performed work and amending discovered errors. The cost of this rework could climb to as high as 20% of their project fee. At the end, this only helps in diminishing the consultant's profit (Love et al., 2006; Mohammed, 2007).

2.5.9 Consultant's image

Errors found in the design documents form a negative image for the consultants, which, consequently, diminishes the prospect of future business. To support this argument, Mohammed (2007), in an interview, identified that the chief deterrent of clients from consultants was the quantity of errors contained in the construction documents, especially those associated with the designer.

2.5.10 Designer indemnity insurance

Since governments enforce indemnity insurance against the consultants, they will be held solely accountable for any error found in the design documents. This will lead to litigations imposed on them due to any lack of performance (Mohammed, 2007).

1. Higher costs
2. High estimates
3. Financial issues

2.5.11 Design changes

A case study, in which two projects were reviewed, performed by Love et al. (1999) (LOVE, MANDAL, & LI, 1999, p. 511) found that design changes were a regular theme across the projects. These design changes were rooted in errors contained in the documents. These design changes will in turn effect the projects duration and cost. In addition, the enthusiasm of the workforce will also suffer. Figure 2.8 below is an illustration of the connection between design errors and design changes.

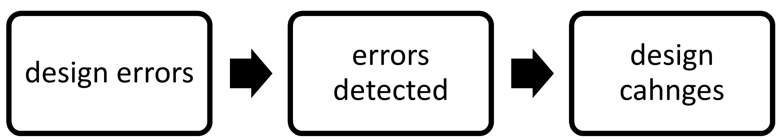

Figure 2.8: Relation between design errors and design changes (Love et al., 1999)

2.6 *Error prevention strategies*

While being able to discover errors is imperative to accomplishing a project's objectives, equally vital is the ability to determine the factors that produce them, that is, the causes (Mohammed, 2007). Love and Josephson (2004) acknowledged the difficulty in finding the causes of error as a result of the availability of numerous palpable causes which lead to the same error. Nonetheless, this quandary is resolved by focusing on primary cause of the issue at hand. This primary cause is called the ‘root cause.’ Similarly, Andi and Minato (2007) emphasized the importance of determining the “critical factors” that lay the ground works for repeated defective designs. Therefore, it is believed that by extinguishing these ‘root causes’ at the initiation stages of a project, the possibility of any future emergence of the error will be stifled and this will extend to enhancing control during the construction phase (Love & Josephson, 2004; Mohammed, 2007). Figure 2.9 depicts the apparent and root causes of an error.

Stasiowski and Burstein (1994) asserted that one of the paramount stepping stone on the endeavor to enhancement is eliminating the roots of the problems. He then references the work of Juran and Deming who stated that 85% of issues can be controlled by the management and not by workers.

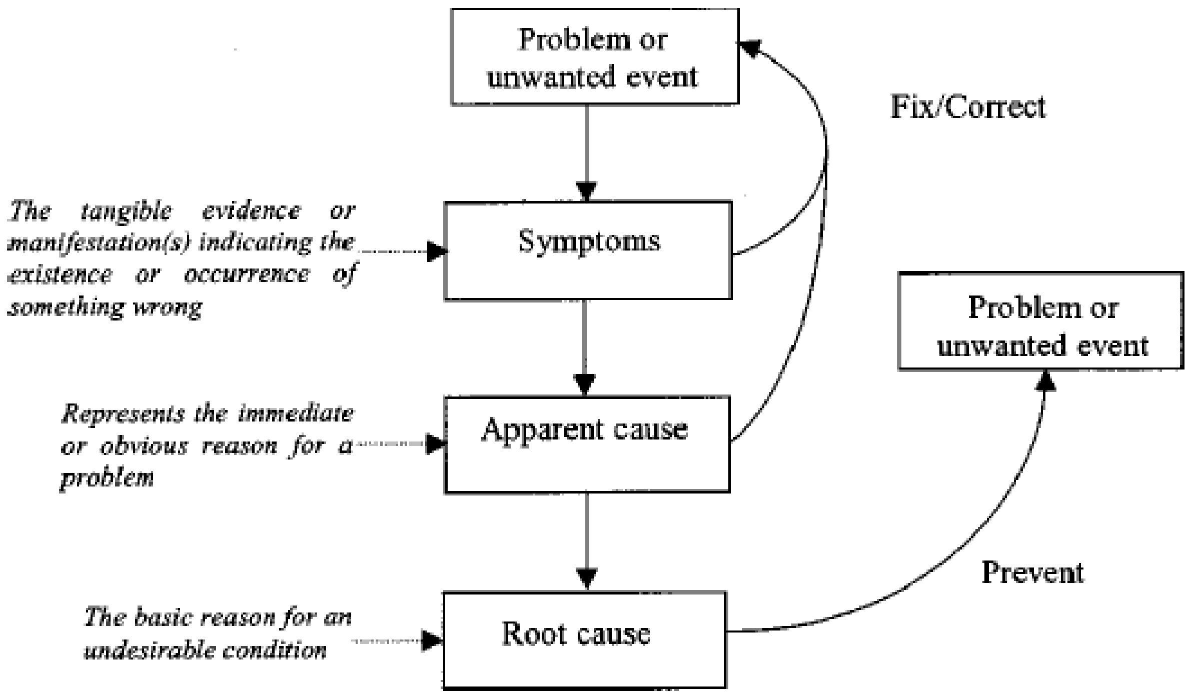

Figure 2.9: Apparent cause adding to the difficulty in determining true cause (Love & Josephson, 2004)

Error prevention should be looked upon holistically as an entire process within a complex matrix of interconnected factors. It requires the analysis of people, organization and project management to determine their relationships and interfaces that play a role in averting errors. The generation and consequence of errors occur in a complicated loop rather than in a linear single directional fashion. Thus, in order to mitigate the errors, it is mandatory to have a deep understanding of this correlation. The best error prevention strategy is to look at errors as indications of deeper issues within a system. As such, they become a means of understanding the inner workings of the system. Furthermore, in order to prevent design errors and rework from occurring, it is becomes necessary to treat them as instruments that help establish the levels of risk and safety (Lopez et al. 2010). Listed below are some of the steps that can be taken to alleviate chances of errors (Lopez et al., 2010):

1. Allocate more feasible time to the design phase so as to promote revision and quality assurance
2. Introducing the process of "constructability analysis, quality management and risk management"

According to Figure 2.10, the most effective procedure to prevent errors can be realized by educating the personnel. Analyzing the graph, it can be seen that "people" are placed on top of "organization" and "project" to emphasize the need of the right working ecosystem and the appropriate project methods applied to construct the project. These two

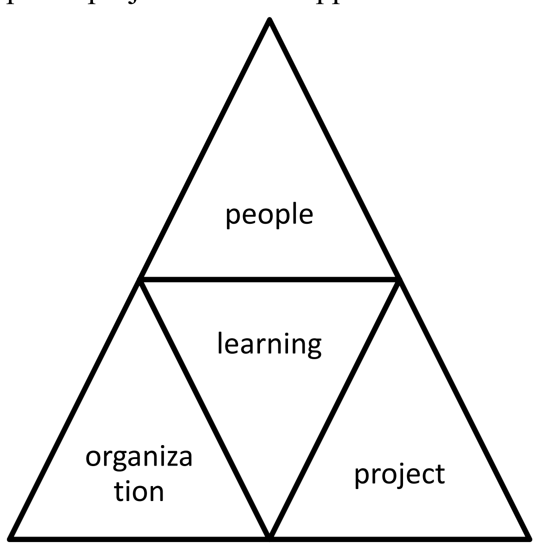

Figure 2.10: Proclivity to reduce error by people, organization and project (Lopez et al, 2010)

aforementioned factors have a direct bearing on the capability of personnel to conduct the work. Put simply, by improving “organization” and “project”, error due to people will automatically decrease (Lopez et al., 2010).

Love and Josephson (2004) noted that there was a possibility to discover design errors before the inception of site work. Compared to detecting the error at site, this process will be a less expensive undertaking since more often than not it may only entail amendments be made to the drawings.

2.6.1 Quality management

Quality management relates to monitoring the quality of design by means of reviews, checks and remedial control. By raising the amount of review performed on the documents, more errors may detected. As a consequence the errors will corrected and any liability or other adverse effect that may have otherwise resulted will be removed. Several tools are available to monitor the quality of documents, including CAD (computer aided design) standards, checklists, document layouts etc. Commissioning of third party firms to review documents may also be utilized to ensure quality (Mohammed, 2007).

On the authority of Koskela, design errors may be eliminated by the consultants embracing the practice of quality management. In his paper he indicates that in some occasions it appears that the expenditure resulting from design waste exceeds that of the design. He then goes on to state that making corrections or preventing errors while still at the design stages is less expensive and tedious than when the project has advanced into later phases (Koskela, 1992; Love et al., 1999).

2.6.1.1 Design review

A number of researchers, e.g. Love et al. (2009) and Love et al. (2011), have asserted that by introducing design audits/reviews, the quantity of errors may be lowered. The design review, as advanced by Brown (2002), is comprised of 7 phases.

1. Scoping: choosing the team and initiating the schedule at least 3-4 weeks before the date at which the review is planned to start
2. Preparation: arrange period to conduct the revision, notify team members, and obtain the design documents
3. Overview: the architectural engineer(A/E) gives a small presentation to the participating members on the arrangement and elements of the documents
4. Review: the team will use a checklist to assess any issues with items. The purpose of the workshop is to gain feedback from the various discipline experts
5. Completion: the annotated design documents are gathered together, and a sheet containing all the comments is composed. At the end, the findings are presented orally to the owner

6. Back check: once the A/E has attended to all the issues that were noted, the head of the review team or the owner is required to ensure that the comments made at the review were dealt with
7. Follow up: on completing the construction phase, a follow-up should be conducted to verify the study's efficacy

For the review to be successful, the following components are necessary (Brown, 2002):

1. Quality checklist (more on this in section 2.6.1.1.1 below)
2. Interdisciplinary team members with experience
3. A light-table: The plans of various disciplines can be compared/coordinated with the help of a device known as a light-table. Essentially, a light-table allows the plans to be super-imposed, thus, making it easy to identify any inconsistencies. Also, additional discrepancies may be detected by altering the configuration. i.e. exchanging the top plan with the bottom one

2.6.1.1.1 Checklist

The aim of checking is to detect mistakes. Checklists are tools that facilitate the checking process. They act as reminders to issues that need to be checked. Following are the attributes of a good checklist as proposed by (Nelson, 2006):

1. Has to be simple to complete
2. Should not contain items that are not related to the particular project
3. It is necessary for the checklist forms to be compatible with numerous checking phases

Leveraging checklists is indispensable to reviewing design documents due to their ability to ensure reviewers do not overlook crucial items. In addition, checklists remove the need for an individual to recall items from memory. Moreover, checklist are able to counteract the factors of the reviewer's insufficient experience, an overloaded, or a horrible day (Brown, 2002)

Checklists may be quite comprehensive spanning reviews on civil engineering, mechanical engineering, electrical engineering, architecture, etc. One such checklist goes by the name of Multi-Check, a checklist composed of more than 300 items (Brown, 2002). Other checklists have also been devised to help in the design review process. Some examples of these checklists are redi-chek, project management checklists, and the US Army Corps of Engineers coordination checklists. Brown (2002) noticed that in many occasions 80% of change order costs could be traced to the same 20% design document errors. He then went on further to state that more than 50% of errors and omissions contained in the contract documents could be attributed to lack of coordination amongst the various specialties and that therein lies the biggest cost contributors to change orders.

Therefore, according to him there is a potential to form a checklist that cover all the essential items to be reviewed.

2.6.1.1.2 Redicheck method

The Redicheck method is the brain child of William Nigro, who between 1970s and 1980s observed that about 50% of change orders had their roots in coordination mistakes which had a potential of being prevented during design (Stasiowski & Burstein, 1994; Nelson, 2006). Some of the issues encountered by Nigro included (Nelson, 2006):

- Contradiction between structural and architectural drawings in which the placement of columns and grid lines interfere with architectural locations
- Architectural floor plans in disagreement with floor plans of other specialties
- Electrical drawings specifying equipment item performance distinct from the ones shown in either the mechanical or specification

The method encompasses spot checks, final checks, and the juxtaposition of plans composed by different specialties (Nelson, 2006). It is an easy to apply, all-inclusive, and potent technique for performing design reviews (Stasiowski & Burstein, 1994).

Nigro set up the following fundamental guidelines to be adhered to by the design organization (Stasiowski & Burstein, 1994):

- Every plan should be drawn at the equivalent scales to facilitate superimposing on light tables
- Display correct information minimum amount of time, if possible only one time
- For every plan, maintain equivalent north-south orientation
- Wherever possible, sidestep match-lines

2.6.1.1.3 Red green yellow checking technique

Is a method employed for checking contract documents. The heart of the technique consists of two parts. One, eliciting the joint effort of all specialties. Two, perform amendments efficiently and effectively. To achieve this technique, the ensuing methods are recommended by Mr. Braley (Stasiowski & Burstein, 1994):

1. For the review, one set of finished documents are prepared.
2. The documents are first inspected by the lead discipline. On completing, the lead discipline then transfers the check set to the succeeding discipline. It is compulsory that one reviewer be an individual having no direct work connection with the project.
3. Prior to the review team head approval, every comment produced by the reviewers are taken to be proposals
4. There are two distinct notations. One signifies "potential change recommendations" and the other represents "definite change recommendations." "potential change

recommendations” are produced in the occasion that the reviewer is indecisive on whether or not an alteration should be made, has a query, or would like to suggest an improvement on the design of another discipline. These recommendations are distinguished by a green color. When the reviewer is definite that a review is required they mark the documents with a “definite change recommendations” indicated by a red color

5. Once the review is finalized, the reviewers sign the check set‘s cover sheet with their names along with the date on which the review was conducted. In a similar manner, the reviewers will place their initials beside every comment put in the check set. Also, the reviewers should place their initials on all the drawings to ascertain that no drawings have been unintentionally overlooked
6. When all the reviews have been concluded, the main members of the design team will go through the check set. As the meeting progresses, the change recommendations will be analyzed and their effect assessed. The deliberation covers effects on the cost of design, the schedule, interdisciplinary coordination, constructability, and operability
7. The head of the review team will chose to accept or deny the change recommendation according to the effect discussed in point 6. The review team head designates the approved change recommendations by placing his/her initials next to them.

2.6.2 Learning from mistakes

The frequency of error occurrences may be alleviated through the process of learning. Love and Josephson (2004) distinguished two systems of learning: (1) the ‘single loop’ and (2) the ‘double loop’ learning. In the ‘single loop’, people working in a cooperation may discover errors, perform necessary actions to correct them, but this is as far as they go. No further actions are implemented to prevent the error from recurring. An instance of this may be a contractor that constantly experiences design errors. Instead of attempting to identify the root causes of the DDD and consequently taking the appropriate actions to prevent future reiteration of the shortcoming, the contractor may instead resort to adding a contingency that covers the cost of such an event. This practice, although appealing to the contractor, will eventually lead to future loss due to a fall in reputation.

“Double loop” learning, contrary to “single loop”, aims to correct the discovered errors in ways that may modify the operating mechanism of the entire organization. Hence, the error is prevented from resurfacing in the future. Construction organizations may face difficulty in implementing this form of learning due to the necessary precondition of having to transform the way the organization runs (Love & Josephson, 2004).

2.6.2.1 Developing a corporate memory

All individuals are susceptible to generating mistakes. Rather than have only a single individual learn from a mistake committed by them, corporate memory seeks to gain more from this shortcoming by allowing everyone involved in an organization to gain insight from oversights performed by their colleagues (Stasiowski & Burstein, 1994). In essence, corporate memory is what the organization recalls from prior experience (Nelson, 2006). To implement this process, the initial step requires the formation of a feedback mechanism that obtains information from the design team's customers, that is, the contractors and maintenance staff. Once these informations have been acquired, they can be transferred to training strategies, design checklists, standard drawings, and specifications (Stasiowski & Burstein, 1994). In the opinion of Nelson (2006), the advantages gained from corporate memory are:

- Elimination of non-value adding time caused by all employees searching for remaining corporate memory
- The organization will be able to react to challenges more seamlessly, while at the same time not being under the mercy of their expert's time commitments
- Individuals will be less crucial. Nevertheless, they will be treasured for contributing
- The probability of the firm becoming impaired due to the turnover of an important personnel will fall

- Quantity of errors will fall

In quality management terminology this method of acquiring knowledge on all tasks performed to the extent that the tasks are constantly going through inspections and alterations is known as feedback (Nelson, 2006).

2.6.2.2 Reviewing past error

Another potential method for decreasing errors is by reviewing past errors. This process was proposed by Andi (2005) and is comprised of the following steps:

1. Define the defective design
2. Recognize the flaws of the design review
3. Recognize the direct mistakes of the designers
4. Recognize workplace issues that may have stimulated these direct mistakes
5. Recognize organizational issues that may have led to the workplace issues
6. Once enough instances have been identified, disclose the defective design pattern
7. At the end, implement required actions in the short-term management policy to prevent future repetition of defective design

When the final design review has been finalized, an individual, with the aid of pre-prepared forms, should be authorized to quantify the total quantity of design errors that have been encountered. After obtaining enough data, bar charts can be leveraged to give each specialty manager insight into the prominent deficiencies. Hence, with this knowledge at hand, the managers are able to rank the order of precedence of their quality improvement programs (Stasiowski & Burstein, 1994).

2.6.2.3 Proactive measures

To accomplish proactive measures, it is essential for manager to obtain information relating to the defective designs and active failures, but, more importantly to the workplace and organizational levels. In other words, the reduction of active failures can be achieved effectively by focusing on removing the root causes instead of the acts. Thus, the actions taken to counter the errors will be found on the assumption that even though people may not be changed, the workplace can. Figure 2.11 illustrates management actions based on

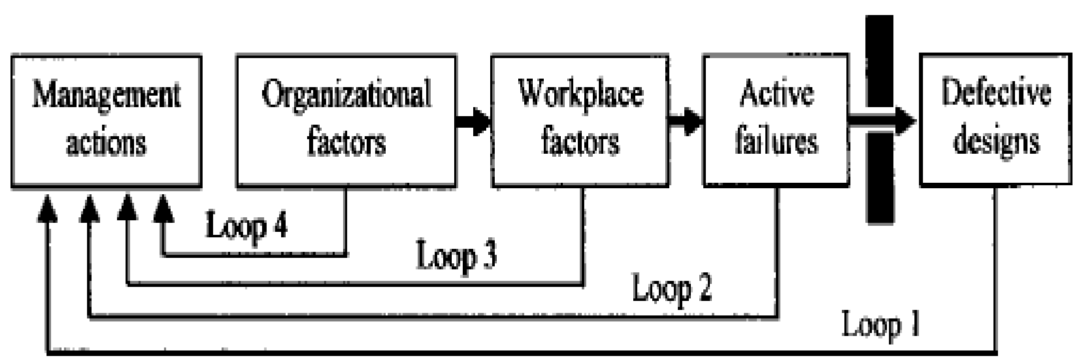

Figure 2.11: Actions of management based on information from loops (Andi, 2005)

the acquisition of information from various levels (Andi, 2005). Relating to the figure, defective design denotes the negative outcome of the error (Andi & Minato, 2007).

2.6.3 Improving coordination

Alarcón and Mardones (1998) suggested that one of the procedures that can be adopted to suppress rework at the ‘design-construction interface’ was the coordination of the numerous disciplines by logically ordering the transmission of information, ensuring erroneous assumptions are not made, and assigning levels of precedence to changes so that poor coordination is evaded and the compatibility of design is ameliorated.

Likewise, (Brown, 2002) recommended a team approach that features various disciplines in conducting reviews. It is of primary significance for this team to include contractors, architects, engineers, and experts. Although it is not necessary for them to work concurrently, coinciding there contribution time will ensure the greatest coordination between the various disciplines.

2.6.4 Error recovery process

Sometimes errors simply cannot be avoided and the best that can be done is to suppress them from dispersing further in to the project and producing other potentially more detrimental errors. This is where a procedure known as the “*error recovery process*” comes into play. This process is comprised of three main phases: (1) identify the error, (2) place the error into the awareness of the person directly responsible for its rectification, and (3) make the necessary corrections to the error. It is critical to conduct the last step in a timely manner, otherwise the problem will be further exacerbated and learning from the mistake hindered since the cause will be deeply buried in the process. In a perfect world, the errors should be detected before initiation of the construction work, but inadequate planning, poor knowledge of subordinates, and ignorance of quality management deem this not possible (Love & Josephson, 2004).

2.6.5 Effective design management

Effective design management can go a long way in lowering the amount of changes, errors, and omissions once the construction phase is initiated. The respondents in a research by Love et al. (2004) listed the following design management techniques that were capitalized in their projects:

1. Value management
2. Design for construction
3. Computer visualization
4. Subcontractor/supplier involvement in design
5. Constructability analysis

6. Design scope freezing
7. Team building

Love et al. (2006) argued that for an organization to become ‘prevention focused,’ it is imperative that they endeavor to enhance design management so that:

1. The requirement for revising documents is eradicated
2. Management issues concerning the control of the design process which result in the squandering of resources is attenuated
3. Variables resulting in substandard performance is lessened

Love et al. (2009) argues that rather than placing more resources and raising the productivity of a project that is either running late or on the verge thereof, as is commonly practiced, management should focus its energy on remedying the more fundamental issues. As such, a robust technique would be to lower the amount of errors or time span of their discovery. It is therefore recommended to employ techniques such as design audit, verification, and reviews.

2.6.5.1 Value management

Love et al. (2004) discovered that value management (VM) was amongst the factors that had a strong influence in decreasing costs related to rework. VM is a procedure that aims to reassess the functionality and the client’s needs. Hence, by doing so, VM serves to suppress changes made by the client that occur at the construction phase of a project. Also, VM has the ability to lower errors. Despite these advantages, clients may still hesitate to pay for VM due to its expense (Love et al., 2004).

2.6.5.2 Constructability

As was mentioned previously in ***section 2.4.2.7***, one of the contributors to DDD is lack of coordination and integration between the design and construction teams. One remedy to this problem is the concept of constructability. This notion will give the design team a thorough insight of the construction process while at the same time advocate integration between the parties (Lopez et al., 2010). It is a technique that acts as springboard in attaining the best incorporation of construction knowledge all through the project (Love et al., 2004). Though the initial implementation of constructability will undoubtedly introduce cost to the design firm, which one may argue will reduce the competiveness of the firm, the benefits of having a buildable design will introduce numerous benefits that may far outweigh this shortcoming (Arditi et al., 2002). With respect to the benefits, Arditi et al. (2002) found that advantages of constructability encircled: (A)building stronger ties with both the clients and contractors, (B) undergoing fewer litigations, and (C) gaining a better image. Nonetheless, drawing from the same research by Arditi et al. (2002), it was found that a number of issues prevented the application of constructability in projects. These included:

1. Poor designer knowledge of construction needs
2. Designer and constructors varying goals
3. Client unwillingness to formal procedures as a result of budgetary constraints and added costs

2.6.6 Diligence in the selection of consultant

Al-Far (2005) emphasized that rather than choosing consultants on a minimum fee basis, the clients should base their selection on competency. Furthermore, the procedure in selecting consultants should be made clear. That is to say, explicitly stating the conditions for selection, minimal service obligations, and least fee amounts. At the end, these practices will assure that the consultant with required skill levels and experience are chosen (Al-Far, 2005).

Tilley and Barton (1997) advocated the use of a procedure like “qualification-based selection (QBS).” Essentially, this system suppresses design and documentation deficiency by placing the competency of the consultant at a higher priority than their cost.

2.6.7 Involvement of client and contractor

Al-Far (2005) asserts that the consultant should appropriately take into account the responsibility and the involvement of the owner and contractors during the process of producing the project's documents to guarantee that documents are not out of step with their conditions and targets. Also, the participation of the client and contractors at the initial phases of the design review will go a long way towards enhancing the design document's quality. As a result, the consultant will be provided with opportunity ample time to rectify any errors, oversights or vagueness at the design stage, prior to the onset of the construction stage.

2.6.8 Decomposition of tasks

Love et al. (2012) proposed that dissecting a task into smaller sequences is one answer to detecting error traps. Similarly, Dr. Edward Deming viewed all work as a process that could be portrayed as a flow chart. Since design projects contain phases, they can also be presented as flow charts. Design projects will have a certain order of tasks that will result in the optimal produced product (Stasiowski & Burstein, 1994).

2.6.9 Concurrent engineering

Concurrent engineering (CE) is a process that has seen success in the manufacturing industry. This success has presented its self in the form of enhanced performance and productivity. Essentially, CE requires that all the stages of the life of a product be considered at the design stage. That is to say, beginning at the conceptual stage all the way to the detailed design stage. The goal of CE is to improve the quality of the product while also lowering cost and time needed to develop the product. This is all accomplished by integrating the numerous disciplines (Love & Gunasekaran, 1997).

It has been observed that conducting a project using concurrent engineering (CE) may result in cost and time savings commensurate to 30%. For the full of benefits of CE to be realized, the various parties involved are required to communicate with each other, interchange visions, strive for the same targets, and tackle the design and construction process in a holistic manner. While there is potential benefits in applying this practice, this process, nonetheless, poses a risk. This risk manifests itself in the form of rework. This is explained by the complexity that occurs due to the many activities being performed simultaneously and at the same time having interdependencies between each other. All these concurrency mean that performing a “system freeze” becomes a complex process, resulting in a form of domino effect (where problems in one area spread to other non-infected areas (Mohammed, 2007).

2.6.10 Partnering

It has been widely argued that partnering may be a viable resolution in alleviating the antagonism between the various parties within the construction industry. This practice can spur a project by helping it attain project targets that include elimination of disagreements, better safety, improved quality, and reduction in time and expenditure. Furthermore, partnering may be leveraged to facilitate communication thereby avoiding any potential of misunderstanding among the various members. All these benefits are reaped due to the ability of partnering to bridge the gap between the designers and contractors, enabling them to transfer and receive knowledge on issues pertaining to constructability and buildability(Mohammed, 2007).Hence, it is vital for the construction organization to take part in the design process so that problems associated with inadequate construction knowledge of the designers may be avoided (Alarcón & Mardones, 1998). Additionally, the chance of design changes will lessen (Love et al., 2011).

Love et al. (2004) also echoed the need for the members in a construction project to embrace a ‘multidisciplinary team approach’ in composing contract documents. Instead of performing tasks in sequential steps, members should resort to working in concert. As a result, communication and coordination will all be effected in a positive manner. Subsequently, reduction in the quantity of errors and client changes will ensue.

Andi and Minato (2003) underlined the significance of having the designers and contractors communicate with each other during the design stages, providing an opportunity for both sides to learn from each other.

2.6.11 The principle of single statement

The problem of design errors can be alleviated by using a technique known as 'The principle of single statement.' In essence, every dimension, coordinate, elevation, callout, etc., are displayed a single time. Moreover, they should be presented where they may be easily located. The rationale for using this method is that due to information changes that may occur along the length of the design process, some necessary information corrections might be omitted. As a result of the conflicting information disputes will arise (Stasiowski & Burstein, 1994).

Additionally, placing redundant information in every drawing consumes time. In the unfortunate scenario that a change is obligatory and the designer is meticulous enough to detect all information requiring change, the process entails additional time which is further magnified if the problems find their way into the construction phase (Stasiowski & Burstein, 1994).

2.7 *Discussion*

From the literature review it was discovered that deficient documents greatly influenced the designer's ability to make profit. In addition, poor documents also creates a rift between the numerous parties the designer interacts with. Furthermore, studies have demonstrated that errors may be extreme to the extent that they result in injuries or even fatalities. Moreover, the chapter also explored the various major categories of errors that may be encountered in design documents. The types of errors were grouped into 5 broad categories, as was previously outlined by Mohammed (2007), namely:

1. Failing to comply to design parameters
2. Coordination issues
3. Failing to follow procedures
4. Omission
5. Errors
6. Other

In the case of causes, three categories were utilized:

1. Designer
2. Client
3. Project

In regards to the consequences, factors identified demonstrated that errors did not only impact the designer but also spilled over to the owner and contractors.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 *Research technique*

To achieve the goals of the thesis, it was of prime importance to devise a methodology. This method came in form of adopting a set of activities that aided in the realization of numerous objectives. In all there were four main objectives that had to be considered. A brief description of these objectives is displayed below.

Objective1: Identify type of DDD

Objective2: Define causes of DDD

Objective3: Understand the outcomes of the errors

Objective4: Determine possible preemptive measures

The succeeding portion of this section provides an in depth discussion of these objectives.

3.1.1 Objective 1-4: Recognize the various factors

The objectives of the research consisted of 3 activities, presented below:

Part 1: Recognizing the type of DDD, causes, outcomes, and possible preemptive measures

1. Analyzing the literature relating to the various factors

Part 2: Appraisal of DDDT, causes, outcomes, and preventive measures

2. Generating a questionnaire survey to analyze the factors obtained from the literature review. The questionnaire is comprised of two sections
   a. The first portion of the questionnaire embodies general questions relating to the background of the respondents, such as years of experience and size of organization. In addition, the respondents are asked if they wish to receive the findings of the research.
   b. The second section seeks to find the prevalent DDD, significant cause, effects, and preventive measures by way of a ranking system. The evaluation criteria utilized are: 1= Not significant, 2= Low significance, 3= significant, 4= high significance, and 5= Very high significance.
3. To assess the effectiveness of the prepared questionnaire and ensure that there was no trace of ambiguities, a pilot test was performed prior to mass circulation of the

questionnaire. Further factors were also solicited from the professionals by the inclusion of an open ended question. This was of great importance since it gave more insight on any overlooked factors (Atkinson, 2002).

4. On ensuring that the questionnaire had no problems, it was then distributed to selected consultants and contractors.

<u>Part 3:</u> Data evaluation

1. The function of this stage was to transform the data acquired from the field into meaningful information. The following formula was enlisted (Dominowski, 1980):

$$\text{Importance index} = \frac{\sum_{i=0}^{4} a_i x_i}{4\sum_{i=0}^{4} x_i} \times 100\%$$

Where: i = response category where i = 0,1,2,3,4

a_i = responses given weight where i = 0,1,2,3,4

x_i = is a variable representing frequency of i

- x_0 = frequency of "very high significance" response corresponding to $a_0 = 4$
- x_1 = frequency of "high significance" response corresponding to $a_1 = 3$
- x_2 = frequency of "significant" response corresponding to $a_2 = 2$
- x_3 = frequency of "low significance" response corresponding to $a_3 = 1$
- x_4 = frequency of "not significant" response corresponding to $a_4 = 0$

The importance index was categorized based on the scale depicted in Table 3.1 (Hassanain & Juaim, 2011). Figure 3.1 graphically summarizes the steps of the four objectives.

Table 3.1 Ranking and categorization of importance index

Importance	**Index Classification**
0–<12.5%	Not significant
12.5–<37.5%	Low significance
37.5–<62.5%	Significant
62.5–<87.5%	High significance
87.5–100%	Very high significance

The correlation between the various parties was identified with the use of the Pearson product moment correlation coefficient. The formula is as follows (Anderson, 2012):

$$r_{xy} = \frac{s_{xy}}{s_x s_y}$$

Where: r_{xy} = sample correlation coefficient

s_{xy} = sample covariance

s_x = sample standard deviation of x

s_y = sample standard deviation of y

To further verify the agreement/disagreement between the parties the t-test for independent sample was used to test the null hypothesis that there's a consensus between the contractors and consultants. The test was performed on the mean values of each of the identified elements. The formula for the test is shown below (Al-Dubaisi, 2000; Anderson, 2012):

$$t = \frac{(\overline{x_1} - \overline{x_2}) - D_0}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}}$$

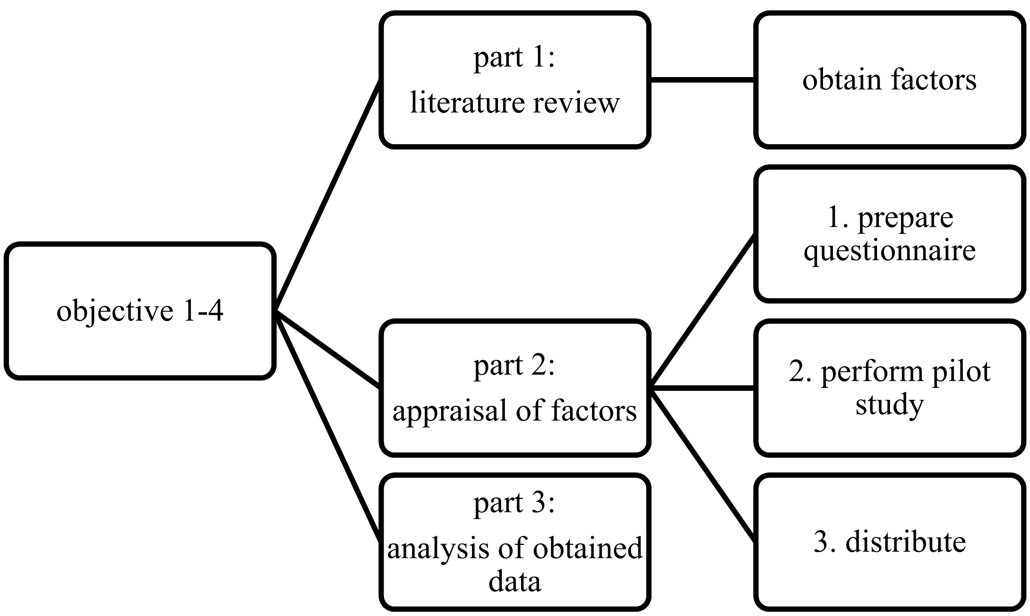

Figure 3.1: Schematic of the four objectives

3.2 *Questionnaire design*

The questionnaire (Appendix B: Quesitonnaire) was composed with the aid of the literature review. Great care was practiced to ensure that all the most relevant and significant factors were derived from the various sources. On obtaining a list of factors, a pilot study was undertaken to verify the validity of the listing. While conducting this pilot study, it was noticed that there was confusion owing to the brevity of the factor’s title. Thus, these brief names were supplemented with short explanations in parenthesis and more concise terms to aid in understanding.

3.2.1 Contents of questionnaire

The questionnaire was sectioned into five parts.

The first section was concerned with the general information relating to the respondents. Information such as level of experience, and types of undertaken projects.

The second section dealt with the types of deficiencies regularly seen in the documents. A detailed description of all these factors was covered in a previous section (section 2.3). a Likert scale ranging from 1(not significant) to 5 (very high significance) was presented for rating the factors.

The third section addressed the factors that play the biggest roles in causing deficient documents. A Review of these factors may be found in section 2.4.2 . Like the aforementioned questionnaire section, the respondents were asked to rank the factors from 1 to 5.

The forth section explored consequence of having deficient documents. Explanations of these factors are given in section 2.5. A 5 point scale was appointed here, too.

The final section of the questionnaire assessed the methods that were most effective in eliminating the incidence of deficient documents. More information about these factors may be found in section 2.6. Again, a 5 point scale was commissioned to rate the various factors.

3.3 *Gathering of data*

In addition to email, whenever possible frequent visits to the contractor's and consultant's organizations were undertaken. The virtues of meeting the professionals in person were: (1) the contents and goals of the questionnaire could be explained lucidly in person, and if required a translator would accompany the researcher assist him, though such translations were seldom needed (2) haphazard filling of the questionnaire could be avoided (3) the assistance provided by the researcher in answering the questionnaire would make it less tedious for the respondents, and (4) important comments or observations could be taken first hand. In addition, follow ups were conducted frequently to expedite the replies. The data collection phase spanned a month and a half. Whenever any questionnaire was completed, the data was numerically coded for analysis in statistical packages (excel and SPSS).

3.4 *Scoring*

An ordinal scale was used in the four key sections of the questionnaire. This scale is qualitative in nature. As a result, the problem with this scale is its inability to allow for quantitative comparison between intervals. The implication of this is that parametric methods such as the t-test may not be applied. To remedy this shortcoming, the scale had to be converted into an interval scale. This was accomplished by giving each interval a weight. Essentially, the scale 'not significant' is given a weight of 0% and 'very high significance' a weight of 100%. The intermediate scales receive weightage of 25%, 50%, and 75%, respectively (Al-Dubaisi, 2000). The formula utilized to generate this importance index may be found in section 3.1.1.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapters details the findings obtained from the survey of the research.

Section CHAPTER 4: represents the general details of the respondents such as the number of respondents, their field, and the type of projects conducted by their organization, just to mention three.

Next, sections 4.2.1. through 4.2.4 elaborate on the perceived ratings of the frequencies of deficiencies types encountered in the design documents, the most impactful factors responsible for their manifestation, the most significant consequences, and the most effective error prevention methods, respectively. In each of these sections, a line graph of factors against the importance index will be plotted. Both the rankings of the contractor and consultant will be shown on the same figure to analyze any similarity or trend. To assess agreement or disagreement, the Pearson correlation will be conducted. Afterwards, the top factors will ranked according to their importance index. In addition, the hypothesis that contractors and consultants agree on the factors will be tested.

Before commencing through these sections, it is worth mentioning that, apart from a single factor in deficiency types, namely, the discrepancy of the bill of quantities with other documents, no additional factors were suggested by the participants. In fact, all the participants who conducted the interview positively expressed the comprehensiveness of all the factors collected. Remarks from these participants concerning the questionnaire may be found in section 4.4 of this chapter.

4.1 *General information*

This section outlines the general information relating to participants who partook the study. Table 4.1 is a summary of the proportion of the contractors and consultants who participated in the study. The consultants represented more than half of the respondents. Figure 4.1 summarizes this data in a graphical format.

Table 4.1: Respondents by category

Respondents	**Number**	**Percentage**
Contractors	30	42%
Consultants	41	59%
Total	71	100%

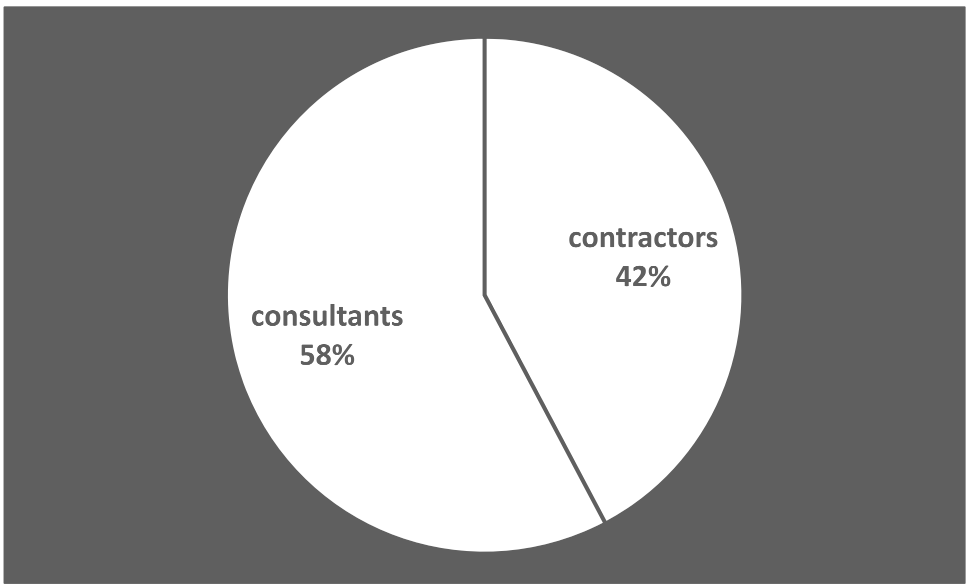

Figure 4.1: Percentage of contractor and consultant who were involved in study

The years of experience of the respondents are categorized below:

1. Very long: more than 20 years
2. Long: between 16 and 20 years
3. Moderate: between 11 and 15 years
4. Short: between 6 and 10 years
5. Very short: less than 5 years

The experience distribution of the contractors are given in Figure 4.2. Here the prevailing experience category is “very short,” representing 30% of the contractors. “short” and “very long” are tied at second with 23% of the contractors having these years of experience.

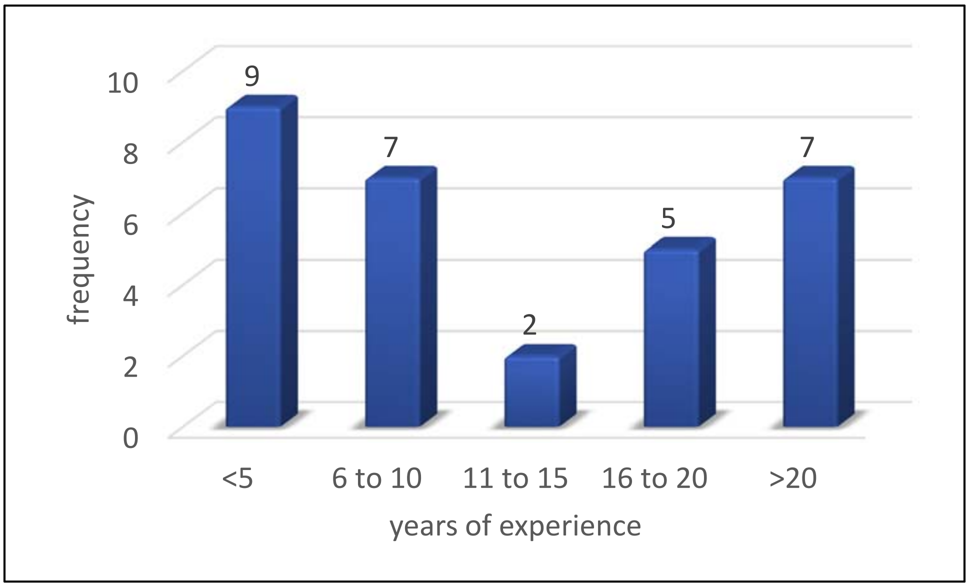

Figure 4.2: Contractor's experience distribution

The years of experience of the consultants who were involved in the research are summarized in Figure 4.3. In this case, a significant proportion of the consultants had experience under the category “short”. This was followed by “moderate” and “very long”, with 22% and 20% of consultants, respectively.

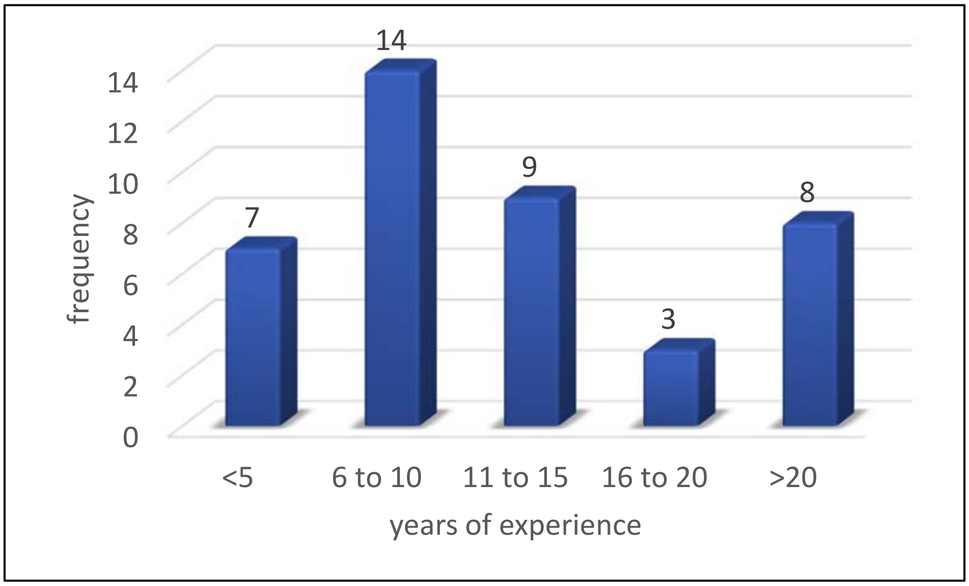

Figure 4.3: Consultant's experience distribution

The aggregate summary of all the respondent's experience regardless of the profession is displayed in Figure 4.4. From the figure, the most frequent experience falls under the "short" category, with 30% of all the respondents belonging to this range. 77%

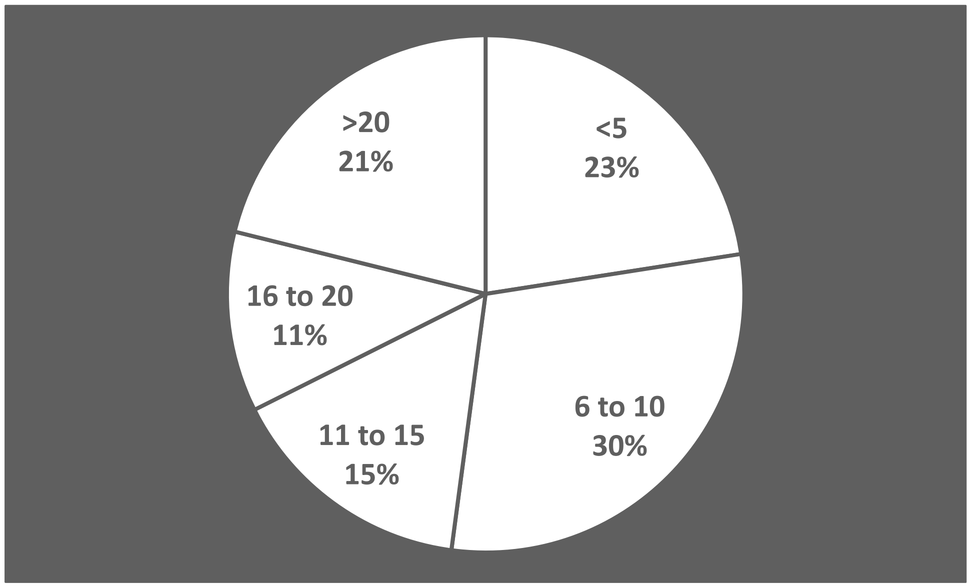

Figure 4.4: Combined respondents experience

of all the participants had at least 6 years of experience. This collection of replies from professionals with diverse experience helped in ascertaining that the results obtained from the survey were not bias to the extent that professionals with disparate experience might perceive the quantity of errors differently. The educational qualifications of the contractors is summarized in Figure 4.5, while that of the consultants is shown in Figure 4.6. With reference to the former figure, a majority of the contractors had acquired BS degree. Conversely, none of the contractors had a PhD degree. Similar to the contractors, a large segment of the consultants had a BS degree with approximately 68%. Unlike the contractors, though, there was a single consultant who had received a PhD.

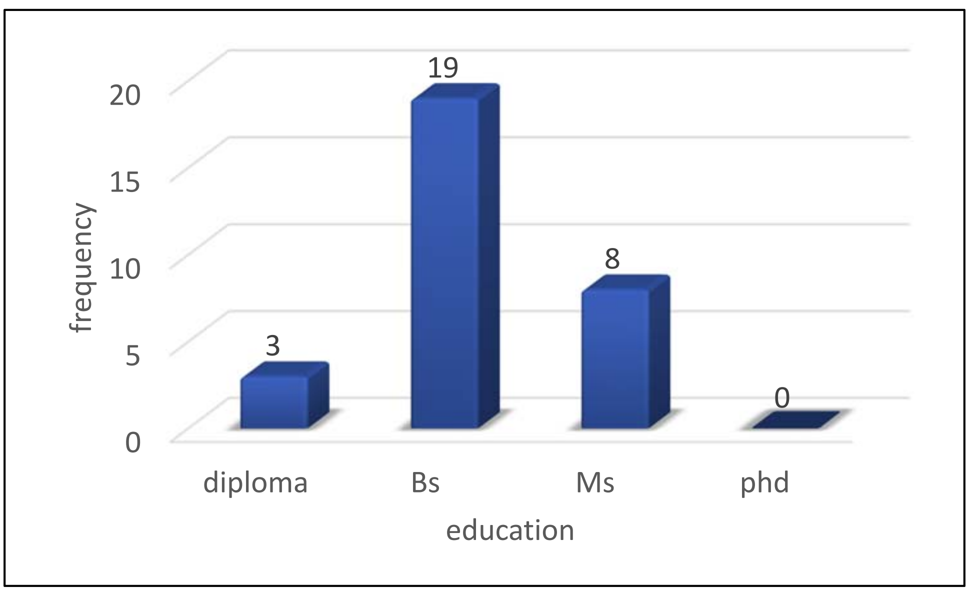

Figure 4.5: Educational qualification of contractors

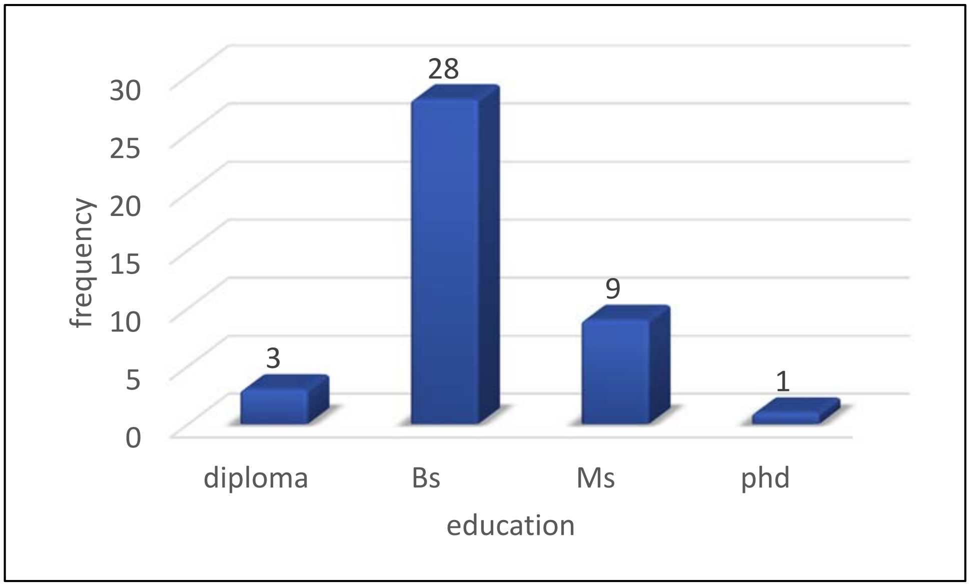

Figure 4.6: Educational qualification of consultants

The overall distribution of educational qualification of the research participants are provided in Figure 4.7. Appraisal of the pie chart shows that more than half of the respondents attained a BS degree. This is followed by the MSc. degree. This statistics demonstrates the high educational qualification of the participants. As a result, this ensures that the answers of more technical questions provided by the participants will be more credible. Nonetheless, it was observed that some participants though lacking in educational qualification had superior experience that compensated for this lack of education. Ultimately, this rich mix of experience and education adds to the quality of the research.

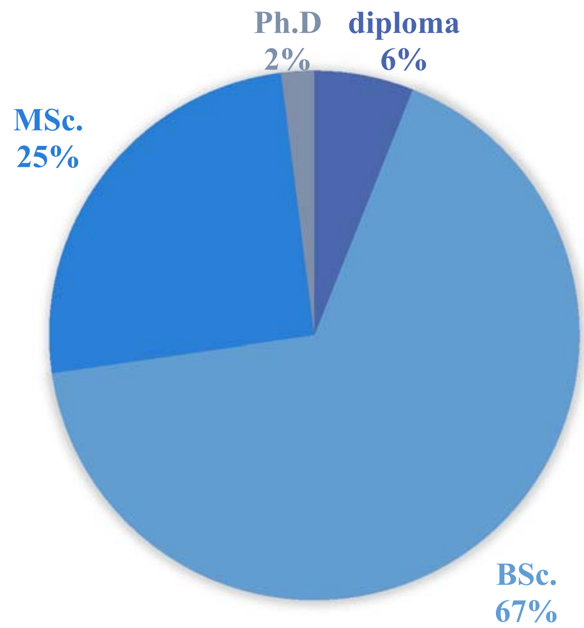

Figure 4.7: Respondents educational qualification

Table 4.2 represents the distribution of the types of projects undertaken by the organizations that the respondents were affiliated with. Referring to this table, it is observed that the majority of the projects performed were governmental.

Table 4.2: Types of projects performed by organizations

Types of projects	Count	Percentage
Government	28	39%
Semi-government	6	8%
Private	25	35%
Government & semi-government	5	7%
Government & private	3	4%
Semi-government & private	1	1%
All	3	4%

4.2 *Analysis*

4.2.1 Analysis of deficiency types

This section will examine the data obtained from the field. The first portion will rank the factors based on the importance index they were given. Next, the results of the parties will be compared to see similarities, if any, of the frequent deficiency types. The categories of deficiency types that are faced on a regular basis will then be ranked for each party. After this, factors will ranked based on the combined importance index. At the end, findings of other researchers will be compared to the outcome of this study to show any agreement or disagreement.

Interestingly, all the identified factors were ranked no lower than significant. Stated differently, none of the factors fell into the “low” or “no significance” class (46% being the lowest ranked factor). This result serves to substantiate the relevance of the identified DDDT in the Saudi Arabian construction field.

The criteria for classifying the factors as top/critical factors was that they had to be in range of the high significance or higher, i.e. the factor should have an importance index of at least 62.5%. With this criteria in mind, the top 6 commonly encountered DDDT identified by the contractors are shown in Table 4.3. On the other hand, Table 4.4 details the top 9 factors nominated by the consultants.

Table 4.3: Top 6 commonly encountered deficiencies identified by contractors

Category	Factor	Mean
Not complying with design parameters	Nonconformance to building codes	0.71
Errors	Design errors	0.69
Coordination	Design team coordination	0.68
Coordination	Coordination amongst drawings	0.68
Errors	Specification errors	0.67
Other	Operational issues	0.67

Table 4.4: Top 9 commonly encountered deficiencies identified by consultants

Category	Factor	Mean
Coordination	Design team coordination	0.70
Other	Constructability	0.70
Other	Operational issues	0.69
Not complying with design parameters	Nonconformance to building codes	0.69
Errors	Design errors	0.68
Errors	Specification errors	0.68
Errors	Insufficient detail	0.66
Coordination	Coordination amongst drawings	0.66
Not complying with design parameters	Nonconformance to client's specification	0.66

Although the relative sequence of the factors differed between the two parties, as can be seen from the tables above, there was some extent of unanimity in what comprised these top factors. In particular, "nonconformance to building codes", "design errors", "design team coordination", "specification errors", "operational issues", and "coordination amongst drawings" were all critical factors in the perception of both the parties. Another observation is that the gap between the first and last factor, for both the parties, is virtually insignificant. To be specific, the maximum difference is 0.04 or 4%. This illustrates that the regularity of the top DDDT are nearly the same in the viewpoint of the two groups. Finally, it can be noticed that the consultant listed more factors (9 overall factors) than the contractor (6 overall factors).

With respect to the categories, the contractors viewed “coordination” issues to be most prevalent, while the consultant regarded “other” problems as being ubiquitous. These findings are shown in Table 4.5 and Table 4.6.

Table 4.5: Contractor ranking based on category

Rank	Index	Category
1	0.68	Coordination
2	0.65	Errors
3	0.64	Other
4	0.63	Not complying
5	0.55	Omission
6	0.53	Not following procedures

Table 4.6: Consultant ranking based on category

Rank	Index	Category
1	0.69	Other
2	0.68	Coordination
3	0.68	Errors
4	0.62	Not complying
5	0.53	Omission
6	0.51	Not following

The combined mean ranking of both the parties are shown in Table 4.7. Sunday and Afolarin (2013) showed that the top two types of errors commonly contained in drawings in the Nigerian construction industry were “design errors” and “poor coordination between design disciplines”. Examining Table 4.7 reveals that the 2nd and 3rd most frequent DDDT in Saudi Arabia are also poor coordination and design errors, respectively. Additionally, the findings from the interviews and surveys conducted in Chile by Alarcón and Mardones (1998) showed that “lack of coordination among specialist”, corresponding to “design team coordination”, “inconsistencies among drawings and specifications”, corresponding to “coordination amongst drawings”, and “designers with insufficient knowledge of construction", corresponding to "constructability", were amongst the most critical issues in design. This, similarly, was in sync with the results of this research.

Table 4.7: Contractor and consultant mean ranking of frequent DDDT

Factor No.	Factor	Contractor	Consultant	Mean
2	Nonconformance to building code	0.71	0.69	0.70
6	Design team coordination	0.68	0.70	0.69
12	Design errors	0.69	0.68	0.69
15	Operational issues	0.67	0.69	0.68
13	Specification errors	0.67	0.68	0.68
5	Coordination amongst drawings	0.68	0.66	0.67
16	Constructability	0.62	0.70	0.66

One participant who was interviewed by the researcher stated that one cause of frequent deficiency in the design documents is the existence of poor professional regulation in Saudi Arabia. In light of this information, a reasonable explanation for the parties' perception of "nonconformance to building codes" as an omnipresent deficiency might be due largely to Saudi Arabia's lack of standards that specify the types of codes to abide by. As a result, you have design firms that adopt the codes that are most suitable to their personnel, i.e. the codes specific to the personnel's country (Abolnour, 1994; Al-Far, 2005). Subsequently, the contractor and consultant have to deal with different codes whenever they switch designers. Additionally, Al-Far (2005) reported that consultants may alter design to their clients liking irrespective of whether they adhere to engineering codes or not. All these factors lead to confusion pertaining to what constitutes correct codes. To make matters worse, Abolnour (1994) found that the nonexistence of building codes to consolidate the measurement units adopted engenders a culture of errors whereby omissions and contradictions materialize and the process of administering and locating construction and design deficiency becomes a more demanding task.

With respect to the design team coordination, the contractors in Al-Far (2005)'s's research identified the issue of there being no office or individual responsible for design coordination in Saudi Arabia as a common occurrence.

Concerning the overall ranking of deficiency types, the factor "design errors" received an importance index equal to that of the "design team coordination" factor. It was asserted by Al-Far (2005) that a cause for deficient design and documentation quality was the tendency for clients to "shop around more for design services." Stated differently, clients seek designers who charge the least price, irrespective of their experience. Also, Burbridge discovered that the principle cause of design quality failure was inadequate technical skill (Mohammed, 2007). Therefore, experience may play a key role in the production of 'design errors'. As will be seen in the succeeding section, the respondents accepted that, out of all the potential causes identified, "designer's experience" had the most profound influence on the quality of the design documents.

Regarding specification errors, Al-Far (2005) ranked the factor "difficulty in finding good staff" 16th out of a total of 39 causes of deficient documents in Saudi Arabia. This factor encompasses the difficulty in obtaining good specification writers. Simply put, the lack of proficient specification writers coupled with other problems may result in the proliferation of specification errors.

"Constructability", similar to "design errors," may be ascribed to designer's lack of experience.

4.2.2 Analysis of factors impacting document's deficiency

Similar to the rating of DDDT usually encountered, both parties displayed some extent of congruence when ranking the most significant causes of DDD. Noteworthy, the contractors considered the ensuing factors (Table 4.8) more critical in the causation of deficient document than the consultants.

Table 4.8: Factors given relatively more weight by contractors

Factor No.	Category	Factor
4	Designer	Reputation of designer
5	Designer	Design team cohesiveness
13	Designer	Design reuse
14	Designer	Lack of staff
23	Client	Unreasonable client expectation
24	Designer	Misinterpretation of client on part of designer
28	Project	Authority approval

It should also be noticed that, even though there were a total of 21 factors constituting the designer category, which comprised about 72% of the total identified impact factors, five out of the seven factors elected by the contractor fell under the designer category. By contrast, the consultants selected the subsequent factors (Table 4.9) has having a bigger impact on the design document’s quality as compared to the contractors. Here too the consultant attributed the causation largely to the designer, with seven out of the eight factors placed under the designer category. It is important to point out that the difference in ranking between the two parties was not considerable in so far as the differences only ranged between 3 to 10%.

Table 4.9: Factors given relatively more weight by consultants

Factor No.	Category	Factor
1	Designer	Poor training
2	Designer	Designers education
7	Designer	Communication amongst team members
10	Designer	Lack of quality assurance
18	Designer	Transfer of knowledge
19	Designer	Quantity of work allocated to designer
21	Client	Type of client

The top factors, along with their corresponding importance index, ranked by the contractors and consultants, are given in Table 4.10 and Table 4.11, respectively. Referring to Table 4.10, it is worth noting that the contractors recognized design reuse as a factor that contributed highly to the materialization of deficient documents. This sentiment was not shared with the consultant. Regarding the findings of other studies on this poor practice, the contractors and owner’s representatives in Al-Far (2005)’s’s study similarly believed that design reuse occurred often. All these factors are within the high significance range (i.e. importance index exceeding 62.5%).

Table 4.10: Contractor’s ranking of significant causes of DDD

Rank	Factor No.	Factor	Mean
1	8	Coordination of design team	0.73
2	20	Poor design management	0.73
3	6	Effective design team	0.73
4	3	Designer’s experience	0.73
5	5	Design team cohesiveness	0.72
6	7	Communication amongst team members	0.72
7	14	Lack of staff	0.70
8	2	Designer’s education	0.70
9	24	Misinterpretation of client on part of designer	0.69
10	28	Authority approval	0.68
11	18	Transfer of knowledge	0.67
12	23	Unreasonable client expectation	0.66
13	10	Lack of quality assurance/management	0.65
14	15	Difficulty in finding good staff	0.64
15	19	Quantity of work allocated to designer	0.64
16	13	Design reuse	0.63

Table 4.11: Consultant’s ranking of significant causes of DDD

Rank	Factor No.	Factor	Mean
1	3	Designer’s experience	0.76
2	7	Communication amongst team members	0.75
3	2	Designer’s education	0.74
4	8	Coordination of design team	0.74
5	20	Poor design management	0.72
6	6	Effective design team	0.70
7	18	Transfer of knowledge	0.70
8	10	Lack of quality assurance/management	0.69
9	19	Quantity of work allocated to designer	0.67
10	1	Poor training	0.66
11	15	Difficulty in finding good staff	0.65
12	14	Lack of staff	0.64
13	5	Design team cohesiveness	0.63

The combined mean ranking of both the consultant and contractor are portrayed in Table 4.12. Notably, 16 out of the 28 factors appeared in the highly significant category, the rest that did not make this list were within the significant category. Referring to the table, the findings revealed that ‘designer’s experience’ and ‘coordination of design team’, in the opinion of both the parties, had the greatest influence on the quality of the design documents. Lack of quality management also made this range. This result was in harmony with the research conducted by Sunday and Afolarin (2013), who made an equivalent conclusion (“professional inexperience” and “lack of quality management” are general causes of errors). Similarly, Dosumu and Iyagba (2013) found that the designer’s experience, poor coordination between the disciplines and poor design management (lack of design reviews, value engineering studies and constructability) were amongst the top 10 causes of errors in construction document. Hence, this latter study was also in alignment with the outcome of this research. Furthermore, Mohammed (2007) cited designer’s experience and education as chief causes of error reproduction in Saudi Arabian construction documents.

Table 4.12: Overall respondent's ranking of highly significant causes

Rank	Factor no.	Factor	Contractor	Consultant	Mean
1	3	Designer's experience	0.73	0.76	0.74
2	8	Coordination of design team	0.73	0.74	0.74
3	7	Communication amongst team members	0.72	0.75	0.73
4	20	Poor design management	0.73	0.72	0.73
5	2	Designer's education	0.70	0.74	0.72
6	6	Effective design team	0.73	0.70	0.71
7	18	Transfer of knowledge	0.67	0.70	0.68
8	5	Design team cohesiveness	0.72	0.63	0.68
9	14	Lack of staff	0.70	0.64	0.67
10	10	Lack of quality assurance/management	0.65	0.69	0.67
11	19	Quantity of work allocated to designer	0.64	0.67	0.66
12	24	Misinterpretation of client on part of designer	0.69	0.62	0.65
13	15	Difficulty in finding good staff	0.64	0.65	0.64
14	28	authority approval	0.68	0.59	0.64
15	1	Poor training	0.60	0.66	0.63
16	23	Unreasonable client expectation	0.66	0.60	0.63

Designer's experience is vital in a project. In particular, more experience will equate to the resolution of more problems and improved communication between members of a team (Mohammed, 2007). In reviewing several projects in Australia, (Love et al., 2006) found widespread deficiency in the form of errors and omissions could be attributed to a firm's practice of commissioning the production of contract documentation to inept staff members, such as fresh graduates.

In considering the designer's education, an interviewee specified that appropriate and continuous professional education offered to the consultant was imperative. Moreover, exposing the professionals to the latest technology available in the market, materials and construction methods need to be encompassed in the education.

In the case of the project budgeted cost, a construction manager acknowledged that though budgetary restrictions may not influence the quality of the documents, the designers may be inclined to select 'border line material specifications' which might not be environmentally friendly, necessitate costly maintenance, and have a short life span.

Table 4.13 illustrates the factors that received the lowest importance index. Admittedly, this would seem to contradict a number of studies, such as Love et al. (2008) and Andi and Minato (2003) that reported the contrary. Nonetheless, analyzing the values of the importance index show that these factors are within the significant category. To state this another way, these factors, despite receiving the lowest scores, are relevant to both the parties.

Table 4.13: Least impacting factors

Factor No.	**Factor**	**Contractor**	**Consultant**	**Mean**
17	Simultaneous design work	0.58	0.56	0.57
4	Reputation of designer	0.60	0.54	0.57
27	Project budgeted cost	0.57	0.57	0.57
9	Improper use of CAD (computer aided design)	0.56	0.56	0.56
21	Type of client	0.53	0.57	0.55
11	Accepting low design fee	0.52	0.54	0.53

4.2.3 Analysis of consequences of deficient documents

Following a similar pattern to the earlier section, the factors that were prioritized by the contractors and consultants are presented in Table 4.14 and Table 4.15, respectively.

Table 4.14: Factors given more precedence by contractors

Factor No.	Factor
3	Raised estimates
4	Impact on contractor
5	Change orders

Table 4.15: Factors given more precedence by consultants

Factor No.	Factor
7	Rework
9	Bad consultant image
10	Designer indemnity insurance
11	Design changes
12	Disputes/litigation
14	Decrease in consultant's administration time
15	Owner's time
17	Contractors aborting tender

It's worth noting that the three factors given more importance by the contractors are all in some way linked to themselves. Also, some of the factors given more priority by the consultants were tied to the consultants. For example, bad consultant image, designer indemnity insurance, and the diminishing of the consultant's administration time are all factors that the consultant would be more concerned with.

Table 4.16 and Table 4.17 outline the most significant repercussions, based on the views of the contractors and consultants, respectively, which materialize as a result of deficient documents. Surprisingly, the contractors indicated that error exploitation was a highly significant impact of deficient documents. This view was not shared by the consultant, as is evident from this factor not appearing in the top rank of the consultant's list.

Table 4.16: Significant effects of DDD in perspective of contractors

Rank	Factor No.	Factor	Mean
1	5	Change orders	0.76
2	4	Impact on contractor	0.74
3	3	Raised estimates	0.72
4	13	RFI (request for information)	0.68
5	1	Impact on project performance	0.68
6	9	Bad consultant image	0.67
7	16	Conflict amongst parties	0.66
8	2	Impact on progress monitoring	0.65
9	6	Error exploitation	0.63

Table 4.17: Significant effects of DDD in perspective of consultants

Rank	Factor No.	Factor	Mean
1	11	Design changes	0.72
2	9	Bad consultant image	0.71
3	4	Impact on contractor	0.71
4	5	Change orders	0.69
5	16	Conflict amongst parties	0.68
6	1	Impact on project performance	0.68
7	13	RFI (request for information)	0.66
8	2	Impact on progress monitoring	0.66
9	3	Raised estimates	0.65
10	15	Owner’s time	0.64
11	14	Decrease in consultant’s administration time	0.63
12	7	Rework for both consultant & contractors	0.63

One participant asserted that deficient documents were well capable of altering the initial scope of a project. In the scenario that the scope is expanded, the contractor will submit variation or change orders to compensate for the extra expenditure. Regarding the conflict between parties, inadequate or vague specifications have the ability to markedly change the cost of the project. This leads to conflicts and disputes between the client and contractor, which end in arbitration. In the case of error exploitation, before the submittal of the bid the contractor may seek clarification for any ambiguities that may have been noticed. Yet, there are some instances where the documents deficiency will not be made conspicuous until after the contract has been awarded for the purposes of gaining revenues from changes.

Examining Table 4.18 reveals that it was jointly recognized that the deficient documents had their biggest impacts on the contractor and change orders. Al-Far (2005), who conducted a study in identifying the factors affecting design and documentation quality, found that RFI, change orders, and disputes were ranked 1^{st}, 2^{nd} ,and 4^{th} , respectively, as the main detrimental effects of design and documentation deficiency. In a similar manner, Table 4.18 reveals that both parties consider change orders, RFI, and conflict amongst parties as among the most significant corollary of deficient documents.

Table 4.18: Combined mean of most significant effects of deficient documents

Rank	Factor No.	Factor	Contractor	Consultant	Mean
1	4	Impact on contractor	0.74	0.71	0.72
2	5	Change orders	0.76	0.69	0.72
3	9	Bad consultant image	0.67	0.71	0.69
4	3	Raised estimates	0.72	0.65	0.68
5	1	Impact on project performance	0.68	0.68	0.68
6	13	RFI	0.68	0.66	0.67
7	16	Conflict amongst parties	0.66	0.68	0.67
8	11	Design changes	0.61	0.72	0.67
9	2	Impact on progress monitoring	0.65	0.66	0.65

In comparing the highly significant consequences (outlined in Table 4.18) with the frequent DDDT (Table 4.7), a relation may be observed. For instance, the first ranked consequence, impact on contractor, is directly correlated with all the highly significant DDDT, barring operational issues. This same observation is repeated for all the other consequences reported in Table 4.18. Admittedly, all the recognized consequences in the study are related to the identified DDDT. Figure 4.8 illustrates the connection of one of the consequence with the DDDT.

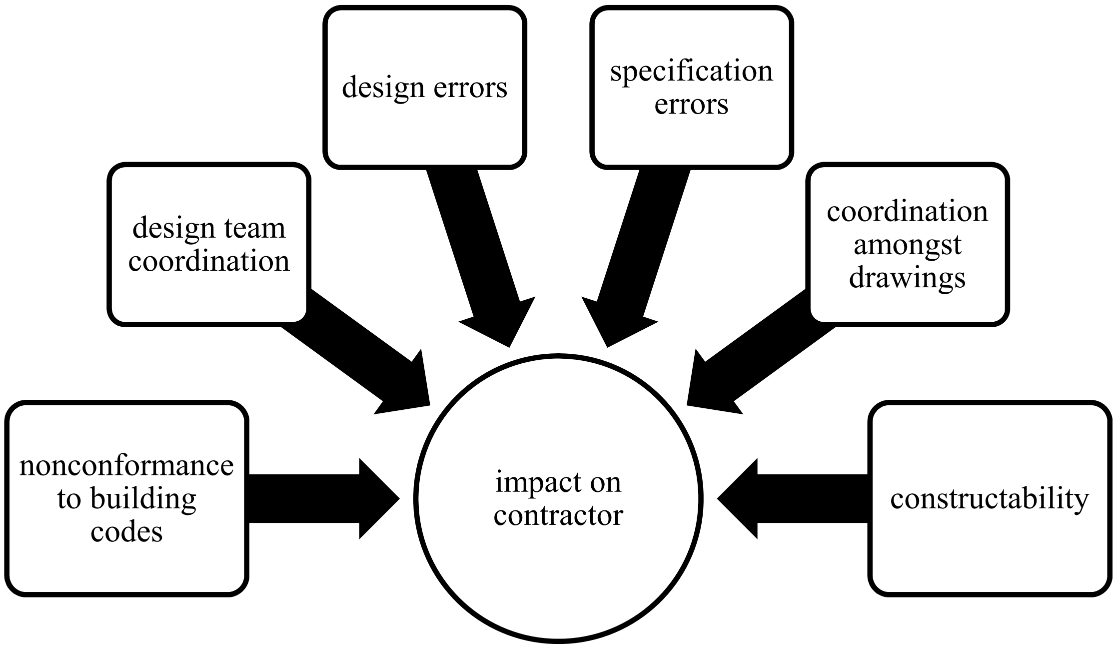

Figure 4.8: Impact on contractor and relation with DDDT

4.2.4 Analysis of error prevention strategies

Table 4.19 displays the preventive techniques that were believed to be most effective in impeding deficient documents. Of these top selected approaches, quality management was nominated as the best approach. In regard to this result, Love et al. (2008) also suggested that design review and verification, though not able to stop errors from materializing, were the first line of defense in diminishing the effects of errors. In the case of the contractor involvement at the design stage, Andi and Minato (2003) also emphasized the importance of coordination between the designer and contractor at the design stage.

Table 4.19: Most effective approaches to combating DDD

Rank	Factor No.	Factor	Contractor	Consultant	Mean
1	3	Quality management	0.78	0.76	0.77
2	6	Learning from mistakes	0.77	0.76	0.76
3	8	Improving coordination amongst various specialties	0.78	0.73	0.75
4	4	Error recovery process	0.73	0.74	0.73
5	7	Effective design management	0.73	0.72	0.73
6	20	Scope of design works are complete and clearly defined	0.74	0.71	0.72
7	5	Improvement of personnel	0.64	0.75	0.70
8	21	Using information technology to improve communication	0.70	0.68	0.69
9	19	Regular design team meeting	0.65	0.68	0.66
10	16	Client stating requirements concisely at the brief	0.64	0.66	0.65
11	15	Diligence on client's part in the selection of competent consultant	0.63	0.65	0.64
12	17	Involving client and contractor at design stage	0.68	0.60	0.64
13	9	Decomposition of tasks	0.65	0.61	0.63
14	2	Concurrent engineering	0.62	0.63	0.63

Quality management, as was explained in section 2.6.1, enforces the use of interdisciplinary teams to review the design. Within these meetings light tables may be leveraged to test compatibility of different disciplines. This guarantees that "design team coordination," the DDDT that was reported to be among the highly frequent DDDT, do not emerge at the construction phases. In addition, the review is capable of identifying any breach in building codes and resolve them well before construction initiates. Furthermore, since design review utilizes checklists, the effect that the most impactful cause of deficiency that was identified in section 4.2.4, i.e., “designer’s experience”, will to a certain degree be compensated.

“Learning from mistakes” is a seemingly simplistic notion, but in the settings of an organization, learning from past projects is vital. For instance, gathering field information relating to conflicts in systems may illuminate common clashes which can then be added to design checklists, similar to the Redicheck method, elaborated on in section 2.6.1.1.2. This introspection guarantees that the same mistakes are not performed in the future by different staff.

4.3 *Test of agreement*

In this section the agreement between the two parties will be tested by exploiting two statistical tests, namely, the Pearson correlation test and the t- test for independent samples. For the t-test, the variables being tested are the mean values for the deficiency types, causes, effects, and prevention methods.

4.3.1 Agreement on deficiency types

Figure 4.9 is a line graph displaying the ranking provided by the two parties. The trend of the graph indicates that there is a level of concurrence amongst the parties. That is to say, they agree on the frequencies of the deficiency types. In order to verify this conclusion, Pearson correlation coefficient was enlisted. The coefficient produced a value of 0.82, showing a strong linear relation. Restated, the parties have an agreement of 82%. In addition, a t-test at a 0.05 level of significance with df (degree of freedom) = 15 was conducted. The null and alternative hypothesis, respectively, are given below:

H_0 Contractors and consultants agree on most frequent deficiency types
H_A Contractors and consultants disagree on most frequent deficiency types

This test yielded a p-value of 0.42. Since the p-value exceeded $\alpha = 0.05$, the null hypothesis, namely the statement that the average of the rankings provided by the parties were equal, could not be rejected.

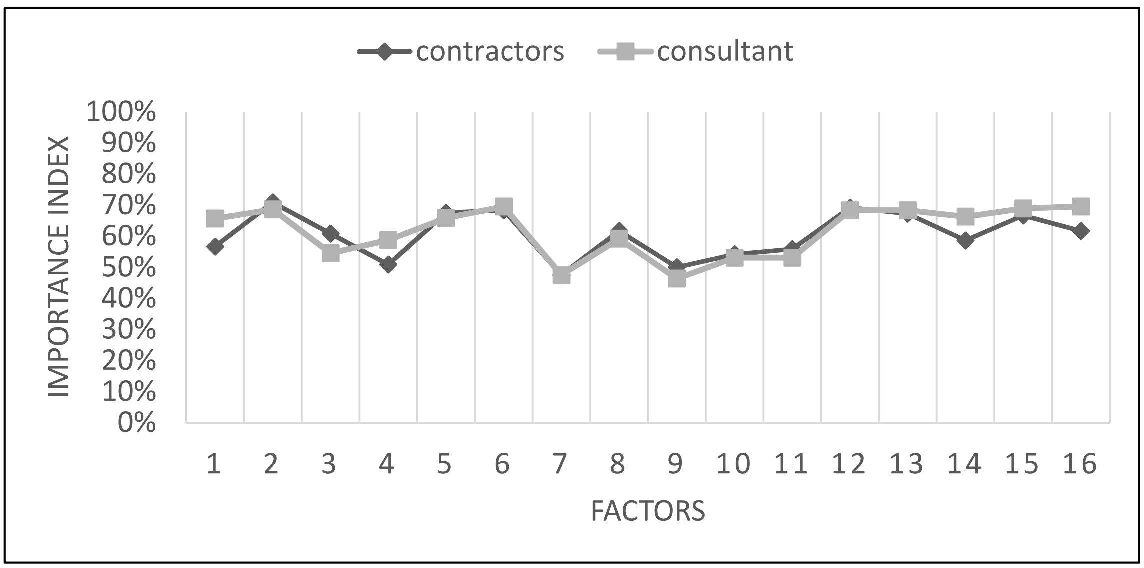

Figure 4.9: Line graph displaying ranking of the frequency of deficiency types

4.3.2 Agreement on causes of document's deficiency

Figure 4.10 is plot of importance index and the corresponding causes provided by both the contractor and consultant. The Pearson correlation produced a value of 0.803052685. This indicated that, once again, there was a strong level of agreement, 78% in this case between the contractor and consultant.

The null and alternative hypothesis, respectively, are formulated as follows:

H_0 Contractors and consultants agree on factors impacting document's deficiency
H_A Contractors and consultants disagree on factors impacting document's deficiency

Conducting the t-test at a 95% confidence resulted in p-value = 0.32. Due to this value exceeding α=0.05, the null hypothesis could not be rejected. Therefore, there was not enough proof to reject the hypothesis that there existed an agreement amongst the parties on factors pertaining to the causation of document deficiency.

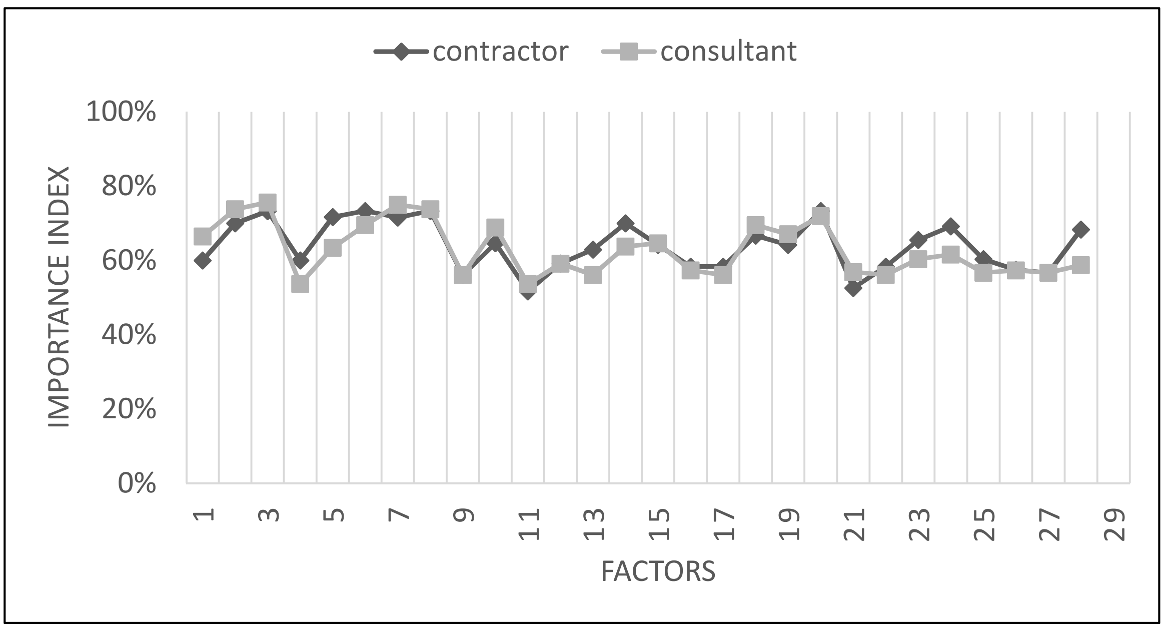

Figure 4.10: Line graph displaying importance index of causes of DDD

4.3.3 Agreement on consequences of deficient documents

Figure 4.11 is plot of importance index and the corresponding effects of DDD provided by both the contractor and consultant. Likewise, this plot reflects a consensus between the two parties.

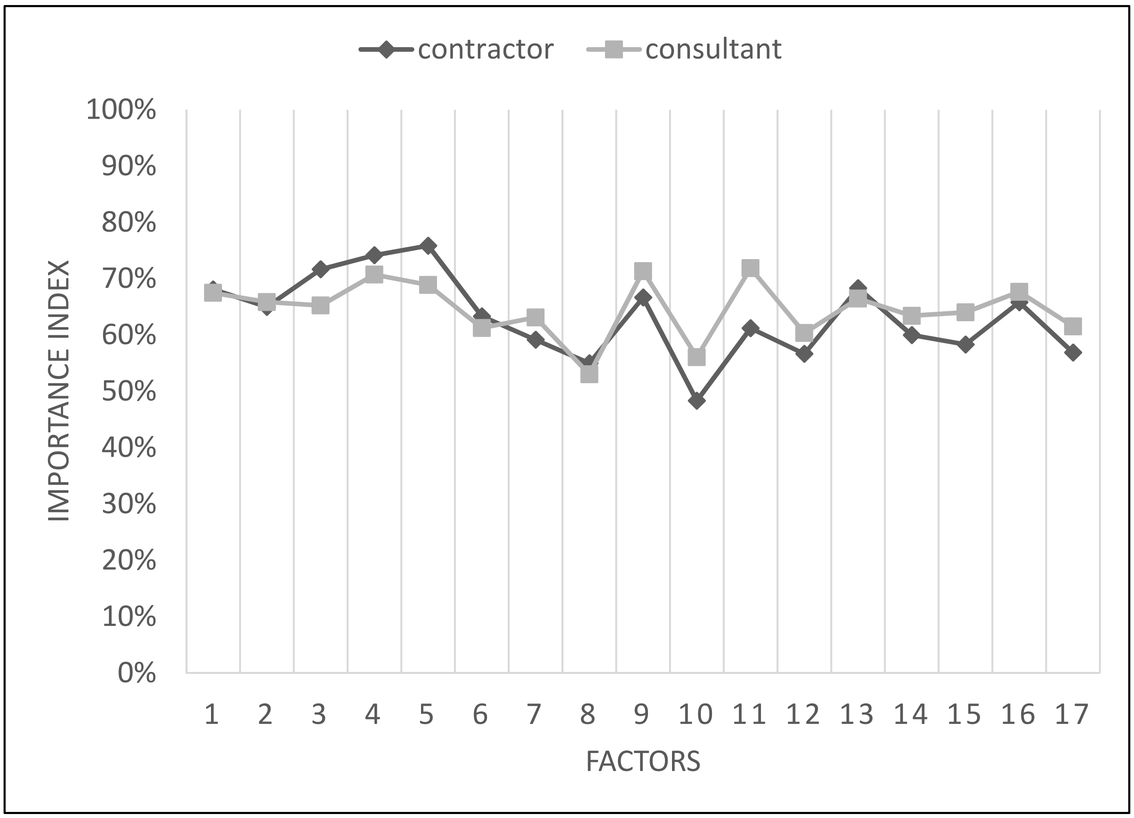

Figure 4.11: Line graph displaying importance index of the effects of DDD

There was a strong relation in the response of the two parties with the Pearson correlation generating a value of 0.74, meaning that there was a 75% agreement. This value is slightly low in comparison to the preceding two sections. This indicates less agreement relative to the two prior sections. A plausible explanation to this might be that the two parties view impacts based on their interests. That is, there is some tendency of bias towards the factors relating to them.

The null and alternative hypothesis, respectively, are presented below:

H_0 contractors and consultants agree on consequences of deficient documents
H_A contractors and consultants disagree on consequences of deficient documents

The t-test at 95% confidence generated p-value = 0.425804. Like before due to this value being greater than α=0.05, the null hypothesis could not be rejected. Therefore, there was not enough proof to reject the hypothesis that there existed an agreement amongst the parties on the consequences of deficient documents.

4.3.4 Agreement on error prevention strategies

Figure 4.12 depicts a plot of the responses provided by both parties on their perception of the most effective methods to prevent the materialization of deficient documents. The graph shows, to a moderate extent, a level of disagreement between the rankings of some factors. The Pearson correlation produced a value of 0.72, signifying a 73% agreement.

For the hypothesis test, the null and alternative hypothesis, respectively, are presented below:

H_0 Contractors and consultants agree on prevention strategies
H_A Contractors and consultants disagree on prevention strategies

The t-test resulted in p-value = 0.08, which again is greater than α = 0.05. The conclusion is that the hypothesis that the two parties agree on prevention methods cannot be rejected. Overall, it appears that both parties concurred on what were the most effective means of preventing deficient documents.

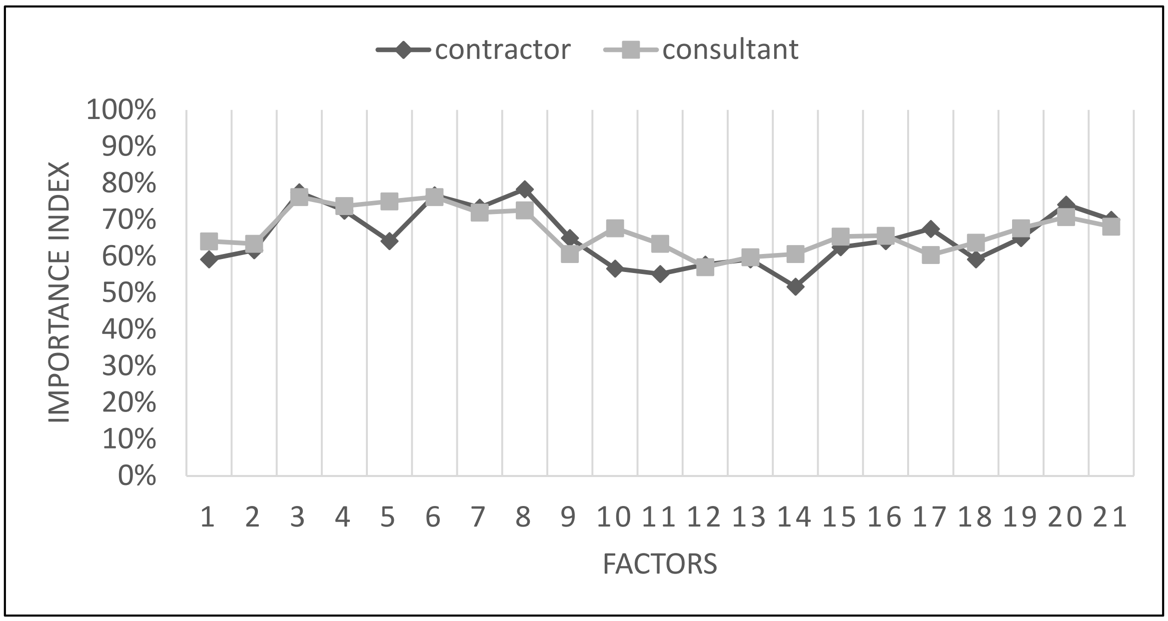

Figure 4.12: Line graph displaying importance index of DDD's prevention methods

4.4 *Comments from respondents*

The suggestions provided by the consultant and contractors, both in writing and orally, are specified in this section.

4.4.1 Contractor

1. In one project, change orders resulting from deficient documents reached 15%-20% of the entire project cost
2. Contractor completely dependent on BOQ. Hence, key specifications should be included in BOQ. In addition, a word in BOQ will drastically impact the price
3. A common problem is design reuse, where the designers resort to copying design/specifications from other completed projects, even if the projects are in a totally different context. As a result, some specifications may not be suitable for a project, due to the difference in environment
4. Designers need to be aware of current items in the market. For example, one designer specified a 25cm hollow core block. Consequently, the contractor wasted time only to find that the block was not available
5. Ambiguous specification. For instance, I came across a specification that stated that a 10x10 ceramic should be used without making mention of the

required thickness. In the eye of the contractor this is a cardinal omission since it has a strong sway on the cost of the project

6. Insufficient time provided to designers lays the foundation for the manifestation of these mistakes
7. Specification reuse are a big contributor to errors. Usually, specifications are not compatible to the project
8. The level of design diligence is dependent on the type of client the designer is working with. For example, when working with governmental clients such as Aramco, the designer will practice more care in comparison to private projects. This is because the designer is more concerned with the securing future jobs with bigger clients
9. In my opinion, short time frames given to the designers will not introduce mistakes. To the contrary, the stress caused by this time restriction will in fact spur work
10. A competent consultant is essential. Sadly, though, I would say that 99% of Saudi owners have yet to realize this vital aspect
11. There is a wide spread tendency to copy specifications regardless of the setting for which they were primarily intended for. As a result, the specifications employed are not compatible to the environment

12. Having construction field experience is of prime importance in composing a design that is of quality and constructible at the same time
13. A project construction manager may facilitate in introducing construction field experience into the design
14. The estimated time for the design should be analyzed carefully and negotiated with the design professionals
15. There is discrepancies between drawings, specifications, and the BOQ

4.4.2 Consultant

1. CPD – continuing professional development
2. BOQ errors (materials and activities indicated in the BOQ are not sufficient)
3. Design time frame is not adequate
4. Delay in actual construction progress
5. Proper time management
6. Deficient documents influence the project’s estimated time of completion
7. There is no commitment from all the parties involved
8. Not enough follow up to completed projects
9. There is an absence of offices control to evaluate the quality of the documents
10. Professional ethics and code of conduct amongst the parties involved in the project
11. No regulations from municipality

12. Clients poor choice of consultants and lack of knowledge about the contract deliverables

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 *Summary*

DDD greatly impede a projects ability to materialize successfully. They are capable of spawning many unwanted repercussions that present themselves in the form of change orders, design changes, contractor idle time, to name but a few. If not discovered in a timely manner the effects can snowball into larger and costlier issues. The aim of the research, therefore, was to conduct a review of the literature and a field survey to recognize and bring into awareness the various facets of deficient documents in the context of Saudi Arabia. Consequently, this research touched on the four crucial aspects of document deficiency, namely, (1) types, (2) causes, (3) impacts, and (4) prevention methods.

This study was divided into five chapters. Chapter 1 introduced the topic, underlining the criticality of the study, the goal it intended to achieve, and its limitation.

In chapter 2, previous studies on the topic were reviewed. In conducting this review many sources were utilized, including articles, master and Phd dissertation, and books on the topic. This chapter had four sections. The first detailed the outcomes of various studies.

The second discussed the definition of design. The third explored the types of document deficiency identified by other researchers. The last section was a discussion of the chapter.

Chapter 3 introduced a large portion of the study. Specifically, the causes, impacts, and prevention methods were presented.

Chapter 4 describes the work that went into producing the questionnaire for the survey, the method employed to gather the data, and the scoring system utilized to generate the importance index.

Chapter 5 disseminated the results of the study in seven units: (1) general information, (2) deficiency types, (3) factors impacting document's deficiency, (4) consequences of deficient documents, (5) error prevention strategies, (6) test of agreement amongst the parties, and, lastly, (7) comments of respondents.

5.2 *Conclusion*

Drawing from the results obtained in chapter 0, the conclusions of the research are summarized below:

1. In addressing the deficiency types, failing to follow codes appeared to be the most frequent DDDT. This was closely followed by "design team coordination" and "design error." With respect to the categories, the contractors identified the

"coordination' category, which encompassed "coordination amongst drawings" and "design team coordination", as being common. On the other hand, the consultant viewed the "other" category, covering "operational issues" and "constructability", as being most regular. In analyzing the importance index given to the factors, it was observed that the lowest importance index attained by any of the factors was 46%, which was within the significant category. Stated differently, all the deficiency types listed in the questionnaire were viewed as frequent by both the parties.

2. For causes, the experience of the designer was regarded as having the biggest sway on the incidence of deficient documents. This was supported by the findings of several other researchers both within the context of Saudi Arabia as well as outside the region. It is worth mentioning that, in contrast to the consultant's view, the contractor considered design reuse as a highly significant contributor to deficient documents.
3. In the case of impacts, both "impact on contractor" and "change orders" were nominated as the factors most impacted by deficient documents. It is worth restating that, unlike the consultants, the contractors acknowledged that error exploitation was a highly significant outcome of deficient documents. This result was somewhat surprising as one would expect consultant accusing contractors for such practices, not the contractors acknowledging this shortcoming.

4. It was believed that the best prevention strategy was quality management. This strategy was closely followed by "learning from mistakes" and "improving coordination amongst various specialties."
5. Overall, the outcome of the research displayed a high degree of parallelism on the ranking of the factors between the two participating parties. More precisely, the first two sections that corresponded to the types and causes of DDD demonstrated stronger congruence than the last two sections, consequence and prevention strategies.
6. These findings depict a grim image of deficient documents being a real and recurring problem in Saudi Arabia. This claim is bolstered by the fact that none of the identified deficiency types in this research went below the significant category. In other words, all deficiency types were persistent problems.

5.3 *Recommendations*

1. It was mentioned previously in section 4.2.1 that KSA lacked standard building codes. Naturally it follows that in order to mitigate the problem of non-conformance to building codes voiced by all the participants as the most frequent DDDT, it is imperative for the government to establish standard building codes that are most appropriate to KSA. Furthermore, regulations that penalizes organizations that fail to adhere to these codes should be enacted.

2. To alleviate coordination issues, both disciplinary and interdisciplinary, it is suggested that management conduct design team workshops that features various disciplines on a regular basis. Also, incorporating design reviews to ensure the coherence of the design documents is highly recommended.
3. Design errors can be prevented by ensuring, whenever possible, that the technical aspects of the design are performed, or at least supervised, by experienced personnel and by periodically conducting design reviews. Training that focuses on frequent design errors should also be provided.
4. In tackling the operational issues, the designers are urged to solicit feedback related to the facility from both the contractor and client after the project has been in operation.
5. Applying constructability analysis during the design stages should reduce constructability issues. To accomplish this, personnel with extensive construction knowledge should be commissioned at the design stages. In addition, contractors may be enlisted to provide their construction experience.
6. An organization should adopt the method suggested by (Stasiowski & Burstein, 1994, p. 93) in which the organization delegates an individual to log all the deficiencies encountered in a project. Next, this data is transformed into meaningful information with the aid of barcharts. Once the managers are armed with this knowledge, they can appropriately device their quality improvement programs.

5.4 *Recommendations for future studies*

1. Research conducted in the future should consider, in covering the four aspects, the procurement methods used by a project. This should bring into light what influence, if any, this dimension will have on the frequency and impacts of the deficiency on a project.
2. The factors identified in this research should be appraised across distinct types of projects (e.g. building, highway, bridges, etc.) in order to analyze the factors sensitivity to such variability. Moreover, a correlation test should be conducted to test the agreement of the factor's ranking between these various projects.
3. Comparison of the significance of the established factors among varying projects sizes should be made thereby providing insight on the degree of impact defective design documents have as project scale varies.
4. While this research dealt exclusively with the drawings and specifications, which constituted an important part of the design documents, it failed to consider B.O.Q and design schedules. To illustrate the important role of B.O.Q. in a construction project, a contractor stated that B.O.Q were crucial in pricing any project, so much so that any discrepancy or ambiguity found in these documents would drastically raise the risks involved in a project. In light of this information, future research on

this topic should examine deficiency in B.O.Q.s and design schedules and the impacts they have on a project.

5. In an interview, a contractor asserted that, in a previously performed project, deficient documents were responsible for change orders that accounted for 15-20% of the entire project cost. Other than this sparse detail, information pertaining to the proportion of change orders contributed by deficient documents were not sought in this study. Therefore, it is recommended that future studies seek to uncover the percentages of change orders defective design documents are responsible for within KSA. Furthermore, similar to point 2, these percentages should be analyzed across various project types and project scales.
6. Information technology is an essential contributor to a building's and engineering structure's design process. Indeed, technology has greatly improved the design procedure and fostered the formation of novel solutions. Nonetheless, problems leading to bad project performance continue to plague the industry (Love et al., 2011). This has led to a new paradigm known as Building Information Modeling (BIM). Briefly, BIM takes all information relating to a building together with all its design documents and stores it an interrelated database (Krygiel & Nies, 2008). Though information technology was considered in general by the research, BIM in particular was not mentioned, and since BIM has yet to receive widespread recognition in Saudi it is assumed that the participants are unaware of the

technology. Hence, because BIM was not explicitly covered in the scope of this research as one the prevention strategies factors, future study should focus on how the introduction of BIM in the Saudi Arabian context may facilitate in alleviating defective design documents.

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APPENDIX A: INVITATION LETTER

Dear Respondent,

The Construction Engineering and Management Department of the College of Environmental Design at King Fahd University of Petroleum & Minerals is presently engaged in a study that will help to understand how the quality of design documents in a construction project impacts the performance of construction projects in Saudi Arabia.

We are asking you to participate by providing needed information related to different aspects of document problems as per your experiences in projects that have either been already completed or are currently in progress. We hold all data of individual firms in strict confidence. We know that there are numerous demands on your time. But your involvement is important in contributing to the study. The questionnaires will take about 20 minutes of your valuable time.

The attached questionnaire consists of four sections. The first section seeks information about types of document deficiency commonly encountered. The second section deals with factors that have an effect on the quality of the documents. The third aims to find the detrimental impacts deficient design documents will pose to a project. Finally, the fourth section looks at the most effective prevention methods employed.

We shall therefore highly appreciate your kindness towards us in rendering the information as per our needs. Your contribution in this regard is highly appreciated. It will be a pleasure for us to share the results of this research with you.

Your immediate action will be highly appreciated. Please return your completed questionnaire in an enclosed self-addressed envelope as soon as possible.

Thank you in anticipation for your cooperation.

Sincerely yours,

Dr. Khalaf A. Al-Ofi

Department Chairman

Construction Engineering and Management

APPENDIX B: QUESITONNAIRE

Contact Information: Email: g200683260@kfupm.edu.sa FAX: 0138604453 mobile:0503028108 tel: 038606534

Dear participant, this study evaluates the various types of design document (i.e. drawings and specifications) deficiency, the root causes, the extent to which they may impact a project, and the possible prevention strategies that can be capitalized to prevent their recurrence. Where needed a brief explanation or an example is provided in italics. Please also notice that the first section is divided into 6 main categories. Thank you in advance

1	working field: contractor □ consultant □ owner □ if other, please specify:
2	if answer to 1 is contractor, select grade: 1□ 2□ 3□ 4□ 5□
3	type of construction projects: building□ infrastructure□ industrial□ special purpose□ if other, please specify:
4	organization's nationality: saudi□ joint venture□ if other, please specify:
5	types of projects commonly completed: government□ semi-government□ private□ if other, please specify:
6	respondents name(optional):
7	position:
8	educational qualification(optional): Diploma□ BSc□ MSc□ PhD□
9	experience (years): <5□ 6-10□ 11-15□ 16-20□ >20□
10	experience in KSA (years):

scale designation				
1 = no significance	2 = low significance	3 = significant	4 = high significance	5 = very high significance

1. Types of document's deficiency							
No	Category	Factors	1	2	3	4	5
1	Not complying with design parameters	Nonconformance to client's specification (not meeting client's wants)					
2		Nonconformance to building code (e.g. not adhering to safety codes)					
3		Incompatibility with vendors data (e.g. specifications out of date, and conflicting equipment)					
4		Nonconformance to law (e.g. not utilizing local materials or suppliers)					
5	Coordination	Coordination amongst drawings (e.g. conflict between plan and elevation, section)					
6		Design team coordination (e.g. clashes between structural & mechanical systems)					
7	Not following procedures	Errors in symbol and abbreviation (e.g. annotations not consistent between drawings)					
8		Errors in dimension (e.g. dimensional conflict between drawings, or dimensions not summing)					
9		Failing to follow drafting standards (e.g. inconsistent paper size, scale, arrangement)					
10	Omission	Wrong or omitted callouts on drawings					
11		Wrong or omitted notes on drawings					
12	Errors	Design errors (technical errors, such as inadequate structural design)					
13		Specification errors (omitted items, items in drawings but not in specifications or vice versa, and items not meeting client requirements)					
14		Insufficient detail (e.g. not enough detail relating to connections or intersection)					
15	Other	Operational issues (poor quality and high maintenance cost of final built project)					
16		Constructability (e.g. inadequate materials)					

Please supply, in the space provided below, any factors that you think I have omitted. In doing so, please also mention the factor's respective ranking.

2. Factors impacting document's deficiency							
No.	Category	Factors	1	2	3	4	5
1	designer	Poor training *(training courses not provided to personnel)*					
2		Designer's education					
3		Designer's experience					
4		Reputation of designer					
5		Design team cohesiveness *(compatibility of the team members. i.e. ability to get along with each other)*					
6		Effective design team *(team having members with a good mix of technical, problem solving and interpersonal skills)*					
7		Communication amongst team members					
8		Coordination of design team					
9		Improper use of CAD (computer aided design)					
10		Lack of quality assurance/management *(e.g. neglecting quality review)*					
11		Accepting low design fee *(consultant accepting low fee due to competitive nature)*					
12		Time boxing *(consultant allocating insufficient fixed time to design)*					
13		Design reuse *(reusing previous design solutions and specifications)*					
14		Lack of staff *(not enough manpower)*					
15		Difficulty in finding good staff *(e.g. specification writer, construction detailer etc.)*					
16		Staff turnover *(e.g. key personnel leaving)*					
17		Simultaneous design work					
18		Transfer of knowledge *(Learning from past errors)*					
19		Quantity of work allocated to designer					
20		Poor design management					
21	client	Type of client*(private, government, developer)*					
22		Client experience					
23		Unreasonable client expectation *(in terms of insufficient fees and time)*					
24		Misinterpretation of client on part of designer					
25	project	uniqueness of project					

26		project size					
27		project budgeted cost*(the higher the budget, fewer the errors and vice versa)*					
28		authority approval *(long period of approval results in lost of interest & change of team members)*					

Please supply, in the space provided below, any factors that you think I have omitted. In doing so, please also mention the factor's respective ranking

3. Impacts of document's deficiency						
No.	Factors	1	2	3	4	5
1	Impact on project performance					
2	Impact on progress monitoring *(deviation between actual and apparent progress due to rework)*					
3	Raised estimates *(risk money included in the bid)*					
4	Impact on contractor *(e.g. idle time, time spent solving problem, rework for contractors)*					
5	Change orders					
6	Error exploitation *(contractor not revealing errors found in documents at biding stage to file for change orders during construction)*					
7	Rework for both consultant & contractors					
8	Decrease in consultant's profit					
9	Bad consultant image					
10	Designer indemnity insurance *(consultant accountability for errors found in documents)*					
11	Design changes					
12	Disputes/litigation					
13	RFI (request for information)					
14	Decrease in consultant's administration time *(consultant spends majority of time in correcting problems)*					
15	Owner's time *(reviewing and approving change orders and RFIs)*					
16	Conflict amongst parties *(e.g. rivalry between contractor and consultants)*					
17	Contractors aborting tender *(due to high risk levels)*					

Please supply, in the space provided below, any factors that you think I have omitted. In doing so, please also mention the factor's respective ranking

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4. Error prevention strategies						
No.	Factors	1	2	3	4	5
1	Partnering *(contractors involvement during design stage)*					
2	Concurrent engineering					
3	Quality management					
4	Error recovery process *(1.identify error, 2.Inform responsible personnel, and 3.Take necessary measures)*					
5	Improvement of personnel					
6	Learning from mistakes *(documenting lesson learned about design documents quality from previous projects)*					
7	Effective design management					
8	Improving coordination amongst various specialties					
9	Decomposition of tasks *(sequencing the work process. i.e. breaking a process into smaller tasks)*					
10	Risk management					
11	Risk audits					
12	Redicheck method					
13	The principle of single statement *(each dimension, coordinate, elevation, callout etc. shown only once in a set of drawings & specifications)*					
14	Red-Green-Yellow checking technique					
15	Diligence on client's part in the selection of competent consultant					
16	Client stating requirements concisely at the brief					
17	Involving client and contractor at design stage					
18	Training on recent design and construction practices					
19	Regular design team meeting					
20	Scope of design works are complete and clearly defined					
21	Using information technology to improve communication					

Please use the space provided below to enter any factor that I might have overlooked and that in your opinion is important along with its corresponding ranking. In addition, if you have any objections to the contents of the questionnaire (e.g. redundancy of factors or irrelevant factors), please do not hesitate to include them below

VITAE

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Educational Qualification

Institution name	Degree	Passing year	CGPA
King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia	BSc. Architectural Engineering	June 2012	3.48
King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia	MSc. Construction Engineering & management	November 2014	3.90