Collaborative Risk Management within a Design Phase of Green Buildings

by

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Declaration

I declare that this thesis is my unaided work. It is being submitted for the Degree of Doctor of Philosophy to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

Lungie Maseko

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The successful completion of this dissertation would not have been possible without the support and assistance of many people. I would like to sincerely thank each of those individuals for all of their support and encouragement throughout this journey.

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Dedication

To my loving husband, Chonko

Thank you for your patience, love, friendship, humour, and willingness to eat out (almost daily).

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List of Abbreviations

AEC	Architecture/Engineering/Construction
BIM	Building Information Modelling
CDM	Collaborative Design Management
CDT	Collaborative Design Team
CPM	Critical Path Method
CRM	Collaborative Risk Management
DSM	Design Structure Matrix
DMM	Domain Mapping Matrix
GB	Green Building
GBCSA	Green Building Council South Africa
GEPF	Government Employees Pension Fund
IPD	Integrated Project Delivery
MDM	Multi Domain Matrix
MOCAA	Museum of Contemporary Art Africa
PERT	Program Evaluation and Review Technique
PIC	Public Investment Corporation Limited
PMI	Project Management Institute
RM	Risk Management
RQF	Request for Qualifications
SACI	South African Construction Industry
SM	Stakeholder Management
SNA	Social Network Analysis
RSA	Republic of South Africa
VM	Value Management

Research Outputs

Published Work

The following papers are the direct outputs of this thesis. They include published work, and working papers.

Maseko, L. and Root, D. (2018) Interdependent tasks and inseparable risks within the design phase of green buildings, Association of Schools of Construction of Southern Africa – 12th Built Environment Conference Proceedings, 6-7 August 2018, Durban, p338-350

Maseko, L. and Root, D. (2018) Collaborative Risk Management within the Design Phase of Green Buildings, 09th International Conference on Engineering, Project and Production Management, 24-26 September 2018, Cape Town

Maseko, L., Root, D. and Venkatachalam, S. (2018) Conceptual Framework for Collaborative Risk Management during the Design Phase of Green Building Projects using DSM, 20th International Dependency and Structure Modelling Conference, 15-17 October 2018, Italy, p23-32

Maseko, L. and Root, D. (2021) Collaborative Risk Management Within the Design Phase of Green Buildings In: Scott, L and Neilson, C J (Eds) Proceedings of the 37th Annual Association of Researchers in Construction Management Conference, 6-7 September 2021, UK, p381-390

Maseko, L. and Root, D. (2021) A Collaborative approach for Risk Management in the Design Phase of construction projects in South Africa, 44th Annual Australasian Universities Building Education Association Conference, 28-29 October 2021, Australia, p431-440

Working Papers

Maseko, L. (2022) The interdependency of risks within collaborative design management of green projects, Journal of Construction Project Management and Innovation.

Maseko, L. and Root, D. (2023) Professional Indemnity within collaborative circumstances of interdependent tasks.

Maseko, L. and Root, D. (2023) The application of Blockchain systems in Collaborative Risk Management.

Abstract

Construction projects are ambitious in terms of the complexity of structures, design requirements, information flow, stakeholder integration and technological integration especially in green building projects. Consequently, management of these projects is increasingly integrated. However, risk management has taken little account of these emergent interdisciplinary and iterative trends in the building design process. This leads to poor risk management outcomes, where traditional risk management practices that rely on allocating risks to specific individual entities are not able to accommodate the collaborative facets. As part of a comprehensive research into Collaborative Risk Management (CRM) implementation to green building projects, a case study strategy was adopted using a mixed-method approach to seek practical solutions on how stakeholders in collaborative design teams can manage inseparable risks within their interdependent tasks. Experienced practitioners were interviewed regarding their current practices and techniques. With the view of exploring interrelationships among stakeholders, risks and tasks; a Dependency Structure Matrix (DSM) approach was used. To manage inseparable risk, stakeholders suggested regular team meetings including the client, proper and timeous information sharing with proportional risk sharing approaches. To regulate the sub-minimal information to proceed with tasks because of inexperience stakeholders, all stakeholders should get GB accreditation training and have engagements that can benchmark performance. The project should have a shared insurance cover that will balance the risks fairly between stakeholders; in absence of bad faith; leading to a reasonable price; qualitative performance and the minimization of disputes. This will dedicate specific contingency budgets and reserve margins to each risk area. Also, use a project risk manager to evaluate risk, identify potential cost impacts and develop contingency plans.

Keywords: *Dependency Structure Matrices, Inseparable risks, Interconnected stakeholders, Interdependent tasks, Risk sharing*

1. BACKGROUND TO THE STUDY

1.1 Preface

Green building designs assemble various stakeholders with different and potentially incompatible objectives, creating high levels of risks (Edward *et al*., 2019; Abdelaal & Guo, 2021; Kumar & Agarwal, 2022). However, it is well acknowledged that the collaboration of these stakeholders' objectives plays a critical role to the success of a design process (Nguyen *et al*., 2021; Ikudayisi *et al*., 2022). The main objective of this chapter is to introduce the reader to the disciplines of collaborative design and collaborative risk management in green buildings.

Combining collaboration and risk management will take into cognisant the interwoven relationships of stakeholders involved, their tasks, the formation of inseparable risks and an efficient way of risk sharing. The grounding models that describe the structure, relationships and influences between phenomena of this research are justified in the theoretical framework.

The goal is to provide the construction industry with a rational and economical decision-making mechanism that will provide an alternative to the current practice of typically sharing risks by aversion. And, the results of the study suggest that CRM can be a tool to transform risk management into be a proactive, continuous, value-based, focused and process-driven practice.

1.2 Research Rationale and Motivation

Building designs are characterised by a high level of uncertainty, due to the ill-defined nature of requirements, solutions, or outputs (Carpejani *et al*., 2020; Qiang *et al*., 2021; Wang *et al*., 2021). Multiple alternatives are considered, developed, evaluated, and reconsidered or discarded in order to reach an unconstrained and satisfying set of solutions, resulting in iterations (Al Hattab & Hamzeh, 2015; Mujumdar & Maheswari, 2018)). In addition, the intensive interdependence of design information and tasks of a large number of disciplines make design further complex and intertwined (Anand *et al*., 2020; Shen e*t al*., 2022). Given that, work done by design professionals is characterised by nonlinear, iterative and interactive processes that require effective collaboration between the multidisciplinary teams from the early stages in order to achieve green outcomes (Gomes *et al*., 2016; Kay *et al*., 2018).

With the increase in the interdependence and complexity of design tasks, the present construction industry is described as high-risk, high-tech and a multiparty business that deals with conflicts between diverse stakeholders regularly (Raouf & Al-Ghamdi, 2019; Cao *et al.*, 2022). Thus, a need for an effective risk management that will inspire better relationships and cooperative teamwork, under better contract conditions. Not that collaboration in managing risks is not there, it can be traced to organized risk sessions in most design processes. However, stakeholders still do not mitigate and manage risks, collaboratively. There continues to be a culture of division, blame and mistrust; as stakeholders may use the same risk management methods, but would not implement this together.

Current practices regarding design risks and risk management do not facilitate the shift towards collaboration and traditional project management has ignored the need for design management, specifically design workflow management, where upstream design disciplines neglect the needs of each other, as well as the needs of downstream disciplines. Furthermore, project management is solely concerned with the transformation process and task completion, with little to no attention given to workflow and value generation (Al Hattab & Hamzeh, 2017; Koseoglu *et al*., 2018). Therefore, relying on the same management techniques can be counterproductive. The efficacy and challenge of design and risk management are rooted in appropriately managing collaboration within their workflow.

1.2.1 Green Building Designs

Going green has become a mind-set that describes a set of actions and choices, which has a positive impact on the planet and the environment. In a technical sense, the design of a green building is different from that of a traditional building because designers need to adopt an integrated design approach that can consolidate current building design theory with the best practices necessary to ensure that a building can reduce its initial carbon footprint over time (Hwang *et al.*, 2017; Agyekum *et al.*, 2022). During this process, designers should understand interactions between special design factors such as solar or wind-powered fixtures, paint and other materials that have a lower impact on the environment. These design factors are thought of as, best practices in the context of a traditional building design, but not a necessity.

Compared with traditional construction designs, green buildings (GB) are characterized by the need to manage many different types of relevant collaborative interactions and stakeholder-related risk networks, making this type of project more difficult than traditional projects (Fang & Marle, 2013; Akintola *et al.*, 2015; Ngobeni *et al.*, 2023). Effective collaboration is emphasized in green designs because of its higher complexity and enormous fluidity.

Defining GBs, the USGBC (2009) referred to it as a process that aims to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy, water, and other resources and by reducing waste, pollution and environmental degradation. GBs are further described as those that have a higher environmental performance compared with that of typical buildings (Cole, 2011; Mushi et al., 2022). The key attributes of GB performance typically included by most assessment tools (e.g. BREEAM, LEED, GBCSA, and GBI) are shown in **Table 1.1** that is adopted from Cole (2011), cover resource use, emissions/waste, and health, and comfort issues.

Table 1. 1: Key attributes of green building performance

1	Reduces the contributions to global environmental damage
2	Reduces the need for new construction projects
3	Reduces the impacts on natural features and site ecology during construction
4	Reduces the potential environmental damage from emissions and outflows
5	Reduces resource use of energy, water, and materials
6	Minimises the discomfort of building occupants because of harmful substances

Designing these GBs requires close collaborative relationships that needs to improve its holistic approach to programming, planning and designing buildings. Green design is the thoughtful integration of architecture and interior design, as well as electrical, mechanical, and structural engineering components (Darko *et al*., 2017; Ngobeni et al., 2023). It is more of a philosophy of building than a prescriptive building style.

The added expertise and experience of various stakeholders involved create a complex coordination because of the variety of backgrounds and communication styles involved. These stakeholders carry specific knowledge for specific tasks within a design process, and are dependent on each other for information (Darko *et al*., 2017). This tight coordination requires an ability to share and communicate complex information about activities, people, teams, and organisations involved and their relationships. These areas are interwoven, creating further complexities and uncertainties for project stakeholders (Danilovic & Browning, 2007).

Traditionally, design tasks are tackled in an independent manner, creating inconsistencies and rework in the design development. However, there has always been a measure of interdependence between tasks, but the management of the process has focused on isolating and minimising the interfaces between the design professionals.

With GB designs, tasks have become increasingly interdependent; information needs to flow in more than one direction or more rapidly, and communication tasks have increased (Lather, 2016). This evolution requires collaboration and high information sharing among project stakeholders (Oh *et al.*, 2015); where communication, coordination and negotiation of decisions between stakeholders are fundamental. Moreover, GB designs are far from being a linear process; they are highly uncertain with multiple and unexpected changes resulting in iterations and rework (Chen *et a*l., 2015). To foster creativity, the collaboration needs to be non-hierarchical (Kaufmann & Meier, 2015).

Yet, the majority of today's design projects are still carried out in accordance with traditional methods and norms. There is still a tendency to try to fit GBs into existing work practices rather than modify practices to accommodate the needs of green buildings. Consultants are still hired in chronological phases (Reed & Gordon, 2000). This traditional hiring model has delayed the selection of key team members and these common practices have created impediments to delivering green projects on time and on budget (Robichaud & Anantatmula, 2010). The most recorded challenge to delivering a financially successful green project has been communication and coordination across a multidisciplinary team (Ben-Menahem *et al*., 2015). Green technology and its practices are complex in their function, form, and integration, among other aspects (Keast & Hampson, 2007; Gluch *et al*., 2009). Its complexity is defined as an intricate arrangement of the varied interrelated parts in which the elements can change and evolve constantly with an effect on project objectives (Bakhshi *et al*., 2016). This then requires, using a single method to assess a building's environmental performance that will satisfy all needs of stakeholders by designing for recycling and eco-labelling (Ding, 2008).

1.2.2 Design Professionals as Project Stakeholders

Project stakeholders in this context are defined as design professionals actively involved in the design processes of GB projects. Although they may have different interests, perceptions and needs, which may positively or negatively affect productivity or results; they still work together systematically to accomplish the common goal of the design (Olander, 2007). In GBs, these various stakeholders have diverse occupational and professional backgrounds, increasing the complexity (Mok *et al*., 2018). The complex and volatile nature of GB projects require systematic approaches and appropriate skills of accommodating stakeholder interests, to achieve the best design value outcome. Stakeholder management (SM) is then regarded as an effective approach for bringing stakeholder concerns to the surface and developing robust stakeholder relationships in complex project environments (Bourne & Walker, 2005).

The increasing size and complexity of construction projects demand an increased ability to manage stakeholders and risks throughout the design process to prevent unwanted consequences within their different tasks (Du *et al*., 2016). These tasks often proceed in parallel, relying on preliminary information from other tasks and information that has not yet been finalised. Handling such information requires knowledge about the variety of tasks and the degree of interdependencies within tasks. It also requires the instability of the assumptions upon which the tasks are based (Steward, 1981) and a suitable stakeholder management system for the accomplishment of these tasks (Eskerod & Jepsen, 2013).

Complexities in task performance seem to stem from uncertainty (William, 1999). Though complexity and uncertainty are separate concepts, together they produce difficulties and messiness of projects (Gidado, 1996). The increased complexity in GBs has meant that, despite improved methods, many projects still fail to meet expectations (Bryde *et al*., 2013). Therefore, a transition towards collaboration in RM is required, to do away with failures of traditional RM (Rotmans & Loorbach, 2009).

1.2.3 Risk Management: The Traditional Approach

Risks are inherent in all projects (Peckiene *et al.*, 2013) and all design stakeholders face them. This is attributed to the design complexities, the strategic nature of construction products (Dutta, 2014), and the numerous stakeholders involved (El-Sayegy, 2008). Eliminating risk from a design processes is impossible (Tauron, 2014), as risk can only be minimised (Kutsh & Hall, 2010). Due to its importance, one would expect project risk management practices to be not only the state of the art but also highly effective. However, some recent studies have raised concerns regarding the effectiveness of risk management tools in the construction project environments (Zwikael & Ahn, 2011).

Traditionally, a construction process has been sequential, based on rigid and impermeable boundaries that have made collaboration a challenge. This process has been divided into phases: programme, design, procurement and production (Azhar, 2011). In the programme phase, the client has an idea about the project and analyses conditions for its execution. During the design phase, the architects and engineers produce design and construction drawings according to the client's requirements. In the procurement phase, the client chooses the contractor and the parties sign the contract. Finally, the contractor executes the job in the production phase (Lam *et al.*, 2007).

Within this sequence, the client tends to allocate more risks to the contractor and accept as little risk as possible. Contractors would transfer risks to their domestic and specialist sub-contractors and through insurance premiums (Akintoye & MacLeod, 1997). Project professionals then resort to professional indemnity insurance to transfer risks associated with their services (Karimi-Azari *et al.*, 2011). It is generally recognised that risk should be transferred to the party that is in the best position to deal with it (Alsalman & Sillars, 2013). The process in which a contractor transfers all risks involved in a project does not bode well for innovation initiative within the industry. The result of this has been poor project performance characterised by cost overruns, poor quality, late completion and tensions (Ibid).

Presently, the AEC industry is steadily shifting from this linear process towards a complex system, which has increased transparency and has become subject to stricter regulatory compliance requirements. This shift requires all stakeholders within GB projects to take a closer look at their own risk selves. In this shift, the traditional Critical Path Method, which is based on the descriptions of task flows using graphic symbols, is unsuitable for modelling information flow that controls the design phase (Yassine *et al*., 1999). It lacks the ability to model feedback and iteration, as it only allows for one-way progression in activity sequences (Eppinger & Browning, 2012). The design phase of GBs differs, as they require a collaborative design process, which encompasses an iterative flow of interdependent decisions from different design stakeholders (Pektaş & Pultar, 2005). This task interdependency and interdisciplinary is however pushing boundaries, and requires collaboration that will align flow processes (Cataldo *et al.*, 2006).

It has become increasingly clear that traditional design and risk management approaches do not adequately identify, evaluate and manage unknown risks, which mostly follow non-linear processes. Traditional approaches tend to be fragmented, treating risks as disparate and compartmentalised (Thamhain, 2013). These risk management models limit the focus to managing uncertainties around physical and financial assets (Tang, 2006), and it is impossible to fit dynamic risks into. As these focus largely on loss prevention, rather than adding value. Traditional approaches do not provide the holistic framework most projects need to redefine the risk management value proposition in this rapidly changing world.

1.2.4 Risk Management: The Problem of Green Buildings

With the green movement, designing projects has become increasingly complex and difficult to manage (Chan *et al*., 2004). The complexity is exacerbated by the reciprocal interdependencies, not only from the design professionals but added stakeholders, such as financing bodies, green rating authorities, lawyers, suppliers, councils and trades, which makes it necessary for construction projects to improve integration, cooperation, communication and coordination (Clough *et al*., 2008; Gustavsson, 2015). This collaborative approach aligns the incentives and goals of the design team through shared risk and reward, the early involvement of all parties, and a multiparty agreement (Kent & Becerik-Gerber, 2010). However, how risks are shared among stakeholders in the design phase is largely governed by the dynamic evolution of management and the different types of responses. In order to manage such risks successfully, collaborative efforts among project stakeholders should be aligned because, even risks that have been identified and shared; change in scope.

This effective risk management needed will focus on efforts to gather all the necessary information to have timely decisions during the design phase. This will also include a broad spectrum of risks that may be dynamically distributed throughout the design phase (Hwang & Ng, 2013). Errors produced during the design phase can have severe impacts on subsequent phases and the overall project. Omissions or errors in design that are discovered late are responsible for approximately one-third of the outturn cost (Al Hattab and Hamzeh, 2015). They also lead to schedule delays due to rework and changes required to mitigate the errors. Thus, risk management can move from a predominantly intuitive process to a disciplined structured one that involve all project stakeholders. However, with complexity comes an enormous difficulty of predicting specific risk situations, their timing and root causes (El-Sayegh, 2008). How then do stakeholders deal with these risks will be through a strict integration of design management, which is a key enabler to eventually a cultural shift.

The involvement of all stakeholders in design processes leads to a detailed understanding of project objectives and a collective sensitivity as to where risks lurk and how to deal with issues effectively (Yang & Zou, 2014). However, risk means different things to different stakeholders and RM should go beyond traditional analytical methods to deal with unknown risks. Thamain (2013) said that, although analytical methods provide the backbone for most risk management approaches, and have the benefit of producing an assessment of a known risk situation. Analytical methods provide economic measures of gains or losses, with many limitations. The most obvious limitations are in identifying potential, unknown risk situations and reducing risk impact by engaging people from the onset of the project.

1.2.5 Collaborative Risk Management System

The transition will be to improve the design process towards having a collaborative risk management (CRM) system. Osipova and Eriksson (2013) define this approach as the importance of collaboration between the design stakeholders in managing risk that cannot be identified at the outset of the project. Within this development, an improvement in information flow within the design phase will be required and collaboration will rely on a process that is able to foster and transfer innovative products, services and practices (Keast & Hampson, 2007).

CRM is a system that can continuously adapt to a changing project environment (Rotmans & Loorbach, 2009), meaning it will influence the process of change. It is fundamentally a decision-making approach to accommodate all stakeholders, finding compromise zones, and narrowing differences between antagonists (Williams, 1997). The transition within an integrated and collaborative framework will have the potential to overcome the traditional dispersion of responsibilities (Jaafari, 2001). It will include risk management processes, techniques and tools, organisational aspects, and contracting strategies to avoid contractual rivalry (Tang *et al.,* 2007). The objective of CRM is to be flexible and adjustable at any design level. CRM should transforms risk management to a proactive, continuous, value-based, focused and process-driven activity.

Despite the recognition of improving information flow in design management research in the literature, the use of CRM in practice appears to be infrequent. Risk in construction is still the object of attention because of time and cost over-runs (Perry & Hayes, 1985, Lam *et al*., 2007), which are perceived to have become a norm rather than an exception in design and project delivery.

While some risks can be foreseen at the beginning of a project and allocated among design stakeholders, other risks are difficult to predict (Rahman & Kumaraswamy, 2005) and can only be dealt with when they occur. Early efforts injected into a design are said to improve the design quality and reduce errors in deliverables, project costs, and negative iterations (Al Hattab and Hamzeh, 2015). GB designs can be very abstract and involve risks that are derived from uncertainty about project scope and its duration. Other risks include unproven technology that can be monopolised, integrated teams and collaborative management, and responsibilities and liabilities of different stakeholders. These risks can be difficult for stakeholders to share at the project outset. This drives the risk management business to acquire specialised expertise to underwrite the industry's projects (Loosemore *et al.*, 2006).

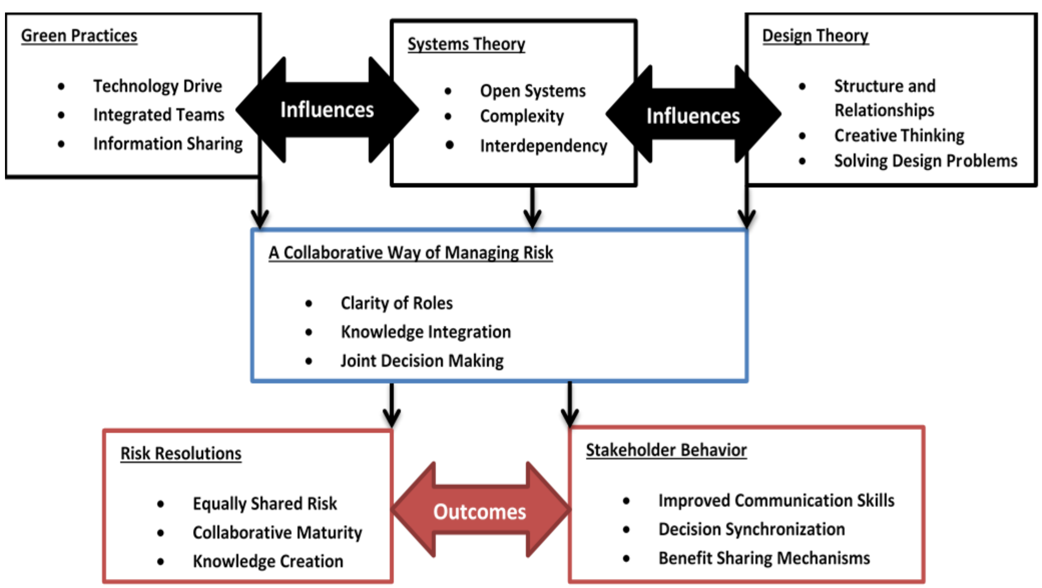
Bufaied (1987) and Odeyinka *et al*. (2012) recognised that stakeholders within the construction industry are continually faced with a variety of situations involving many unknown, unexpected, frequently undesirable and often unpredictable factors. South Africa is no different in this regard; yet, despite the variety of available tools and techniques, risk management (RM) is often criticised for being inadequate (Tang *et al*., 2007, Osipova and Eriksson, 2011a) and not achieving its main objective, to bring more certainty to a project by minimising threats and maximising opportunities. The need for risk analysis and management in design activities is significant but, little is known regarding the industry's response, and in particular, the techniques employed for RM within the GB evolution.

1.3 Theoretical Framework

Theoretical framework should highlight a collaborative way of managing risks which is able to take advantage of the different views from different stakeholders involved in designing GBs and identify risks that cannot just be shifted to one stakeholder but have to be collaboratively managed.

The theories used will assist in describing processes, actions, and dynamic situations that illustrate related elements and structures by addressing their actions or influence of one upon another (Forlizzi *et al.*, 2009). **Figure 1.1** illustrates a merger of green practices, systems theory and design theory. These theories are adaptive in the sense that they have the capacity to change and learn from experience (Mitleton-Kelly, 2003). Expressed differently, they can respond to and adjust themselves to changes in their environment.

Figure 1. 1: Research theoretical framework



Systems theory is an interdisciplinary field of science that studies the nature of complex systems in society, nature, science, and technology (Von Bertalanffy, 1968; Anderson, 1999). It will provide context by which a group of interrelated tasks that influence each other will be analysed. Within this theory, complex systems are open systems that interact with their environment and constantly evolve; their interactions are nonlinear (Cilliers, 2002).

Design Theory is problem solving and is regarded as the most important cognitive activity in professional contexts (Jonassen, 2000). It focuses on the varying nature of the problem, as each kind of problem calls on different skills (Mayer & Wittrock, 1996). This problem solving theory will address the contextual richness (factors more related to structuredness) because most complex problems are dynamic, that is, those in which the task environment and its factors change over time (Funke, 1991).

Green practices include architects, engineers, and builders who are highly specialised but deliver services in technical isolation. This "silo effect" has made it difficult to manage changes, mitigate risks, and contain costs with a holistic view of the project (Robichaud & Anantatmula, 2010). Nevertheless, diversity helps avoid rigidity within the system and helps the system to respond flexibly to changes in its environment (Liu *et al.*, 2012).

Coherence in these theories refers to the level of interrelatedness among the stakeholders and their tasks (Loorbach, 2007). For collaboration procedures, stakeholders need to acquire new knowledge and understanding that leads to a new perspective on advancement. For progression, multiple in-depth discussions will take place, structured according to the system approach (De Haanm, 2006). Then, a shared understanding of the persistence of a problem, the necessity for radical change, and the definition for a solution will be presented.

Key outcomes are a new, shared perspective; where integrated teams and the technology drive will enable interdependencies and complexity to model stakeholder benefits. For each design, this collaboration will enhance stakeholder behaviour and achieve better risk resolutions, leading to better-informed decisions and cooperation.

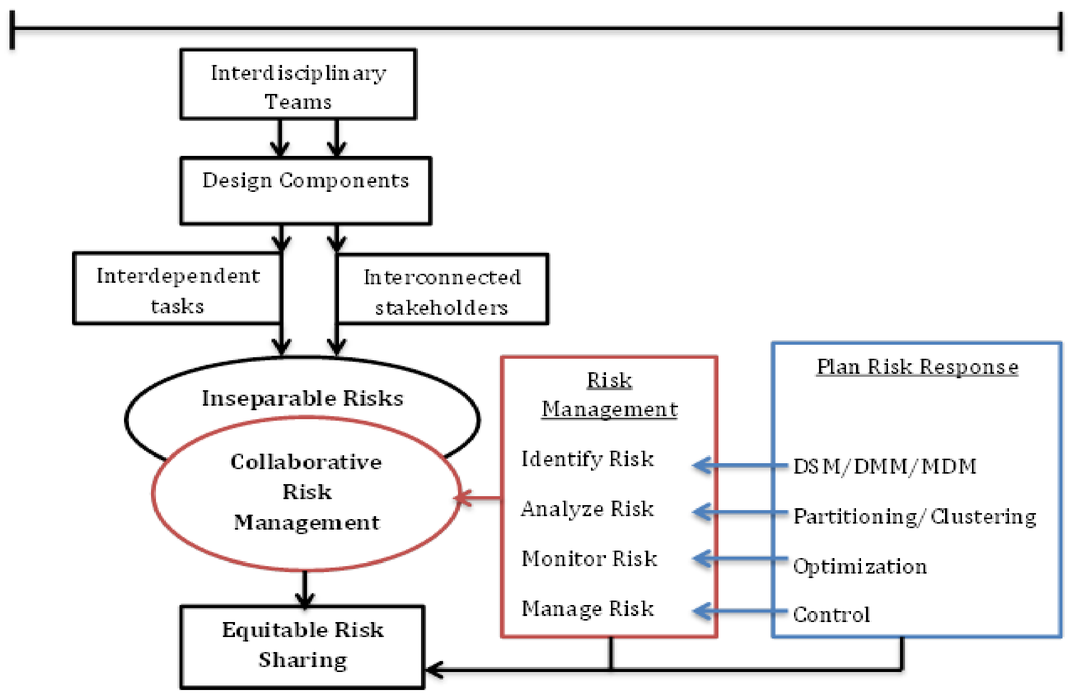
1.4 Conceptual Framework

Inseparable risks can only be shared between stakeholders collaboratively (Fang & Marle, 2015) and would require a systematic risk management system, that will provide guidance for implementing a risk control strategy that is appropriate to control the design process and allow for early detection of risks (Mills, 2001). This risk management system is not a-once-off activity; it is the logical method of establishing the context of identifying, analysing, evaluating, monitoring and managing risk (Jaafari & Anderson, 1995).

However, many studied methods of risk management independently evaluate the characteristics of risks, and focus on the analysis of individual risks (Baccarini & Archer, 2001). Generally, these methods do not take into account the subsequent influence of risks and cannot represent the interrelationships between them. These methods are unable to model complex interactions among different risks. Few specific methods can model risk correlations with a network structure (Marle *et al*., 2015). Several papers on the application of the Bayesian Belief Network (BBN) have appeared in recent years in the field of project risk management (Fan & Yu, 2004, Lee *et al.* 2008, Trucco *et al.,* 2008), which could model risk interrelations, from multiple inputs to multiple outputs. Nevertheless, BBN demands oriented links, is inherently acyclic, and hence does not easily model the loop phenomenon. These methods are thus not always applicable for practical purposes and fail in some cases to represent the real complexity of the interdependencies among risks.

With a view to exploring the interrelationships among design risks, a matrix-based approach is proposed for such inseparable risks. Existing methods, like the Dependency Structure Matrix (DSM) for dependency modelling, is employed to identify and evaluate risk interactions. The aim will be to provide more reliable risk response planning decisions and facilitate better risk sharing.

Figure 1. 2: Research conceptual framework



Risk sharing aims for an optimum way of managing risk with benefits, as it helps to allocate resources more efficiently and improve project efficiencies. The process used to decide equity depends on the right time to share risks, the willingness of stakeholders to accept risk and on the risks that have to be shared. However, to achieve CRM, the outcomes mentioned in the theoretical framework are necessary.

1.5 Problem Identification

Increased design requirements, the influence of diverse stakeholders, information flow and the extent to which technology is integrated into buildings has made it possible to design and construct GBs. However, the complexity of designing with interdependencies of tasks, relations, and their dynamic and unexpected interactions, involves a systemic approach to cope with complications. Unfortunately, risk management has not scaled up for new approaches to better cope with this increased complexity.

GB designs have adopted a more holistic, socio-technical and evolutionary approach, putting the growth of the social and technical complexity at the centre. Concurrently, they have increased interdependencies of tasks and stakeholders and this has resulted in inseparable risks.

It is not only important to understand and evaluate design complexity but also to visualise the complex interaction between interdependent tasks, interconnected stakeholders and inseparable risks. This evaluation will prioritise critical risks and select optimal risk mitigation strategies, such as risk sharing.

An equitable risk-sharing objective for the CRM approach is to decrease the total disputes and the costs of risks from the design phase. In other words, an optimal risk sharing will not be able to pass all risks to other stakeholders, but to seek a solution minimizing both the total management costs of all stakeholders. Unfortunately, this criterion may too cause contrasting results in the risk-sharing context, as stakeholders in a project might not have the same interest or even, perceive risks and risk sharing differently. This behaviour of project stakeholders can influence or impact on project cost and performance. Thus, the need for a high degree of collaboration when managing risks in order to integrate the different perspectives into a coherent and holistic risk management strategy.

Collaborative risk managed designs intend to promote equitable risk sharing procedures that aim to assign responsibility and accountability of risks to various stakeholders involved in the design phase. A risk sharing problem concerns both qualitative issues (what type of risk is allocated and to whom), as well as quantitative issues (how much of the risk is allocated). These risks can arise out of a stakeholder's engagement with the design processes, which need to be identified and the perceptions of stakeholders should be considered when establishing the context and dealing with risks. Inappropriate risk sharing has led to adversarial relationships between contracting stakeholders (Lehtiranta, 2014) and how risk sharing will be organised under a systematic, collaborative risk management scope needs to be discussed.

1.6 Identifying the Research Gap

The construction industry is heterogeneous and enormously complex (Seku *et al*., 2015). Its success is measured by the time of completion, within a specific budget and requisite performance (technical requirement) parameters (Zou *et al.*, 2007). However, construction projects can be unpredictable. Though the SACI is very vibrant and contributes immensely to the national economy; it suffers from numerous risks that have forced many construction businesses to close shop and the surviving ones are running a business at a loss or making lower profits (Ngobeni et al., 2023).

Risk and approaches to its management are heavily influenced by its effective adoption (Nolan, 2018). Over the years, it has been identified that design risks have been informally managed (Yirenkye-Fianko & Chileshe, 2015) and risk sharing has been improperly done. This practice is due to differing perceptions of risk in solution developments and deliveries. As a result, there are no known records that stakeholders can rely on to improve their performance with regards to handling risk collaboratively.

The construction industry is generally a good indicator of economic performance, as it is a significant contributor to employment and economic growth. In South Africa, in 2017, it contributed an average of 3.9% to the country's gross domestic product (PwC's report, 3rd edition, 2017). However, the country's constant changing economic environment is very challenging for construction activities, which are seen as capital intensive. Inflation and fuel prices keep increasing, coupled with high exchange rates. Thus, the need for RM systems that will manage risk effectively using RM capabilities, which are the processes, the data, the tools and the culture that enables proper RM (Mu *et al.*, 2014).

Eliminating risk is impossible (El-Sayegy *et al.*, 2021); risk can only be minimised (Kutsh & Hall, 2010). This makes the use of effective RM strategies inevitable in the construction industry. However, the contracting vehicle for risk sharing among design stakeholders (Peckiene *et al*., 2013) still relies on the traditional system (Ren *et al.*, 2012) that promotes 'The Silo' effect. Where designers were separated to deal with the planning and design away from the rest of the construction and engineering team. This received much criticism for being prone to disputes and adversarial relationships, time consuming, fragmentation of project team, cost overruns, impaired quality and poor customer satisfaction (Ren *et al*., 2012).

Previous studies focused mainly on exploring design errors from a static cognitive perspective and on solutions targeting individuals' actions in isolation (Al Hattab & Hamzeh, 2015). Other studies have focused on formulating risk-sharing models (Lehtiranta & Juunonen, 2014; Faris *et al*., 2022), but the practical applicability of these are questionable, as unfair risk sharing practices are still common and this continues in the industry. Nonetheless, the models do not fully address the risk-sharing problem because the industry is still dependent on traditional management methods of RM (Ahadzie & Amoa-Mensah, 2010), which lead to time and cost overruns (Nkobane, 2012).

In addition, other studies conducted have shown different judgments. The Project Management Body of Knowledge Guide (PMBOK, 2000) indicates that design risks may change as the project moves forward. New risks emerge; foreseeable risks may change in nature and anticipated risks may disappear. However, with the current practice of risks sharing in the construction industry, risks are usually only allocated statically at the beginning of a construction project, through contractual clauses, even though the construction project is dynamic by nature. Olsen and Osmundsen (2005) indicated that the choice of time and resources put into engineering and design affects the level of risk in the project. Wibowo and Mohamed (2008) confirmed the balancing of risk in construction projects remains ambiguous, as indicated by a high disagreement level among the respondents of their survey of risk allocation. Jin and Doloi (2008), Jin and Zhang (2011) and Valipour et al. (2014) did their studies on risk allocation, when risk must be allocated or apportioned to the contracting parties that can best manage it. Peckiene et al.'s (2013) study was quantitative in nature, whereas Zhang and Fan's (2014) study was purely mathematical, with integer programming. These studies have had limited practical applicability.

Despite all the modifications, the construction practical situation remains the same as clients are risk averse and push much risk onto the contractor, who in turn passes it onto a subcontractor (Baloi & Price, 2003). Hence, the risk lands in the hands of the party who lacks the expertise to manage it (Alsalman & Sillars, 2013). The result is rampant delays, cost overruns, work completed behind schedule, abandoned projects, sub-quality of completed projects and disputes. Risk sharing remains the weakest link in the RM process of the construction industry.

This suggests that problems still exist when stakeholders are meant to efficiently share the risks to ensure successful project design (Osipova & Eriksson, 2011; Lehtiranta, 2014). These problems reinforce the need to achieve equitable risk sharing. It is in this context that this research work will be carried out to assess the optimal way of collaboratively managing risks in complex designs using Dependency Structure Matrix

(DSM) to manage the interdependencies. This will lead the green building industry to accelerate globally and its professionals will acquire the latest data and trends to inform their decisions.

1.7 Problem Statement

Inseparable risks cannot be transferred or allocated to an individual to manage, but would have to be shared collaboratively. When solving design problems in green buildings, because of the holistic approach due to their integration in design, different stakeholders face complexities and task interdependencies, which have resulted in inseparable risks. Consequently, risk is not allocated equally between different stakeholders.

This research will use DSM to integrate both the stakeholder dimension and the task dimension to solve for inseparable risks, using a CRM method to improve the accuracy of risk analysis and the effectiveness of risk management.

Main Question: How do project stakeholders in collaborative design teams manage inseparable risks within their different design tasks?

Sub Questions: How to identify inseparable risks within collaborative design tasks during the design phase?

How to manage inseparable risks when they occur in collaborative circumstances?

How does CRM facilitate the management of inseparable risks in advance?

1.8 Research Aim

Efficient risk management is to reduce the impact of risk on the overall project objectives: time, cost, safety and quality (Iqbal *et al*., 2015). This benefit is not just for one or two stakeholders but, for the whole project team. However, this has not been the case in the construction industry.

CRM involves managing complex interdependencies between design processes, tasks and project stakeholders. However, each of these individual stakeholders perceives risk differently; and undertakes risk differently, while on the same project. The continuity of this uncertainty suggests the existence of a problem relating to efficient risk sharing among different stakeholders.

- **The aim of this research work is to investigate the high-level interaction between stakeholders during the design phase and find an optimum way of risk sharing when encountering inseparable risks.**

1.9 Objectives

The main objective of the study is to determine the optimal way of risk sharing within a collaborative risk management approach. To meet the general objectives, the study will focus on the following intents:

- **Explore the implications of Collaborative Risk Management during the design phase**
- **Identify how inseparable risk will be managed in collaborative circumstances**
- **Explore the current risk practices and how can design problems which can only be dealt with collaboratively be identified in advance**

The practical objective is to provide all stakeholders with a mechanism that will provide an alternative option to the traditional risk-sharing approach and aid them in making rational and economical decisions. This approach could minimise disputes, delays and project costs; so to increase project efficiency and overall quality.

Table 1. 2: Research Map

Problem Question	Research Aim	Research Objectives	Research Questions
How do project stakeholders in collaborative design teams manage inseparable risks within their different design tasks?	The aim of this research work is to investigate the high-level interaction between stakeholders during the design phase and find an optimum way of risk sharing when encountering inseparable risks.	Explore the implications of Collaborative Risk Management during the design phase	How to identify inseparable risks within collaborative design tasks during the design phase?
		Identify how inseparable risk will be managed in collaborative circumstances	How to manage inseparable risks when they occur in collaborative circumstances?
		Explore the current risk practices and how can design problems which can only be dealt with collaboratively be identified in advance	How does CRM facilitate the management of inseparable risks in advance?

1.10 Research Approach

1.10.1 Research Paradigm and Perspective

Pragmatism is the research philosophy used, as it recognises different ways of interpreting the world and undertaking research (Saunders *et al*., 2016). Its reality is that no single point of view can ever give the entire picture because, research goes beyond matching theory and reality. It is a philosophy of direction and re-direction that goes beyond problem solving (Morgan, 2014). It is characterised by an emphasis on communication and shared meaning-making in order to create practical solutions to social problems (Shannon-Baker, 2016). It places the primary importance on the research question (Tashakkori & Teddlie, 2003). The pragmatic style can use both quantitative and qualitative data analysis methods (Creswell, 2013).

The research paradigm is abductive as it allows the researcher to provide a better explanation of the continuous interplay between theory and various real-life examples (Ridenour *et al.*, 2008). It is an inclusion of expert knowledge, providing theoretical guidance while the researcher's objective is to discover new things. Having both deductive and inductive reasoning helps in eliminating (deductive) or reducing (inductive) uncertainty. In this research, the use of abductive reasoning creates a fruitful cross-fertilization where new combinations are developed through a mixture of established theoretical models and new concepts derived from the confrontation with reality. This then connects with the research as it uses multiple case studies to assist in combining the sources of evidence, while shifting between analysis and interpretation.

Data is collected through semi-structured interviews; where questions on stakeholder techniques on carrying out inseparable tasks, as well as their options and suggestions on risk management processes for green buildings, were asked. Then theory is matched with evidence to further direct the research.

1.11 Scope and Limitations

The interviewees contribute valuable information about the problem area and the expected results of the study. Bearing in mind that, there are many risks in GBs related to different stakeholders, this might limit stakeholders to develop a common risk response strategy because they all deal with risks differently. A limitation that may influence CRM practice. The sample target will deal with projects that are within tight timeframes and on technically complex specifications. The willingness of identified respondents to participate due to their tight schedules and other commitments can also influence the limitations. Research can be affected by different kinds of factors, which, while extraneous to the concerns of the research, can invalidate the findings (Seliger & Shohamy, 1989). This then requires the researcher to be able to control all possible factors that can threaten the research's validity.

The research is limited to inseparable risks. There are three basic types of relationships between risks pairs. That is independent risks, dependent risks and interdependent risks. This research focuses on risks that are engaged in a mutually dependent relationship, directly or within a bigger loop, which involves different stakeholders. Another limitation is the amount of studies done in Africa relating to CRM in GBs. RM is a rigorously researched area within the GB development and is still developing but CRM has limitations in terms of techniques employed for GBs. Another important limitation observed in the system of GB related studies is an overemphasis on the use of certified GBs as a subject of investigation.

1.12 Validity, Reliability and Generalisability of the Research

The various stakeholders interviewed were interested in how CRM would benefit their projects and their inputs were relevant for other cases. For the research case studies, the intention was to enable analytical generalization where the results are extended to other cases, which have common characteristics. Hence, the findings are relevant for defining the theory.

This research tried to understand the CRM phenomena by seeing how respondents perceived their roles, tasks and risks in the design phase; determining the history of situations and building theory. However, the question of reliability becomes how well the study represents what it was designed to do and, how consistent the data was.

This CRM approach will aid the construction industry to better its risk management; cost and time savings; and improve overall quality of designing complex projects. The results found will provide innovative and useful tools to both researchers and practitioners by introducing a better decision support mechanism for collaborated risk management.

1.13 Ethical Consideration

Ethical issues involve confidentiality towards participants. The researcher made sure to protect the anonymity of participants even though the case studies are known projects and, to gain support she had to explain the purpose of the study. The research is solely for research purposes and it followed the research processes as outlined by the University of the Witwatersrand's ethics committee.

1.14 Research Overview

Research activities are categorized by design science and natural science which considers innovative processes that are developed and evaluated to create new knowledge (Johannesson & Perjons, 2014). The focus is to build (creating of the artefact), evaluate (assessing the quality, and efficiency of a designed artefact), theorise (theory formulation explains how and why something happens), and justify (proving a theory by gathering supporting or proving evidence) [March & Smith, 1995:258; Tommelein, 2020]. The purpose of natural science is to expand knowledge. On the contrary, design science is realised in an open environment, where results deliver a type of design. This study starts by understanding the context of interdependence, then evaluates a shift towards assessing the 'usefulness' of information that will improve the theories. It then, aims to improve the stakeholders' management of inseparable design risks and their understanding of the benefits of equitable risk sharing. Whilst, developing and refining the theories used.

The research process is dividing the research into four main phases: 1) Orientation, 2) Research, 3) Solution and 4) Implementation. **Figure 1.3**, below presents an overview of the research.

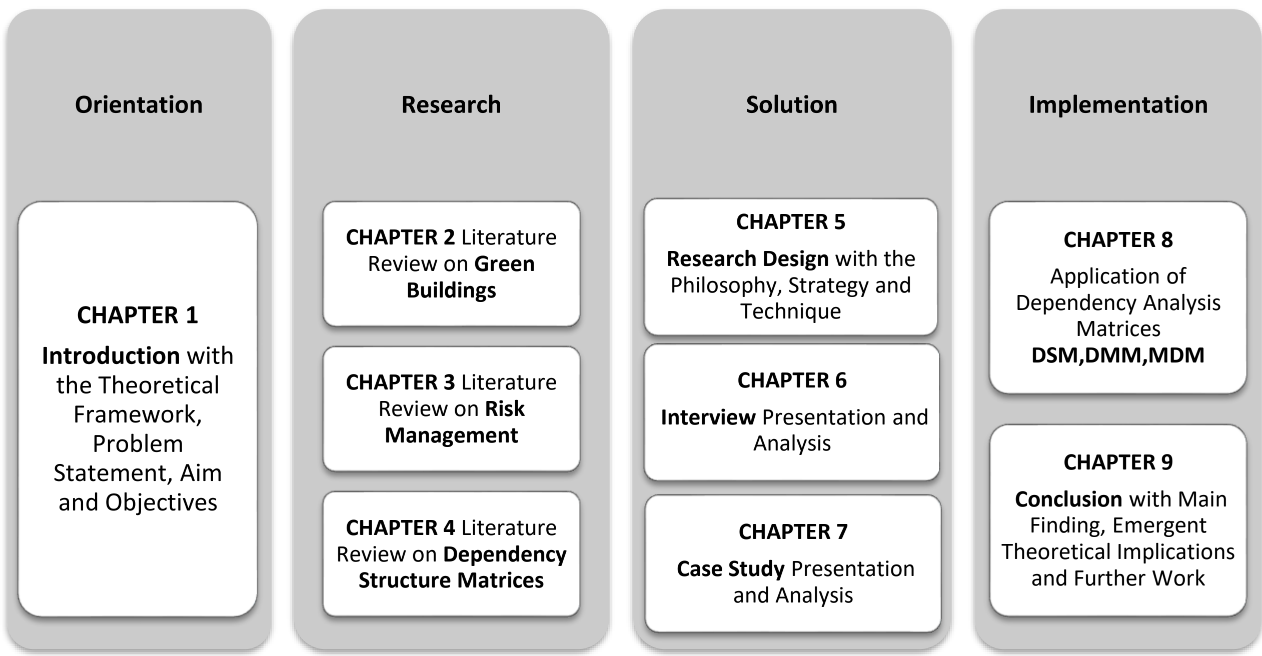
"*Orientation phase*": **Chapter 1** introduces the reader to the changing nature of risk management within the design phase of the construction industry. This chapter states the problem by identifying the research gap in current practices of collaborative risk management and clarifies the research aim within the subsequent research objectives.

"*Research phase*": A theoretical package of published work will be collected by means of an extended literature study. **Chapter 2** will discuss the makeup of green buildings. The whole spectrum of risk management operations in the construction of GBs will be considered in sequence with the prevalent practices of inefficient risk-sharing in **Chapter 3.** And, **Chapter 4** proposes the use of the dependency structure matrix (DSM) to overcome the encountered challenges within the design management and the collaborative risk management processes.

"*Solution phase*": The research design (**Chapter 5**) will describe how data will be obtained using structured interviews through the process of abductive approach within a multi-case study background. Interpreting and theorizing data signifies a search for general statements among categories of data. Data presentation of all the information from the interviews was analysed in **Chapter 6**, using both qualitative and quantitative methods. **Chapter 7** analyses the data from the different case-studies. These case studies provided research results from real-world projects, focusing on the stakeholders' experience with CRM and the trends used in GBs.

“*Implementation phase*”: The complexities involved in the design phase justify the application Dependency and Structure Modelling techniques such as the DSM and the DMM to support, the management of complexity by focusing on the elements of a design process, capture dependencies and risks (**Chapter 8**). A matrix-based approach that comprises of three different types, DSM, DMM and MDM will be used. The study will conclude by presenting the main findings, contributions to knowledge, emergent theoretical and practical implications, some limitations and structuring future work proposals – **Chapter 9**.

Figure 1. 3: Research overview



2. THE SHIFT TOWARDS GREEN BUILDINGS

2.1Preface

Collaboration invites diversity, which promotes flexibility and establishes innovation that will help in improving a process or system or individuals to view things differently. Green buildings have invited novelty that has encourage reconstruction efforts that foster environmental and social sustainability. The rapid advancement of technology continues to leverage change and innovation, offering opportunities to totally reinvent traditional construction designs and delivery practices for future, green developments.

Collaborative Designs and Collaborative Design Teams have been evolving and are considered as a key for advancement. Yet, despite major technical advancements within Collaborative Design Management, adoption is still plagued with barriers. And, definitive benefits have not been fully capitalised upon by industry stakeholders. The lack of widespread uptake in collaboration appears to be linked to the risks and challenges that are potentially impeding its effectiveness.

This chapter reviews the literature pertaining specifically to GBs as complex systems. Considering findings from studies done on collaborative teams when designing green buildings and the problems encountered in current practices.

Literature Objectives:

How different stakeholders interact with each other during the design phase?

How design problems, which can only be dealt with collaboratively, be identify in advance?

2.2The Green Movement in Africa

Several negative environmental issues are attributed to the activities of the construction industry globally with South Africa as no exception (Oguntona *et al*., 2019; Masia *et al.*, 2020). The green movement in Africa is one of the most effective solutions to increasing the efficiency of buildings through resource utilisation and recycling, mitigating the negative impact of the construction industry on the environment (Zuo & Zhao, 2014; Nyakalale & Madimutsa, 2021). GB's have a significant impact on resource consumption and on combating global warming (Zhang & Tu, 2021). However, as part of construction innovation, GB has faced numerous challenges to its penetration into a market crowded with traditional buildings.

In Africa, the built environment ranges from sophisticated modern cities to isolated traditional villages in deep rural areas. The continent faces a number of challenges regarding the provision of adequate housing, infrastructure delivery and dealing with rapid urbanisation (Yudelson, 2010; Masia *et al.*, 2020). In many countries, a large percentage of the population, including those in urban areas, lives either in traditional dwellings built with compost or in shacks constructed of a range of discarded materials. South Africa is no different in this regard, with its rapid economic growth adversely affecting its infrastructure and environment (Gelan & Girma, 2021). The increasing demand for buildings, the growing population and over-urbanisation still predict insecurity of energy supply, and environmentally detrimental and negative impacts of the climate change. These impacts create a need for a more sustainable built environment (Nguyen & Gray, 2016; Ojo-Fafore *et al*., 2018; Jacobs *et al.*, 2021).

Despite all these challenges and the need for resolutions, construction is still accused of causing environmental problems. These problems range from excessive consumption of global resources in terms of construction practices and building operations (Ding, 2008). Traditional buildings also add to environmental pollution by generating a significant amount of waste during their lifecycles (Li *et al.*, 2016). However, relying on construction designs to achieve sustainable development goals, or to minimise impacts through appropriate management on site, is not sufficient to handle the current African problem. The aim for sustainability goes even further than at the design stage of a project. It is vital to consider sustainability at an early stage, before any detailed design or even before a commitment is made to go ahead with a development (Ding, 2008). Generally, little or no concern is given to the importance of selecting more environmentally friendly designs during the project appraisal stage; the stage when environmental matters are best incorporated.

To pave the way for the African problem, GB practices would need to be structured for all cultural inconsistencies and values (Tandon, 2016). The difference between the market economies, transition economies and developing economies influence its implementation priorities. The mature economies pay attention to a sustainable building stock, either by new construction or by refurbishment. In the transition economies, the emphasis is on new developments reducing the housing shortage and improving their transportation networks. In the developing economies, the social agenda (e.g. job creation) is much higher on the agenda than environmental concerns (Yudelson, 2013; Triches, 2021).

For green infrastructure to be widely adopted, legal frameworks must be encouraged or at least not be hostile (Popescu & Petrişor, 2021). Policies to encourage or require green infrastructure adopted at a national scale must be implemented at the local level by multiple agencies. The success of implementation depends not only on the strength of the national commitment, but of local governance (Ngobeni *et al.*, 2023). Local markets would need to adopt and diffuse innovations theory as a vital ingredient in the recipe for market differentiation. This will creates competitive advantage by creating new market opportunities for future green cities (Matthews *et al*., 2015).

Government's involvement is considered one of the essential and effective ways to promote GB (Chan *et al*., 2009). Shafii and Othman (2006) suggested that governments can stimulate and ensure the development of a sustainable construction industry. This is done both indirectly, through legislation and planning control, and directly, through their involvement as client, designer, supervisor and/or producer in the construction process. Promotion of healthy, energy efficiency and being environmentally friendly has made green building concept a primary consideration in the construction of infrastructure. Ho *et al.* (2010) revealed that public leadership of green procurement determines overall effectiveness of GB's and this has also been motivated by the private sector. It has, therefore, become imperative for the construction industry to adopt the implementation of green building concept due to urbanisation and high-energy usage. Zhang *et al.* (2011b) proposed a green strategy plan to guide actions on the more systematic use of green technologies. However, it is debatable which government intervention instruments are the most effective and efficient tools for promoting GB (Agyekum *et al.*, 2022) and what works for each country. The question of whether a government should be applying a mix of economic and regulatory tools, focusing more on market-based instruments or setting up an institutional framework that is effective. This will consist of volunteer organisations, depending on these three factors: the current situation of the market system, economic development and the political environment (Nguyen *et al*., 2017).

But, the problem still remains. While there is an upturn for green buildings, the industry is still trying to deliver GBs on traditional practices. In order to identify what triggers the adoption of green innovation practices, it is necessary to firstly define what green construction represents.

2.3What are Green Buildings?

Readiness! This is a concept interchanged with preparedness and, many assume, adequate knowledge. Simple as it may be, readiness denotes a complex interaction of parameters and conditionality required for the uptake of a phenomenon, in the context of this study, a green transition (Nhamo, 2013; Ngobeni *et al*., 2023).

There are many definitions of green building. For example, Kibert (2008) defines green building as healthy facilities designed and built in a resource-efficient manner, using ecologically based principles. It is worth noting that *green building* has been used as a term interchangeable with *sustainable building* and *high-performance building* (Owoha *et al.*, 2021). Robichaud and Anantatmula (2010) pointed out that there are four pillars of green buildings, i.e., minimisation of impacts on the environment, enhancing the health conditions of occupants, the return on investment to developers and local community, and the life cycle consideration during the planning and development process. Common elements of these definitions are life cycle perspective, environmental sustainability, health issues and impacts on the community.

The Green Building Council of South Africa (GBCSA launched 2007) defines a green building as a resource-efficient, energy-efficient, and environmentally responsible building that reduces its direct and indirect impact on the environment throughout its life, from the beginning of construction, during occupancy, and when it is later demolished. On the other hand, the US Green Building Council (2009) refers to green buildings as processes aiming to reduce the overall impact of the built environment on human health and the natural environment by efficiently using energy, water, and other resources and by reducing waste, pollution and environmental degradation.

As a result of increased interest in green building concepts and practices, a number of countries have developed tools for designing and measuring green buildings, for building professionals and developers to embrace this concept with confidence. Well-known tools, such as BREEAM (United Kingdom); LEED (United States and Canada); DGNB (Germany); Green Mark (Singapore); CASBEE (Japan) and Green Star (South Africa). These tools are all helping to adopt a credit- and score-awarding system for design features that can minimise a building's environmental impact in categories such as location and site, conservation of water, energy, and materials, and occupant comfort and health (Owoha *et al*., 2021).

2.3.1 What really is a green building?

A green building is a design that embodies the increase of efficiency with which buildings and their sites use energy; water; raw materials and which reduces the negative impact on human health and the environment over the entire life cycle of the building. With new technology, this makes green buildings more resource efficient, energy efficient and environmentally safe throughout a building's life cycle (Tandon, 2016; Ngobeni *et al*., 2023).

A green building fosters the habit of integration and optimisation among all building measures (Korkmaz *et al*., 2010; Mushi *et al.*, 2022). This helps to recognize a balance, by requiring mandatory attention to all principles from different stakeholders. Moreover, GBs take into account the flexibility of building use, the way buildings are organised (for example, joint use of certain facilities) and land use planning (for example, public transport, problems of segregation). Furthermore, GB's consider the organisation of the design and planning process, as well as the forms and desirability of social life created through living in such buildings (Ries, 2006; Agyekum *et al.*, 2022).

Scholars such as Li, Su, Chang, Zhang and Wu (Li *et al*, 2020 & 2021; Chang & Hsieh, 2020; Su *et al*., 2021) see green buildings as high-performance buildings **(Figure 2.1),** as they require these eight design objectives: accessibility, aesthetics, cost effectiveness, functionality, productivity and health, history, safety/security, and sustainability. Unlike the traditional approach in which design decisions are made one after the other, the whole building approach relies on careful consideration and integration of all key design objectives during every phase of the project.

Figure 2. 1: Green buildings are high-performance buildings

There is a growing level of public awareness in green buildings (Olubunmi *et al*., 2016; Ngobeni e*t al.*, 2023). However, there have been extensive debates on what a green building is or what the green building should cover. Indeed, the lack of clear definition of green building creates further challenges for promoting and implementing green buildings. McGraw Hill (2013) defines green building as a construction project that is either certified under any recognised global green rating system; or built to qualify for certification. Furthermore, McGraw Hill's research indicated that green buildings are rapidly taking hold in South Africa and he estimated that by 2015, 51% of most firms in South Africa would achieve high levels of green building activity.

Figure 2. 2: Constituents and Benefits of Green Buildings

The need for green buildings is attributed to the deterioration of the environment in recent decades (Van der Merwe, 2013), including increased carbon dioxide emissions evident in the melting of the polar ice caps (Hassol, 2005) or global warming. However, what do green buildings involve?

Technical and environmental aspects

Traditionally the focus of green building studies is placed on the environmental aspect of sustainability. Taking the GBSCA Green Star Healthcare V1 as an example, 87% of unweighted points are related to environmental sustainability. It is also evidenced in the extensive studies on the environmental sustainability of buildings, for example, energy efficiency, water efficiency, resource efficiency and greenhouse gas emission reduction (Danatzko *et al.*, 2013). For example, utilising precast slabs in temporary construction works has a number of benefits, such as mitigation of obsolescence and cost savings (Shen *et al*., 2009). In addition, prefabrication is recognised by both design and construction professionals as one of most common methods to prevent injuries, particularly related to hazards of sustainable elements such as construction at height, energised electrical systems, and confined spaces (Dewlaney & Hallowell, 2012).

Social aspects

Recent decades have witnessed growing concerns about social sustainability in buildings. This is because construction activities are a social process (Abowitz & Toole, 2009). In the construction context, social sustainability mainly covers the quality of living, occupational health and safety, and future professional development opportunities (Zuo *et al*., 2012). In a building context, social sustainability means providing a healthy and safe environment for all stakeholders, for example, construction personnel, users and operators, which is taken into account during the sustainable design process (Wong & Fan, 2013).

Economic aspects

Berardi (2013) pointed out that there are social and economic requirements of green buildings, such as access, education, inclusion, cohesion, affordability, and economic value, impact on the local economy, indoor health, cultural perception and inspiration. Popescu *et al.* (2012) pointed out that the benefits of energy retrofitting initiatives reflect not only the cost savings derived from improved energy efficiency but also the potential value added to the property. This helps to reduce the payback period of investments in energy efficiency measures.

Therefore, a green building could take either a narrow definition (for example, purely environmental sustainability) or broad definition (i.e., adopting a triple bottom line approach: social, economic and cultural aspects), said Alwaer and Clements-Croome (2010).

2.3.2 A Comparison of the Traditional and the Green Approach

To further understand green buildings beyond the social and environmental aspects, a comparison of traditional and GB projects is made according to the management knowledge areas specified by the guide to Project Management Body of Knowledge (PMBOK®, 5th Ed). GBs would also require guidance on application of knowledge, in its processes, skills, tools and techniques for project activities to meet project requirements. A refined review of research conducted by Robichaud (2011), Zhang (2011) and Hwang (2012, 2013), compares traditional and green buildings under different headings of these knowledge areas.

Cost management

Traditional construction	Green construction
During the traditional design, economic thrift is the determining aspect.	Higher costs are characteristic for green construction practices, green appliance design and green material. Financial consideration is the biggest barrier in promoting green strategy.
The preliminary budget estimate is based on the previous experience and benchmarked typical projects.	The cost/benefit analyses compose the root of the preliminary budget.

In GBs, the initial project expenses are higher because of the special environmentally sound materials, tools and designs. When creating budget, future energy savings and financial benefits are taken into consideration, as they will positively affect the green property investments.

Schedule management and planning

Traditional construction	Green construction
The initial project schedule is based on the previous experience or benchmarked on typical projects.	Longer time is required to implement new green technologies and time-consuming sustainable practices in pre-construction process are taken.
Schematic design and general concepts are sufficient since building is routine.	Holistic and integrated designs are needed for the novel green buildings.

Green design processes are lengthier because of the unprecedented high-tech green solutions and time-consuming sustainable practices. On the one hand, these precise designs gain time because of integration and avoidance of unwanted rework. The sustainability goals and project priorities for green features have to be clear during the whole design process.

Human resources management and communication

Traditional construction	Green construction
Subcontractors work separately with no cooperation. The highly specialised services are in technical isolation.	The specialists work in an integrated team for better communication.
An integrated design team is considered a waste of time and costs.	A diverse planning team with architects, engineers, and contractor is optimal.
The most important skills of the project manager are delegation, leadership and team work	The most important skills of the project manager are decision-making, delegation and analytical skills.

In green buildings, the CDT communicates from the beginning, when the architects, engineers and contractors have to develop the project together. Emphasis is placed on persistent training, initiative team building and systematic meetings with green specialists for effective cooperation. The effective communication inside the team is as essential as the continuous informing of the client and concerned people.

Risk and quality management

Traditional construction	Green construction
There is a minimal risk when using traditional methods because of a repetitive mode.	A significant risk factor is the inadequate information regarding green building systems.
The quality characteristics have to correspond to the obligatory regulations.	Green buildings get certifications, which they fulfil, for certain requirements.

Green projects can be riskier because of lack of experience with new green technologies, inadequate information and uncertainty. On the other hand, green projects are less risky concerning environmental, economic and regulatory aspects. A certificate can prove their quality and they can always over-fulfil the compulsory requirements.

To achieve GB benefits, multidisciplinary teams need to shift to an open communication process (Larsson, 2009). Where information is freely exchanged between the different stakeholders, bringing together various skills and knowledge, and removing the traditional barriers between those with responsibility for design and construction. This benefit can then improve the effectiveness and efficiency in delivering a project (Austin *et al*., 2002; Ahn *et al*., 2016). Understanding this co-creativity of experts creates a synergy within the process of decision-making, planning and design, implementation and management of complex systems (Wetzel

& Thabet, 2015). Designing green enhances the sharing of information and improves the efficiency of design work, while improving the green building evaluation content (Li *et al*., 2016).

2.4Stakeholder Communication in Green Buildings

While sustainability awareness has seen progression (Owoha *et al.*, 2021) in developing countries, the design of green projects encounters many risks due to the traditional conservative and reactive behaviour of stakeholders in the built environment (Elsayegh & El-adaway, 2021), and the transient relationship of design teams with other stakeholders (Ngobeni et al., 2023). However, the rapid development of the construction industry, inevitably involves a large number of specialised project teams (for example, owners, contractors, consultants, and sub-contractors) with specific core competencies. A project team is characterised by diversity, multi-disciplinary knowledge, with dynamics and temporary features, while the ultimate goal of the project team is to achieve project success (Wu *et al*., 2017).

The traditionally conservative stakeholders cling to project success being achieved by following a series of steps and processes for planning, executing and controlling activities and tasks (Elsayegh & El-adaway, 2021). Traditionally, design is a process of creating the description of a new facility, usually represented by detailed plans and specifications; construction planning is a process of identifying activities and resources required to make the design a physical reality (PMBOK®, 2000). This is where architects and engineers are responsible for planning and design; contractors are responsible for constructing the building or structure; and building owners are left to deal with the outcome. This assembly line approach very rarely works to create a building that is optimised as a system (CEC.org, 2015). However, for green buildings, an interdisciplinary collaboration approach is undertaken, which emphasises value for the customer, tightly controlled process flow, and emphasis on integrated goals that are shared and project-centric.

In GBs, the design phase is the most important stage in determining the green performance of building projects. A detailed design level of the design process is the most extensive and a complex stage, particularly in terms of the volume of information produced by the design team and the degree of detail (Mitchell *et al.*, 2011). This stage requires all stakeholders to exchange design information using technical drawings and specifications. Design teams of any discipline need to submit information timeously between team members for project progress (Tribelsky & Sacks, 2010). Intricate multidisciplinary collaboration between a wide range of stakeholders, all of whom work closely together to generate innovative and effective green building solutions (Ngobeni *et al*., 2023), is the typical feature of the increasingly complex environment.

Given that designing green projects are characterised by high uncertainty, complexity and inter-organisational task interdependence, communication is more important (Badir *et al*., 2012), because the knowledge background, cultural values and benefit demands of each project team vary, which often lead to conflicts (Buvik & Rolfsen, 2015). Communication provides design teams with efficient coordination to complete their tasks and reduce the risk of conflicts (Kennedy et al., 2011). During project design, these teams are involved in extensive resource exchange and information communication; projects increasingly apply inter-organisational and multidisciplinary partnerships, highlighting the need for effective communication to realise timely delivery (Nielsen & Erdogan, 2007). This effective communication enables design teams to clearly understand each other's views and intentions, to explicitly determine the rights, responsibilities and benefits, and to facilitate teamwork (Tai *et al.*, 2009). Poor communication, on the other hand, not only leads to asymmetric information between project teams, but also ferments confrontation between teams and leads to conflicts (Clark & Brennan, 1991).

A lack of strategic direction and objectives-related communication can lead to time and cost overruns, and reduction in profits (Siew, 2015). If design teams process and exchange information in an effective manner, the volume of unnecessary expenditure can be reduced. However, these design teams have certain unique characteristics, such as being task-oriented, having different project goals, and inconsistent core competencies (Ibadov, 2015). Therefore, the role of communication is even more important because of construction's decentralised nature due to different responsibilities of various design teams, and different stages of joining the project (Tai *et al.*, 2009). In addition, team communication is an effective means of conflict resolution (Senaratne & Ruwanpura, 2016).

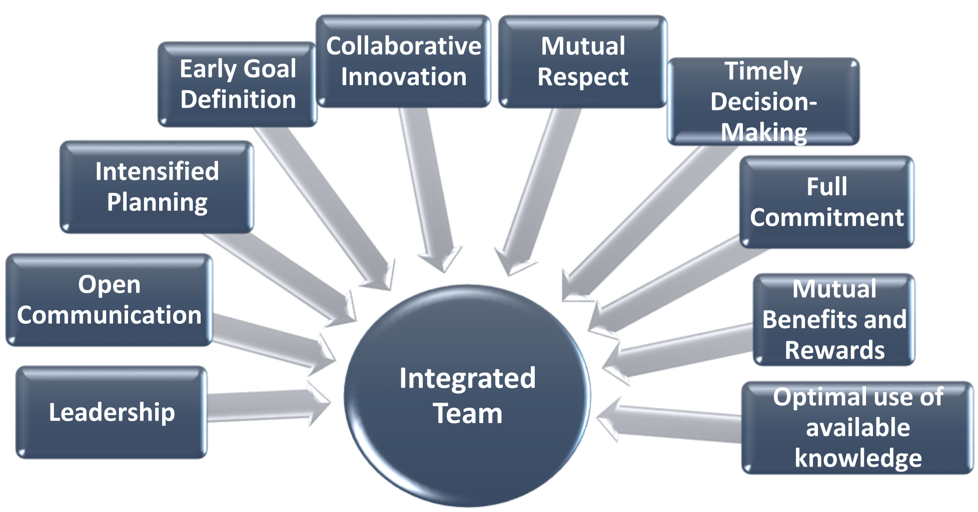
Communication is also a multidimensional phenomenon that can be conceptualised with a number of attributes (Badir *et al*., 2012), one being the process that starts with capturing and quantifying the exchange of dependency information. A contemporary scheduling tool, the dependency structure matrix (DSM), aids in generating the shortest (overlapped) schedule based on dependencies among the different design disciplines (Srour *et al*., 2013). All efforts of collaboration and utilisation of any process and any software, allow designers to push the boundaries of design. By providing stakeholders with efficiency and effectiveness in project management knowledge areas; future collaboration opportunities that promote trust between parties will be undertaken (Wu *et al*., 2017).

Regardless of all that is done and that needs to be done, the construction industry is continuing on the green building approach. This is happening even when there are criticisms of still using a fragmented approach to project delivery and a failure to form effective teams that have a high frequency of communication (Ali & Al Nsairat, 2009). The higher levels of communication willingness enhance a team's work enthusiasm, the sense of belonging and team pro-activeness, ultimately generating more ideas and creativity to solve problems encountered in the process of designing projects. These make project teams more willing to communicate and express their capabilities to process information (Reinders, 2014). Moreover, communication willingness helps to strengthen a team's emotional wellbeing, increase trust between members and build rapport relationships among teams. This enable teams to cooperate for the accomplishment of design goals, thus helping to achieve project success.

2.5Stakeholder Interaction in Collaborative Design Teams

As a branch of green innovation, a CDT refers to integrated working practices, methods and behaviours that promote an environment of open information among various stakeholders. Within a CDT, various skills and knowledge are seen as shared, and traditional barriers separating the design process from construction activities are removed (Austin *et al.*, 2002; Baiden *et al*., 2003). Designing green buildings requires a set of tasks to be identified, recognised, and assigned across all stakeholders (Mohamed *et al.*, 2014), including the new stakeholders to the project (Laurent, 2017).

Figure 2. 3: An integrated design team



Effective application of teamwork helps to improve many aspects of a design, such as coordination, innovation, horizontal communication and flexibility. However, it is not a panacea for solving all coordinating problems and poor application of management tools, if people are resistant to change. Its effectiveness lies in its proper application for a given design context (Nurmi, 1996) and these inappropriate functions cause losses of various resources (Lichtig, 2006). Dickinson and McIntyre (1997) identified and defined seven key components of teamwork, which are critical to any improvement exercise: communication; team orientation; team leadership; monitoring; feedback; backup behaviour; and coordination. This, however, highlights key challenges for a successful design with high-quality attributes (Kumaraswamy *et al.* 2003a) but enhances collaborative project implementation. Furthermore, this dynamic process is the mutual respect and trust between stakeholders, which produces creativity because of open interlocution (Kahvandi *et al*., 2017)

The design process is iterative in nature, meaning shared understanding and commitments are needed (Mohamed *et al*., 2014). The challenge is ensuring that the right information gets to the appropriate person at the right time. Other challenges within the team environment include an alignment of attitudes. Furthermore, communication gets to be a dynamic process that continues during the early design phase of the project and develops from general to detailed features as it progresses. In this context, Cunningham *et al.* (2015) mentioned that the utilisation of Information and Communications Technology (ICTs) is one of the most important means of improving the performance of a design team. For example, the British government through the Technology Strategy Board, made investments in innovation and training to give the industry the ability to design and construct resource and energy efficient buildings (Blackwell, 2015). One of these technologies is the use of Building Information Modelling (BIM), which represents the evolution of Computer Assisted Design (CAD).

BIM allows architects, engineers and contractors to communicate using a virtual environment, providing a model of the project, as well as the cost, schedule and specific information related to each component (Laurent, 2017). The use of BIM could make projects save up to 10% of the cost through clash detection and could reduce up to 7% of the construction time for a return on investment of about 634% (Azhar, 2011). Moreover, BIM brings design stakeholders together and enables greater communication and efficiency instead of following traditional adversarial behaviours. Thomsen (2010) emphasised the need for appropriate management related to the BIM model and the significance for the manager to enhance collaboration by making sure each stakeholder understands its role and responsibilities related to the model. By nature, BIM brings the team to collaborate and, if appropriately managed and implemented, it contributes significantly to increasing integration (Ashcraft, 2008).

Another objective of collaboration is to achieve appropriate value and improve the overall performance in designs through developing a new relationship-based culture different from the traditional one, which is seen as static in nature (Rahman & Kumaraswamy, 2008). Integration leads to collaborative risk management within green buildings. Yang *et al*. (2016) perceive this development as a sophisticated system in which numbers of risks and problems created by various stakeholders are intertwisted with the consequent impacts among them. Stakeholder and risk analyses are important for not only developing a comprehensive risk list and recognising the causes of risks but also contributing to effective decision-making and efficient communication in green management.

2.6Integrated Information Management

The high complexity of collaborated design decisions has intensified the management of the interactions between tasks and people (Eppinger *et al*., 1994) because considerations need to be given to information flow, security and shareability between collaborators in addition to the collaboration itself (Handel & Wang, 2011). With collaboration, comes information influx. Veidekke (2013) described this influx as a way to increase the value of the product and reduce production costs and the design process. However, the goal is to make the process more efficient through planning and coordination through mutual adjustment so people get a better understanding of their design tasks (Fundli & Drevland, 2014). People in this context are all design stakeholders that have information as their deliverables.

Information flow is a type of collaborative process, which exists behind every collaborative team (Lee & Kim, 2012). This process is where design knowledge is no longer limited merely to geometric model data exchange, but to exchange more knowledge about the design itself and its processes. This will then include design concept, principle, proposition, methods, skills (algorithm and strategy), and design experience (Wang *et al.*, 2017). Different design forms from different stakeholders contain different states of information, which requires effective design and information management to facilitate a coordinated building design within budget, ensuring the smooth running of all tasks (Eckert & Clarkson, 2010).

The capability to plan and manage design efficiently takes into account the iterative nature of the process and changing needs of the client and contractor as a solution, known as Design Knowledge Evolution (Wang *et al*., 2017). This promotes the notion by Knotten *et al.* (2015) to say that design problems and design solutions are interdependent. Current design practices take into account the interdisciplinary, iterative nature of the design process and the inter-connectedness of stakeholder's results in the reciprocal interdependency of tasks.

Figure 2. 4: Reciprocal interdependency of tasks

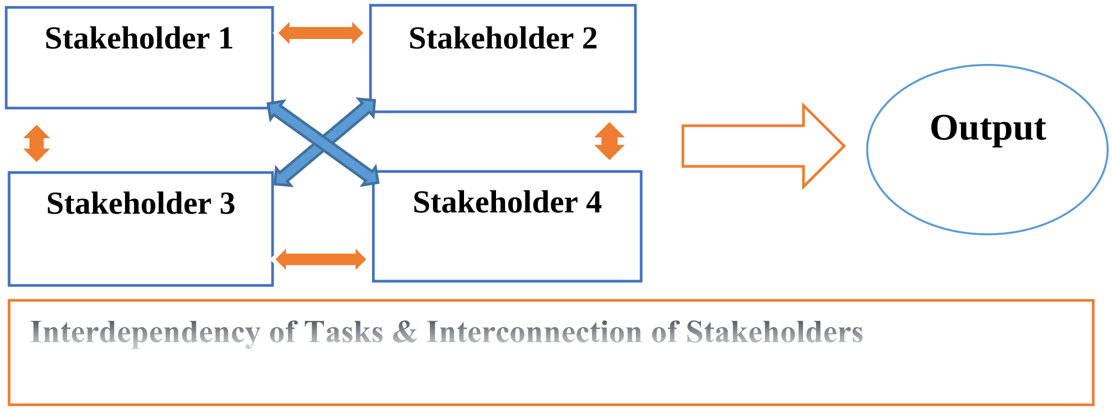


Figure 2.4 represents the reciprocal interdependency of tasks, when the outputs of each unit become inputs for the others (Davies & Mackenzie, 2014). This ensures that actions taken by one part or phase of the design are consistent with others. Assuming that design information data is made available and communicated between stakeholders, and it is linked via a dependency table to a DSM analysis tool (Steward, 1981; Austin *et al*., 2000). This data is then used to identify iterations within the design process and schedule the activities with the objective of optimising the task order (Eckert & Clarkson, 2010).

As a result, the increased complexity and sophistication of designs necessitate more information flow, which increases the need to coordinate cross-domain interactions (Wynn & Eckert, 2017). This in turn increases the risks stakeholders have to deal with because the way that information is considered is different, as analytics may be used to seek insights from the flow of information, as well as its content (Whyte *et al*., 2016). The many-to-many non-linear data relationships that arise in large and evolving data sets (Wu *et al*., 2014) lead to challenges in ensuring reliability, which has implications for decision making. Thus, the need for a systematic risk method that will be a comprehensive approach to identifying and analysing these risks. And, treat them to benefit stakeholders in these diverse representations and relationships that makes it difficult to discover useful patterns (Whyte *et al*., 2016) that can improve and accelerate design development, as well as projects in the domains (Smith & Eppinger, 1997a).

2.7Risk Management for Green Buildings

Risk management is an important and integral part of project management (PMI, 2000), and GB construction needs information on effective risk management ideas and plans. The success or failure of a construction project may vary depending on the approach that is adopted toward managing the risks. However, the difficulty in risk management is complexity and interdependency.

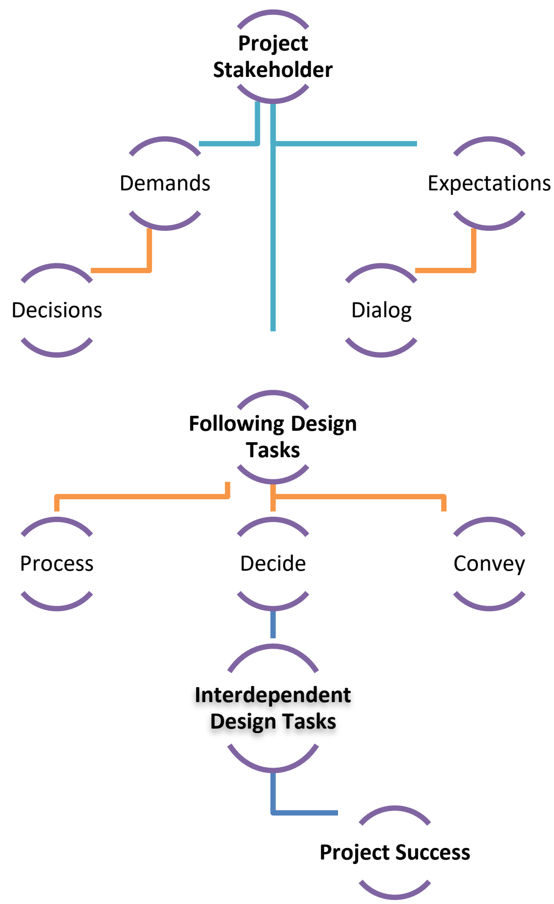
GB designs inevitably involves complexity, task and risk interdependencies which assist the progressive generation of knowledge, enabling concurrency and integrating necessary changes, but this also increases the duration and cost of a project (Wynn & Eckert, 2017). It also involves management of multiple risk perspectives. The term ‘‘risk” in the construction industry has a two-edged nature, for example, Zou *et al*. (2007) described it as the likelihood of unwanted hazards and the corresponding consequences, whereas Williams (1996) said it is the likelihood and consequence of risks, and Vrouwenvelder *et al*. (2001) said it is a combination of the likelihood and consequences of the hazard. Therefore, risk and opportunities are linked; there are no opportunities without risks related to them. Risk management is a system aiming to recognise, quantify, and manage all risks exposed in the project (Flanagan & Norman, 1993).

GB designs emphasize increased levels of design collaboration and coordination processes. Potential effectiveness of these practices depends on the key tools of project management and the high levels of interdependence and interaction. However, most GB projects are still carried out in accordance with traditional methods and norms, where short-term solutions are favoured over long-term ones. Planning practices such as the critical path method (CPM), Gantt charts and programme evaluation and review techniques (PERT) still take little account of the interdisciplinary and interdependent nature of the green design process. This has led to a compromised design process containing inevitable cycles of rework associated with time and cost penalties (Reason, 2016), as well as stakeholder disputes because of poor RM and a lack of collaborative risk practices. It has led to design tasks that are interdependent with risks that are inseparable and this interdependency requires effective RM to ensure that design risks are explored from different angles and this coherent strategy is used at all times (Demir et al., 2012).

GB design planning tools should outline interdependent tasks, determine the overall pace of the programme and measure its progress. These tools should foster mutual collaborations, assist in adjustments needed to work collectively and be responsive to unforeseen problems in real-time. However, project reality is that current risk management practices are reactive and they promote competitive attitudes between project stakeholders involved because they tend to work for their self-interests and thus safeguard their existence in the project life (Alsalman, 2012). These practices involves a great deal of uncertainties and has negatively impacted the industry. To overcome those limitations, it is vital to change not only RM practices but also mind-sets to shift towards mutual adjustments and rapid adaptation, where parties will be in give-and-take interdependence (Morris, 2013).

The well-known iron triangle (time, cost and quality) has already proven insufficient for enabling the project management to effectively manage and control green project activities (Norrie and Walker, 2004). So, additional and influential green dimensions are developed, such as, mutual-decisions made by all stakeholders. These will require several alternatives and each alternative branching out into sub-alternatives. These then divide further, resulting in a tree-like image revealing all likely decision pathways, as seen below in **Figure 2.5**. The consequences of each branch can then be analysed in subjective or objective terms to determine the risk exposure, or the Expected Value (EV) of the risk level for each alternative. The method will aim at determining an expected value for each risk response action, particularly recommended when considering the cost implications of a task in a design process. This will become a fundamental part of risk analysis when considering risk sharing within a design phase.

Figure 2. 5: The stakeholder decision-making tree



Fixing the collective stakeholder experience will need to move beyond a narrow dependence on just simple models, to the integration of various tools, often combining quantitative and qualitative methods to cast a wider net for capturing and assessing risk factors beyond the boundaries of traditional methods (Skelton &

Thamain, 2006). Because, stakeholders still rely on pre-existing knowledge for managing risks, instead of rational approaches to problem solving, which is by analysis, evaluation and communication (Whelton and Ballard, 2002). An effective RM practice is critical to the success of green designs (De Marco *et al*., 2015). Therefore, the use of CRM would require knowledge creation, not just knowledge application. However, the change from traditional RM to CRM will be loaded with uncertainties, which include risk sharing among all project stakeholders and their response to this cultural shift.

Undoubtedly, risk will be present in any design stage and the performance of risk management will have a direct influence on whether the project can be fulfilled successfully on time and within budget. However, green projects promote collaboration with risk specialists (experts from multiple disciplines) who are hired by the project team to work with project members to identify and investigate the risks, by interviews and discussions (Zou *et al*., 2017). To implement risk management, specialists who play facilitating roles during the risk management process attend the project control meetings and keep tracking progress, and give generic advice on design activities (Ghaffarianhosein *et al*., 2017). Moreover, the design team is still required to be responsible for the application of the risk management cycle. Because, RM is now a process that involves all stakeholders; and the starting point of the risk reviews is working collaboratively, to gain a thorough understanding of the project objectives and achieve project success (Zou *et al*., 2017). In such instances, effective RM will be expected to facilitate efficient risk communication and support the dynamic development process of the design process. Though this is no complete solution so far, this area is important and will provide interesting opportunities in the future, as design and risk management is evolving. And, an understanding of inseparable risks and how stakeholder can manage them in GB designs is critical for all stakeholders to align risks and thresholds and to develop responding strategies proactively. This would aid the construction industry to better its risk management; cost and time savings and improve the overall quality of designing complex projects. The results found will provide innovative and useful tools to both researchers and practitioners by introducing a better decision-support mechanism for collaborative risk management.

2.9Key Concepts

Table 2. 1: Literature Review Table for Green Buildings

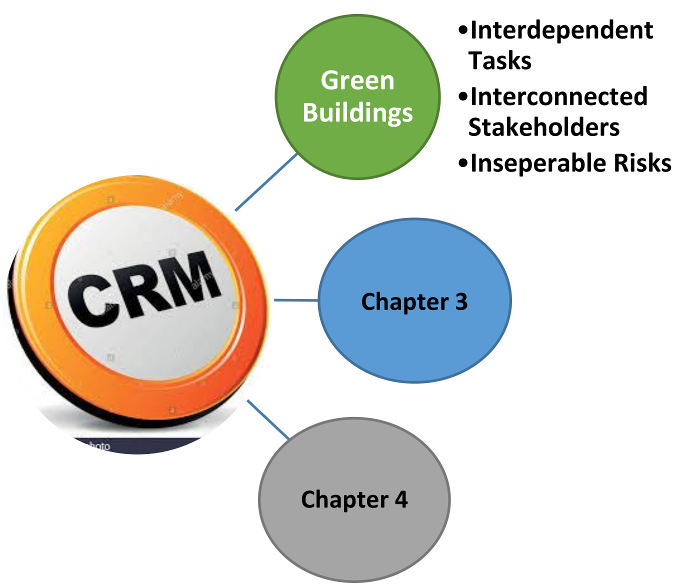
Concept	Key Literature	Source
Green Buildings	Complex undertakings which require a participation of multiple and diverse stakeholders Interdisciplinary collaboration approach GB as an effective solution	Fang & Marle (2013) Akintola et al. (2015) Tribelsky & Sacks, 2010 Zuo & Zhao (2014)
Design Planning	Holistic approach to programming, planning and designing Outline interdependent tasks, determine the overall pace of the programme	Dubey et al. (2018) Alsalman, 2012
Iteration and Rework	Reciprocal interdependency of tasks Non-linear data relationships Managing iteration relates to risk	Davies & Mackenzie, 2014 Wu et al., 2014 Zou et al. (2007)
Complexity and Interdependence	Tasks often proceed in parallel, relying on preliminary information from other tasks People, teams, tasks and risks involved interwoven relationships which, further creates complexities and uncertainties	Steward (1981) Danilovic & Browning (2007)

	Design problems and design solutions are interdependent	Knotten et al. (2015)
Stakeholder Management	Diverse professional backgrounds, with different levels and types of interests in the project	Mok et al. (2015)
	Complexities require a suitable stakeholder management system to accomplish interdependent tasks	Eskerod & Jepsen (2013)
Communication	Clearly understand each other's views and intentions	Tai et al., 2009
	Team communication is an effective means of conflict resolution	Senaratne & Ruwanpura, 2016
Collaborative Design Team	Integrated working practices, methods and behaviours	Austin et al., 2002;
	Backup behaviour; and coordination	Kumaraswamy et al. 2003a

2.10 Knowledge Area 1

Green practices are the first knowledge area that associate collaboration and process performance. The GB brings together a vast array of practices, techniques and skills that require an integrated environment. Unlike traditional designs, GB designs need a coherent and self-directed collaborative system that connects stakeholders, tasks and risks. But, this collaborative model is associated with interdependent tasks, interconnected stakeholders and inseparable risks, which requires a cultural shift from all stakeholders. The next knowledge attempts to understand the actual perceptions of risk and the behaviours of project stakeholders under risky situations and elaborate on CRM practices that ideally balance the stakeholders' objectives in the form of proper risk sharing principles, which are equitable. The synthesis of all three knowledge areas will be done at the end of Chapter 4.

Figure 2. 6: Synthesis of the Three Knowledge Areas



3. THE CHALLENGE OF RISK MANAGEMENT

3.1 Preface

Differences in technical experience, management styles, and organizational structure between stakeholders has led to differences in risk-taking disposition, benefit distribution, and responsibility sharing. Yes, every human being interacts with buildings in some shape or form, but very few understand its complexity. This complexity has resulted in design risks that are completed collaboratively. The hindrance of collaboration is owing to the difficulty in adopting new processes and working methods in order to apply new technologies, entailing the perception of possible risks and unforeseen costs.

This chapter will introduce the concept of risk in the construction industry, offer definitions of risk and uncertainty, and detail risk management in green buildings. The literature also focuses on collaborative risk management and the problems of the current practices in CRM, clarifying in detail other terms used in their interrelating nature. It will also, identify the controversies, and emergent gap which leads to the research literature questions.

Literature Objectives:

- What are the implications of CRM during the design phase?
- How are inseparable risks managed in collaborative circumstances?
- What are the current risk practices?

3.2 Definitions

Designing projects results in the delivery of physical facilities, which, in their construction and use, have an impact on the environment and the wider society, which naturally leads to the creation of stakeholders with different interests (Kay *et al*., 2018; Sami *et al.*, 2022). Due to rapid changes in technology, demographics, business and the economy, a new business rule for competitiveness has become ‘‘collaborate or perish” (Bratton & Tumin, 2012). This rule applies to all societies and industries but there are risks involved when dealing with collaborated stakeholders and their often-competing interests (Mohammed, 2020; Okudan *et al.*, 2021). Interests are a combination of desires, concerns, and needs (Fong, 2001). They motivate people and underpin or undermine the choice of positions for collaboration efforts. For example, stakeholders may want to group together in coalitions to represent their interests, meaning the goals of the collaboration should not be in conflict with the goals of the individual stakeholder (Ding, 2008). Subsequently, the need for stakeholder collaboration and RM to provide an effective way of managing risks, might arise, from potential actions of stakeholders is present and unavoidable (Sonnessa *et al*., 2020).

Risks existing in green construction projects are poorly managed by traditional non-collaborative approaches leading to problems such as higher prices, inappropriate indoor environment quality, technological failures and legal battles that in turn adversely affect all stakeholders (Okudan et al., 2021). Standard RM frameworks are currently focused on separable risks, whereas in practice, project RM involves multiple stakeholders. To reduce the cases of failure in GBs, it is necessary to collaboratively identify, analyze and treat risks, considering benefits and concerns of all stakeholders inside the network. The adaptation of RM required stretching the standard RM to embrace a multi-stakeholders’ perspective.

People, technology and the nature of multidisciplinary tasks influence every collaborative risk management solution in the early design stages (Sharma *et al*., 2013; Istomin *et al.*, 2019). The complexity of the collaborative design process is related to the nature of the processes, and involves the social interplay that ultimately generates design (Gomes *et al*., 2016; Mok *et al.*, 2018). This fundamentally affects the way people work, in the purposeful action of designing together. Low levels of collaboration have been identified especially at early design stages, where the collective design creation is hindered by the lack of ability of the team to build shared understanding, embracing a multitude of expertise in tasks (Gomes *et al*., 2016; Raouf & Ghamdi, 2019).

CRM has become an important opportunity for improvement to the collaborative design process of green buildings because stakeholders and tasks in this design process can be hampered by different views of fundamental topics (Froese *et al*., 2007; Schöttle *et al*., 2014). Hence, the lack of shared understanding causing unnecessary iterative loops (Valkenburg & Dorst, 1998) that can be correlated with wasted design effort. The involved stakeholders (including owners, architects, engineers, contractors, sub-contractors, and suppliers), and their use of heterogeneous software and hardware tools makes collaboration an important prerequisite to achieving efficient and effective risk management (Podean *et al*., 2011, El-Sayegh *et al*., 2021).

Collaboration is not a new research topic in the built environment. With the rapid advancement of information and communication technologies, particularly Internet and Web-based technologies in the past 15 years, various systems in integration and collaboration technologies have been developed and deployed to different application domains (Gallaher *et al.,* 2004). This includes architecture, engineering, construction, and facility management (Schöttle *et al*., 2014, Melander & Pazirandeh, 2019). However, while there is a continuous need to support better collaboration through innovation, the shift in practice and expertise remains uncertain.

3.2.1 What is collaboration?

Collaboration and cooperation are often used synonymously (Atkinson *et al*., 2022). Polenske (2004) reasoned that the similarities between cooperation and collaboration lead to the interchangeable use of the concepts. Both concepts occur between different stakeholders and are often adapted to increase the competitiveness in a project (Thompson *et al*., 2009). The Oxford dictionary (2019) explains both words with the same meaning of working together.

Appley and Winder (1977) described collaboration as a value system, which is a relational system in which, individuals in a group share mutual aspirations and a common conceptual framework. In addition, a system considers interactions among individuals characterized by justice as fairness. And, the aspirations for this value system is characterised by each individual's consciousness.

Figure 3.1 show studies done by Mattessich and Monsey (1992) over the period from 1975 to 1991, classifying collaboration into six elements. In the design process, collaborations vary enormously depending on their goals, settings, teams and resources. Yet all collaborations are a human activity, and the following six elements play an important role in all of them. These elements also play an important role in the questions of the interactive structure tool.

Figure 3. 1: Collaboration's six elements that play an important role

Motivation

The driving force of collaboration is **Motivation**. For collaboration to succeed, all stakeholdersneed to feel that - they have gained something.

Communication

Open communication on the design needs and the project's goal is vital, as this can help stakeholders to decide whether to participate or not - ensuring collective management.

Diversity

Collaboration benefits from from a **wide range of skills, knowledge and expertise**. A diverse group of stakeholders is often the best way to ensure collaboration.

Sharing

Flexibility and transparency promote a collaborative culture. it is important for stakeholders to agree on ideas or concepts at the onset.

Support

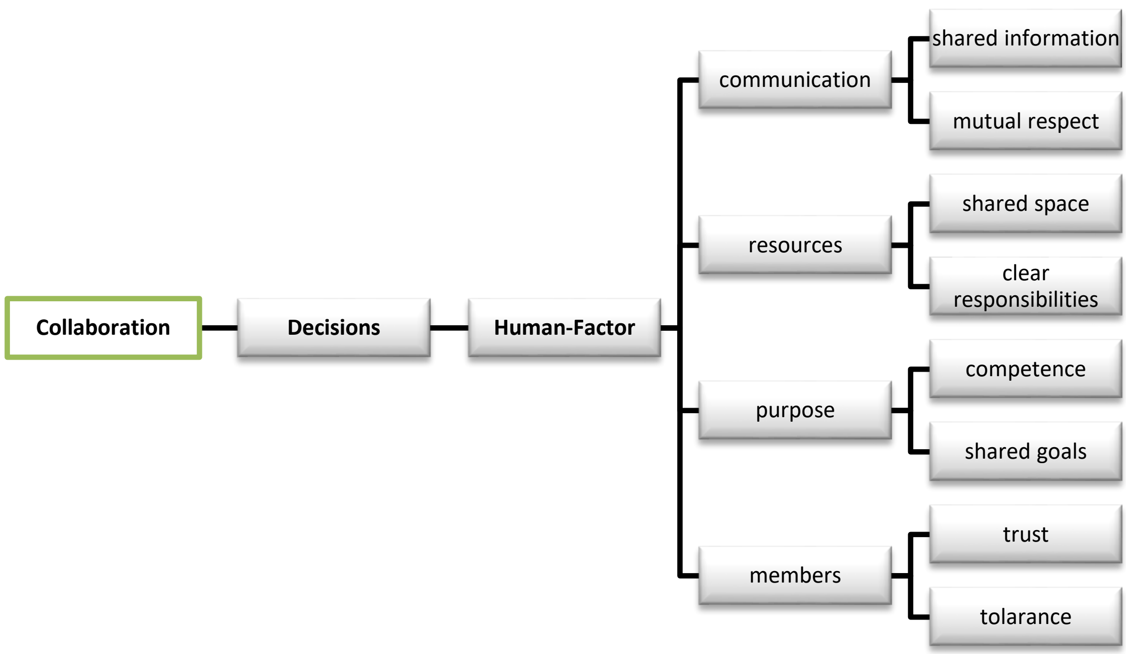
Collaboratiove teams need to work on the basis of **trust and commitment** that if someone needs support - that support will be available.

Problem Solving

The design team needs to **solve problems collectively**; and understand the principles of equity and fairness in distributing responsibilities.

Studies by Schrage (1995) on elements, which influence collaboration, also focus on the human factor needed in collaborative circumstances, which means decision making as shown in **Figure 3.2**. While there are different factors that may affect decision-making, risk perception and risk propensity (risk attitude) appear to play a central role in decision-making involving risk (Keil *et al.*, 2000). Decision-making processes fall into two general categories, defined as intuitive decision-making processes and rational decision-making processes (Elsayegh & El-adaway, 2021). These two broad categories provide variations to arrive at a decision in any situation.

Figure 3. 2 Collaboration categories and ingredients studied by different scholars



Based on their findings, Mattessich and Monsey (1992) define cooperation as informal relationships that exist without any commonly defined mission, structure or planning effort; whereas collaboration brings previously separated organizations into a new structure with full commitment to a common mission. Schrage (1995) defines collaboration in context of value creation, as the process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding that none had previously possessed or could have come to on their own. Here, creativity can be explained as a process to achieve innovative outcomes, which is expected in complex projects (Podean *et al*. 2011). Like Mattessich and Monsey (1992), Schrage's (1995) components centralise the human factor. Shelbourn et al. (2007) ascertained that the human factor, rather than technology, is the key factor of collaboration, which, besides own knowledge, it is important whom you know.

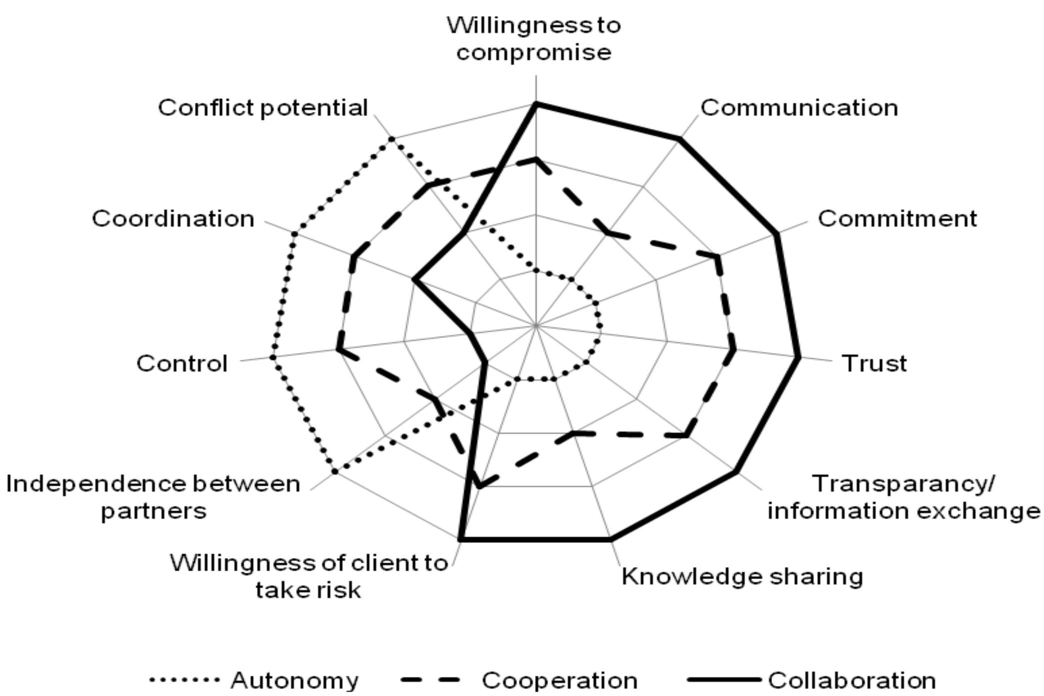
Most researchers acknowledge that their definitions are incomplete because they do not clarify who or how many stakeholders should participate; nor do they describe organisational levels, the time horizon, or the nature of the outcome. Influenced by Wood and Gray's (1991) definition, Thomson and Perry (2006) and Thomson *et al*. (2009) emphasised that collaboration emerges over time, while stakeholders interact formally and informally with each other to create new rules and structures. Furthermore, Thomson *et al.* (2009) said collaboration is multi-dimensional, affecting the governance, administration, mutuality, norms, and autonomy of an organisation. Compared to cooperation, Thomson and Perry (2006) said collaboration suggests a higher level of collective action than cooperation.

However, a definition of collaboration is agreed by different scholars to be temporary (Polenske, 2004 and Garmannet *et al.*, 2012) because, if the goal is achieved, the collaboration ends. Moreover, some of the studies explain the difference between cooperation and collaboration using a continuum of integration, commitment, and complexity. Collaboration will have a high level of integration, commitment, and complexity. Cooperation, at the other end, will have a low level of integration, commitment, and complexity (Thomson & Perry, 2006).

3.2.2 Comparing Cooperation and Collaboration

Figure 3.3 presents the evidence that different authors define the terms *cooperation* and *collaboration* based on different perspectives, reflected in different characteristics.

Figure 3. 3 Comparison of the terms collaboration and cooperation in projects

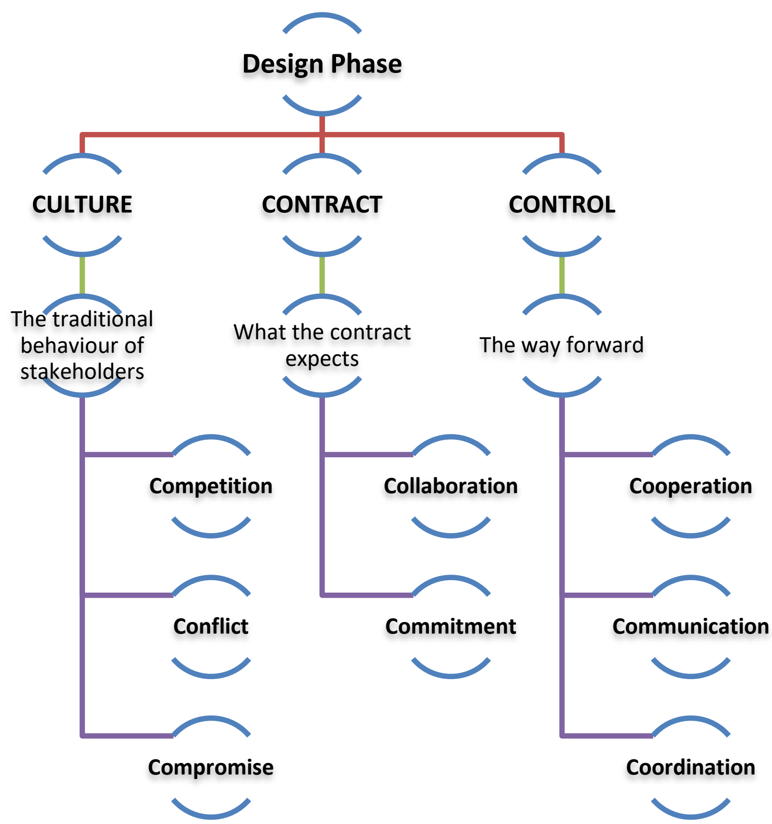


(Schöttle et al**., 2014)**

Thus, collaboration within the project context is an inter-organisational relationship with a common vision to create a common project organisation. This organisation will have a commonly defined structure and a new and jointly developed project culture, based on trust and transparency. The goal will be to jointly maximise the value for the customer by solving problems mutually through interactive processes; which are planned together, and by sharing responsibilities, risk, and rewards among the key stakeholders (Schöttle *et al*., 2014; El-Sayegh et al., 2021).

Hence, it is important that all stakeholder understand that, they are unable to achieve complex design goals on their own and soft factors have a strong impact on collaboration. This explains that collaboration does not exist automatically from the beginning of a project. Collaboration requires a process of development (Elsayegh & El-adaway, 2021). Therefore, all stakeholders need to keep in mind that problems may occur and mistakes will be made during the phase of creation where political, financial, choice of technology and procurement route are some of the risks and communication, commitment and compromise will be needed for this multicultural team.

Figure 3. 4: Collaboration and cooperation in a creation phase



In this creation phase, designs are subject to more risks and uncertainties than in other phases (Rashid *et al.*, 2008). Furthermore, the introduction of new technology and management methods add to the complexity and dynamic nature of the information flow (Tah & Carr, 2001). Project complexity and stakeholder diversity add more risks and uncertainties to the phase (El-sayegh, 2008; El-Sayegh et al., 2021). Risks and uncertainties in complex projects come from various sources throughout the entire life cycle phases (Rashid *et al*., 2008). These sources could be the diversity of the temporary project teams and the political, economic, and the social conditions of project location (Zavadskas *et al.,* 2010). Therefore, a CRM process is needed to manage these risks and uncertainties in any situation where more than one party (such as, owner, designer, contractor, subcontractor, or material supplier) is involved (Zou & Zhang, 2009).

3.2.2 Risk and Uncertainty Defined

The quest towards GBs in our societies has put a spotlight on the built environment and the construction industry. Human activities have adapted to greener habits over the last two decades (Yang & Zou, 2014), drawing on lessons learnt from the world's natural ecosystem. The green actions in the construction industry are urgent when viewed through the lens of energy consumption statistics because buildings and infrastructure are the main consumers of resources: materials and energy (Zhang *et al*., 2012).

Traditional design and construction has always focused on cost, performance and quality objectives; green construction adds to these criteria the minimisation of resource depletion, the minimisation of environmental degradation, and creating a healthy built environment (Wu & Low, 2010). The shift to green is a paradigm by which sustainable objectives within the building design are considered for decision making at all stages by all stakeholders (Kent & Becerik-Gerber, 2010).

The risk factor in green designing is considered very high (Zavadskas *et al*., 2010). The project's life cycle is full of various risks, which need proper CRM (Li & Liao, 2007). Risks come from many sources: a temporary project team that is assembled from different companies; construction site; modern construction technology, which requires countless processors, sim cards and other high-tech components; to name a few. The size and complexity of the projects is also increasing, which adds to the risks (Banaitiene & Banaitis, 2012). This is in addition to the economic and social conditions in which the project is to be undertaken. Project risk can be defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost and quality (Project Management Institute Standards Committee, 2004). These risks and uncertainties have caused great cost and time overruns in projects.

There have been debates on the differences and common features of risk and uncertainty. The notions are related but they do not coincide. Many people in different fields use two terms that are interchangeable to them.
Migilinskas and Ustinovicius (2008) said many decision makers usually make a common error of confusing the concepts of uncertainty and risk, especially as both concepts are used in project management. They are related but described as two different concepts. For the sake of this research, the two terms will be defined from different views starting from their everyday usage, their meanings in different industries and then focusing on their meaning in the construction industry.

Merriam Webster's online dictionary (2016) defines the word *risk* as the possibility of loss or injury: peril and the word *uncertainty* as the quality or state of being uncertain: doubt. In common everyday use, the distinction between risk and uncertainty is that risk implies a positive probability that something harmful will happen, while uncertainty implies the state of doubt and does not imply any probability (Rose, 2001).

In economics, the definitions of risk and uncertainty are different, and the distinction between the two words is clearer (Rose, 2001). In his book, Risk, Uncertainty, and Profit; Knight (1921) established the economic definition as:
Risk is present when future events occur with measurable probability

Uncertainty is present when the likelihood of future events is indefinite or incalculable

Adams (1995:25) simplifies these concepts as: “if you don’t know for sure what will happen, but you know the odds – that’s risk. And if you don’t even know the odds – that’s uncertainty”.

Under these definitions, risk is measurable and can be quantified. Uncertainty is not measurable and cannot be quantified. Given these definitions, people can arrange to protect themselves against risk (Rose, 2001). Another definition of *uncertainty* from a business decision-making perspective defines *uncertainty* as: A situation where the current state of knowledge is such that the order or nature of things is unknown. The consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable. In addition, the credible probabilities to possible outcomes cannot be assigned (Business Dictionary, 2016). From a statistics standpoint, uncertainty is defined as a situation where neither the probability distribution of a variable nor its mode of occurrence is known. To further understand the distinction between risk and uncertainty, it is helpful to review these definitions in the context of the construction industry. The following paragraph presents are some examples of how risk and uncertainty are defined in the construction industry.

Jaafari and Schub (1990) define risk as the presence of a potential or actual event that could stand in the way of project performance causing partial or complete failure either during construction and commissioning or at the time of utilisation. Akintoye and Macleod (1997) define risk as the possibility of unexpected events occurring which can badly affect the successful execution of the project with regards to time, cost and quality. Loosemore *et al*. (2006) define risk as a probable future event whose manifestation and impact are unknown, however, which can affect the company’s ability to obtain its project goals. The Project Management Institute (PMBOK, 2008) defines risk as an uncertain event or condition that, if it occurs, can either create a negative or positive effect on at least one of the project objectives. According to Mahendra *et al.* (2013), risk is any event or action, which may hinder the realisation of project goals. The distinction between risk and uncertainty through various disciplines gives diverse views and suggest that there is some similarity between the two terms. Thus, the risk event is because of the uncertain situation.

The definition provided by the Project Management Institute (PMI, 2000) denotes that risk is because of uncertainty. Uncertainty in this regard is closely linked to the project performance objectives: time, scope, cost and quality. However, this also considers in a broader perspective that risk is calculable from events that can impact negatively or positively on project performance. To sum up, one can say that risk is a state or condition in which the decision maker is handicapped as far as adequate data, information and experience are concerned. This makes decision making tougher. Therefore, risk is a situation in which project stakeholders lack the knowledge to take effective decisions on project variables at the outset or during project design, which can negatively or positively affect project goals.

3.3 The Risk Concept in the Construction Industry

Risk has always been part of the human race. Arguably, each significant breakthrough in human civilization has been possible through people's readiness to take risks and challenge or confront the state of affairs (Ansong, 2015). This implies that risk and survival in man's history have a correlation. Therefore, risk management is not new, nor does it employ black box magical techniques. Traditionally it has been applied instinctively, with risks remaining implicit and managed by judgement, and informed by experience (Mills, 2001).

Zack (1996) said that, in the past, normal risks associated with construction were primarily physical in nature and related to acts of God (like hurricanes, volcanoes, and floods) and safety accidents causing losses, damages and delays to construction projects. The risks of underground conditions, availability and productivity of labour, the ability to obtain materials and equipment, or other onsite problems that prevented work from proceeding were predicted.

In recent times, there has been a built up of a vast knowledge base on risk (Ansong, 2015), affirming the two concepts of risk, namely, objective and subjective (Zhang, 2011). Objective risk is a material fact, which can be elaborated, forecasted and managed by science. This is devoid of people's perception and subjective values (Bradbury, 1989). Thus, risk is real, factual and quantifiable through statistical analysis. In this concept, risk is often analysed as a product of the probability of the risk occurring and its impact (Thompson & Dean, 1996). Subjective risk considers risk analysis to be based on the influence of people's interest, values, culture and organisations (Busby & Zhang, 2008). The consideration of these two concepts reveals that risk cannot be defined in isolation of either concept; both must be integrated to give a more concise meaning and understanding because risk is very complex (Hansson, 2010).

The complexities of design risks in green buildings lurk in many areas, not only associated with the technical part of the work, but also include social, cultural, organisational and technological dimensions (Hillson, 2010). For example, in today's global village, fast-changing business world with broad access to resources anywhere, and pressures for quicker, cheaper and smarter solutions, stakeholders can leverage resources and accelerate their risk management skills by forming alliances that range from simple collaboration agreements to 'open innovation' (Antikainen *et al*., 2010). This extends the risks further.

Furthermore, design risks are amplified by the interdependencies of stakeholders and their tasks that require integrated databases to ensure the consistency and integrity of project data, enabling efficient data sharing and exchange throughout the design life cycle. This interdependency enables timely access to up-to-date project information (Halfawy & Froese, 2005), commonly known as common data environments

(Zamojski *et al.*, 2012). Pavan (2017) defines this environment as a single source of information used to collect, manage and disseminate documentation, the graphical model and non-graphical data for the whole project team (i.e., all project information whether created in a BIM environment or in a conventional data format). These information dependencies have resulted in dependable tasks, which in turn result in inseparable risks, which are highly intertwined and difficult to uncouple (Poirier *et al.*, 2016).

With the worldwide increased awareness of sustainability and energy efficiency of GB's, research is still focused on technical methods, environmental impact and site safety, which evidently are common themes (Zou & Zhao, 2013), and is not focusing on the unique risks as a whole. Inseparable risks are those risks that have arisen specifically through the introduction of sustainable materials and practices in collaborative designs. Collaborative designs also tend to focus on knowledge creation; integration between stakeholders from different disciplines; and on communication between stakeholders about both the design content and the design process (Liu *et al*., 2017), not about the risk approach. However, there are other aspects, which are as important as technical issues for the efficient and effective design of complex green projects (Li *et al*., 2011).

Design risks change. As the project moves forward, new risks may emerge, foreseeable risks may change in nature that may magnify or ease the consequences of some other foreseeable risks, and anticipated risks may disappear (PMBOK, 2000). This generates new event patterns in an environment where there exist an unusually large number of internal and external uncertainties (Pryke, 2004). These uncertainties are formed by the theory of risk stating, "that everyone willingly takes risks" (Adam, 1995:14). For example, gamblers may not like losing, but they do like gambling (Ibid). Therefore, according to Marker *et al*. (2014) people who adopt green building technology are people who enjoy experimenting with technology; those who enjoy working complex systems and the large group are those who have a sense of belief that they can provide for the needs of future generations.

The risks imposed by these innovative customs of collaborative designs are subject to the ‘risky shift phenomenon’, that groups are inherently more inclined to live with greater uncertainty than are the individuals that comprise the groups (Stoner, 1961; Greene *et al*., 2001). For example, individuals will take greater risks in order to show that they are willing to take responsibility for their decisions to achieve a leadership position while also receiving the accolade for the success (Vinokur, 1971; Greene *et al*., 2001). This additional risk means a stakeholder in a group discussion that is somewhat off the group average (i.e., seem to be accepting less risk than fellow group members) will tend to alter their position to bring themselves more into line with the risk-taking level (Brown, 1965; Greene *et al*., 2001). This change of a stakeholders' propensity for risk-taking as being influenced by the group's propensity for risk-taking is called a ‘risk thermostat’ (Adam, 1995:15). A risk thermostat is a process by which people incorporate perception and experience and then modify their behaviour to a level they believe will appropriately mitigate the risks (Adams, 1995). Inseparable risks will then need a CRM strategy that considers the stakeholder's thermostat (Adam, 1995) and a risky shift phenomenon (Greene *et al*., 2001), because green projects have multiplied the level of uncertainty and they distribute risk over a wide area, often creating more risks (Thamhain, 2013). **Table 3.1** below shows how risk management has transformed from the old to a new paradigm.

Table 3. 1: Managing business risks	
Old Paradigm	**New Paradigm**
• Historically focused and fragmentation (Silo Approach)	**• Strategic, focused and coordinated - with optimal use of different knowledge and expertise (Holistic)**
• Focus on people with a 'blame culture'	**• Focus on processes and people that have a collaborative mind-set**
• Ad hoc activities that are sequential	**• Continuous activities that have a joint problem-solving solution**
• Accounting, treasury and internal audit	**• All of managements that includes an unambiguous decision-making process**
• Financial risk with an aim to claim or have disputes	**• Business risks with an agreed process of dispute resolution**
• Inspect, detect, react	**• Anticipate, prevent, monitor**
• Organizational culture compatibility	**• Compatible organizational cultures**
• Expectation of future work	**• Possibility of future work**

This paradigm shift to a different kind of risk management would be effective in dealing with the broad spectrum of risk factors. Design stakeholders will need to go beyond the mechanics of analysing the work by the components of the "triple constraint," but will have to examine and understand the sources of risks and uncertainty before attempting to manage them. Moreover, in GB the collaborative situation is accounted for in the "risk is a value" hypothesis by the simple assumption that society dictates levels of risk in a situational context (Brown, 1965). This collaborative situation is where groups are of equal status, not where rank is an issue, as maybe found in many decision-making groups and negotiating situations (Greene *et al*., 2001).

Therefore, design stakeholders need to practice a collaborative team working approach which is a complete examination of all alternatives by different parties and should always remember that collaboration is not an endpoint, something to be achieved but, an evolving process (Bedwell e*t al*., 2012). During design processes, all stakeholders' needs should be assessed so that a satisfactory and realistic solution to the problem is addressed (Love *et al*., 2004). By making an allowance for the conflicted nature of stakeholders' perceptions for a project, which in complex green projects may have an impact on project success, the risk management strategy will not be done relying solely on one concept but on an integrated and reliable principle.

3.4 Risk Management Practices

The design phase has a progressively elaborative meaning where work becomes broader as it progresses and, for that matter, the information flow is monitored, as certain decisions should be taken. However, as there are more stakeholders involved, more data is processed and risk sources change (Goh & Abdul-Rahman, 2013). Therefore, risk management becomes a process, which unravels design risks, analyses them and find actions to solve the consequences (Mahendra *et al*., 2013). According to Loosemore *et al*. (2006), risk management is a proactive decision-making process which entails accepting known risks and taking actions to reduce their effect and probability of occurrence in order to minimise threats and maximise opportunities.

From these definitions of risk management, one could realise that the objective of managing risk is not to eliminate it but to reduce its probable occurrence and impact on project objectives (Potts, 2008). This is true for risks that have a negative impact on the project but risks that provide opportunities or impact positively on the project should be exploited.

Irrespective of the numerous risk management processes proposed in the literature (Chapman, 1997; Tah & Carr, 2001; Loosemore *et al.*, 2006; PMBOK, 2008), the five major risk management processes used extensively in the industry include risk planning, risk identification, risk analysis, risk response and risk monitoring and control.

These project risk management processes are explained below:

Risk planning: laying down procedures that foretell how any risk inherent when designing will be dealt with. If one fails to plan then one has already planned to fail; therefore, this first stage of the risk management process is very vital, as it provides enough resources and timing requirements for managing the risks and sets the stage for the other processes.

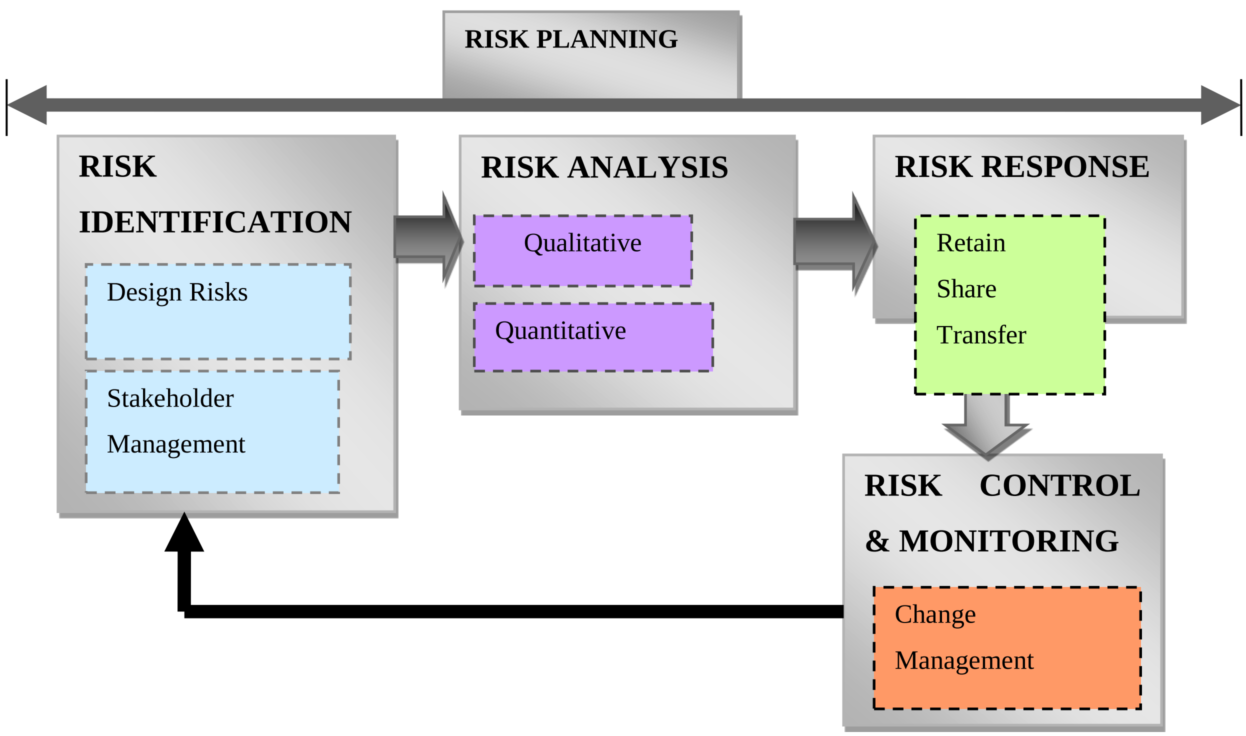
Risk identification: is discovering threats that are related to the project using tools and techniques such as brainstorming, root cause analysis, Delphi techniques, projects, charts and checklists. This identification process is an art not a science (Barkley, 2004), based on years of experience and gut feelings.

Risk analysis: this involves the evaluation and prioritisation of risks identified. It takes two forms: first qualitative risk analysis followed by quantitative risk analysis. The qualitative risk analysis aims at assessing the priority of risks identified, taking cognisance of their relative likelihood of manifestation. The resultant threat on design objectives should they occur, will consider the time period of response and the tolerance level of risk by the organisation with regards to design tasks (PMBOK, 2008). This also prepares the ground for the quantitative risk analysis by which risks that were prioritised by the qualitative risk analysis use techniques like probability distributions, sensitivity analysis and expected monetary value analysis (decision tree diagrams) to quantitatively analyse the effect of those risk events.

Risk response: refers to the strategy responses that were outlined by the project team regarding the various risk events at the initial stage of the project. This is a proactive attitude towards risk events as contended by Loosemore *et al*. (2006) and will do the project team much good as far as the management of risk is concerned on the project. The different number of risk response approaches that the project team can rely on are

- risk avoidance, acceptance, mitigation, transfer and sharing. However, the decision is best arrived at using decision trees to compare alternative outcomes (El-sayegh, 2014). *Risk monitoring and control*: The monitoring aspect deals with observing changes that have taken place as the project progresses concerning risk while the control deals with the risk responses as risks emerge and are dealt with on the project. This is accomplished through the updating of the risk register and through frequent meetings (Webb, 2003). Monitoring and control of risk makes use of trend and variance analysis, which requires data collected as the project is being executed. Another object of risk monitoring and control is to check whether the project assumptions are still valid, risk has changed or can be removed, the risk management plan is being adhered to and contingency reserves are in alignment concerning cost and schedule (PMBOK, 2008).

Figure 3. 5: Systematic risk management practices



These risk management processes need to be constantly reviewed because of the dynamic and diverse nature of risk and the design phase respectively. However, Forbes *et al.* (2008) indicated that, over time and across countries, the construction industry tends to use risk management techniques that have always been used, instead of trying relevant techniques that are appropriate for a situation. These risk management techniques can influence stakeholders' behaviour and therefore have a significant impact on how they enhance project performance during operation and the total cost (Osipova, 2007).

3.5 A Link between Stakeholders and Risk

Green designs normally involve diverse stakeholders such as clients, end-users, customers, suppliers, consultants, contractors, financial institutes, green groups, governmental agencies and local communities (Leung & Olomolaiye, 2010). In order to gain an overall view of construction stakeholders, it is helpful to classify them into different categories. Construction stakeholders can be categorised into two groups according to their legal relationship with a project: internal (or primary) stakeholders and external (or secondary) stakeholders (Olander, 2003). Internal stakeholders refer to those who are members of the project coalition, provide finance or have a legal relationship with the project. External stakeholders are those who influence or are influenced by the project, but are not normally engaged in transactions with the project and may not be essential to the survival of the project.

Stakeholders in a green designs are by no means isolated from one another, they are actually closely interrelated through formal or informal ties (Ngobeni *et al.*, 2023). The internal stakeholders are linked via legal contracts or direct interest, while the external stakeholders will also affect or be affected by the construction product through indirect ties (Mushi *et al.*, 2021). Furthermore, external stakeholders, though they are not decision-makers in the project, still have a link to the design and can influence the project in a number of ways. Each party has his or her own background and contributes towards project success (Agyekum *et al.*, 2022). Since stakeholders' inputs are often interdependent, conflicts may arise in some circumstances, which is another risk the project encounters.

In order to assess the risks imposed by construction stakeholders, a systematic risk assessment process should be followed (see **Table 3.2**), listing risk identification; risk impact analysis; risk occurrence probability estimation and risk prioritisation; as adopted from Leung and Olomolaiye (2010).

Table 3. 2: Risk assessment process and the relevant techniques

Risk assessment process	Risk assessment techniques	Purpose
1. Risk identification	Collaborative ideas Database	➔ facilitating a comprehensive list of risks ➔ listing foreseeable risks
2. Risk impact analysis	Power–Interest Matrix Appropriate strategies Interaction	➔ identifying key stakeholders for the risks ➔ understanding the importance of RM stakeholders ➔ having a collaborative approach
3. Risk occurrence probability estimation	Discussions	➔ improved communication on relevant risk patterns with estimated probabilities of cost overrun and delayed schedule from relevant stakeholders
4. Risk prioritization	Impact–Probability Matrix	➔ decision synchronization for planning risk response

Stakeholder risk identification can be broken down into two steps: (1) to identify as many project risks as possible; and (2) to determine the stakeholder associated with a particular risk. There are several techniques for identifying risks and the stakeholders associated with them. Brainstorming is a powerful tool for tackling project risks, as a comprehensive list of risks can then be addressed in the risk assessment processes that follow (Olander, 2003). This technique enables stakeholders to hear what the other stakeholders see as risks, and promotes the inspiration to identify additional project risks associated with stakeholders (Olander, 2007). Since the selection of members of a brainstorming session is crucial, it is suggested that all key stakeholders are included in the session to stimulate the identification of as many risks as possible. In order to have a clear concept of design risk, the checklist is another useful tool for listing foreseeable risks in the design phase. As the stakeholders gain more experience and knowledge of the project, the checklist can be correspondingly expanded (Leung & Olomolaiye, 2010). Once the risks have been identified, they can be prioritised according to their impact and probability of occurrence.

The purpose of the risk impact analysis is to assess the severity of a risk in a design. The impact of stakeholders consists of two dimensions: power and interest. Power is the ability to influence others and to get things done (Pinto, 1998; Olander, 2007). The more powerful a stakeholder is the more damage his or her or its influence might cause to the project. The more interest a stakeholder has in the project, the more active the stakeholder may be in design activities and the more uncertainties this will bring to the project. One of the frameworks to assess the impact of stakeholders is the Power–Interest Matrix (Olander, 2003). The stakeholders in a design phase can be classified into four categories according to the degree of power and interest they have:

- those that have great power in the design and a high level of interest;
- those that have great power but a low level of interest;
- those that have little power but a high level of interest; and
- those that have little power and a low level of interest.

3.6 Managing Stakeholders using Risk Management Principles

The views, perceptions and perspectives of stakeholders have to be considered when establishing the context and defining the risk criteria (Demir *et al.*, 2012). This linkage between stakeholder and risk management is related to the decision making and engagement of all stakeholders (Du *et al*., 2016). This is more of a communication and relationship management issue because the multiple stakeholder perspectives affect risk perception and thus decision making (Demir *et al.*, 2012).

Due to the dynamic nature of society, the complex nature of green designs and the interplay of multi-stakeholders, RM processes require cooperation between the stakeholders (Phillips, 2003). An amount may be allocated in the budget to recover minor cost overruns and to keep the project on track, but the benefits and costs of any alternative plan need to be evaluated so that the optimum solution is selected. This applies to critical stakeholder risks; that have impacts on the design and would probably lead to a crisis if the risk materialised (Leung & Liu, 2003). By adopting a risk management framework, construction stakeholders can manage risks using the following steps:

- Identify design risks and relevant stakeholders
- Assess risks systematically
- Prioritise stakeholders' risks
- Respond to risks

Key stakeholders need to propose contingency plans at the outset to allow sufficient additional resources to be allocated to managing the risks in the design phase. As each action involves expenditure, the stakeholders need to balance the cost and the benefits when considering action plans (Olander, 2007). With design conditions constantly changing and with different stakeholders and their tasks being interdependent, there is a need to monitor inseparable risks. The strategies that stakeholders can adopt to deal with such risks include:

- Avoid risks.
- Mitigate risks.
- Transfer risks to other stakeholders.
- Share risks with other stakeholders.

Avoiding risk caused by stakeholders, means completely removing the risk from the work to be done. A method of this kind always involves redefining the project scope and redesigning the project plans. However, it can only eliminate specific risk events and can only be applied on some occasions.

Risk mitigation involves reducing the impact of a risk event caused by stakeholders or reducing the probability of its occurrence. In most cases, risk mitigation can be a cost-effective method involving stakeholders. These stakeholders would predict their actions and the consequent impact on the design phase, and then take the necessary action, such as the establishment of formal communication mechanisms and the extension of the coordination period for each task, in order to reduce risk event probability and impact.

Transferring risk means transferring the impact to other parties if the risk event occurs. A client can try to transfer the costs of calculation errors, or the design faults, or management mistakes through different contracts.

However, this strategy may introduce other additional risks to the project. Therefore, transferring the risk does not always help the parties of a project in the long term. The strategy of transferring risk should therefore be used tactically in combination with other methods, like a Framework Agreement. A Framework agreement is a set of terms and conditions, which is reached between two or more stakeholders to cover a long-term collaborative arrangement (Glover, 2008). It allows stakeholders to agree on contract terms regarding to price and, where appropriate, the risks envisaged, during that specific period (Watermeyer, 2012). This agreement is not a binding contract in itself but a way of managing services from different organisations. Framework

Agreements provide stakeholders with options to a stream of work where the risk model has already been negotiated (Rawlinson, 2009).

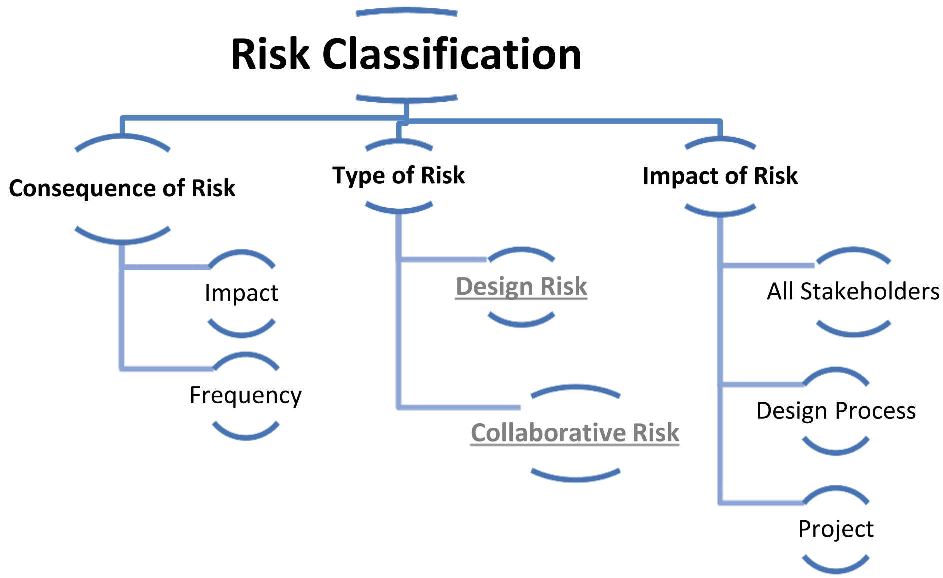
Sharing risk is a useful method for handling complex designs. If there are too many risks for a specific stakeholder, the impact of failure could be shared among more parties. This method often needs the involvement of multiple parties, and requires good coordination and communication capabilities.

Stakeholders need to take appropriate actions to tackle risk events if they become critical to the design phase because risks do not impact projects equally. Relevantly, it is not possible to identify all risks that are inherent in the project at its inception stage. This makes it clear that new risks are likely to be identified or may emerge as the designs progress (Schieg, 2006). Therefore, classification of risks can help the project team to know where to place the newly found risk with respect to their initial classification and largely informs them of what response action to take.

3.7 Risk Classification within the Design Phase

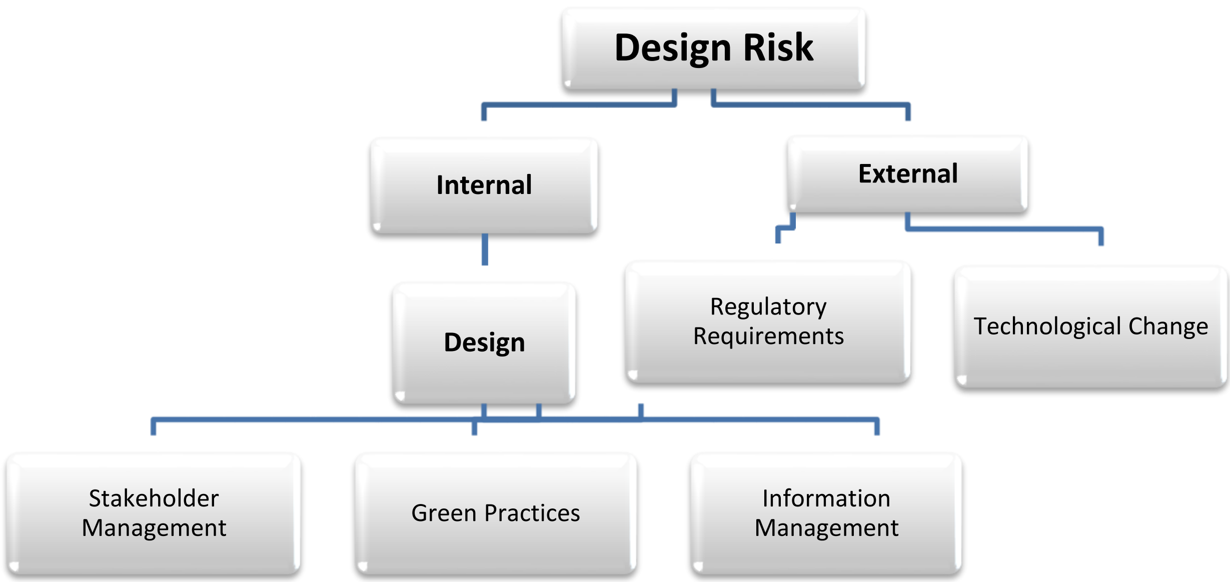
Stakeholders classify risks differently but this significant step in project risk management is important as it attempts to structure the diverse risks that may affect a phase. Risk classification equips the design team with the ability to identify risks and thereafter choose the best risk management strategy (Walke *et al*., 2011). Many approaches have been suggested in the literature for classifying risks. Perry and Hayes (1985) presented a list of factors extracted from several sources, which were divided in categories according to risks retainable by contractors, consultants and clients, these were used as risk classifications. Alternatively, Flanagan and Norman (1993) classified risk based on consequence, type and impact. But, the design phase of GBs is responding to the ever-increasing complexity associated with the design and stakeholders are still striving to secure more innovative ways of facilitating the process in order meet client needs and collaborative requirements.

Figure 3. 6: Classification of risk



Combining the holistic approach of general systems theory with the discipline of a work breakdown structure as a framework, Shen *et al. (*2001) grouped risks into six groups in accordance with the nature of the risks, i.e., financial, legal, management, market, policy and political, as well as technical risks. In a word, many ways can be used to classify the risks associated with designs and the rationale for choosing a method must service the purpose of the phase. Tah and Carr (2001) suggested a two-level hierarchical approach to risk classification; external and internal. Despite its importance to any project, risks in design phase have not received sufficient attention. The quality of the information feeding into the design process is the main determinant of the occurrence and extent of the design risks. **Figure 3.7** shows a risk classification in the design phase.

Figure 3. 7: Risk classification hierarchy of the design risks



Classification of risk in projects can be done according to their sources, consequence or impact, frequency of occurrence and the mitigation measure required (Ansong, 2015). This review of the literature shows the perceived inadequate management of risks and reveals that there is no consensus as to which particular method of classification of risk is completely accepted. Zavadskas *et al. (2*010) also suggested three points of risk classification, external, internal and design risks, as shown in **Figure 3.8.** When zooming into the management of risks, design risks have been considered one of the most prevalent as it can lead to a domino effect to subsequent phases.

Figure 3. 8: Risk classification by different points during the design phase

In short, any of the many ways can be used to classify the risks associated with designs but the choice method should serve the objective of the project. This research seeks to examine how project stakeholders share inseparable risks they encounter in their interdependent tasks and thus find an optimum way of risk sharing. The design risk classification will be used throughout the study to identify risk sharing problems and the obstacles to optimal risk sharing.

3.8 Identifying Inseparable Risks within a Design Phase

The emphasis on effective RM in dealing with the broad spectrum of risks has gone beyond the traditional RM mechanics to examining the sources of unknown risks (Jarkas & Haupt, 2015). Though the construction industry has managed to identify and analyse known risks, it has recognised that dealing with the hidden, less obvious aspects of uncertainty is complicated and inseparable risks in the early stages need one to be proactive (Smith & Merritt, 2002). Inseparable risks are from uncertainties, ambiguities and arrays of risk factors that are intricately connected.

In practice, when known risks are identified and anticipated within a project, RM processes can be set to manage them. However, the industry within green projects, anticipates new or unknown risks. These follow non-linear processes, which develop, into issues that ultimately affect design stakeholders (Apgar, 2006). These unknown risks also involve multiple interconnected processes of technical, organizational and human factors, all associated with some imperfection and risk (Thamhain, 2013). It may be difficult to trace the causes when dealing with new or unknown risks. Predicting and controlling such risks may appear impossible for some design stakeholders because different stakeholders tend to have a consistent risk preference, which dictates their risk attitude and thus makes the risk sharing process challenging (Walker, 2015).

For risk sharing, it is important to realise that design risks are not the same in all countries but vary depending on the local political, cultural, economic and social conditions. In RSA, for example, the industry is changing fast, and there are many green projects underway (McGraw-Hill Construction, 2016). However, these projects have placed a burden on the industry and created many unknown risks. El-Sayegh (2008) stressed that the identification and assessment of risks in projects is a key step in managing risks. He observed that, generally, every design will contain a certain degree of risk, but stakeholders are not prepared enough to identify or adequately address risks. El-Sayegh et al. (2021) further suggested categorising design risks as internal or external, depending on the source of the risk (this method of dividing risks is also supported by the Project Management Institute; PMI, 2004).

The goal of identifying inseparable risks is to make the process of risk sharing more efficient through planning and coordination by mutual adjustment, so to get a better flow in design (Fundli & Drevland, 2014). Design risks have been classified in a number of ways. Arguing that risks arise as a result of interactions between stakeholders, obsolete technology and organisational factors. Smith *et al.* (2009) suggested that they may be grouped as either involuntary or voluntary, depending on whether the incidents that create the risk are uncertain or beyond the control of the people in charge.

Studies have found that design stakeholders tend to overemphasise the ‘consequence’ side of risk and overlook the ‘probability’ dimension (Hartono *et al.,* 2014). Such consequences are the negative publicity and environmental manipulations, human and economic costs (Ayyub & Wilcox, 2001) that are always being taken into consideration during planning. Others studies have found risk sources to be financial, strategic or operational (Xenidis & Angelides, 2005) and can lead to higher than predicted expenses or poor accounting during the design management phases.

The increasing complexity of projects and knowledge processes makes it imperative for stakeholders to be keenly aware of the intricate connections of risk variables among complex systems and processes (Thamain, 2013). This limits the effectiveness of traditional RM methods. Stakeholders argue that no single person has all the insight for assessing multi-variable risks and their cascading effects. Design stakeholders realise that, while there may be good RM methods, which provide a critically important toolset for risk management, it takes the collective thinking and collaboration of all the stakeholders to identify and deal with the complexity of inseparable risks in today's green projects.

Yet, though there are revolving project management tools that are forcing the risk management principles to evolve, the contract management components remain stagnant. The problem faced by stakeholders is the contracts signed do not correspond with the green movement advancements.

3.9 Collaborative Risk Management of Green Buildings

CRM is about the dynamic management of risk (Rahman & Kumaraswamy, 2005), which plays a major role in achieving value-for-money and cost-efficiency in designing complex projects. A dynamic approach implies that the identification and assessment of design risk, along with the response to it, are performed proactively and jointly throughout the design phase (Hartman et al., 1997). However, GBs deal with complexities that surface in the design process through the interdependency of stakeholders, their interdependent tasks and new risks that are interdependent and are inseparable. These inseparable risks cannot be transferred or allocated to an individual, but have to be shared between stakeholders and can only be resolved or mitigated through collaboration (Laurent, 2017). Despite the fact that CRM is arguably an effective tool, the use of CRM still seems to be uncommon because of the blurred risk-sharing lines (Osipova & Eriksson, 2011b).

In construction, the purpose of this contract agreement is to allocate rights, duties, responsibilities and risks between stakeholders. However, too often risks are usually allocated to stakeholders that might not be the most competent in managing or even financially handling the misallocated risk. This inappropriate risk sharing method has often led to additional resources (cost and time) to manage the claims and disputes when the stakeholder goes bankrupt.

For the design phase, risks can hardly ever be eliminated; they can either be transferred to another party or be shared (Andi, 2006). Proper sharing of risks between contractual parties is obviously very important in order to put stakeholders on equal footing. If not, only one party or none of them would benefit from the project (Peckiene *et al.*, 2013). A lack of proper training and understanding in the area of risk shifting encourages stakeholders to continue their risk-averse ways (Hanna *et al.*, 2013). The common practice of shifting risk to the contracting party with the least amount of bargaining power is recognised as inappropriate risk sharing.

The subject of risk sharing among stakeholders has been studied by Roumboutsos and Anagnostopoulos (2008); Jin and Doloi (2008); Perera *et al*. (2009); and Jin and Zhang (2011). A review of these studies reveals that risk must be shared or apportioned to the parties that can best manage it (Valipour *et al*., 2015). The party who can best manage the risk should be one who has the capacity to precisely examine the risk (Loosemore & McCarthy, 2008) and the resources to satisfy the threat of the risk. However, stakeholders should bear in mind that, to handle risk appropriately, all parties need to realise the contents and effects of all alternatives before making decisions (Wang & Chou, 2003). Bearing in mind, it is difficult to correctly measure the risk tolerance level of each party at the inception stage of the project so that it could be a guide in the sharing of design risks (Shenfa-fa & Xiao-ping, 2009). Practices like partnering (*Eriksson et al*., 2007; Bohnstedt *et al*., 2017), alliancing (Sakal, 2005; Young et al., 2016) and framework agreement (Glover, 2008; Watermeyer, 2012) have been used to describe a collaborative management approach that encourages openness and trust between parties to a contract. In these approaches, stakeholders become dependent on one another for success and this requires a change in culture (Bohnstedt *et al*., 2017), which will promote risk and responsibility sharing, innovation, and the alignment of design interests between parties who aim to deliver a project in a collaborative and constructive way (Young *et al*., 2016).

Though stakeholders use these contracts or agreements, there are still disagreements from the absence of related contract clauses that accommodate dynamic risk allocations, unclear stipulations, or queries about the fairness of risk allocation (Wang & Chou, 2003). In construction projects, only parts of the risks are distributed by the contract, and the other risks are appointed simply through common practice (Ibid). The practice used in FIDIC, NEC and GCC (engineering and construction contracts) and JBCC 2000 (building works).

The financial risk allocations of all the contracts used in the South African construction industry are stated below:

FIDIC - Red, Yellow and Silver books

Each main contract has its own independent **(but fixed)** risk allocation strategy typical of the sector the contract is designed to target. Red - Employer carries quite a few risks. Yellow - Contractor carries the most risk, but employer still carries some. Silver - Contractor carries virtually all risk. Time and cost effects are dealt with differently by each stakeholder depending on the risk event.

GCC

The risk allocation is **fixed** based on the principle that the risk is carried by the party best suited to deal with it.

JBCC

The risk allocation is **fixed** based on the principle that the risk is carried by the party best suited to deal with it.

NEC3

Combination of main and secondary options can provide an almost unlimited range of contract strategy risk allocations in any of the traditional industry sectors. In addition, through the use of 'compensation events' the employer will only pay for the effect of certain risks if they occur and the contractor does not have to include these in his prices. Basis of compensation is the **same irrespective** of the risk event, with the (separate) time and money effect considered in the same quotation at the same time.

Even if stipulations do exist, they are often unclear or controversial (Wang, 1994) because the contractual arrangements used are not suited to the RM evolution towards collaboration. Bing et al. (2005) analysed the process of risk sharing in public-private partnerships. The authors argue without question that contractors offer higher project implementation prices when the burden of risk is shifted on the private sector than they would offer if the public sector (i.e., the owner) accepted more risks.

The authors further suggested dividing risks into three major levels: micro, mezzo and macro. They identified four categories of risk sharing. Namely, (1) risk should be allocated to the public sector; and (2) risk should be allocated to the private sector. As well as, (3) risk should be shared between the public and private sectors; and (4) risk allocation is highly dependent on the individual circumstances of a project (when risk cannot be allocated to any of the aforementioned three categories). A survey of professionals in the public and private sector served as a basis for allocating particular risks (such as force majeure, and tax changes) to the above-mentioned four categories. Yet, four risks, including "level of public opposition to project", "delay in approvals and permits", "unproven engineering techniques" and "excessive contract variations", were found to be difficult to clearly classify into the above first three risk allocation preferences (Hwang *et al.*, 2013). Roumboutsos and Anagnostopoulos (2008) suggested that these risks should instead be negotiated based on specific project circumstances.

Khazaeni *et al*. (2012) carried out a research of risk sharing among stakeholders to a standard contract agreement. A hierarchy structure was developed for risk sharing criteria. The research was based on the principle that the party best able to manage it at the least cost should accept risk. Experts were invoked to evaluate the significance of each risk criterion. This implied that a need for some flexible contract conditions that can enable a selection of the best available options at the time of their occurrence and with the joint efforts of all contracting parties (Rahman & Kumaraswamy, 2002). However, contract language alone is insufficient to clearly specify risk apportionment between contracting parties (Hartman *et al.*, 1997; Rahman & Kumaraswamy, 2002).

Though much research has been done in the area of design risk, there are still several gaps in the research to be filled. Each of the existing studies presents a portion of the solution, but the industry is still lacking a comprehensive, multiparty, widely accepted risk allocation solution that would cater for all possible scenarios. Given that the nature of the present construction industry is a very complex, high-risk, multiparty business, with conflicts between the diverse participants, these need to be minimised through better relationships and cooperative teamwork, under flexible contract conditions (Rahman & Kumaraswamy, 2004). Flexible contract conditions are structures that allow adaptation to changing conditions and help in delivering value rapidly (www.flexiblecontracts.com, 2018).

In brief, risk sharing among stakeholders appears to be a relevant problem currently explored by a vast number of researchers from all over the world (Peckiene *et al*., 2013). Review of research papers on this topic leads to a conclusion that equitable and balanced risk sharing among stakeholders is emphasised on the one hand, but, on the other hand, the task of risk sharing among stakeholders is dealt with on one side only, i.e., by the owner. This approach predetermines improper or contractor-unfavourable risk allocation outcomes which result in cost and time overruns and, undoubtedly, in legal disputes.

Risk sharing can be categorised into qualitative and quantitative approaches (Nasirzadeh *et al.*, 2014). The qualitative approach leads to the development of the risk-sharing matrix, which identifies what type of risk is allocated to whom (Yamaguchi *et al*., 2001). Quantitative approaches to risk sharing have been developed to extend the analysis to redress the limitations of the qualitative approach, especially the problem of how much of a risk is borne by each party. The quantitative approaches are based on the assumption that there is an optimal allocation of risk between stakeholders that can be achieved if the parties behave rationally (Levitt & Ashley, 1980). Designs are confronted by strategic issues, which may influence their performance in the long term. Ideally, the ability to balance the stakeholders' objectives in the form of proper risk sharing is an imperative (Abednego & Ogunala, 2006). Therefore, it is necessary to comprehensively consider the critical risk-sharing principles and influencing factors, to share the risk equitably (Xu *et al*., 2010).

However, according to Peckiene *et al*. (2013), risk sharing among stakeholders should employ a cooperative decision-making technique, which is a method of game theory. Game theory applies when two or more contracting parties are confronting each other. In this case, decisions can be made in a conflict situation of risk sharing (Shoubi &

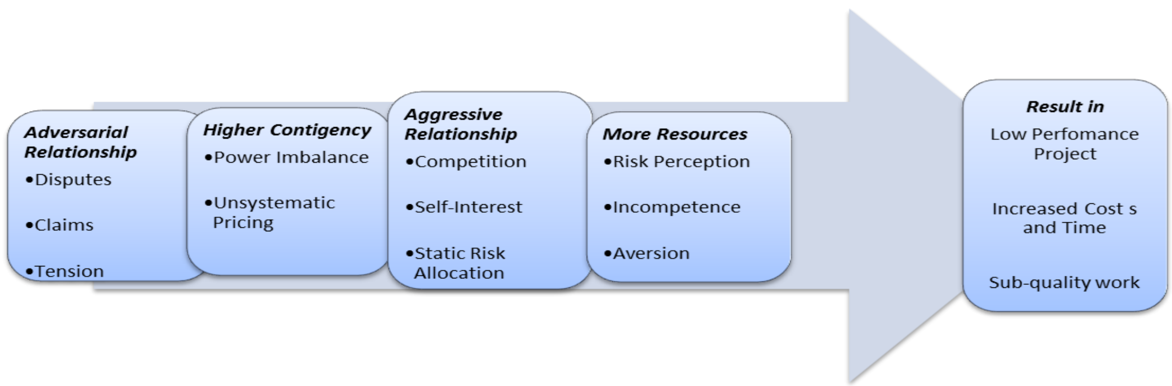
Barough, 2012). Game theory is a method that originated from the mathematical sciences in which it is used in a competitive or cooperative position to find optimal choices that will lead to a desired outcome (Dresher, 1961). Non-cooperative game theory is applied where players only focus on their objectives and attempt to bring more benefits for themselves. However, in cooperative game theory, the cooperation of players can lead to win-win situations and bring more benefits for all involved players. Researchers use cooperative game theory for allocating the costs or benefits from a cooperative coalition to find a distinct ratio vector of all outcomes. This ratio vector should be not only optimised but also be fair and equitable, especially for risk sharing (Shoubi & Barough, 2012; Peckiene *et al*., 2013).

Although the above-mentioned studies show equitable risk sharing is the best way to allocate risk among stakeholders in the industry, in reality not only is this elusive but the decision lies with the owner, since he or she usually prepares the contract agreement (Peckiene *et al.*, 2013). As a result, owners still tend to push more risk to the contractor and this often leads to higher pricing on the part of contractors to cover risks (Dell'Isola, 2003) and disputes among contracting parties (Zaghloul & Hartman, 2003). Hence, the current practices of risk sharing are not optimal and have problems.

Furthermore, while initially it may be the case that risk is assessed from several dimensions (experience, market supply and demand, economic and political situations, among others), these considerations are subsequently translated into financial terms (Alsalman, 2012). In theory, the expected value of a risk event is based on two factors: probability and impact. The expected value is equal to the probability of occurrence multiplied by the impact, yet both the probability and the impact are often very subjective and depend on many factors, such as the experience, risk attitude, and capability of the risk assessor. Stakeholders still use their intuition, experience and judgments in making decisions. Making decisions in construction risk management is no exception, especially in the assessment of project risks, both in estimating the probability and the impact of risk. The effect of this has been the constantly inappropriate risk sharing practices and thus overall poor project performance, because risk-sharing practices remain in theory and not in practice.

These risk-sharing problems of the current practices are represented in a Cause-Effect diagram **Figure 3.9** below (adapted from Alsalman, 2012). This shows that there are barriers that might prevent progress or make it difficult to achieve optimal risk sharing, as previous researches have asserted that progressive RM is CRM.

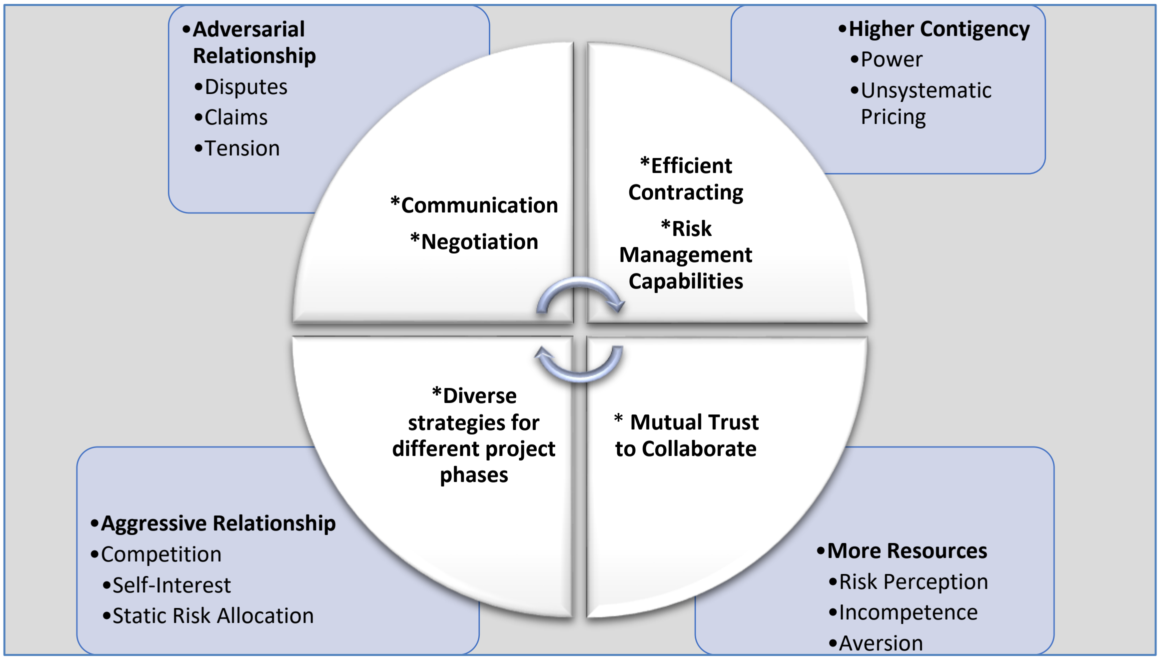
Figure 3. 9: Cause-Effect diagram of barriers affecting the practice of risk sharing



(Adapted from Alsalman, 2012)

However, this research seeks to find an optimal risk sharing approach that minimises the total cost of the project and not necessarily the cost to the individual stakeholder. It also seeks to establish and manage the relationships between the design stakeholders to encourage each other to aim for maximum contributions in return for project success. Trust, fairness, and optimal risk sharing will be some of the main principles of CRM, going forward. This will be represented by the Cause-Effect-Response diagram to see how stakeholders can improve the current situation faced daily in the projects, **Figure 3.10**:

Figure 3. 10: Cause-Effect-Response diagram of mitigating barriers that affect risk sharing practices



The literature shows us that previous studies found ways to achieve optimal risk sharing. The question is - are these methodologies being implemented as projects still encounter cost/time overruns? For this research, will these practices assist when stakeholders deal with inseparable risks? Risks that they cannot shift to any stakeholder but will have to deal with or share. Do stakeholders have to consider improved contractual arrangements that will best suit CRM? One measure of a contract's efficiency and effectiveness is its ability to clearly assign risks between contracting parties. Considering that, these parties have an identical understanding of risk accountability, because current practice relies upon all contracting parties interpreting the intent of the written contract the same way and, in reality that this is not the case. Therefore, to what extent are the risk sharing measures guided by the contractual arrangements that do not correspond with the green collaborative management?

This research will consider practical experiences from multiple case studies in which collaborative design and risk management are applied, and interpret their risk sharing methods. The essence of a case study is that it tries to illuminate a set of decisions: why they were taken, how they were implemented, and with what result (Wang & Chou, 2003)? It would be practical to see how these risk-handling practices are resolved in existing design processes.

Since the CRM includes processes and stakeholders, the application of dependency structure matrices (DSM) techniques will be used to identify where the interdependencies exist in the design process where collaborative designs are required. It will also be used to sequence activities in an optimal way by identifying where shared risks may lie, within these processes, tasks and stakeholders.

3.10 Key Concepts

Table 3. 3: Literature Review for Risk Management

Concept	**Key Literature**	**Source**
Risk	Design risks are amplified by interdependencies Risk factor in green designing is very high Inseparable risks are highly intertwined and difficult to uncouple	Halfawy & Froese (2005) Zavadskas et al. (2010) Poirier et al. (2016)
Risk Management	Inseparable risks considers the stakeholder’s thermostat and a risky shift phenomenon Risk management is a proactive decision-making process Project complexity and stakeholder diversity add more risks	Adam (1995) Loosemore et al. (2006) Rashid et al. (2008)

Risk Attitudes	Stakeholders can leverage resources and accelerate their risk management skills by forming alliances	Antikainen et al. (2010)
Risk Management Practices	Tendency to use risk management techniques that have always been used, instead of trying relevant techniques that are appropriate for a situation	Forbes et al. (2008)
Construction Contracts	Contract clauses that accommodate dynamic risk allocations	Wang & Chou (2003)
Procurement Methods	Although stipulations do exist, they are often unclear or controversial Risk allocation preferences	Wang (1994) Hwang et al., 2013
Collaboration	Collaboration is a value system Collaborations vary depending on their goals, teams and resources	Appley & Winder (1977) Mattessich & Monsey (1992)
Collaborative Risk Management	Trust and transparency Opportunity for improvement to the collaborative design process To go beyond the traditional RM mechanics to examine the sources of unknown risks	Tah & Carr (2001) Schöttle et al. (2014) Jarkas & Haupt, 2015
Risk Sharing	Risk-sharing problems of the current practices Handling the misallocated risk	Alsalman, 2012 Peckiene et al., 2013

	Identifying inseparable risks makes the process of risk sharing more efficient	Fundli & Drevland, 2014
Client Knowledge	An opportunity to hear what other stakeholders see as risks, and promotes the inspiration to identify additional project risks associated with stakeholders	Olander, 2007

3.11 Knowledge Area 2

Risk Management is the second knowledge area. Initiating, developing and implementing collaborative practices introduce definite risks that all stakeholders have to be aware of. These interactive risks are related to achieving goals of the collaboration. Effective collaboration is claimed to lead to fewer disputes, lower design task iterations and a better quality building. Effective RM needs to adapt to diverse situations, whilst maintaining an open dialogue to enhance multi-stakeholder participation and risk sharing to produce an atmosphere of mutual trust. Implementation of these interlocking pieces takes place through participative, flexible and iterative processes and activities. To achieve CRM, a co-operative culture that promotes a shared understanding before it can perform a joint sense-and-decision-making process, which collectively can resolve any design problems, is necessary. The synthesis of all three knowledge areas will be done at the end of Chapter 4.

Figure 3. 11: Synthesis of the Three Knowledge Areas

4. DEPENDENCY STRUCTURE MATRICES

4.1 Preface

Green design management is a complex and dynamic structure owing to the interdependencies of tasks and risks, which need to be coordinated by different stakeholders. Yet, planning practices takes little account of the interdependencies between tasks, risks, interdisciplinary decisions, and iterative nature of green design processes. This has given rise to compromised design processes containing independently made decisions, inevitable cycles of rework, together with associated disputes, time and cost penalties.

As the processes of design and risk management continues to grow in complexity, the use of the dependency structure matrix (DSM) to overcome the encountered challenges within the design management process is needed. Steward (1965) developed a theory that a complex problem such as design could be solved more efficiently by representing the interrelationships between activities in the form of a matrix.

This chapter reviews the DSM as a tool used to plan and improve the execution of GBs through managing the interdependency between tasks and risks, allowing for a smooth flow of information between different stakeholders (Yassine, 2004). It will help represent the different levels of interactions within the design phase (Eppinger and Brown, 2012). And, a synthesis of the three knowledge areas and the objectives.

4.2 Rationalizing the use of DSM

Completing a project on time and within budget is not an easy task (Agyei, 2015). Yet, in spite of all the advances and the evolution of requirements for multifaceted processes; most projects still face cost and time over-runs which increases with the increase in complexity. And, stakeholders have increasing pressure to integrate additional features and functions from various design disciplines (Wichmann *et al*., 2021).

Network models are traditional means of finding the most skilful way to link a number of activities directly or indirectly in order to complete a project on time and within budget. For many years, two approaches that have been proven to be useful for planning, scheduling and controlling construction projects have been the Critical Path Method (CPM) and the Project Evaluation and Review Technique (PERT) [Vanhoucke, 2013].These techniques enables project managers to evaluate the early and late times at which activities can start and finish, calculate activity float (slack), define critical activities, and evaluate the impact of changes in duration, logical relations and cost on the overall project duration (Samman & Brahemi, 2014). Both CPM and PERT are network based techniques and therefore help in programming and monitoring the progress of the stages involved so that the project is completed within the deadline (Ba'Its *et al.*, 2020). In doing this, it specifies the part of the project that are crucial which if delayed beyond the normal time would increase the completion time of the project as a whole. It further assists in allocating resources, such as labor and equipment and thus helps to make the total cost of the building project a minimum by finding the optimal trade-off between various costs and time involved (Taha, 2007).

But for CPM and PERT to work, all required resources to cover every activity must be assembled and prioritized to eliminate interruptions that could bring delay and unnecessary cost implications (Bagshaw, 2021). This has put pressure on design stakeholders to continuously integrate additional features and functions into the existing systems, due to complexity. However, this has caused uncertainties on whether an adapted tool fulfils its intended function when there are continuous adaptations due to the need to accommodate changes and still guarantee functionality (Burmeister *et al*. 2015).

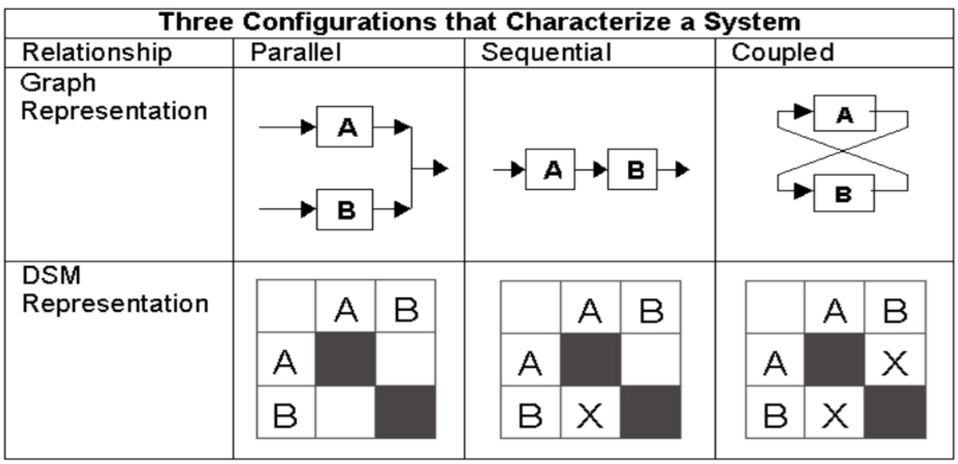
The PERT Method is helpful when there is previous information and data; whereas CPM can identify activities that will delay a project from being completed on time. However, both these tools do not consider the tasks are interdependent and iterative; with risks that are intricately connected. To understand inseparable risks, it is helpful to identify the interconnected stakeholders and interdependent tasks as well as their effects. Since, network models cannot model the iterative nature of design processes; this typically leads to risk management being postponed to later stages with the impracticalities of delayed iteration and costly rework (Ehrlenspiel, 2017). DSM will integrate both the stakeholder dimension and the task dimension to solve for inseparable risks, using a CRM method to improve the accuracy of risk analysis and the effectiveness of risk management.

4.3 DSM: A Tool for Complex System Management

GB designs are complex undertakings which require the participation of multiple and diverse stakeholders (Fang & Marle, 2013; Akintola *et al.*, 2015). They are characterised by multiple interdependent tasks, people, processes, and hence a high dependence on information (Antoniadis *et al.*, 2008; Narayanan *et al.*, 2021). This complexity is the problem characterisation, which justifies the requirement for Dependency Structure Matrices (DSM). Moreover, this complexity has influenced the design process to grow towards an open system, which has led to wicked problems. In the design phase, every wicked problem is essentially unique (Rittel & Webber, 1973), meaning it has similarities but up to a point, and this results in a problem with definitive formulation. To solve such wicked problems in design processes, the DSM method, was established to address these unique problems. It has its roots in the 1960s, when several efforts were devoted to understanding complex systems. Donald Steward first coined the term "Design Structure Matrix" in 1981 (Steward, 1981). The Design Structure Matrix method gained credibility and has expanded to include many new areas, and a more general term, "Dependency Structure Matrix" (DSM), came to be used.

A DSM is a matrix representation of a design where information flow dependencies are considered (Eppinger & Browning, 2012). The method has been used to show the dependencies and interactions between system elements, analyse iterations and rework in design. The method also shows visualise interdisciplinary change impact, develop a collaboration plan and design information exchange processes, optimise design information flows, among several other applications (Austin *et al.*, 2001; Venkatachalam & Varghese, 2009). **Figure 4.1** illustrates the graphical and matrix representation of parallel, sequential and coupled (iterative) tasks experienced in GB designs. This is where the rows and columns of the symmetric matrix consist of a list of all tasks of the project; while matrix elements represent the corresponding dependency patterns (Cho & Eppinger, 2005).

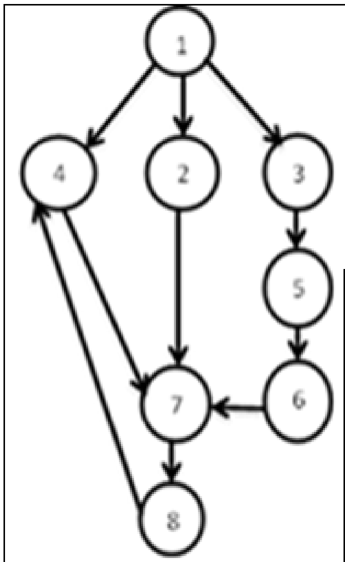
Figure 4. 1: Three configurations that characterize a system in DSM analysis



(Pektaş, 2014)

Each entry of the DSM represents a particular kind of relationship in the system (for example, belonging to the same team or information flow) between two entities (for example, components or tasks). For example, two tasks with information flow form an information flow dependency (Kusiak, 2008). Representing the complex dependencies of a system with a DSM allows the system to be decomposed into manageable subsystems (Bilalis *et al*., 2004). Valuable insights from the system structure can be derived after examining the interactions within and among the subsystems. An example of the DSM is shown in **Figure 4.2.** It shows task interdependencies that manage changing needs for communication, how inter-organizational and supplier integration will be managed, identifies indirect relationships among stakeholders by examining implications of design process interactions on project design. Moreover, it shows how clusters of related skill sets can be identified by actionable transparency, which does not affect technical communication. It also identifies misfits or misalignments between tasks units, determining the stakeholders' impacts of change propagation.

Figure 4. 2: DSM relationships on tasks



		Tasks Interdependencies							
		Client Needs	Feasibility	Architecture	Costing	Engineering	Other Services	Contractor	Suppliers
1	Client Needs		x	x	x				
2	Feasibility							x	
3	Architecture					x			
4	Costing							x	
5	Engineering						x		
6	Other Services							x	
7	Contractor								x
8	Suppliers				x				

The DSM brings advantages of simplicity and conciseness in representation (Bekdik *et al.*, 2017). The analysis of the single-domain interaction patterns leads to learning about a particular situation and how to improve it. Meanwhile, comparing patterns across the domains (multi-domain interactions) allows an assessment of the effectiveness of the design process and teams to develop (Eppinger, 2002).

Danilovic and Browning (2007) present a framework that distinguishes the single- and multi-domain interactions using DSM and Domain Mapping Matrices (DMM). The DMM examines the interactions across domains: the rows represent nodes of one domain, while the columns represent nodes of another domain. Unlike the DSM, the

DMM is an **m**x**n** rectangular matrix since the rows and columns are not identical. By combining both DSM and DMM methodologies, the analysis results are enriched, providing an expanded view of the system (Bartolomei *et al*., 2007). It is suggested that DMM methods help to focus the analysis results on interdependencies, interactions, and the exchange of information within and across domains. Such capabilities are recognized as increasingly beneficial and essential in this age of ever-more complex design projects, processes and organizations (Lindemann & Maurer, 2007). **Figure 4.3** depicts a generalised view of the DMM representation.

Figure 4. 3: DMM Framework

	Stakeholders	Objectives	Functions	Objects	Activities
Stakeholders	**S x S**	J x S	F x S	O x S	A x S
Objectives	S x J	**J x J**	F x J	O x J	A x J
Functions	S x F	J x F	**F x F**	O x F	A x F
Objects	S x O	J x O	F x O	**O x O**	A x O
Activities	S x A	J x A	F x A	O x A	**A x A**

DMM

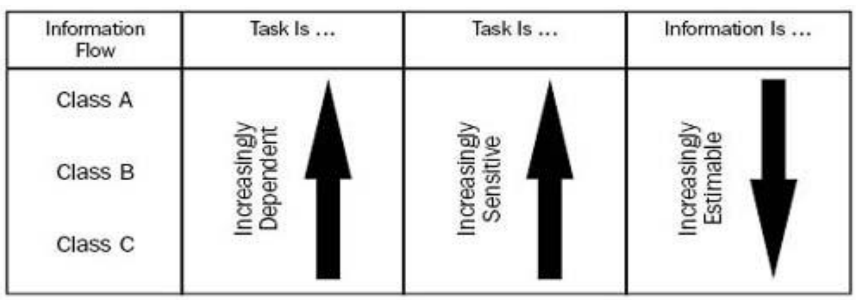
DSM

In green design phases, the DMM method aims to capture information flow as well as informal knowledge held by professionals, which would include the stakeholders' behaviours towards risks. The relationships between people assigned to tasks will be mapped to indicate the presence or absence of the direct relationship. This will show the strength, sensitivity or ease of the task. A classification system to represent information flow is based on 3 factors as shown in **Figure 4.4**:

- Strength of dependency of the task
- Sensitivity of the task to slight changes
- Ease with which the information can be estimated

This means that three separate subjective judgements must be made by designers and resulting classification is given a rating of either A, B or C, where A = is strong and C = is weak.

Figure 4. 4 The basis for allocating information classifications



(Austin et al., 2000)

The philosophy adopted by DMM is that weak dependencies (classified C) can be omitted from the matrix and, therefore, the size of iterative loops can be reduced, and the design process clarified.The allocation of classifications to the information flows is a DSM tool that can prioritize dependencies while partitioning the matrix. A three-point dependency classification system was devised specifically as an appropriate means of rating information in the building design process. This also showed degree or type of relationships risks, tasks and stakeholders have (Eppinger & Browning, 2012) as shown in **Figure 4.5**. The main advantage of these matrices was to indicate four types of person-to-task relationships, responsibility, accountability, consultation and information (Danilovic & Browning, 2007).

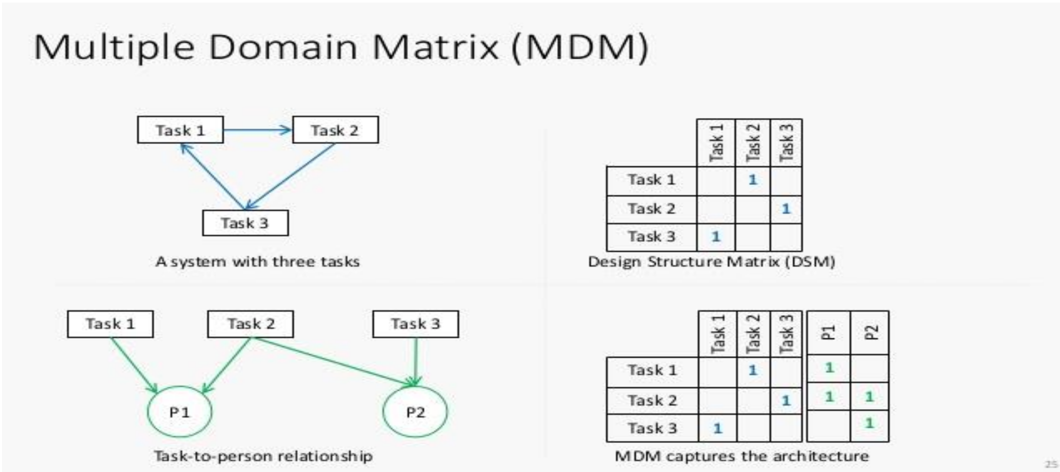
Figure 4. 5: MDM mapping system for capturing the design process interfaces in various domains

	Stakeholders	Design Tasks	Design Components
Stakeholders	People DSM	People Activity DMM	People Design Components DMM
Design Tasks		Activity DSM	Activity Design Component DMM
Design Components			Component DSM

Figure 4.5 shows how the use of DSM/DMM aims to handle inseparable risks during the design phase by identifying interdependencies. On DMM people-activities and people-components, stakeholders can discuss communication plans on how identified inseparable risks might be managed. These matrices can potentially identify clusters of risks; improve coordination and management, for inseparable risks to be shared equitably.

Furthermore, a Multi Domain Matrix (MDM) should be used, as it is able to capture different relationship types that coexist simultaneously (König et al., 2008; Pimapunsri, 2021). This way, represent a process that has multiple networks within different domains or that is using different relationship types within one domain can easily. This reduces the risk and uncertainty, as stakeholders understand the whole situation and have a better insight into their responsibilities. **Figure 4.6** displays a generalised MDM.

Figure 4. 6: MDM mapping system



(www.dsmweb.org, 2018)

Complexity can result in risk clusters, where high levels of relationships may require intense coordination across domains (Eppinger & Browning, 2012). That is why, when all stakeholders became hands-on, task sharing and risk identification became the most influential factors in risk handling decisions. In this, all parties are required to know about task interdependencies and be familiar with what kinds of risks stakeholders may face, articulating how to manage inseparable design risks and possibly turning such risks into opportunities (Zou & Zhang, 2009). This risk handling needs to advocate CRM processes as an agent of change in current established practices and a highly effective tool in the on-going improvement of risk efforts that may lead to equitable risk sharing. CRM has the potential to transform the existing problems and challenges, which are the underlying reasons for any change. CRM is also trying to correct the existing inefficiency, and this continuous loop will evolve until there is progression.

4.4 Synthesis of the Three Knowledge Areas

As GBs continue to grow in complexity collaborative design processes have become a prerequisite, to help different stakeholders manage their collective actions while designing. This process requires systematic planning, communication techniques and decision-making protocols that can cope with interconnected stakeholders, interdependent tasks and risks that are interdependent and are inseparable. Traditionally, risks are usually listed as individual risks and ranked by one or more parameters that do not take into account the interrelations between risks, tasks and stakeholders. But, inseparable risks are intricately connected. They cannot be transferred or allocated to an individual, but have to be shared between stakeholders and can only be resolved or mitigated through collaboration (Laurent, 2017).

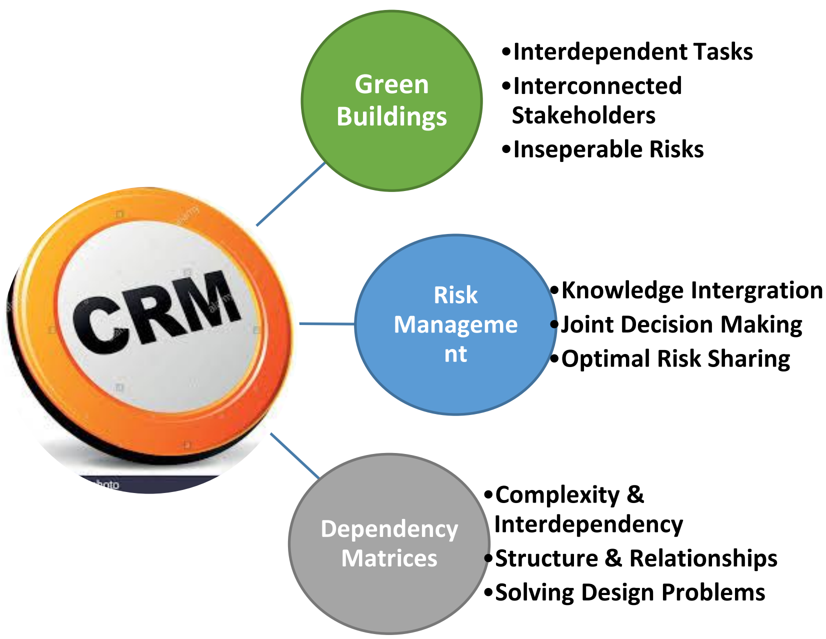
To understand inseparable risks, it is helpful to identify the interconnected stakeholders and interdependent tasks as well as their effects. However, most RM methods still concentrate on individual risks for simplifying the problem. They have limitations for modeling the complexities of inseparable risks. A good number of existing risk analysis methods are restricted to one of the two dimensions, which also can reduce the results of risk management. Some of these methods represent the stakeholder dimension, quantitatively evaluating the networks formed by stakeholders and their relationships, but doesn't meet the dynamic characteristics of the network caused by the risk factors. At the same time, other methods represent the task dimension, which can analyze the risk factors in the design phase and present risk mitigation actions. But these do not match the interdependency of stakeholders and their interdependent tasks which has resulted in inseparable risks and, they cannot represent the interrelation between them. And, they are unable to model complex interaction. Hence the need for this research to put forward a matrix-based approach of using DSM to integrate the stakeholder dimension and the task dimension to solve for inseparable risks, using a CRM method to improve the accuracy of risk analysis and the effectiveness of risk management.

The DSM tool is capable of dealing with a design process comprising over a thousand activities and still prioritize dependences (Austin et al., 2000). CRM is about the dynamic management of risk (Rahman & Kumaraswamy, 2005). CRM and DSM are powerful methods to solve for inseparable risks. Amalgamation of both approaches results in an extremely powerful tool that can lead to impressive technical, managerial, and economic benefits. It provides an insight of the projects in an easy and manageable way that the all stakeholders can benefit from. Further, DSM provides a better planning methodology for the risk sharing decisions (Maheswari & Varghese, 2005).

The theoretical framework highlighted a collaborative way of managing risks which has the ability to take advantage of the different views from different stakeholders involved in designing GBs and identify risks that cannot just be shifted to one stakeholder but have to be collaboratively managed. It focuses on the three knowledge areas: green practices, risk management and dependency theories.

Bringing together these theories refers to the level of interrelatedness among the stakeholders, their tasks and their risks. For collaborative practices, stakeholders need to acquire new knowledge about the dynamic management of risk which plays a major role in achieving value-for-money and cost-efficiency in designing green buildings. For advancement, this dynamic collaborative approach implies that the identification and assessment of design risk, along with the response to it, are performed proactively and jointly throughout the design phase. To make the process of risk sharing more efficient through planning and coordination by mutual adjustment of stakeholders (Fundli & Drevland, 2014), CRM should achieve optimal risk sharing.

Figure 4. 7: Synthesis of the Three Knowledge Areas



4.5 The Objectives of the Study

To meet the objectives: a new shared perspective driven by the dependency matrices; where collaborative teams will enable interdependencies and complexity to model stakeholder benefits for equitable risk sharing outcomes. For each design, this collaboration will enhance stakeholder behaviour and achieve better risk resolutions, leading to better-informed decisions and cooperation.

The use of CRM would then require knowledge creation, not just knowledge application. But, the change from traditional RM to CRM will be loaded with uncertainties which include risk sharing among all project stakeholders and their response to this cultural shift.

Table 4. 1: Literature Review for DSM and all other Knowledge Areas

Objectives:	**<u>Synthesis of 3 Knowledge Areas:</u>** **Green Buildings, Risk Management and Dependency Matrices**	**Proposed Questions**
What are the implications of CRM during the design phase?	Green Buildings are inherently different from traditional ones and they require interdisciplinary coordination, due to the interconnectedness of green systems design (Zuo et al., 2017) Interdisciplinary collaboration approach - Complex undertakings which require a participation of multiple and diverse stakeholders (Fang & Marle, 2013; Antintola et al., 2015) Inseparable risks are highly intertwined and difficult to uncouple (Poirier et al., 2016) due to interconnected stakeholders with their interdependent tasks This complexity is the problem characterization, which justifies the requirement for Dependency	- State the implications you have faced - Where they positive or negative? - Practical example

	Structure Matrices (Steward, 1981). Moreover, this complexity has influenced the design process to grow towards an open system, which has led to wicked problems (Rittel & Webber, 1973)	
How are inseparable risks managed in collaborative circumstances?	GBs deal with complexities that surface in the design process through iterations between tasks (Hickethier et al., 2012), to go beyond the traditional RM mechanics to examine the sources of unknown risks (Jarkas & Haupt, 2015), one requires a collaborative framework, which encompasses all views and perceptions of project risks from different stakeholders (Demir et al., 2012) Identifying inseparable risks makes the process of risk sharing more efficient (Fundli & Drevland, 2014) DSM is used to show the dependencies and interactions between system elements, analyze iterations and rework in design (Eppinger & Browning, 2012)	- Have you encountered inseparable risks and what were they? - How did you manage them? - What steps were taken in that instance? Alone or collaboratively?
What are the current risk practices?	Diverse professional backgrounds, with different levels and types of interests in the project affects risk practices (Mok et al. 2015) because, stakeholders still rely on pre-existing knowledge for managing risks (Whelton and Ballard, 2002) Tendency to use RM techniques that have always been used, instead of trying relevant techniques that are appropriate for a situation (Forbes et al., 2008) calls for CRM	- What have you experienced, w.r.t risk practices? - How can this be improved? - How can we forecast design problems that can only be dealt with collaboratively?

	DSM brings advantages of simplicity and conciseness in representation (Bekdik et al., 2017)	
How different stakeholders interact with each other?	Traditional design management methodologies are linear and fragmented (Al Hattab & Hamzeh, 2015) and most stakeholders still want to use those practices. There is a need for integrated working practices, with methods and behaviours changes (Austin et al., 2002) Risks and stakeholders do not exist in a vacuum (Yang & Yeh, 2014), how then do we clarify the risk-stakeholder interrelationships? The combination of DSM and DMM methodologies makes the analysis results enriched, providing an expanded view of the system (Bartolomei et al., 2007). DMM methods help to focus the analysis results on interdependencies, interactions, and the exchange of information between stakeholders	- Do stakeholders have a choice on who to deal with? - Who associates with whom and in what ways do these stakeholders depend on each other for green-related decisions?
How design problems, which can only be dealt with collaboratively, be identify in advance?	Have a holistic approach to programming, planning and designing (Dubey et al., 2018) Jing and Qin (2011) revealed that an evaluation of influence by stakeholders and the risks should be considered as a necessity or an important step in the planning of GBs. Try to outline interdependent tasks then, determine the overall pace of the program (Alsalman, 2012) CRM will correct the existing inefficiency, and a continuous loop will evolve until there is progression	- How are the concerns of bridging the gap in RM becoming a generic area in construction projects?

What could be the solution?	CRM includes processes and stakeholders, the application of dependency structure matrices (DSM) techniques will be used to identify where the interdependencies exist in the design process where collaborative designs are required. CRM and DSM will also be used to sequence activities in an optimal way by identifying where shared risks may lie, within these processes, tasks and stakeholders.	- Remedies to solve the negative outcomes? - Are GBs that encompass risk entirely and have established proper stakeholders' risk assessments achievable?

5. RESEARCH DESIGN

5.1 Preface

Case studies provide research results from real-world projects; these results would be difficult to achieve with any other research method (Runeson *et al*., 2012). For that reason, there is no substitute for a case study when wanting to find out what is really happening in actual projects. Construction projects have become more ambitious in terms of the complexity of structures, number of requirements, information flow, the influence of stakeholders and the extent to which technology is integrated into buildings (Mok *et al*., 2018). The interdisciplinary and iterative trends in the building design process have resulted in the need for a collaborative risk management approach that requires synchronization in contracts for future adjustments of changing circumstances (Østergård *et al*., 2016). With the combined efforts of all related stakeholders to manage unforeseen risks at the design phase, the best holistic options to accommodate a collaborative design environment should be used.

This chapter establishes the research design that determines how the research was conducted and how research steps were linked logically to the objectives of this study. This methodology includes the prior-discussed literature review of the available work reported on collaborative risk management in green construction projects and risk sharing in the design phase. An instrument to gather data, the population and sample are identified. Context is crucial when trying to answer a particular research question, to understand what is happening in a project (Runeson *et al*., 2012). This chapter also covers the case studies, data analysis method, and approaches used to ensure that these processes are done in terms of quality, validity, reliability and within ethical boundaries and presents the justification for the chosen research design.

5.2 Main Research Question

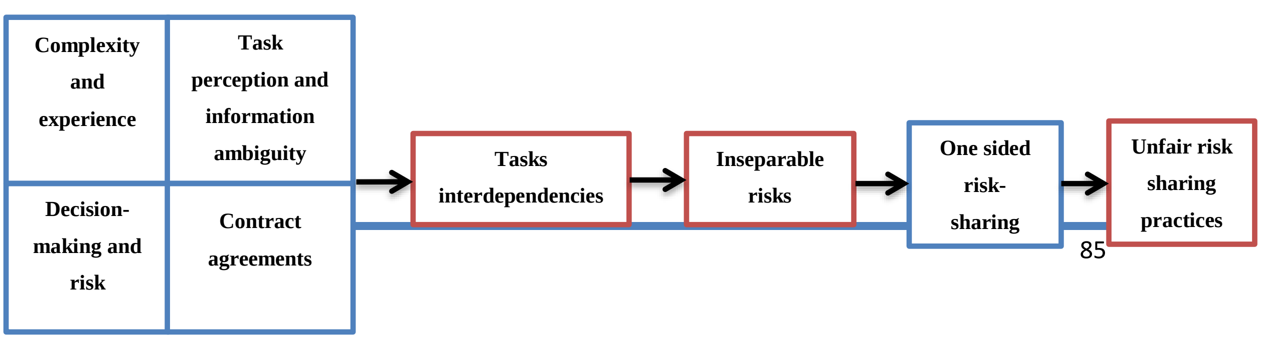
Different stakeholders face complexities and task interdependencies when solving design problems in green buildings due to the holistic approach to their integration in design, which has resulted in inseparable risks.

How do project stakeholders in collaborative design teams manage inseparable risks within their different design tasks?

The design process is a collection of tasks that needs to be performed (De Marco *et al*., 2015; Vrana & Singh, 2021). These tasks have dependencies on one another, either because of physical items that must flow from task to task or because of information that one task requires and which another task provides. However, there are risks linked to these tasks and to the project objectives (Qazi *et al*., 2016). These risks and tasks are tightly coupled usually forming iteration between tasks, the iteration frequency and who participate in each cycle depends on the characteristics of the project (Ye *et al*., 2013). The need for a high degree of collaboration when managing risks has led design processes to integrate the different perspectives into a coherent and holistic RM strategy. However, while collaboration may be advantageous for knowledge management, it may also result in risks that may not be separable and thus cannot be transferred or allocated to an individual, but have to be shared.

Figure 5.1 shows how the flow of interdependent tasks leads to inseparable risks, which ultimately result in an unfair risk-sharing situation. Inappropriate risk sharing has led to adversarial relationships between contracting stakeholders. The current research will show how risk sharing can be organized under a systematic CRM scope.

Figure 5. 1: Interdependent tasks and risks can leads to an unfair risk sharing situations



An efficient CRM should provide all stakeholders with a mechanism that offers an alternative option to the traditional allocation of risks. It should assist stakeholders in making rational and economical decisions that could minimize disputes, delays, adversarial relationships and project cost and in this way, increase project efficiency and overall quality.

5.3 Research Philosophy

Research is an art aided by skills of enquiry, data collection, and analysis by interpretation or by presentation (Greenfield, 2002). Rajasekar, *et al*. (2013) defines it as a logical and systematic search of new and useful information on a particular topic. It is also a project that consists of several phases beginning with the selection of an issue to study and ending with the dissemination of the research findings (Brink 1989). Each step in this research process has the potential to influence the research output and it is essential that a researcher attempt to avoid as much error as possible during all phases of the research in order to increase the credibility of the results (Mertens, 2014).

Pragmatism is the research philosophy used as it recognizes different ways of interpreting the world and undertaking research (Saunders *et al*. 2012); its reality is that no single point of view can ever give the entire picture. However, the philosophy goes beyond problem-solving (Morgan, 2014). It is characterized by an emphasis on communication and shared meaning- making to create practical solutions to social problems (Shannon-Baker, 2016). It places primary importance on the research question (Tashakkori & Teddlie, 2003). The pragmatic style can provide the researcher with the ability to design a single research study that answers questions regarding the nature of phenomenon from a participant's point of view as well as the relationship between measurable variables (Williams, 2007; Creswell, 2013).

Figure 5. 2: The Pragmatism Model of Enquiry

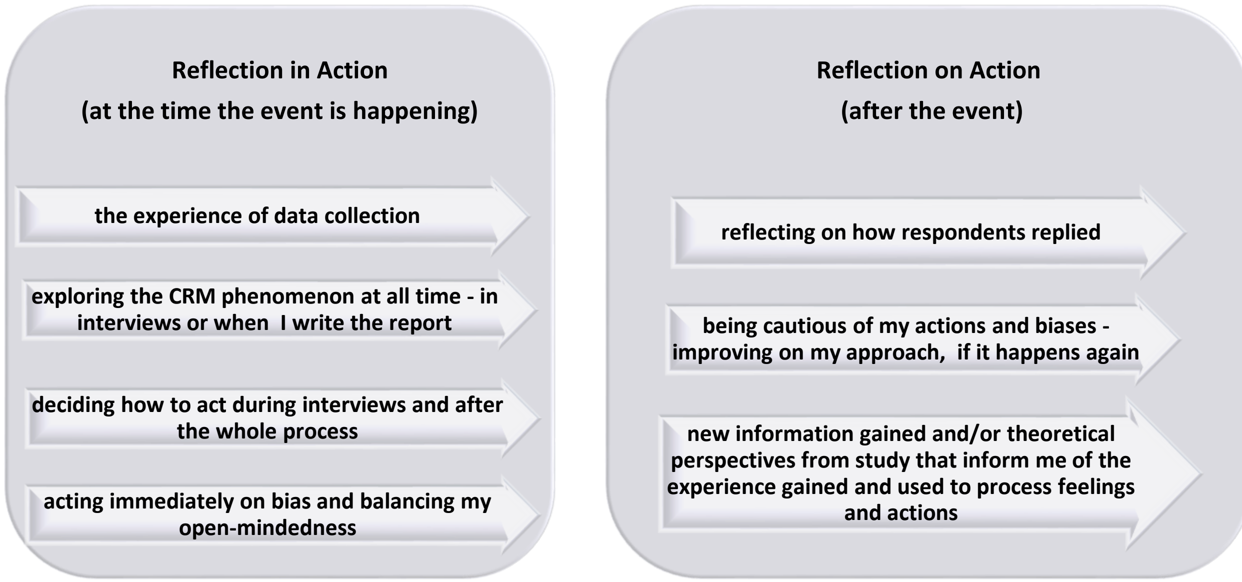


Figure 5.2 shows that pragmatism recognizes the value of different approaches in research communities that guide choices about how to conduct an enquiry. Thus, pragmatism acts as a new model to replace an older way of thinking about the differences between approaches to research by treating those differences as social contexts for enquiry as a form of social action, rather than as abstract philosophy (Morgan, 2014).

For this reason, efficient CRM needs a coherent philosophy that goes well beyond what works to what will work and how. Pragmatism points to the importance of joining beliefs and actions in the process of enquiry that underlies any search for knowledge, including the specialized activities of all stakeholders with a mechanism that will offer an alternative option to the traditional sharing of risk.

The research paradigm used in this study is abductive as it follows a pragmatist perspective, taking observations from experience and reality that may then lead to theory building and the background of theories that state how effective RM may be implemented. (Kovács & Spens, 2005). Abductive reasoning is both deductive and inductive approaches in so far as it is applied to make logical inferences and construct theories. With the abductive approach, the research process starts with puzzles that can then be explained (Mitchell, 2018). It allowed the researcher to provide subjective reasoning with the help of various real-life examples (Ridenour *et al.*, 2008), whilst giving new insight about effective RM and the CRM phenomenon.

An abductive approach leads to a new perspective of creating knowledge by systematic combination of reality and theory. In this process, data is collected simultaneously to theory building, or at least a "back and forth" movement between theory and data in a bid to develop new or modify existing theory (Awuzie & McDermott, (2017). This interactive aspect between theory and data is part of the methods of action research and this can be done through case study research.

In this research, abductive reasoning was based on learning from data experiences and this gave the prism of theoretical background to explain the relationships between stakeholders, tasks and risks. This helped clarify the data reduction process by describing a set of procedures for creating meaning of inseparable risks within the development of risk summary themes from the raw data.

5.4 Research Strategy–Multiple Case Studies

A multiple case study approach was adopted, where real-life events showed different perspectives to enhance and support the different results (Zainal, 2007). The approach helped in testing the process which commenced with established theory and ask to see if the theory applied to specific instances complements it (Hyde, 2000), the underlying intention being to acquire in-depth knowledge for strong theory building (Amaratunga *et al.*, 2002).

In the different case studies, interviews were used to prove that: the research question was appropriate. Where: "in a single reality – it can be measured reliably and validly using scientific principles", and: "in multiple constructed realities – it generates different meanings for different individuals, whose interpretations depend on the researcher's lens" (Onwuegbuzie & Leech, 2005:270).

The adoption of multiple case studies not only help to explore or describe the data in a real-life environment but also to explain the complexities of real-life situations, which may not be captured by experimental or survey research (Zainal, 2007). It provided a stronger foundation for theory building, specifically, when solving design problems that have a holistic approach due to their integration in design and different stakeholders facing complexities and task interdependencies, which resulted in inseparable risks. In this instance, multiple case studies would seek to understand the lived experiences of various stakeholders who have a shared experience of green building construction across different cases.

5.5 Research Approach

There are no ideal solutions for research choices, only a series of compromises on how one collects and analyze data (Amaratunga *et al.*, 2002). CRM is a relatively innovative concept in South Africa, and it is therefore, important to obtain a detailed and comprehensive view of it by investigating it in both completed and ongoing projects. In particular, how CRM is managed in design processes and how various stakeholders manage inseparable risks, were areas of interest. A mixed-method approach to seeking practical solutions for creating a complete picture of real-world problems was used (Creswell, 2013).

As shown in **Table 5.1,** mixed methods are based on the idea that all methods have bias and weakness that can be neutralized (Creswell, 2013). The solutions in italics are how this study has provided explanations to these biases.

Table 5. 1: Strengths and weaknesses of mixed research

Strengths and weaknesses of mixed research	
Strengths and Weaknesses	**Solution**
Words and narrative are used to add meaning to numbers. Numbers can be used to add precision to words, pictures and narrative.	*Use to build theory and test the established theory against literature*
Can answer a broader and more complete range of research questions because the researcher is not confined to a single method or approach.	*Explains the CRM phenomenon clearer*
A researcher used the strengths of an additional method to overcome the weaknesses in another method.	*Using abductive reasoning provided subjective reasoning with the help of real-life examples backed by theory.*
Provided more robust evidence for a conclusion by convergence and corroboration of findings.	*Triangulation is used to combine different methodologies, to interpret conflicting results*
Qualitative and quantitative research used together to produce complete knowledge necessary to inform theory and practice.	*Increases the ability to validate the results, using triangulation*

This mixed methods research offered great potential by bridging the schism between quantitative and qualitative research as there are no ideal solutions, only a series of compromises on how one collects and analyse data (Amaratunga *et al.*, 2002; Onwuegbuzie & Leech, 2004a). The epistemological assumption is that the various stakeholders have different views of the world, and it is thus difficult to generalize findings and draw inferences simply based on quantitative research. The qualitative research approach allowed the researcher to analyse a phenomenon using individual experiences and perceptions of the CRM phenomena.

The rationale for this pragmatic view of fully adopting the integrated mixed methods approach was also to reveal complementarity, convergence and dissonance among the findings (Erzerberger & Prein, 1997; Saunders *et al.*, 2016), leading to a step-by-step summary as shown in **Table 5.2.**

Table 5. 2: Research Theoretical Framework

Step	**Activity**	**Purpose**
Getting started	Research question	*How do project stakeholders in collaborative design teams manage inseparable risks within their different design tasks?*
Selecting cases	Specific population	*Multiple case studies where real-life events showed different perspectives of stakeholders involved in the design phase of GBs*
Crafting instruments and protocols	Data collection methods	*Semi-structured interviews to view how stakeholders in collaborative design teams manage inseparable risks, ethically and their professional issues*
Entering the field	Overlap data collection and analysis	*Speeds analyses with flexibility and taking advantage of emergent themes and unique case features*
Analyzing data	Interviews and case analysis	*Interviews and case studies interpretation – looking beyond initial impressions to see evidence through multiple lenses*
Enfolding literature	Comparison with conflicting/ similar literature	*Triangulation to raise theoretical levels and sharpen construct definitions*
Reaching closure	Theoretical saturation when possible	*Ends process when marginal improvement becomes small*

The process of building theory from case studies research is an iterative one. Although a researcher may focus on one part of the process at a time, the process itself involves constant iteration backward and forward between steps, which is suitable for the process of judging good quality that is reliable and credible (Eisenhardt, 1989; Saunders *et al*., 2016).

Mixed methods also meant describing and developing techniques that are closer to what the respondents use in practice. This was done by applying qualitative data to supplement, validate, explain, or reinterpret quantitative data gathered from the same setting of research design. Triangulation meant taking multiple perspectives to the CRM progression like the real life experiences, the case studies, matrix-based applications and the reviewed literature to see a bigger picture (Stake, 1995; Coghlan & Brannick, 2014). This application was based on exploring the data, finding out a pattern, and suggesting a plausible process to understanding CRM as an effective RM practice (Chong, 1994).

The research question is focused; strengths and weaknesses of each chosen method complement each other; data collection methods are selected according to their relevance to the CRM phenomenon; and a continuous evaluation of the approach is under-taken during the study.

5.6 Development of Instrument

Given the extensive and diverse nature of literature available in other sectors for risk management skills, the literature study focused on issues identified in the conceptual framework of the study (Kumar 1999).The goal of a conceptual framework was to categorize and describe concepts relevant to the study and map relationships among them (Rocco & Plakhotnik, 2009). To achieve this goal, incorporation of both relevant theory and empirical research to help organize the conceptual framework and "to see where the overlaps, contradictions, refinements, or qualifications are" is needed (Miles & Huberman, 1994:22). This can further assist in building an emergent theory that could be built from social creativity (Watson, 2007). Some concepts gain popularity among practitioners; however, research around a concept may also be limited and sporadic.

The qualitative approach was the one that could preserve chronological flow of the gathered evidence, which requires context and repetition, to see which events led to which consequences and provide useful explanations (Amaratunga *et al*., 2002). Interviews were used for data collection; this is a highly flexible method that can produce valuable data and experiences related to the case studies (King, 1994). The goal was to see the research topic from the perspective of the interviewee, and to understand how and why they came to have a particular view.

The primary sources of data were the stakeholders involved in the design phase of GBs, from the different case studies. The instrument designed is intended to provide researchers and educators a tool to evaluate and critique collaborative behaviour, interdependent tasks and inseparable risks in design processes. The information was obtained using semi-structured interviews to determine how project stakeholders in collaborative design teams manage inseparable risks within their different design tasks (see Appendix iii).

The questions were developed with the assumption that most stakeholders have RM preference styles, but how are inseparable risks managed in collaborative circumstances and how design problems which can only be dealt with collaboratively be identify in advance? A series of questions asked the participants how different stakeholders interact with each other and what are the implications of CRM during the design phase? Rather than trying to gather data through one question on what could be the solution, several questions are posed to gather different views and ideas.

Preliminary communication was done by email before the interview providing an opportunity to establish a connection with the participant and review ethical considerations. Moreover, in this initial contact, some research questions were asked, such as the - implications of CRM during the design phase of green buildings, whether the respondent had experienced inseparable risks in the projects they had worked on and how did they manage inseparable risks (the type of risk methodology used). This was to give the participant time to think about the answers and experiences. The interviewees were reassured that the interviews were confidential and that their identities would be kept private.

Ethical clearance for the study was obtained from the School of Construction Economics and Management at the University of the Witswatersrand. Interviews were conducted at a convenient time and place for the participants before the lockdown, usually lunchtime. Each interview lasted an average of 25 – 30 minutes and audio recordings were utilized; careful protection of participants' identity and their institutions was observed. Other respondents were contacted telephonically or via Zoom, and conversations did not last more than 15 minutes due to the interviewee's busy schedules; permission to audio record these interviews were also obtained. **Table 5.3** shows the conveniences of both interview styles and their preferences.

Table 5. 3: Conveniences of both interview styles

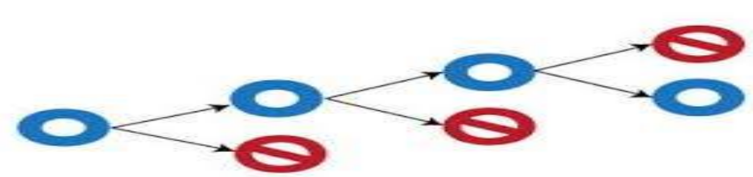
Components	Face-to-face mode	Telephone/Zoom mode
Scheduling	Participant may feel pressure to be available	It was easier to reschedule via telephone
Respondent anonymity and confidentiality	Participants felt like anonymity depended on the interviewer	High perception anonymity via Zoom with cameras off
Sensitive or controversial topics	May be uncomfortable and thus under-report	May ease discomfort and somewhat improved the accuracy of theories
Respondent empowerment	Can see and feel pressure to respond to interviewer	Took more control of the interview and even rescheduled when needed

5.7 Sampling Method for Participants

The selection of participants is an important step in the data gathering process (Englander, 2012). Giorgi (2009) identified four principles for scientific research concerning the knowledge obtained, systematic, methodical, general and critical. In other words, the actual selection of the participants does not prohibit the knowledge gained from being general and critical. To clarify further, Englander (2012) firstly elaborated that it is the results that are general, not the participants themselves. Secondly, it is the researcher that needs to be critical, not the participants.

There were different sample populations in this research, the participants in the case studies and the referral individuals who have dealt with GBs. Even for the referral participants, a non-probability, snowballing sampling technique was used, based on the fact that, only GB stakeholders were interviewed (Saunders *et al*., 2016). The method included identifying and selecting individuals who are knowledgeable about or have experience with, the topic of interest (Cresswell & Plano Clark 2011). In addition to knowledge and experience, Bernard (2002) noted that the importance of availability and willingness to participate, and the ability to communicate experiences and opinions reflectively was important.

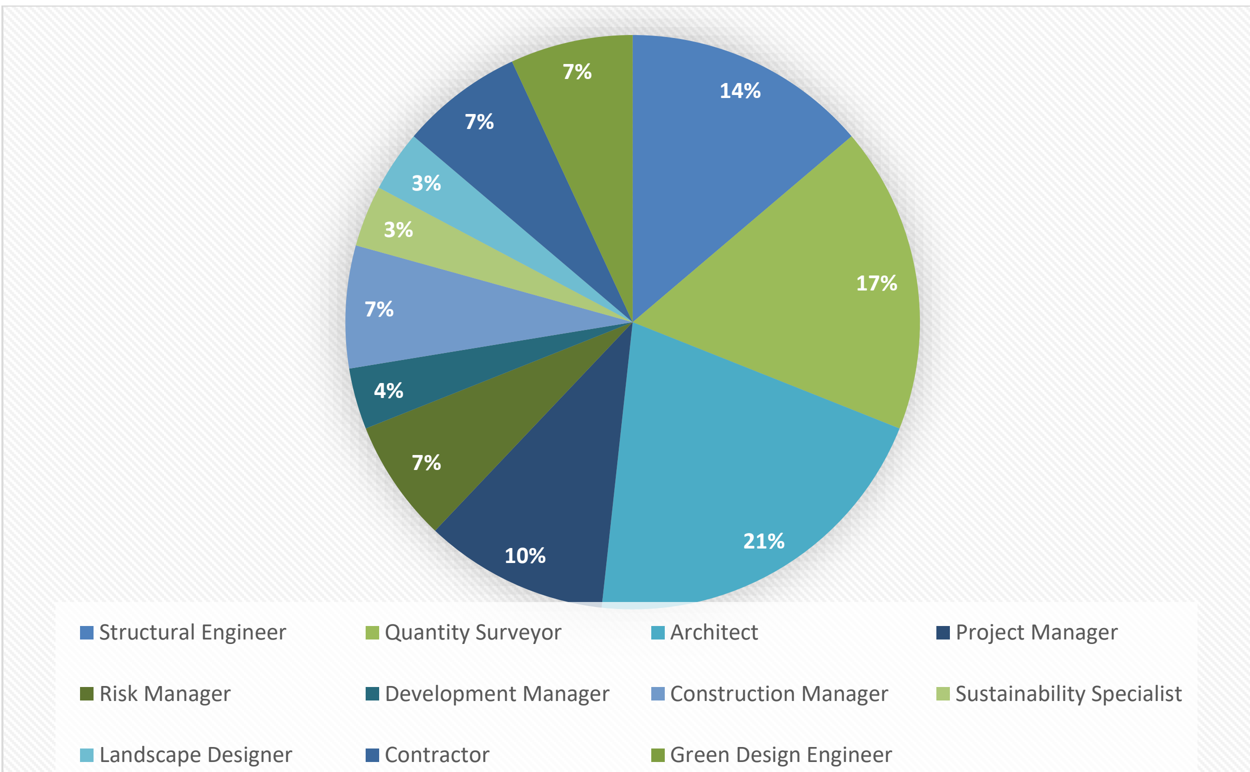
Figure 5. 3: The chain referral network model



(Dudovskiy, 2018)

Figure 5.3 shows the snowballing technique utilized with the key participant who was a reflective member of the community of interest, knew a lot about the topic and the culture, and was able and willing to share his knowledge (Palinkas *et al.*, 2015). The researcher also asked participants in the case studies to suggest other people, sampling participants with a specific type of knowledge or skill (Tongco, 2007). The red circles in the diagram represent referral participants who did not participate. This technique selected interviewees based on their ability to provide relevant answers to the interview questions posed (Saunders *et al.*, 2009). The interviewed participants were selected based on their involvement in the designing of green buildings as shown in **Figure 5.4.** The snowballing sampling technique made it possible for the researcher to be referred to other stakeholders who could answer questions regarding CRM in green buildings.

Figure 5. 4: Demographics of participants



The criteria for this sample, was participants who have worked on green building projects and have experienced collaborative management. **Table 5.4** shows the different participants from different case studies and referral individuals, who are skilled professionals, occupy positions of influence and responsibility, exposed to collaboration as an approach for RM. Individually, the participants held varying dispositions towards risk sharing and collaboration. Their experiences and views were helpful in the research.

Table 5. 4: The structure of the participants' population

Professions	**Description**	**Project 1** *Forensic Pathology*	**Project 2** *Retirement Apartment*	**Project 3** *Apartments and Museum*	**Project 4** *Commercial Development*	**Referral Participant**
Structural Engineer	structural, civil and geotechnical services	1	1	1	1	
Quantity Surveyor	cost management services and contractual advices	1	1	1	1	1
Architect	lead design services and develops the client's brief	1	1	1	1	2
Green Design Engineer	green design and engineering solutions	1			1	
Project Manager	oversees the cost, program, project administration	1		1		1
Risk Manager	Evaluate risk control measures and update risk analysis				1	1
Client	sets the project objectives	1			1	
Development Manager	supports innovation, technology and development		1			
Construction Manager	monitors the overall project development and management				1	1
Sustainability Specialist	sustainable building design and green building certification services					1
Landscape Designer	landscape design and advisory services				1	
Contractor	construct the building development	1				1
Number of Interviews		**5**	**4**	**4**	**6**	**8**
						29

GBs are projects that increase efficiency with which buildings and their sites use energy, water, raw materials and reduce negative impacts on human health and the environment over the entire life-cycle of a building (Tandon, 2016). Preparation was mandatory as the researcher needed to know about different organizations and their involvement in green building construction before sampling the population. The sample group is multidisciplinary, with stakeholders who had experienced working with uncertainty, complexity, interdependencies between multiple and diverse stakeholders, high dependence on information and the connectedness of tasks (Wang *et al*., 2017). Table 5.6 justifies the inclusion of participants as key design members in the process of GBs.

Table 5.5: Criteria for justifying inclusion of participants as key design members of GBs

Rationale	**Criteria**
To increase knowledge about a problem	Personal skills of participants that can be communicated
To provide insight about happenings during the design phase of GBs	Position within the design team that allows willingness to communicate knowledge
To develop a definition of aspects involved with collaboration	Position of influence and responsibility that shows impartiality and an ability to be objective
To cover all boundaries of a project	Role in the project of interest should expose them to the kind of knowledge relevant to the study
To identify extremes	Possession of meaningful relevant knowledge where participants hold a wide range of views

5.8 Interview Process

It is important to decide carefully which data to collect and how to collect it (Lethbridge *et al*., 2005). Interviews are one of the most frequently used and most important sources of data in case studies (Runeson *et al*., 2012). They are not intended to be repeatable as they reflect reality (Saunders *et al*., 2016). They are used either for primary data collection or as a validation of other kinds of data. The reason for this is that much of the knowledge of interest is not available anywhere else other than in the minds of the people working in the cases being investigated.

The case studies selected differ; two were completed projects, and the other two were in the design phase. The completed projects are a commercial development and residential apartments. The project teams in these case studies reflected on the problems they faced. The other case studies are an academic forensic pathology facility and retirement apartments; which are in the design phases. The project teams were still engaging with their risks and experiences. In all these projects, many stakeholders with various backgrounds were involved, and it was interesting to see how CRM could be applied. The objective for the interviews was to explore the possible difficulties of managing green construction projects that had not been identified in the literature review and identifying areas of inseparable risks and how these could be managed. However, interviewees were not limited to stakeholders in these case studies. Other referrals, such as people who worked on other green projects, were interviewed.

Two primary considerations formed the basis for semi-structured interviews. First, they were well suited for the exploration of the perceptions and opinions of participants regarding complex and sometimes sensitive issues and enabled more information to be probed for and clarification of answers. Second, the varied professional and personal histories of the sample group excluded the use of a standardized interview schedules (Barriball & While, 1994).

The flexibility of interviews was a useful method of obtaining information and opinions from selected individuals who have an interest in the research and hold constructive views. The interviews were semi-structured with a mixture of open and closed-ended questions, to allow and invite a broad range of answers and issues from the interviewees and also to get the information necessary for the CRM phenomenon (Englander, 2012;

Brink, 2014). The sessions followed a pyramid model (Runeson *et al*., 2012; Stickler & Hampel, 2015) which began with specific questions, and then the open questions during the course of the interview (Kvale & Brinkmann 2009). The central aspect considered at all times was the confidentiality of the interviewees. The interviews were not numbered neither did they required a name, as this may have discouraged participation.

The interviews questions were categorized to make it possible to determine and understand the following:

The participants' level of experience, knowledge and awareness of the CRM concept
The participants' perception on current RM implementation and impediments
The participants' involvement in collaboration; and how to shift equitable risk sharing practices

These questions were used as a guide and were asked in any sequence depending on the interviewee's response to previous questions. In addition, interview questions were presented using informal language. For example, question three was sometimes presented as; 'tell me about a time you were involved in a green building project, how did you manage inseparable risks?' The questions asked and the covering letter, which explains the purpose of the research, is in the Appendix ii. It was emphasized that this study would be used purely for research purposes and that no traceability to respondent would be possible.

More interviews were conducted with participants' in different case studies. Case studies collect a large, complex and diverse body of data. It was essential to ensure that this data is stored in a structured way to ensure ease of retrieval and completeness of the data set, as well as to support triangulation and the maintenance of a chain of evidence (Kitchenham *et al.*, 2001). The data collected on these measures were then transcribed and stored in a structured way, for processing and analysis.

5.9 Case Studies

A case study may be understood best as a narrative, based on actual events that created an opportunity for conversation, problem analysis, and virtual decision-making (NASA, 2008). An effective case study transfers specific knowledge by placing the researcher in a position to think through choices faced by decision-makers in real-life situations. By confronting actual scenarios, participants develop and refine analytical skills for solving design risk problems in their projects (NASA, 2008).

To determine how CRM theories are used in practice, different GB projects were used as case studies. Subsequently, to get an overview of CRM practices used by various professionals, all stakeholders participating in the projects were asked to take part in the research. The interviews gathered the case study information. In these interviews, there were clear overlaps of different disciplines, such as finance, insurance, management, business, construction and engineering which were all brought together uniquely by green building construction (Runeson *et al*., 2012). Case study research design was useful for testing whether scientific theories and models work in the real world (George & Bennett, 2005).

A case study method was a creative alternative to traditional approaches to description, as it emphasizes the participant's perspective as central to the process (Zucker, 2009). **Table 5.6** shows the case study pattern followed.

Table 5. 6 Case study process

Case study design – objectives are defined and the case studies were planned
Preparation for data collection – procedures and protocols for data collection are defined
Collecting evidence – data collection procedures are executed on the studied cases
Analysis of collected data – data analysis procedures are applied to the data
Reporting – the study and its conclusions are packaged in formats for reporting

(Adapted from Runeson *et al*., 2012)

The case study investigated the CRM phenomena in real-world settings and new technologies, communications, design risks and failure factors were discussed (Zainal, 2007). In the interviews, the aim was to find out what is happening within the collaborating teams, seek new insights on CRM and generate new knowledge. Triangulating this information meant combining multiple perspectives from different stakeholders within the project hearing their views and building a broader picture.

5.10 Sampling Method for Case Studies

The case studies reveal a deeper understanding of the complexity of the green building project environment. They emphasize the significance of collaborative working and project stakeholder engagement for green practices. Taking into account, the certain responsibility of project stakeholders to foster and create a CRM approach for GBs since they takes place in a non-linear, complex, iterative and interactive environment, in which the impact of inseparable risks cannot be identified easily with a dyadic discussion.

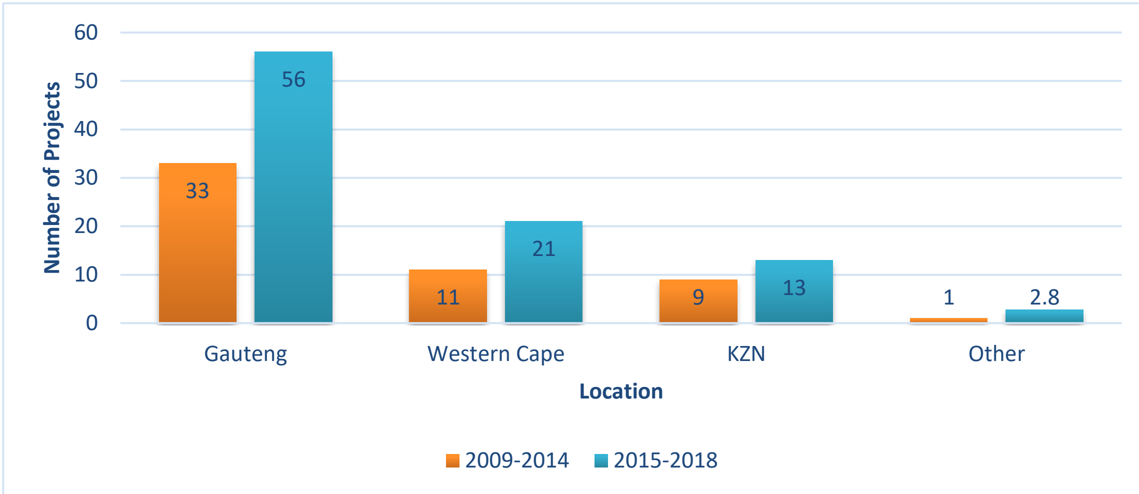
GBs involve an application of new technology and requires new sets of skills, which are not usually applied to ordinary building projects and their management. Furthermore, the collection of the data that is necessary to develop a holistic approach requires several interactions with different project stakeholders rather than a single round of 'tick and flip' survey exercise. Likewise, it would not be suitable to use a population-wide questionnaire survey. Instead, case study methods were the preferred choice.

The completed case studies were green building projects that were certified with an in-depth certification scheme that addresses all 9 categories of Green Star tools. The tools are based on 9 different categories, each with a range of credits that address environmental and sustainability aspects of designing, constructing and operating a building. In the cases that were still in their design phase, a design will have a certification of validated environmental initiatives.

Johannesburg and Cape Town are different cities that could give different insights and stronger analysis. Johannesburg addresses the client's experience and reputation and end-user attitudes. Cape Town needs to address the same factors but with the addition of pressing environmental issues, such as, water shortages. Moreover, the choice of cases was not limited to a certain kind or style of building. Depending on the nature, scale, and type of the GB project, a complex network of stakeholders was involved. These stakeholders usually had conflicting requirements. The ability to reconcile these competing needs was crucial for this research and finding an optimum way of risk sharing when encountered with inseparable risks.

The GBCSA reports show the trend and the different market sectors including office, retail, multi-unit residential, public and educational buildings, industrial, hospitals and mixed- use schemes (GBCSA, 2019). The 2016 report included a sample of 54 office buildings owned by 34 different companies. The 2019 report included a sample of an additional 91 office buildings owned by 52 companies that were certified between 2015 and 2018 (GB Guide to Costs & Trends, 2019). Growthpoint Properties remains the South African leader in adopting green building principles. Despite the economic challenges faced by the commercial property industry, those companies that are aware of the inherent value of green building practices remain committed to their sustainability journeys and acknowledge the obvious financial benefits of green building in a challenging economic climate.

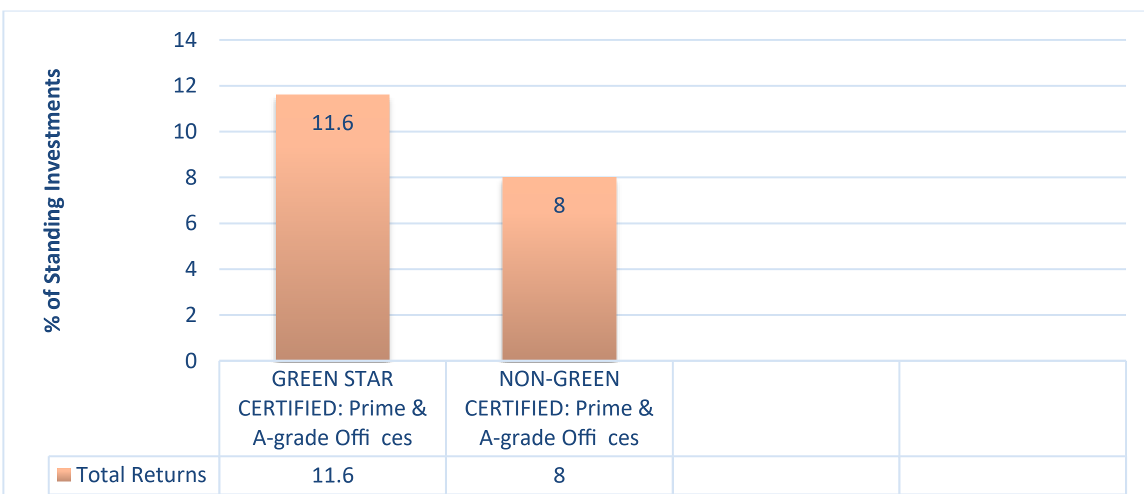
Figure 5.5: Project Location for Office Projects Certified



(GB Guide to Costs & Trends, 2019)

Figure 5.5 shows all certified office projects in the study population; there were 89 office projects (61%) located in Gauteng, 32 (22%) from the Western Cape and 22 (15%) from Kwazulu-Natal. Johannesburg and Cape Town are different cities that could give different insights and strong analysis.

Figure 5.6: Green Star Offices Higher Return In 2017



(GB Guide to Costs & Trends, 2019)

The results of the case projects are compared and explained to assist researchers' and industry practitioners' understanding of project stakeholder-associated inseparable risks in the design phase. CRM is also understood as important for not only developing a comprehensive risk list and recognizing the causes of risks but for contributing to effective decision-making and efficient communication in green building projects.

5.11 Study Rigour

Study rigour was established using the following criteria: confirmability (objectivity), transferability (external validity), credibility (internal validity) and dependability (reliability) [Lincoln & Guba 1985]. Confirmability: To ensure rigour and objectivity, the researcher adopted an open attitude when interviewing participants to reduce bias in the study process and results. The researcher had to be neutral so as not to influence the data. During interviews, the researcher noted the participants' tone of voice and expressions to ensure a comprehensive understanding of respondents' views and meanings and to provide confirmability. And increase sampling variation, participants included individuals with as many different backgrounds as possible (for example, from different types of organizations, positions and professions).

Transferability: Recordings and reports were made with sufficiently detailed descriptions of the data to achieve transferability. During interviews, the researcher made further enquiries and clarified unclear viewpoints. The notes taken during face-to-face discussions were verified with individual participants to ensure that their intended meanings were understood. All of these steps helped fulfil the criterion of credibility. The data was also reviewed for understanding. Inconsistency was examined to ensure that themes were appropriately named. All recordings collected were kept to allow for research review and to serve as an audit trail for dependability.

5.11.1 Response rate

The case study approach offered a means to describe, in some detail, the innovative project, and to analyse its implications for the future of green buildings. It also allowed for opinions on generating new knowledge and understanding. Transferability based on actual events that created an opportunity for conversation to build new knowledge relates to the transferring of the results to other situations or individuals (Vasileiou *et al*., 2018). This means the researcher had to describe both the CRM phenomenon and the case studies as the contexts where the event occurs so that other researchers can safely conclude that they too, can use the results to make sense of other contexts or subjects.

The results of the research reflect the participants' experiences and thoughts and not their ideas and values.

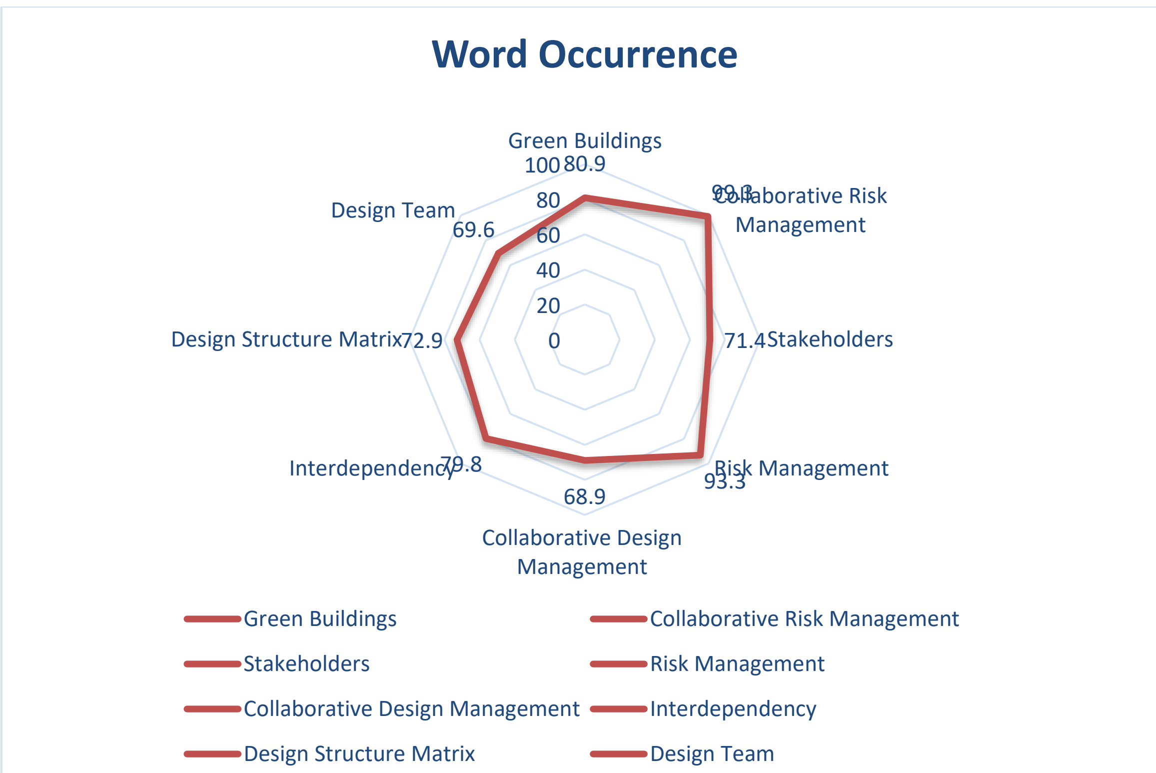
Table 5.7: The Response Rate Percentages for the participants in different projects

Professions	**Project 1** *Forensic Pathology*	**Project 2** *Retirement Apartments*	**Project 3** *Apartments and Museum*	**Project 4** *Commercial Development*	**Referral Participants**
Structural Engineer	1	1	1	1	
Quantity Surveyor	1	1	1	1	1
Architect	1	1	1	1	2
Green Design Engineer	1		1		1
Project Manager				1	1
Risk Manager	1			1	
Client		1			
Development Manager				1	1
Construction Manager					1
Sustainability Specialist				1	
Landscape Designer	1				1
Number of Interviews	**6**	**4**	**4**	**7**	**8**
Response Rate Percentage	**55%**	**36%**	**36%**	**64%**	**73%**
					29 out of 62
					47%

Different percentages were attained from the case studies. In total, 62 participants were identified, approached, and interview details were set, but only 29 participants were interviewed giving a 47% response rate. This is inclusive of case study design teams and different professional referrals. Although the response rate was 47%, the key insight from the interviews was that the data set did not provide new information or themes, which relate to the research questions. The reason for this was that, in collaborative circumstances, all stakeholders are well-informed on the information of the design process.

This allowed the unfolding of richly textured understanding of CRM from the raw words participants articulate which, where then categorized based on their commonalities. With further interviews, it became apparent that there was no longer anything new for more theoretical insights.

Figure 5.7: The Response Rate word occurrences



The coding was performed for each interview to identify the moment when no new themes were derived from the data. The research had then reached the saturation threshold.

5.12 Data Analysis

The analysis and interpretation of research data form the major part of the research. The definition of the analytical method is of paramount importance to any analytical strategy (Amaratunga *et al*., 2002). The interview questions were divided into two sections (Appendix iii):

The demographic background was to identify their experience concerning green building construction, the number of years involved in green building construction and the number of projects. In addition, their risk attitude was established regarding decision-making.

The open-ended questions were aimed explicitly at acquiring implications of CRM during the design phase of green buildings and ways on how inseparable risk can be managed in collaborative circumstances.

An important element is a well-crafted research design and appropriate data targeting to respond to the research questions and the analysis plan. Miles and Huberman (1994) state that study design questions can be seen as analytical, an anticipatory data reduction, as they constrain later analysis by ruling out certain variables and relationships and attending to others. The rest of the research design then influenced the analysis decisions. For example, as Mason (2002) describes, when the researcher determined the sampling strategy as only green building stakeholders, the research team had to think ahead as to what analysis would be useful to ensure a direct link between the sampling strategy, the data analysis and the presentation of the findings.

Data analysis consisted of two major sub-processes, (1) data reduction and pattern identification, and (2) producing objective analytic conclusions and communicating them (Strauss & Corbin, 1998). Qualitative analysis meant making sense of relevant data gathered from sources such as interviews, on-site observations, and documents and then responsibly presenting what the data revealed by breaking down, examining, comparing, conceptualizing and categorizing it (Strauss & Corbin, 1990).

Data analysis also included a qualitative analysis, which suggested steps that are similar to qualitative analysis (Marshall & Rossman, 1989), (1) organize the data, (2) generate categories, themes and patterns, (3) test and search for alternative explanations of the data and then (4) record the findings.

In this study, the researcher followed the steps and listened to all the taped responses of the 29 interviewees a few times to develop a holistic understanding of the concepts involved. This enabled the researcher to break down the semi-structured interviews into units of analysis. The content (words, statements and views) of the units of analysis were extracted from the data to understand whether the respondent had experienced inseparable risks in the projects they had worked on and how they managed inseparable risks. Finally, the common themes were integrated into relevant constructs that were used to re-build a theoretical framework.

5.13 Validity

Quality concerns play a central role throughout all steps of a research process from the inception of a research question and data collection, to the analysis and presentation the findings (Ali & Yusof, 2011), thus the need for verification to check and confirm, make sure. In qualitative research, verification refers to the mechanisms used during the process of research to incrementally contribute to ensuring reliability and validity and, thus, the rigor of a study. These mechanisms are woven into every step of the inquiry to construct a solid product by identifying and correcting errors before they subvert the analysis (Kvale, 1989; Creswell, 1997).

Validity means the appropriateness of the tools, processes and data (Leung, 2015). Whether the research question is valid for the desired outcome, the choice of methodology is appropriate for answering the research question, the design is valid for the methodology, the sampling and data analysis is appropriate and, finally, the results and conclusions are valid for the sample and context. It denotes the trustworthiness of the results and to what extent the results are not biased by the researchers' subjective point of view (Saunders *et al.*, 2016). In the broadest context, it is the truth-value. It refers to the integrity and application of the methods undertaken and the precision with which the findings accurately reflect the data, how the researcher outlined personal experiences and accurately presented the participants' perspectives, without bias.

The validation provided the possibility of generalizing the findings and to what extent the findings would be of interest to other people outside the investigated case (Creswell, 2013). The various stakeholders interviewed were interested in how CRM would benefit their projects and their inputs were relevant for other cases. For the research case studies, the intention was to enable analytical generalization where the results are extended to other cases, which have common characteristics. Hence, the findings are relevant for defining the theory.

5.14 Reliability

This research tried to understand the CRM phenomena by seeing how respondents perceived their roles, tasks and risks in the design phase; determining the history of situations and building theory. However, the question of reliability becomes how well the study represents what it was designed to do and, how consistent the data is.

The notion of reliability is the consistency of the analytical procedures, including accounting for personal and research method biases that may have influenced the findings of qualitative interviews (Saunders *et al.*, 2012). The method used to allowed issues of complexity to be studied in detail and depth. Creswell (2013) asserts that in studies that require in-depth knowledge, rather than to attempt generalizing findings over a population, it is more appropriate to generalize the theory.

5.15 Generalizability

With the rising trend of knowledge, synthesized from qualitative research Saunders *et al*. (2009) affirms that generalization in the design processes is significant if the theoretical propositions and locating of the findings is in existing theory.

A pragmatic approach to assessing generalizability was to adopt the same criteria for validity, which is using constant comparisons in case studies and documentation. The conceptual framework created can be seen as evidence of a multitude of secondary sources of the same and similar ideas, as both South African and international sources, such as academic journal articles, book publications, global reports, and official government reports, were analysed to create this. Thus, the findings of this research can be seen as credible as it has been drawn from existing knowledge.

The interview questions were in simple English, easy to understand and not ambiguous. The constraints of this research were that there were a limited number of respondents because of availability and busy schedules. An additionally problem was, respondents fearing that anonymity and confidentiality would not be kept.

5.16 Delineation

The research may not be repeatable, as the modes of inquiry, interpretations and articulations are particular to this study. However, by openly describing the study context, data collection and interpretation setting, the research can be critiqued for its interpretive possibilities (Seamon, 2000).

A critical conflict in this study was the primary researcher's participation in the development of the research method. It is nearly impossible to conduct a systematic enquiry into the real world while avoiding investigation interference (Archer, 1995). There are potential conflicts and ethical issues: respondents may gear their responses to the researcher, which can create poor reliability and generalization of the experiences. Nonetheless, inherent biases were overcome and assumptions were revealed by combining multiple approaches and theories (Creswell, 2013). Furthermore, the close relationship between theoretical and practical activities in design practice gives the researchers access to in-depth and tacit knowledge.

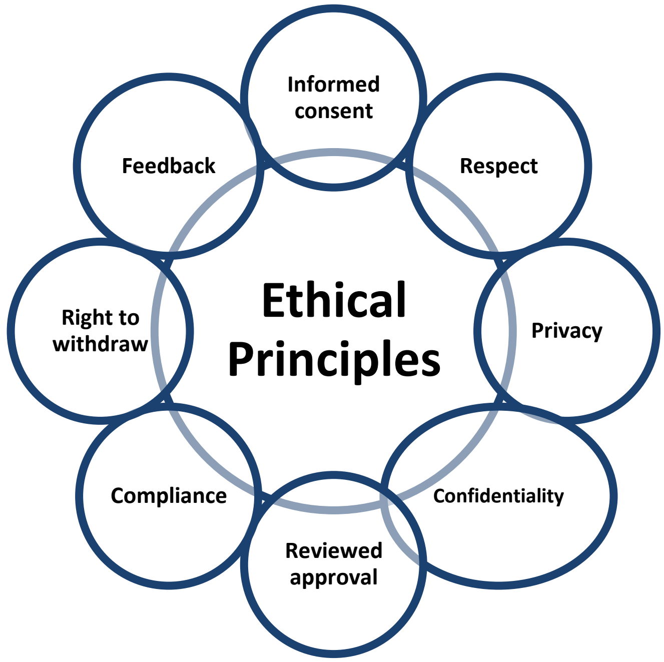
5.17 Legal, Ethical and Professional Issues

Research is a complex process in which several stakeholders are involved (Steane, 2004). The researcher must take account of legal, professional and ethical issues in the design, conduct and reporting of his or her research (Bell & Bryman, 2007). Regardless of the approach, a researcher faces many ethical issues that surface during data collection in the field and in analysis and dissemination of the research (Creswell, 2013). Ethics are the standards of behaviour that guides conduct to participants (Saunders *et al.*, 2016). Ethical issues involve anonymity and confidentiality to participants, gaining traditional access, as well as how data is kept and then destroyed.

An appropriate ethics committee, to ensure compliance with relevant ethical guidelines and standards, must review research involving human subjects (Singer & Vinson, 2001). There can also be pragmatic reasons such as maintaining legal, professional and ethical standards which help to develop and maintain trust with participants and organizations. This trust will help the research to go more smoothly. There is of course, the basic motivation of humans, that they want to be treated respectfully (Singer & Vinson, 2001).

There are many influences and codes of ethics that guide standards of behaviour (Saunders *et al.*, 2016). These contain a list of principles outlining the nature of ethical research to guide the researcher as established in **Figure 5.8.**

Figure 5.8: Ethical code of conduct



The research proposal was submitted to the research processes as outlined by the University of the Witwatersrand's ethics committee. It complied with the university's code of ethics to protect the rights and dignity of the participants and everybody who can be affected by it (Bell & Bryman, 2007). Participants were made aware of their rights and that the research was completely voluntary. Data obtained was anonymous, and the report was in an anonymous format. Accordingly, where confidentiality and anonymity were promised, it was maintained even after access was granted (Saunders *et al.*, 2016).

5.18 Key Principles of the Research Design

The multiple case studies data to this investigation was collected using semi-structured interviews with a mixture of open and closed-ended questions, where participants were asked about stakeholder techniques on carrying out inseparable tasks, as well as their options and suggestions on the CRM processes of green projects. The use of interviews was a highly flexible method that could produce data of great depth and experiences related to the case study. The goal was to see the research topic from the perspective of the interviewee, and to understand how and why they came to have a particular perspective.

A non-probability, snowballing sampling technique was used based on the fact that, only green building stakeholders were interviewed. In addition to knowledge and experience, the importance of availability and willingness to participate, and the ability to communicate experiences and opinions reflectively was also important.

The next chapter contains interview data analysis. This involved the interpretation of data gathered using analytical and logical reasoning to determine patterns, relationships or trends. There was an inseparable relationship between data collection and data analysis to build a coherent interpretation of data because of the ongoing fine-tuning in order to generate the most fertile array of data. In the qualitative data analysis, the process of making sense from research participants' views and opinions, corresponding patterns, themes, categories and regular similarities is described. In the quantitative data analysis the information is presented using graphs and other graphics, to present data visually for quick understanding. These two methods are connected in the pragmatic section to obtain comprehensive data per the aim of the research.

6. STAGE 1-INTERVIEW PRESENTATION AND ANALYSIS

6.1 Preface

This chapter involves the interpretation of data gathered using analytical and logical reasoning to determine patterns, relationships or trends. It clarifies the difference between traditional design teams and green design teams. The previous chapter laid the groundwork by describing and explaining the data collection process, rationale and purpose of the mixed methods used in this research. As was clearly outlined in Chapter 5, a combination of qualitative and quantitative research methodologies was used for more comprehensive responses to provide for unexpected developments and to clarify idiosyncratic circumstances. Furthermore, a theoretical framework based on an extensive literature study in Chapters 1 assured the reliability and validity of the measuring instruments.

Furthermore, it is important to remain mindful of the fact that the data from the qualitative and quantitative sections are connected, in that the results of the qualitative data contributed to the development of the quantitative data.

6.2 Data Presentation

Data presentation is the process of bringing order, structure and meaning to a mass of collected data (Marshall & Rossman, 1999). It is a continuous, developing and repeating process during which transcribed data of interviews are investigated (Henning *et al*., 2004). It is described as messy, ambiguous and time-consuming, but also as a creative and fascinating process (Schwandt, 2007). Generally, although it does not proceed linearly, it is the process of making sense of information. Interpreting and theorizing data signifies a search for general statements among categories of data.

Data presentation of all the information from interviewees was analysed using both the qualitative and quantitative methods. Qualitative data analysis is an ongoing and iterative process, implying that data collection, processing, analysis and reporting are intertwined, and is not necessarily a sequential process (Nieuwenhuis, 2007).

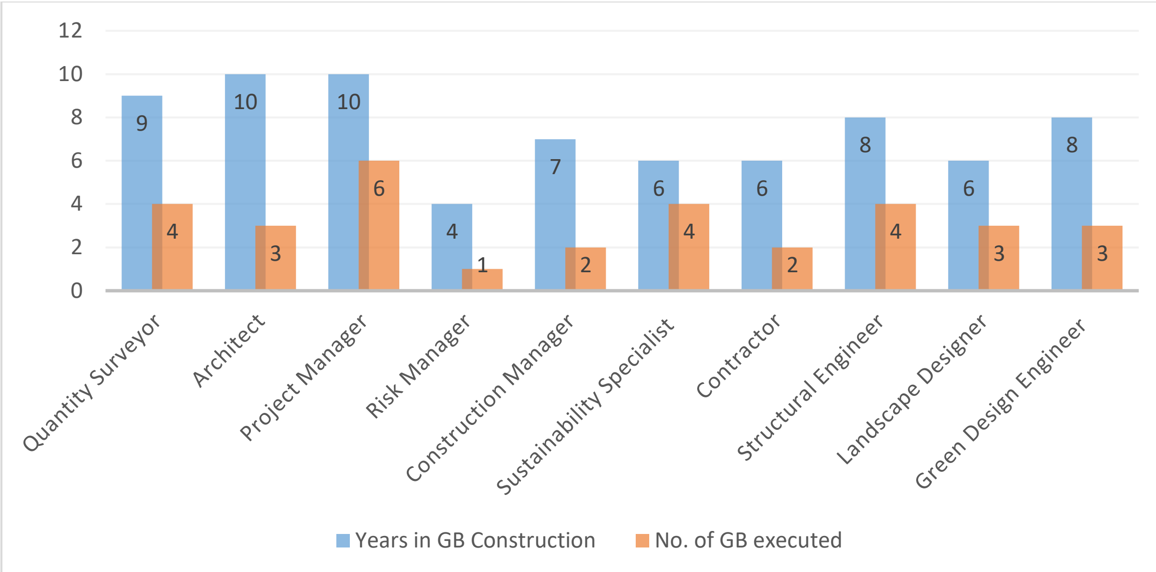
6.2.1 Demography of respondents

Altogether, 29 semi-structured interviews with different practitioners were conducted to understand the current risk allocation practices, evaluate the extent of collaborative practices and the way inseparable risks can be managed in collaborative circumstances. The differences emphasized with these respondents are, their green decision-making innovativeness. The structure of the participants' population was presented in Figure 5.5 showing the profile of respondents and their positions in projects.

A competent design teams is required to have a range of attributes as the basis for design decisions but a competent green design team needs additional attributes such as green design knowledge, green design skill and the experience on design green buildings. These green design skills and knowledge demonstrate conscientiousness on green and commitment to green. However, all this required additional time during a design process to enable design teams to overcome the difficulties such as speed of design process and statutory approval. Furthermore, green design required implementing green building rating assessment tools such as GBCSA; this led to additional participants in the teams.

All respondents were willing to participate in the research and all the interviews were conducted in a friendly, cooperative manner. Nineteen of the respondents were male and ten female. **Figure 6.1** presents the profile of the respondents and shows positions in projects, the number of years involved in green building construction and the number of green building projects they have been involved-in.

Figure 6.1: Profile of Respondents



In the demographics section, respondents were also asked about their risk attitudes to determine their risky decisions. The results showed that 70% responded to their risk attitude as being bold, and they: "… dare to make mistakes" but would: "… gather more information" when faced with a risky problem. Results showed that 40% of the green projects done by the respondents were in Gauteng, 40% in the Western Cape and 15% in different South African provinces, with only 5% projects done internationally. The study also compared the years of respondents' experience in traditional building projects with green building projects and results showed that most respondents have less than ten years' experience in green building projects. This is to be expected, as eco-aware clients are only better understanding building green and design stakeholders who understand sustainable development and environmental responsibility. One of South Africa's main problems is finding enough skilled green professionals.

Green building construction is still at an early stage in South Africa. These kinds of projects require an application of new technology, which require new sets of skills. It is still essential to investigate possible methods and technologies to reduce greenhouse gases, to measure the carbon footprint and especially to use a more holistic approach to reach a broader sustainable scope and bring multiple benefits to more stakeholders during project life cycles (Liu *et al*., 2015).

As has been explored in the literature review, GB construction developments require intensive interdisciplinary collaboration and involvement of all stakeholders to add more value to the design and building modelling. The improvement in design quality reduces cycle times and in turn reduces reworks that generate waste and affect the economic and environmental aspects of sustainability (Jrade & Jalaei, 2013; Jalaei & Jrade, 2015).

6.2.2 Synthesized knowledge areas leading to the Questions

Table 6. 1 Identified concepts

Objectives:	**Concepts**	**<u>Synthesis of 3 Knowledge Areas:</u>** **Green Buildings, Risk Management and Dependency Matrices**	**Proposed Questions**
What are the implications of CRM during the design phase?	Implications of CRM in GB <u>Defined Concepts:</u> Collaboration Green buildings Complex dependencies Risk management Dependency Structure Matrix (DSM)	Green Buildings require interdisciplinary coordination, due to the interconnectedness of green systems design (Zuo et al., 2017) Interdisciplinary collaboration approach - Complex undertakings which require a participation of multiple and diverse stakeholders (Fang & Marle, 2013; Antintola et al., 2015) Inseparable risks are highly intertwined and difficult to uncouple (Poirier et al., 2016) due to interconnected stakeholders with their interdependent tasks This complexity is the problem characterization, which justifies the requirement for Dependency Structure Matrices (Steward, 1981). Moreover, this complexity has	- State the implications you have faced - Were they positive or negative? - Practical example

		influenced the design process to grow towards an open system, which has led to wicked problems (Rittel & Webber, 1973)	
How are inseparable risks managed in collaborative circumstances?	Inseparable Risks <u>Defined Concepts:</u> Green designs Interdependencies Complexity Domain Mapping Matrices (DMM)	GBs deal with complexities that surface in the design process through iterations between tasks (Hickethier et al., 2012), to go beyond the traditional RM mechanics to examine the sources of unknown risks (Jarkas & Haupt, 2015), one requires a collaborative framework, which encompasses all views and perceptions of project risks from different stakeholders (Demir et al., 2012) Identifying inseparable risks makes the process of risk sharing more efficient (Fundli & Drevland, 2014) DMM is used to show the dependencies and interactions between system elements, analyze iterations and rework in design (Eppinger & Browning, 2012)	- Have you encountered inseparable risks and what were they? - How did you manage them? - What steps were taken in that instance? Alone or collaboratively?
What are the current risk practices?	Risk Management <u>Defined Concepts:</u> Risk practices Effective RM Experience Interdependencies Dependency Structure Matrix (DSM)	Diverse professional backgrounds, with different levels and types of interests in the project affects risk practices (Mok et al. 2015) because, stakeholders still rely on pre-existing knowledge for managing risks (Whelton and Ballard, 2002) Tendency to use RM techniques that have always been used, instead of trying relevant techniques that are appropriate for a situation (Forbes et al., 2008) calls for CRM DSM brings advantages of simplicity and conciseness in representation (Bekdik et al., 2017)	- What have you experienced, w.r.t risk practices? - How can this be improved? - How can we forecast design problems that can only be dealt with collaboratively?
How different stakeholders interact with each other?	Stakeholder Interconnections <u>Defined Concepts:</u> Collaborations	Traditional design management methodologies are linear and fragmented (Al Hattab & Hamzeh, 2015) and most stakeholders still want to use those practices.	- Do stakeholders have a choice on who to deal with?

	Task interdependencies Complexity Domain Mapping Matrices (DMM)	There is a need for integrated working practices, with methods and behaviours changes (Austin et al., 2002) Risks and stakeholders do not exist in a vacuum (Yang & Yeh, 2014), how then do we clarify the risk-stakeholder interrelationships? The combination of DSM and DMM methodologies makes the analysis results enriched, providing an expanded view of the system (Bartolomei et al., 2007). DMM methods help to focus the analysis results on interdependencies, interactions, and the exchange of information between stakeholders	- Who associates with whom and in what ways do these stakeholders depend on each other for green-related decisions?
How design problems which can only be dealt with collaboratively be identify in advance?	Managing inseparable risks <u>Defined Concepts:</u> CRM Contracting Risk sharing Multi Domain Matrix	Have a holistic approach to programming, planning and designing (Dubey et al., 2018) Jing and Qin (2011) revealed that an evaluation of influence by stakeholders and the risks should be considered as a necessity or an important step in the planning of GBs. Try to outline interdependent tasks then, determine the overall pace of the program (Alsalman, 2012) CRM will correct the existing inefficiency, and a continuous loop will evolve until there is progression	- How are the concerns of bridging the gap in RM becoming a generic area in construction projects?
What could be the solution?	CRM as an effective RM method	CRM includes processes and stakeholders, the application of dependency structure matrices (DSM) techniques will be used to identify where the interdependencies exist in the design process where collaborative designs are required. CRM and DSM will also be used to sequence activities in an optimal way by identifying where shared risks may lie, within these processes, tasks and stakeholders.	- Remedies to solve the negative outcomes? - Are GBs that encompass risk entirely and have established

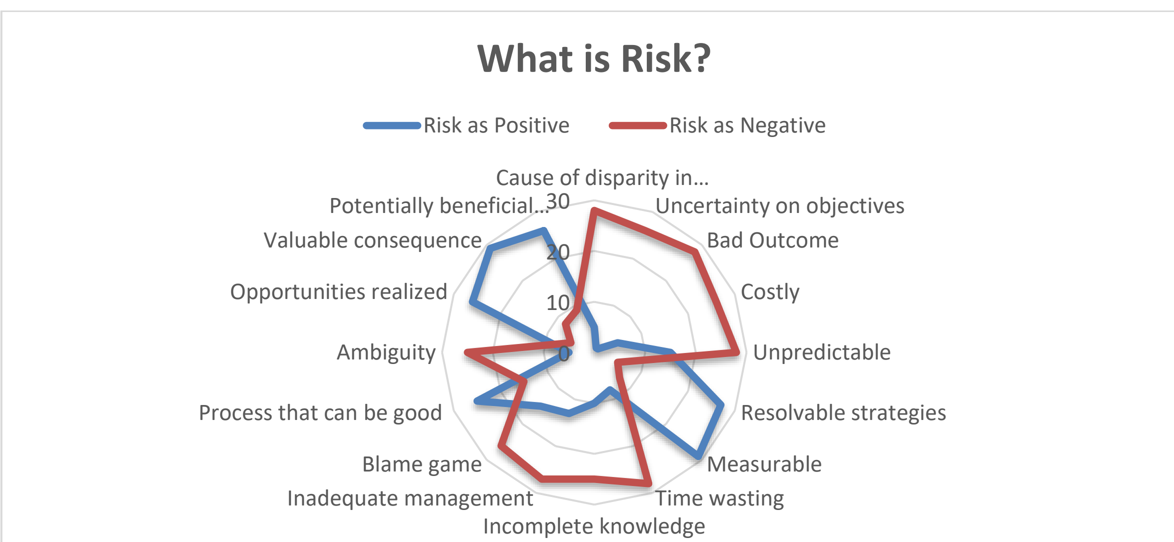
			proper stakeholders' risk assessments achievable?

6.3 Answering Questions from the Interviews, including Participants from the Case Studies

6.3.1 What does risk mean?

Most of the respondents see risk as a negative event that can affect the project negatively, 88% responded to risk as a: "…*cause of problems and danger*" (Contractor 2); "…*unpredictable thing*" (Client 1); "…*bad outcome*" (Contractor 1) and: "…*risks always come with a cost*" (Quantity Surveyor 2). Only a few practitioners mentioned opportunity when thinking about the risk or: "…*something that can be solved*" (Architect 4). Broadly, risk can be categorized as either positive or negative but, very few respondents saw it as positive. **Figure 6.2** shows that different words on what risk is.

Figure 6.2: How participants regarded the meaning of Risk to be



The perception of risk is what constitutes a risk in the first place and the reaction of a particular stakeholder to it (Renn, 2004). Often, it is informed by past experience and influenced by value systems, both personal and organizational (Vasvári, 2015). To control differing risk attitudes, project stakeholders were brought together by project managers to discuss design risks that are likely to occur in the case study projects so that all views and perceptions were brought together in the preparation of a risk management plan.

Including the opportunity view of risk in consideration will improve business focus, project probabilities for success, perhaps occasionally beyond expectations (Lehtiranta, 2014). Thus, a holistic negative and positive view on risk may also have the potential for benefits to CRM and integrated stakeholders.

6.3.2 What is risk management?

Most of the respondents have what might be described as a fair understanding or knowledge of risk management as a process. Despite the general awareness of risk management processes, applying risk management systematically in projects is still limited in practice.

Risk management is a system, which aims to identify and quantify all risks to which the business or project is exposed so that a conscious decision can be taken on how to manage the risks (Flanagan & Norman, 1993). It helps to bring together the risks and risk factors in more than one area that affect the prospect of meeting the scheme of objective: "… *is a process whereby decisions are made to accept a known or assessed risk and the implementation of actions to reduce the consequences or probability of occurrence*" (Client 1). Other participants responded as shown in **Table 6.2.**

Figure 6.2: How participants understood risk management as a process

Participant	**Risk Management Interpretations**
Architects	"a core element of integrated design" "a very important process for collaboration" "a bunch of different concepts"
Project Managers	"a powerful tool to use" "a pillar of group strategy" "a very clear advantage" "incredibly powerful process"
Structural Engineers	"useful, yet complex process "reason to communicate"
Risk Manager	"decision-making process" "platform for different voices to be heard"
Green Design Engineer	"exchange of information"
Sustainability Specialist	"decision model"

Risk identification is the most frequently applied element with checklists and brainstorming as the main techniques. Huemann and Ringhofer (2018) emphasized that without identifying risks no risk management can be performed. Yet, the interviews revealed that formal risk assessment is not performed widely in the projects. Experience, feelings and intuition are the most commonly used tools for risk assessment. Risk analysis also used experience and intuition to quantify and evaluate the risk on the project.

Risk response addresses how the risk will be managed, and it is a less frequently used element because not every identified and assessed risk is subject to risk management. The problem with the assessment, RM is continually updating and evolving (Rostami *et al*., 2015).

Clients, design teams, contractors and project managers have to adapt their approach to risk management because they have different characteristics including role, education and experience (Jin *et al*., 2017). Their differences on risk-related issues, such as risk perception and risk-based decisions, require a better understanding of risk-related conflict to benefit both stakeholder and risk management.

6.3.3 The following have been identified as effects of current risk practices by stakeholders

Current risk practices are influenced by design management practices, characterized by poor communication; lack of adequate documentation; deficient or missing input information; poor information management; unbalanced resource allocation; lack of coordination between disciplines and erratic decision making.

Practitioners contributed to the complex and challenging nature of the design process. However, many current approaches are not fitting to managing the design process. For example, if the design process is seen as unstructured, this may lead to insufficient understanding of the design process between parties and that is a barrier to people working together effectively.

There are different categories of risks related to GBs listed by different practitioners. In the forefront of risk are the inconsistencies associated with design planning, information management and client knowledge. Other categories are mentioned below.

6.3.3.1 Design planning

"…*Improve co-ordination between disciplines and exert managerial control over the design process*" (Architect 1). The construction efficiency and costs are heavily dependent on the quality of the design solution and information, and the quality of the design process should, therefore, be effective and workable. According to Miettinen and Paavola (2018), design planning can prompt changes to collaborative problem solving. This likelihood would revolutionize collaboration between designers and other stakeholders and would lead to an integrated way of working. Currently, little effort is given to planning the design in detail in the belief that it is time-consuming for such a creative and iterative process "…*it is a situation perpetuated by a lack of understanding in the co-ordination of cross-disciplinary information, the task dependencies and availability of fully integrated design techniques*" (Architect 3). Collaborative design planning would transcend the fragmentation of construction projects, which may typically involve tens or hundreds of stakeholders with a wide range of interests and capabilities (Miettinen & Paavola, 2014).

6.3.3.2 Information management

"…*Design activities have to process information*" (Project Manager 2), yet in the construction industry, this is poorly performed. As a result, the timing of information transfer is not properly controlled: "…*designers do not have the right information at the right time and are overloaded with unnecessary information*". This creates the risk of failure of design tasks, deficient analysis and wrong decisions with a potential for waste due to reworking. Information management is vital to project success, and it needs to improve because it has led to the manifestation of errors, omissions and information redundancy, which has, in turn, led to claims and disputes (Dawson, 2008).

6.3.3.3 Client knowledge

"…*Lack of client knowledge on green building development has proven disadvantageous*" (Architect 2). By virtue of their commitment, clients can ensure the successful delivery of green building projects as they are a key source of design inputs. The involvement of project owners in the delivery process of a green building is regarded as owner commitment (Olanipekun, *et al*., 2017). Their commitment will be in vision statements, which contains the goals and objectives written down in a clear, concise and communicable manner for the use of all stakeholders for the delivery of green building projects. The vision statement also contains the scope of green building requirements by the client, and the priorities set for other stakeholders.

6.3.3.4 Risk attitudes

"…*Project stakeholders have differing risk attitudes not only because they come from different disciplines but their attitudes are influenced by their ethics, beliefs and anticipations which consequently define how they calculate the probability of occurrence and impact of a given risk on a project*" (Risk Manager 1). To control these differing risk attitudes, stakeholders should be brought together at the beginning of the project to discuss risks that are likely to occur during a design phase to have all views and perceptions brought together in the preparation of the risk management plan.

Attitude towards risk, according to the rational theory, is reflected by decisions of risky choices (Hartono *et al.,* 2014); risky decision making is not only dictated by the probability, the possible outcome and the risk preference. The Utility Theory suggests three types of risk attitudes, namely: risk-seeking, risk-neutral, and risk-averse (Clemen & Reilly, 2001).

"…*Clients are usually risk-averse agents as they would choose an alternative with less uncertain outcomes*" (Contractor 2), but are likely to expect a project to be completed as quickly as possible without considering the order of nature and design activities.

6.3.3.5 Construction contracts

"…*Construction contracts form the behaviour of the project stakeholders and, have a significant impact on the successful completion of the project*" (Contractor 1). Respondents largely acknowledge the need to account for the dynamic and flexible nature of complex projects by periodically reviewing and changing the contractual specifications where needed, as part of the ongoing contracting process. "…*What we want is a clean contract; just allow for people who want to work collaboratively, to do that without the noise*" (Contractor 2).

Contracts aim at clarifying the role and responsibilities of contracting parties, developing trust and encouraging commitments (Lui & Ngo, 2004). Current contractual relationships are mainly based on the assumption of confrontational situations, and the level of trust is reflected in the contract documents. Contract designs should incorporate flexibility to allow the parties to modify goals and measurement procedures over time.

Mitnick (2013) asserted that all contractual arrangements contain important elements. Trust in a contractual relationship can facilitate the exchange of information and bring about a reduction in control and its associated costs since the parties do not have to fear any manifestations of opportunism (Parker et al., 2018). This is important in technological aspects where there is no clear regulation related to authority, to proprietary intellectual rights or to fair practice for electronic information and documentation.

Furthermore, respondents mentioned that, in true relationships: "…*once you signed the contract, you put it in the drawer. If things go wrong and you refer to the contract to solve the problems, you will lose the relationship. Contract is a document; risks are dynamic and not one-off definitions that need to be managed beyond the contract. You could never prescribe how to solve a problem and how to mitigate risks in a contract*" (Construction Manager 1).

Another source of a problem is that, because complex projects have so many uncertainties: "…*it is in fact impossible to draft a contract to accommodate these uncertainties"* (Project Manager 1), the end result being an incomplete contract.

6.3.3.6 Risk management practices

"…*Contractors have to deal with most risks; we are forced to be active in risk management*" (Contractor 2). The respondent felt that: "…*this is due to current practices where risk management is not a major part of consultants' assignments*". Early involvement of the contractor in the design process is considered to be the main advantage. Besides: "…*contractors' risk management is more thorough if they are part of a design*" (Architect 4). Cooperative work between architects and contractors is argued to result in better technical solutions and help in avoiding many design and technical risks. Tee *et al*., (2019) also maintained that integrating practices help stakeholders address problems related to both coordination (by emphasizing information transparency) and cooperation (by aligning incentives).

"…*Contractors are able to manage many risks, but they need the dialogue with the client, not the situation when risks just appear in the construction phase*" (Contractor 1). To secure effective risk management: "…p*ersonal commitment of the clients is argued to be the most important factor*" (Project Manager 1). When the client is an active party, the contract is claimed to create conditions conducive to better collaboration because the clients and contractors are forced to have a dialogue.

"…*The sooner we get the contractor's expertise in the project; the greater is a chance to avoid the problems in production*" (Client 2).

6.3.3.7 Project funds

Several respondents acknowledged project-funding problems. "…*It seems quite normal for clients not to have sufficient financial capacity on their own to develop projects at the start*" (Project Manager 3). One of the major funding sources is by pre-selling the property (say in residential and commercial projects). If the market demands are not forecasted accurately, lack of funding will become a reality.

"…*Variations by the client*" (Architect 2) can directly result in changes in the planning, design and costs. Variations result from two reasons, a change of mind by clients or a misunderstanding or misinterpretation of the clients' needs in the project brief (Hall *et al.* 2014). In the case of the former, the clients usually bears the responsibility; for the latter, knowledgeable stakeholders should be established as early as possible to define the project scope and functions precisely so as to share the risks equitably.

"…*Incomplete or inaccurate cost estimate*" (Quantity Surveyor 2) is directly related to all consultants' knowledge and attitude towards work. Many unforeseen factors encompass design activities, the fluctuation of market prices and rigid cost estimation methods which often deviates the estimated cost from the real cost. "…*Choosing responsible and experienced stakeholders involved early can help to illuminate the black box and improve accuracy"* (Quantity Surveyor 3).

Other risk factors associated with political instability and corruption that can influence project funds are: "…*fluctuation in currency*", "…*interest rates*", "…*labour-market and material-availability uncertainties*" (Quantity Surveyor 1).

6.3.3.8 Procurement methods

The rapid development of the construction industry has established new procurement methods in projects, such as prime contracting, framework agreement, alliancing, partnering, and so on. However, the industry still heavily relies on old procurement methods that do not fully support collaborative approaches.

"…*All stakeholders should commit to win-win attitude*" (Engineer 2). Alternative procurement methods encourage stakeholders to employ construction techniques and modern technology that improve the quality of the project, or reduce the project duration, or both (Jin *et al.*, 2017). "…*Collaborative procurement is the only way for stakeholders to carry out information sharing platforms*" (Green Design Engineer 1). They make decision-making problems more systemically by repetition to have a clear definition, then facilitate proper judgment and logical decision-making: "…*it allows stakeholders to consider relative priorities of attributes in a design, and it allows interdependence of tasks without insisting on linear thinking*" (Project Manager 3).

In summary, **Figure 6.3** lists the influences identified as the effects of current risk practices by stakeholders in the design phase, mentioned by almost all respondents.

Figure 6.3: Effects of Current Risk Practices by Stakeholders

"…*Even if you design something flawlessly, there's no guarantee that it will be constructed properly*" (Architect 4). Risk aversion certainly paves the way to unfair allocation among contracting parties. When project stakeholders are risk-averse it is the parties who have the low bargaining power that suffers the most because more risks are allocated to them.

6.3.4 How different stakeholders interact in a Green Building design phase

Respondents emphasized that: *"…It is imperative to have shared team responsibilities*" (Quantity Surveyor 1). This will improve stakeholder relationships, that is: *"…all the project team members should share a common set of objectives but stay open minded on contentious issues and even conflicting opinions, and embrace social interaction"* (Project Manager 1).

Reflections from respondents encapsulate this core belief*: "…Common objectives bind people, and through this, people are prepared to accept their responsibilities and confirm what they want to achieve. In the end, you will get the best out of everyone"* (Structural Engineer 1).

"…Team responsibilities show reciprocity in the relationship. It encourages people to take care of others to solve problems" (Architect 2).

"…You need to have the same direction while allowing some differences to exist. Share, accept and be open about differences" (Structural Engineer 1).

"…You need to embrace differences in opinions for a constructive discussion and mutuality" (Green Design Engineer 2).

However, *"…green building projects are characterized by their interconnected, interdepend project networks that are extremely complex, have high risks, long lead-times and are mainly human-oriented"* (Quantity Surveyor 5).

GB design projects are multi-disciplinary, requiring input from several stakeholders, who do not always agree with one another. These projects also involve a group of activities each requiring considerable amount of resources needing effective coordination, interaction and information sharing (Xia *et al*., 2018).

"Commonly, uncertainty and budget limitations have pose a negative impact on building trust among stakeholders" (Risk Manager 2).

"The amount and the type of risks, green projects have caused by errors in designs" (Project Manager 3).

While trust is generally established over time after several interactions (Hwang & Ng, 2016), most of the time, individuals involved in design processes have had little or no prior experience with working with the other stakeholders. This increases the difficulty of building trust at the beginning of the project. Without trust, it is not possible for stakeholders in the network to develop a commitment to others.

"*…There are more dependency relationships between stakeholders in decision-making processes*" this is time-consuming (Architect 1).

"…There is always sensitive information between stakeholders, and this is critical as it determines the level of information detail a party needs to perform well in their process" (Structural Engineer 2).

"…The quality of a project is largely dependent on the appropriate performance management of different stakeholders" (Architect 6).

To meet the differing demands of different stakeholder teams, and to increase the effectiveness and efficiency of the decisions that are made during the design phase, project leaders need to develop comprehensive stakeholder involvement plans. This is because, the interactions and propagating effects of stakeholder concerns can increase uncertainty in stakeholders' behaviours and project decision-making (Mok *et al*., 2017).

"*…We already have a lot of people and the tables are getting longer and longer. That is not good and it is a counterproductive exercise"* (Architect 3).

"…There is extensive subcontracting, where subcontractors subcontract as well" (Contractor 2).

The stakeholder who most contributed to the lack of trust and commitment was found to be subcontractors. One of the reasons may be because subcontractors are not directly employed by the client and are only responsible for a minor part of the design process. This may cause subcontractors to be neglected and their relationship with their employer, who is usually the contractor, is often a temporary one. Hence they do not recognize the need to develop trust and commitment with other project participants.

However, for the whole process to function well, all stakeholders who are involved in the design phase should interact regularly and work in close collaboration with each other.

"…The frequency of communication is an indicator of the strength of connection amongst all project players" (Project Manager 1).

Nevertheless, stakeholders in GB design phases strive to develop communication and collaboration that identifies a learning project organization, by continuous experiments and improvements of stakeholders' problem-solving skills. The design phase is information-intensive and involves work activities, as well as multi-discipline resources where information interdependency exists among the tasks and between resources (Wang & Meng, 2016).

"…Efficient design in terms of layout and cost is crucial and requires close teamwork, which makes it necessary to understand the basics of all disciplines involved" (Structural Engineer 4).

"…Some design tasks in green buildings reveal the possibility of splitting the task along the informational line – and such tasks are not scheduled properly" (Green Design Engineer 1).

Then again, due to the availability of many communication technologies, organizations have adopted many disparate systems. This has led to system incompatibility among stakeholders, which has affected the quality and reliability of information transfer.

Information is a major asset, and information dependency forms the backbone of the design process. According to Howell and Ballard (1997), the success of the project depends largely on how well the information is managed within the network. With inaccurate information delivery, disputes might occur, more cost and time may be incurred, and eventually project performance may be affected (Hwang & Lim 2013).

"…There are various information technology systems that have been developed to support project design management – if only people could use them" (Development Manager).

"…The constant back and forth of information results in rework or redesigns which has actually led to stakeholders having confidence in each other's competence and integrity" (Green Design Engineer 2).

"…The advent of modern web technologies, such as cloud computing, web services and the semantic web have the potential to shape future online collaborative environments in design - but more training is still needed in this sphere" (Sustainability Specialist).

The acquired knowledge obtained by the learning project organization process may still need adjustment; this implies that continuous control and monitoring must take place. Furthermore, this acquired knowledge may not only be documented and stored for future use, but those involved will also benefit in the end, as the newly acquired skills and knowledge can be applied on other projects, leading to more integrated and well-developed management systems. Accordingly, stakeholders may develop their technical and personal skills. To speed up design efficiency, project designers like to utilize experience and knowledge in assisting with the design of new products or in the enhancement of existing ones. What is needed is a systematic and structured way for design knowledge capturing, organization and reuse.

"…The success of a project hangs on well-managed, precision conveyance of information within the stakeholder network" (Project Manager 1).

"…Although BIM is widely used in information management, BIM-based knowledge management is rarely known" (Risk Manager 2).

"…Most stakeholders are brought together as they work on common activities and as they meet mutual engagement in their activities to achieve project success – thus the need to want to work together in future projects" (Architect 4).

Furthermore, stakeholders in GB want to build long-term relationships because assembling a new team every time a new project starts is inefficient and wastes a great deal of money (Ayegba *et al.*, 2018). The conflict of interest is also much less; often when a new team works together, a power struggle takes place between some members who want to enforce their power and influence on other members of the team. Pryke (2012) presented these long-term relationships as interconnections that are multi-layered, including multiple relationships, conceptualized as a relationship network.

"…Tension can be helpful and at the same time you need a structure and clarity because you have to work with many people and complex works" (Client 1).

"…The type of project delivery adopted by project clients, in many cases, determines the stages where both designers and contractors can get engaged in project planning. Therefore, they need to carefully select the right contract type to improve the effective involvement of these stakeholder groups" (Project Manager 2).

"…Opportunistic tricks are very prevalent in contracts because, the awarding criteria is based on the best assumptions of the return on investment and not on realistic benchmarks" (Development Manager).

Adversarial and opportunistic behaviour is common, suggesting that stakeholders are focused on short-term relationships and economic results rather than on long-term cooperation. However, CRM focuses on the improvement of contractual relationships, better risk allocation and more effective risk management (Zaghloul, 2005).

6.3.5 The implications of CRM during the design phase of green buildings

Collaboration in risk sharing offers a solution to handle difficulties. First, it allows the project to utilize the best-in-class expertise and knowledge; second, it reduces the upfront non-recurring investment of time and cost for each partner; third, it motivates all partners to expand the market so everyone can benefit (Friday *et al*., 2018).

"…When risk is shared, stakeholders are alert and the try to keep risks at its lowest impact – this in turn, increases the financial gain" (Project Manager 2).

Open discussions of possible risks in the early phases, as well as collaborative management of risks throughout the project life-cycle, are noted to be important drivers of effective risk management: *"…If stakeholders agree to collaborate, that is an indication of teamwork, it helps in spreading risks"* (Structural Engineer 3). In addition, CRM is acknowledged as "…*a crucial daily job and by doing it jointly the project team will get the bigger picture to perform*" (Development Manager). In this manner, recognition and rewards are considered important to "…*make people feel being respected and motivated on their achievement".*

"…*There are reduce risk-related costs and team works towards the same goals*", "…*risk is dealt with, and changes are catered for at once*" (Sustainability Specialist). Because sharing risks include "…*excessive contract variation*"; "…*a poor financial market*" and "…*influential economic events*." All these risks have the same characteristic that both public and private sectors may not be able to deal with it alone. Hence, a shared mechanism would appear to be the best option.

"…*Financial decision-making requires a simulative risk analysis as an optimal process for the investment*" (Development Manager). This form of analysis is used in areas related to time and cost management, where quantification of risk levels that can affect the budget or completion time of the project can be calculated. "…*This analysis* *helps stakeholders to set milestones and complete them within given time”* (Risk Manager 1)*;* this then can estimate the duration of interrelated tasks.

As different teams learn to break away from traditional design practices, they need to check the workflow using a more proactive approach, where potential changes are communicated to the cross-discipline team, options are explored early and solutions are considered for refinement. Nevertheless, there are still concerns and scepticism about the implementation of CRM. **Table 6.3** shows how other participants believe.

Table 6.3: General Industry Concerns for CRM

Participants	Concerns
Architects	Lack of drive for CRM adoption Skepticism about stakeholders’ competence and capability to apply collaboration with their RM approaches Doubts about risk sharing benefits
Structural Engineers	Need for supportive RM methodologies Stakeholders will not change without knowledge of CRM potentials Processes will not change without client demand
Green Design Engineers	Relatively low maturity of collaborative management in the country Need to promote improved RM competencies Skills development is a challenge
Risk Manager	There is a need for more integration of RM implementations within and between teams in the industry Lack of normalized standards

	Implementing CRM is difficult as its being driven solely by few stakeholders
Project Manager	Need to rethink procurement methods Need for clients to begin driving collaborative facets There is a definite need for guidance through the CRM process & a need for incentivizing adoption and implementation

6.4 Synthesis of Empirical Data and Literature Concepts

Common collaborative practices in the design phase are tabulated in **Table 6.4** below. Information from different authors made an effort to manage stakeholders concerning their perceptions of risks in projects and identifying interrelatedness between RM and SM; and its effect on project performance (Shi *et al.*, 2015; Xia *et al.*, 2018). These efforts, lead to the broad classifications of CRM principles and the responses from the interviews developed into the basics of CRM by understanding, evaluating and implementing effective collaborative principles in the GB projects.

These principles allow different stakeholders to mitigate risks by collaborative advantages, synergies and optimization of resources using unique combinations that are unachievable to an individual. This embraces collaborative arrangements as being at the higher end of the relationship continuum and entails principles that capture effectiveness in utilization of resources, development of competencies, processes, and structures, to address inseparable risks.

Table 6.4: CRM Implications within the Design Phase-Classified

Classifications from the Literature	Collaborative Practices by Respondents
Work pattern (Jaber et al., 2015)	Collaborative decision-making Collaborative developed goals Share BIM models with metric-based decisions Target value design Co-location

Team building (Housley, 2017)	Mutual trust and respect Open communication Leadership Intensified parties' relationships
Legal affairs (Leung and Olomolaiye, 2010)	Multi-party agreements Early involvement of participants Flexible contracts
Technical innovation (Ding et al., 2016)	Appropriate technology Green design process
Financial affairs (Olander, 2007)	Share financial risk/rewards Fiscal transparency
Collaborative risk management (Marle, 2010) (Osipova, 2015)	Early identification of risk Risk sharing methods Record completion time of tasks in the workflow Encrypt information before exchange Manage permissions for using information

According to other respondents, CRM means that each stakeholder is aware of design risks and takes responsibility for them. It is important to start risk discussions early in the project, and risks should be discussed continuously. Known risks should be communicated in detail between stakeholders; discussing a fair sharing of both risks and opportunities is an important driving force for collaborative management of risks.

In the finished projects, different stakeholders stated they had a good collaboration in risk management, especially in the risk identification and assessment processes. The risk response process had a lower degree of collaboration, according to the contractors. They stated that contractors are usually forced to manage most of the risks alone.

6.4.1 Inseparable risks you have experienced

Increased design requirements, integration of stakeholders and information flow have made it possible to build increasingly integrated buildings whose complexity has grown dramatically.

"…As buildings became increasingly complicated, it is more and more common for specialist designers that have emerged to be required to design particular aspects" (Structural Engineer 2).

"…A huge amount of interdisciplinary risks is exchanged in design processes; and there are no lack of tools for representing information flows" (Architect 4).

Complexity has resulted in design risks that are interrelated and interdependent (Williams, 2017). At the same time, the increased interdependency of tasks, interdisciplinary between tasks to be done and iteration have all resulted in inseparable risks (Danilovic & Sandkull, 2005). Inseparable risks cannot be transferred or allocated to an individual to manage but would have to be shared collaboratively.

"…Inseparable risks need a great deal of time management and attention because these risks may prevent achieving the primary objectives of any partnership". "These risks are considered to have a show-stopping effect on partnership formation" (Structural Engineer 1).

These risks relates to the insufficient representation of qualified employees, affecting the potential of project stakeholders to frame the design objectives (Marle & Vidal, 2008). Inadequate technical capacities as well as a lack of information and a trained workforce pool, hinders the spread of green technologies.

"…Trust is a fragile emotion that could be lost in a short period of time, but this is where communication within the team is of the essence. Where one party feels that they experience dishonesty or discomfort, it is necessary to confront one another before the relationships is ruined" (Quantity Surveyor 3).

"…Collaborative practices require a strategic plan for cooperation - all stakeholders should have the project's goal as their higher priority. If there are little involvement and participation from other stakeholders, the whole process suffers" (Project Manager 2).

Since every stakeholder is responsible for their tasks, the need for accountability requires the project team to have a hierarchical structure with authority and decision-making capability to coordinate and align actions between all teams and stakeholders.

Design processes need to have a shared task performance system, including collaborative-based performance matrices to effectively monitor performance. This includes a common set of measures to record task performance, track progress towards outcomes, and to learn what is and is not working in the group's collective approach (Marle, 2010). Lack of performance data can impede the control of shaping the structures of time when performing a task.

"…The majority of consultants do not have any special training in risk management – their knowledge and experience are within the construction industry" (Risk Manager 2).

Lack of knowledge and awareness of risk management and the green technologies of design professionals have resulted in severe conflicts between stakeholders with the main dispute being the unclear allocation of the risks.

"…The BIM environment has not made it easy for other stakeholders who are not trained to use new communication technologies" (Development Manager).

BIM is a computer programme tool to mitigate risks and optimize designs (Hou, 2017). It needs stakeholders to be trained to communicate more easily. The system consists of three parts, BIM as the main information input, a knowledge-based system, and a risk identification module (Zhou et al., 2018). For risk identification, it has an Automatic Rule Checking machine-read rules automatically with results, for example, 'pass', 'fail', 'warning', or 'unknown'.

"…Economic factors are normally the highest priority for owners when new standards or technologies are introduced into the construction industry" (Sustainability Specialist).

"…Green building assessment tools are voluntary rather than mandatory" (Architect 2).

In South Africa, most of the green building technologies still do not have unified design codes and a standardized application process. This has also increased the difficulties of green building design assessment, thereby influencing the fairness. The knowledge and awareness of clients and end-users on building energy efficiency are also still a critical issue which needs improvement.

The major inseparable risk is the unfair distribution of liability and accountability and unequal distribution of profits and expenses between stakeholders.

Table 6.4 lists the different inseparable risks listed by the different stakeholders within their design tasks. Classifying inseparable risks is a significant step in the risk management process, as it attempts to structure the undividable risks affecting project stakeholders in their tasks. Moreover, coding these risks under three main categories arising from the literature studies establishes an interactive process to join efforts that will mitigate risks and related disruptions. Based on the successful GB designs, the successful execution of GBs requires dedication to the three categories of people, technology and process. These three, are complementary and synergistic, building on the measurement and constructs of CRM.

Table 6.4: Classifying inseparable risks

Risk Classification listed by respondents	Inseparable Risks – explained by respondents	Categories from the Literature

Lack of green competencies	**R1** - Sub-minimal information to proceed with task because of lack of qualified and experienced green designers **R2** - Inexperienced stakeholder on green and risk concepts because of company budget **R3** - Poor interdisciplinary information processing skills	**People focus (Stakeholder Interconnectedness)** *Osipova (2015) Establishing Cooperative Relationships*
Design variations	**R4** - Lack of information on the side of the client and rework on designs **R5** - No unified design codes and standardized green application process **R6** - Excessive and complicated governmental approvals	
Variations by the client	**R7** - Incomplete or inaccurate cost estimate due to wasteful modifications to cover GB works **R8** - Failure to meet green code or green certification requirements	
IT capacity and Knowledge management techniques	**R9** - Insufficient communicated design information resulting in incorrect models **R10** - Some information is lost when captured in digital models **R11** - Technology Management: human-to-human or human-to-technology interaction **R12** - Limited GB benchmarks to guide new projects and lack of green technology databases and GB management systems **R13** - No trained professionals on latest computer programs	**Technology focus (Interdependent Tasks)** *Doloi (2009) Importance of communication, trust and confidence*
Potential conflict of interests	**R14** - Complex contractual clauses **R15** - Ineffective communication among project stakeholders **R16** - Unequal distribution of profits and expenses between stakeholders	**Process focus (Interdependent Risks)** (Lehtiranta, 2013) *Improved RM performed by multiple stakeholders*
Unclear allocation of the risks	**R17** - Different stakeholders with different outlooks on risk management **R18** - Lack of understanding regarding collaborative risk management **R19** - Static risk allocation for a dynamic construction industry	

Shared insurance	**R20** - Delayed compensations after the risk has occurred **R21** - Poor service offered by insurance companies because of lack of insurance products to cover GB aspect	

Professionals in the built environment have an obligation to provide services that satisfy the requirements of approved codes as well as the additional requirements of their contracts. When those obligations are not met, problems arise. Green design is no different, except the standards are newer and, in many cases, more complicated; therefore, expectations are higher (Nutter, 2016). Careful attention to requirements, both by code and by the standard as for client requirements, have to be evaluated if they are achievable or not because there is always reputation impact if Green Star is not achieved.

CRM is necessary to correlate the project and task dimension in the risk management for collaborative innovation projects (Ding *et al.*, 2017). This creates an overview of risks that is recognized, acknowledged and supported by all stakeholders, and in which responsibilities are allocated and owned. Such a shared foundation creates transparency and develops trust with respect to the risks in a project.

6.4.2 How inseparable risk can be managed in collaborative circumstances

Stakeholders suggested co-location, where early involvement of the contractor and client would be beneficial to manage inseparable design risks, and the use of design management techniques. Co-location is the concept of placing all the resources of a project team in a single physical location so that the project can be completed in a good way. Co-located teams help to improve communication, productivity, and team relationships.

"…Building performance simulation tools are used to support stakeholders decision-making during the design process and the tools allow designers to analyse and evaluate their building projects" (Quantity Surveyor 3).

These techniques have evolved; they improve co-ordination between disciplines and exert managerial control over the design process. Proper and timeous information-sharing with proportional risk sharing approaches will inspire collaborative work for better technical solutions and help in avoiding many design risks (Du Preez, 2018).

"…There still is a shortage of green building skills" (Architect 5).

"…It is the responsibility of governments to dictate the rules, to define standards and to communicate them through strategic guidelines among the different stakeholders in the construction industry, with fundamental public transparency and economic incentives for both sectors in order to foster the green development of the construction sector" (Landscape Designer).

To overcome the traditional discipline-orientated attitude to design, all stakeholders should get GB accreditation training where attendees have the opportunity to discuss and become familiar with suitable practices of design and risk. The vital feature of interactive training assists in mitigating against the sub-minimal information to proceed with tasks because of inexperienced stakeholders. Clearly defined benchmarking performance on task completion will ensure that stakeholders demonstrate significant commitment, which is fundamental to a successful change system.

"…Risk management that optimizes all decision criteria - this includes taking into account multiple risk dimensions" (Architect 1).

"…Have a more systematic and formal approach to risk management and make use of the different knowledge and experiences of all stakeholders" (Structural Engineer 4).

"…Since complex projects require more attention to the risk management process, as a matter of practice, more advanced tools and better support from risk management consultants should utilized" (Project Manager 1).

"…Underwriters have yet to gauge the risks unique to green building and do not know how to price products covering liability in that market" (Risk Manager 1).

The notion of shared insurance for specific design risks was mentioned, so to balance the risks fairly between stakeholders in the absence of bad faith leading to a reasonable price, qualitative performance and the minimization of disputes (Mikapagaro & Germin, 2018). This will dedicate specific contingency budgets and reserve margins to each risk area. Also, using a project risk manager to evaluate risk, identify potential cost impacts and develop contingency plans.

"…Many disputes arise from miscommunications and misunderstandings on roles, responsibilities, and limitations that could be lessened by using precise contract language" (Quantity Surveyor 2).

The contracting parties should define the scope of the work clearly, schedule, design performance expectations, certification levels and risk allocation in their contracts (Sastoque *et al*., 2016). Stakeholders suggested contracts negotiation and communication as critical to ensuring that all parties perform their respective design tasks adequately. To manage inseparable design risks, stakeholders proposed regular team meetings including the client, proper and timeous information-sharing with proportional risk-sharing approaches. One approach could be an uncertainty allowance.

"…There should be on-going value engineering workshops to promote flexibility and comfort" (Green Design Engineer 2).

The process uses structured, team-oriented exercises that appraise and make clear existing or generated solutions to a problem by reference to the value requirement of the client. With the increasing demands of the design phase in green buildings, many things can go wrong with teamwork. However, value engineering fosters the use of group decision support systems, which provide technological efficiencies and interaction advantages that can overcome some of the difficulties frequently encountered in large teams.

Respondents also require an environment where data can be stored and organized so that individuals and teams can access it easily, evaluate it using intelligent systems and tools, share that analysis with colleagues and act on the findings easily. Such an environment would be integrated and built on a scalable infrastructure; necessary to allow distributed knowledge-enabled software components to thrive and grow across the entire project.

"…Incentive schemes should not be the main driver; instead making people work together should be based on respect" (Architect 6).

Effective collaboration is claimed to lead to fewer disputes, lower design task iterations and a better quality building (Ayegba *et al.*, 2018). The case studies showed that it is important to note that the partnering concept demands high professionalism and very good knowledge of the design principles on the part of the stakeholders. It is: "…*an embedded practice, constructed through individuals' social interaction to support unlearning of old routines and behavior"* (Architect 6). Requiring social interaction between stakeholders should not be restricted, as it will enhance the working relationships.

Some respondents do not consider formal partnering or collaborative arrangement as necessary condition as long as its principles can be put into operation. Overall, the view of a collaborative relationship socially constructed and evolving is most important. Risk sharing in these situations would be by, the stakeholders' decision on appropriate risk sharing and done based on the ability (efficiency) and willingness (fairness) of the stakeholders to manage risks and bear the associated risk consequences (Apollo *et al*., 2018).

The need for the formation of risk sharing, ability to manage inseparable risks and its associated consequences is determined by the knowledge, resources and experience of all stakeholders by which the risks are shared to achieve optimal risk sharing ratios.

6.5 Summary

A process of a stakeholder relationship assessment, where interviews were conducted to get views from GB design stakeholders about their strong interrelated actions in their tasks that have resulted in the existence of a network of inseparable risks was determined. A total of 29 semi-structured interviews with different practitioners were conducted to understand the current risk sharing practices and the way inseparable risks can be managed in collaborative circumstances.

In the next chapter, the case studies will link the two methodologies to provide more insight for theory development and understandings of the CRM phenomenon. Case studies are suited for capturing activities and stakeholders' conducts that have taken place in an authentic context, allowing the researcher to take a deeper look on stakeholder and tasks interdependencies. And, the use multiple case studies allowed for the researcher to learn different and unique things from different perspectives. Furthermore, triangulation assisted in new ways of understanding inseparable risks and how to balance the two methodologies outcomes.

7. STAGE 2-CASE STUDIES PRESENTATION AND ANALYSIS

7.1 Preface

This chapter presents and analyses the data obtained from the information gathering conducted in different case studies. Linking these case studies to the interview outcomes will contribute unique insight on the stakeholders' experience with CRM and the trends used in GBs. The research aims to investigate how CRM can enlighten the construction industry in its heuristic in nature, by gaining knowledgeable views from multiple perspectives.

The clarity in the alignment of this research was fundamental to ensure the authenticity of the research by using coherent processes, to obtain corroborating evidence that can transform the theoretical lens into a developed theory. During this process, an abductive reasoning described the data reduction process by explaining inconsistent and surprising empirical findings against a background of multiple existing RM theories.

7.2 Multiple Case Studies

Case study research is the study of the particularity and complexity of a single case, coming to understand its activity in important circumstances (Stake, 1995). This research examined four case studies and related them to each other. In each of the case studies, interviews were used, which was a highly flexible method that could produce data of great depth (King, 1994) and experiences related to the case study.

Case study research is a qualitative enquiry, which encompasses exploratory, explanatory, interpretive, or descriptive aims (Merriam, 2009). For this purpose, the research could use a broad scope of methods and interpretative practices to analyse the respondents' words. In the interviews, the researcher had to capture the individual's point of view, by examining the constraints of everyday life and securing detailed descriptions (Harrison *et al.*, 2017).

The respondents were from the different case studies and included referral individuals who too, have dealt with GBs as shown previously in Figure 5.5. That, when solving design problems that have a holistic approach due to their integration in design, different stakeholders face complexities and task interdependencies which resulted in inseparable risks. In this instance, the case studies would seek to understand the lived experiences among different stakeholders who have a common experience of GB construction.

7.3 Description of Design Phase Projects

The projects used as case studies in this research are located in Johannesburg and Cape Town.

The Johannesburg project is a forensic pathology laboratory; the design of this facility is meant to consolidate the green requirements to yield modern, purpose-built academic forensic pathology laboratories to replace the existing facilities in Johannesburg, which have become over-utilized and outdated.

The Cape Town project is an 11-storey luxury retirement apartment building, consisting of 58 apartments, two parking garages. This building is specifically designed to cater for the elderly, with wide corridors and door openings, nursing facilities and extensive landscaped gardens.

7.3.1 Description of case study 1—academic forensic pathology facility

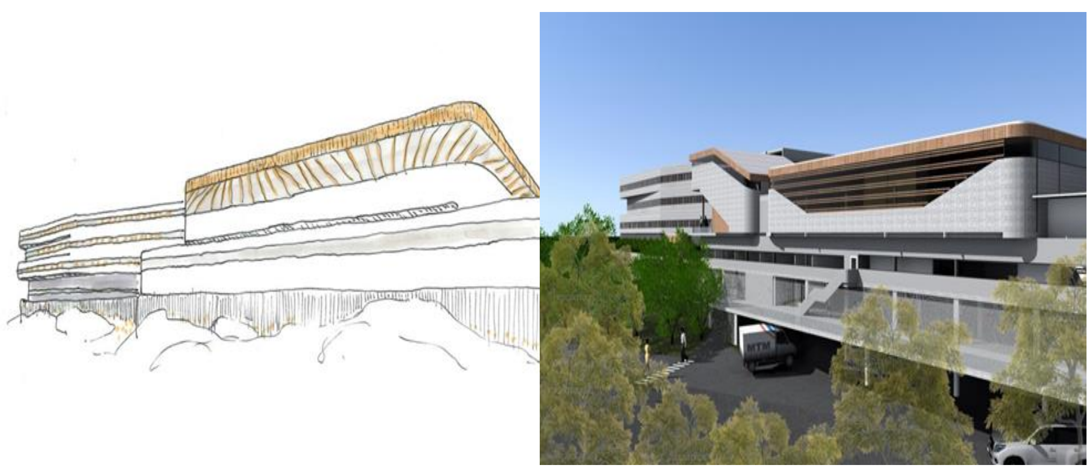
Project requirements: Construction of a forensic pathology laboratory consisting of a three-storey building with a basement.

Project value: The contract was worth approximately R625 823 293.05 (cost including VAT).

Client: The Department of Health jointly with the Gauteng Forensic Pathology Service and the University of the Witwatersrand.

Picture 7.1: Architectural design sketches of the front view of the pathology laboratory

Picture 7.2: Architectural design sketches of the back view of the pathology laboratory



This new facility will have a construction area of 32 225 m², providing integration of the Gauteng Forensic Pathology Service, the academic training provided by Wits University and the Forensic Pathology Service Management offices. To ensure that the final design meets the specified needs of the Department of Health and Forensic Pathology Services, the Gauteng Department of Health was also involved in all the programming and design stages of the facility.

This facility is graded as an M6A Academic Forensic Pathology Laboratory and will serve to collect and admit unnaturally deceased bodies when called upon to do so. In addition, it will be used as a Biosafety Facility of Level 4 (BSL 4) for the use of bodies with dangerous and highly contagious agents.

During the bid evaluation, the expertise of green building construction as well as collaborative abilities, were considered and the contract was awarded to a CIDB Grade 9 contractor, meaning their annual turnover is over R130 million. The collaborative abilities included an effective approach for achieving efficient innovation. The technological complexity and diversity of incentives for green buildings require that innovation involve a joint effort from various areas, such as materials, energy, and waste disposal.

In terms of the uncertainty sources identified by Atkinson *et al*. (2006), the project team did not have any previous experience of working with each other. All stakeholders were appointed by the Department of Infrastructure Development's supply chain. Collaborative culture, norms and practices took time to develop; this implied problems in the context of time-limited projects. Total engagement and interactions directly with day-to-day personnel on the design and construction team was a new experience for the department officials. On previous projects, they were asked to sit in on presentations or in a review of a conceptual design drawing but did not have full involvement. In this project, openness to understanding their priorities and needs was accommodated. To deal with the project team's uncertainty, a relationship-building workshop was organized when the project started. During the workshop, joint objectives to accommodate contractual flexibility were formulated; documented and signed by the client, all the consultants and the contractor.

Contractual flexibility is the ability of the contracting parties to make adjustments that achieve expected outcomes when faced with project uncertainties (Nystén-Haarala *et al*., 2010). This was observed as flexibility in contractual terms and flexibility in the contracting process was important. Flexibility in contractual terms referred to the quality of cost estimates, payments terms, schedule and incentive mechanisms as flexible elements in contractual documents that are negotiated between contracting parties. Flexibility in the contracting process referred to favourable relationships, mutual trust and effective communication between the contracting parties. Necessary risks were considered using CRM workshops, but they focused on the construction more than the design risks. Then again, contractual flexibility allows stakeholders to address unforeseeable contingencies; design risks will be added in a later stage.

During the relationship-building workshop, the factors of appropriate leadership style, facilitation, training and a shared commitment to continual improvement were also emphasized. Project stakeholders also viewed these workshops as beneficial since they promoted: "…*total group collaboration*" (Quantity Surveyor 1); "…*views from all partners*" (Structural Engineer 1); "…*hearing all voices*" (Client 1) and encouraging "…*sharing common interests*" (Contractor 1) concept.

The frustrations of the team were with the client's budget regarding the incorporation of green elements to the project. There were also many variations from Wits University concerning the operational spaces and lecture hall sizes. In the meantime, the team was working hard in installing the latest technologies to enhance efficiency in the building and reduce energy consumption using a range of initiatives.

Bureaucracy also impacted the project because the project partners are local government departments whose habits of slow operation are deeply ingrained. Many of the operational decisions have to be approved by the relevant government officials, which may cause the development of the project to be very complicated and inefficient. To avoid this risk, the project team, especially the project manager, adopted strategies of maintaining close relationships with these government officials and communicating with them as much as possible, and at the same time recording everything in writing.

7.3.2 Description of case study 2—retirement apartments

Project requirements: Construction of retirement apartments consisting of an 11-storey building with two elevators, ample basement and open parking bays.

Project value: The contract value is estimated to be R105, 000 000 (cost including VAT)

Client: Rabie Property Group

Picture 7.3: Architectural design sketches of the front view of the retirement apartments

These retirement apartments ranging in size from 94 to 247 m² and including terraces are priced from R3.4 million to just over R10 million, VAT inclusive. The design of these apartments considered accessibility, aesthetics, cost-effectiveness, functionality, productivity, health, history, safety and security, and sustainability. Green strategies such as conserving energy and water, selecting the right materials, focusing on durability and ensuring great acoustical comfort are incorporated. A flexible design was used and involved what is called long life; this design principle anticipates and allows for future adaptations needed to extend the useful life of a building.

For this project, knowledge was identified to be a significant organizational resource and was used to provide a competitive advantage. There was a lot of emphasis on how to identify, capture and share knowledge between the project stakeholders. However, this project was not initially labelled as a collaborative project; yet the key elements of collaborative systems were observed.

The client modified the existing procurement process to be similar to the Integrated Project Delivery (IPD) team selection. The client solicited self-selected teams that were to respond jointly to a request for qualifications (RFQ) and develop a proposal. The members of these self-selected teams included the architect, engineers, quantity surveyor, construction manager and commissioning agent. They were also strongly encouraged to include mechanical and electrical trade contractors. The client created a screening committee of design and project managers, end-users, building operators, and administrators to review each document submission.

The procurement process required three document submissions from competing teams over six months, (1) a response to the RFQ, (2) a detailed technical proposal, and (3) an initial design concept. After reviewing the documents at each stage, the screening committee used a down-select process to narrow their potential options. Six self-selected teams responded to the RFQ, from which the screening committee identified two of the most qualified teams. These teams successfully conveyed their expertise to the screening committee and were perceived to have a: "*...genuine passion for working in collaborative project environments*" (Project Manager2).

Both teams then prepared an initial design concept submission. The design documents were reviewed, followed by an interview presentation made to the screening committee, and a final team was selected.

The selected team had to use a workshop format, stated by the client, to gain more intimate knowledge of the project and the overall goals and requirements of the programme. The letter further stated that the team should use the workshop to evaluate and improve its leadership potentials, team chemistry, and collaborative nature of what IPD entails.

The workshops were also used to setup for design explorations, one for programme and layout, one for sustainability, and one for technology and construction logistics. Members of the screening committee were asked to choose their table. Lastly, the information gleaned from the workshops was used to develop a design concept and this team excelled at creating a two-way exchange of information.

The client's goal of conducting these workshops in IPD team procurement was to use authentic face-to-face interaction to assess working relationships in an unrehearsed setting. While these indicators could be considered traits, they should not be labelled as such, since the data is based on the selection process, not the performance of the overall project. The indicators that emerged were identified as (1) total engagement, (2) a focus on customer value, and (3) emphasis on interdisciplinary interactions.

7.4 Description of Completed Projects

The Victoria and& Alfred Waterfront (V & A) is a centuries-old working harbour remaining at the heart of a modern, cosmopolitan urban precinct. The Silo District is the re-imagining of a historic grain silo into the internationally anticipated Zeitz Museum of Contemporary Art Africa (MOCAA). This silo is an urban, waterfront living area built over a collection of three cylindrical chambers that have a multitude of unique apartment types with different spaces, orientations and views magnified by projecting window boxes from which to watch different sceneries; collaborated with the MOCAA and situated in Cape Town. The spaces between these chambers house the vertical circulation for the building and provide spectacular views of the city, Table Mountain, the working harbour and the port.

Another completed project is a commercial development in central Sandton, Johannesburg, developed by Zenprop Property Holdings. It incorporates sustainable design features such as rainwater harvesting, treatment and reuse. The building's highly-engineered, fully glazed facades and favourable orientation allow for the maximum natural lighting possible while restricting glare and heat transmission. The 27 000m² of P-grade office space is housed in two-linked towers constructed on a landscaped podium. This development offers 1400 parking bays in its eight basements, seven of which are below ground. The development incorporates a variety of staff facilities including a crèche, a gym and health studio, prayer rooms, a beauty parlour, physiotherapy rooms, a 200-seat auditorium, state of the art AV meeting rooms, staff training rooms, a fully integrated caterers kitchen and canteen, coffee shop, bar and wine cellar.

7.4.1 Description of case study 3—apartments and a museum

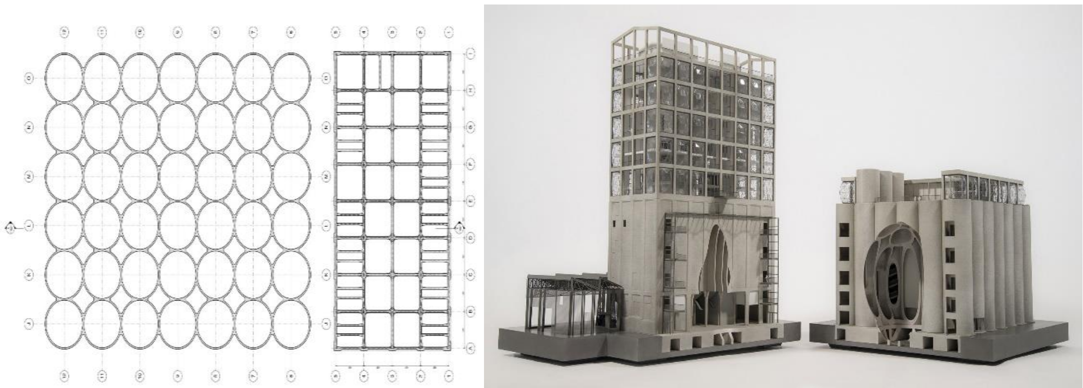
Project requirements: Construction of the international Zeitz Museum of Contemporary Art Africa and 79 residential apartments, six floors above the museum.

Project value: Growthpoint Properties and the Public Investment Corp invested R500, 000 000 for this project.

Client: Growthpoint Properties and the Public Investment Corp.

Picture 7.4: The old and new silo buildings

Picture 7.5: Architectural design sketches of the silos building



The scope and diversity of the V&A Waterfront's growth are showcased across a variety of residential, retail, commercial and leisure developments. This modernization of the wharf, is a joint effort owned by Growthpoint Properties Limited, the Government Employees Pension Fund (GEPF), the Public Investment Corporation Limited (PIC) and the state-owned transport corporation, Transnet Limited.

The original building was composed of two main elements, a grading tower and a block of 42 tightly packed silos. The museum took on the challenge of converting the multitude of concrete tubes into spaces to display art while retaining the silo's industrial character. The perimeter tubes were then, substantially cut back and converted into five floors of galleries for permanent and temporary exhibitions.

The design ensured that the necessary environmental response for sustainability is achieved without compromising the utility, comfort or aesthetic quality. Focusing on the challenges of climate change, energy and water scarcity; also supporting good health and comfort. It was awarded the 4 Star Green Star SA – Multi-Unit Residential v1 Design Rating.

It is widely accepted in the construction industry that many client customer interfaces and the imprecise allocation of risks have long hampered traditional procurement (Xia *et al.*, 2017). Designing an appropriate contract from the outset was perceived as a key enabler for collaboration. "…*Contracts that foster collaboration*" (Quantity Surveyor

4) allows for the legitimization of a collaborative environment in a project. The use of a collaborative contracting procurement strategy provided a degree of confidence concerning managing project uncertainty, together with a reduction for contingency provision typically witnessed with traditional procurement methods. A collaborative strategy encouraged and cultivated the development of a non-adversarial collaborative working environment.

Apart from creating the unusual museum atrium space, the biggest problem with the project was the budget, a source of uncertainty. After the project was started, it transpired that the design was too optimistic, and the costs were going to increase significantly.

The project team uncertainty arose from the blend of the UK lead designers with South African designers. Besides operational risks, the project had to deal with international risks, which include cultural understanding and work practices. Multi-party workshops as key activities in assessing options to achieve the required fitness for the project's purpose and quality standard were conducted; this fostered a more systematic approach to value engineering and management and risk management.

After the contract was awarded, the client requested a partnering approach with the contractor. Project contracts can enable and facilitate stakeholder communication and action, and affect negotiations (Koskinen & Mäkinen, 2009). A partnering facilitator was invited to lead collaborative activities and team-building workshops throughout the project. The changing and complex environment of this project required collaborative practices to address foreseeable uncertainty. In these workshops, a framework for co-operation was provided, rather than a hard and precise risk and reward allocation agreement.

However, an appropriate contract structure, with clear and equitable contractual terms, does not ensure project success because the attitudes of the contracting parties and the relationships among the stakeholders are also equally important. However, financial discussions between the client and the contractor resulted in a conflict, where stakeholders then tried to protect their interests instead of finding the best possible solutions. In collaborative teams with common goals, conflicts may still arise even though there are no actual contradictions in objectives (De Dreu, 2007). In this project, conflict was related to contracting parties' behaviours and was closely associated with project success.

7.4.2 Description of case study 4—commercial development

Project requirements: Construction of the P-grade office space with 1400 parking bays in its eight basements, seven of which were below ground. This building consists of a ten-storey North Tower and fourteen-storey South Tower.

Project value: R560 000 000

Client: Zenprop Property Holdings

Picture 7.6: The architectural design sketch and the finished commercial development building

Picture 7.7: The construction and the finished commercial development buildings

The project consists of a ten-storey North Tower and fourteen-storey South Tower awarded with a 4-Star Green Star SA Office V1 Design certification, offering exclusive landscaped roof terraces on the 8th, 9th and 12th floors. The efficient use of space for 2500 people involved creating state-of-the-art work facilities and upgrading the technology services, with added security.

The design warranted a flexible building, hence the large floor plates, punctuated by two atria to maximize the natural daylight into the office spaces. The north-west orientation of the site also influenced the design with the powerful scalloped elements to capture north and south light and protect the building occupants from east and west light. Other sustainability features included the use of renewable materials such as bamboo, the extensive use of low VOC paint, grey-water collection, the integration of passive heating and cooling systems, waste recycling and planter walls constructed from off shutter concrete.

The client's organizational structure promotes innovation and this reflects in their business strategy. They have implemented a system called Innovation Forum where an employee can submit an idea to the forum and, if it is accepted, he or she receives a small incentive in return. As a result, for their project, they required a cohesive, integrated team that would be successful.

The project team explored options of their management structure collaboratively and from multiple disciplinary perspectives since their project was challenging in scope and technical needs. Therefore, they established a project Intranet system for information-storage, which hosted information such as daily notices, contact lists, standard forms, health and safety information, QA documents, standard work procedures and various other kinds of commonly used information.

This information-sharing platform was updated regularly, so stakeholders in the project did not have to "…*reinvent the wheel*" (Architect 2) when identifying innovative solutions to solve problems of varying project complexities. Besides, the client wanted the stored information for future use, fearing the risk of losing valuable knowledge and thus repeating the same mistakes.

The information-sharing platform was also created in a way that all project stakeholders could comment or update documents to new versions. This meant a learning curve associated with a project because a significant amount of training, dedication and resources were required to implement such a solution across all stakeholders and their organizations. However, even though much time was dedicated to information storage and capturing, it still emerged that even when identified as important, it is not simple to implement a system to manage tacit knowledge.

The project programming issues were discussed in workshops facilitated by a green consultant as well as a BIM consultant. These workshops also included the client and the end-users do most of the talking, with occasional interjections by the facilitator to steer the conversations. In this project, all partners were relatively satisfied with the performance of the other partners. Once they became familiar with their partner's organizational culture, they then preferred to have long-term relationships and planned to collaborate for prospective future projects.

These workshops also influenced the team's understanding of the client's goals of making use of information technologies and integrated team, agreements. This move to a more effective partnership required a change in concepts and tools. Concept changes involved alterations in beliefs, attitude to openness, trust, commitment and compromise. Tool changes needed implementation of novel and innovative tools, management techniques and frequent meetings to achieve better collaboration and cooperation.

The project team also suggested frequent meetings with the partnering committee to prepare a partnering agreement, choosing appropriate project delivery methods, developing the project organization chart, preparing clear definition and understanding of responsibilities and fair allocation of risk and benefits before the tender, as this would help to improve performance.

They agreed that in a collaborative approach, partnering success or failure depends on co-operation between partners. Consequently, any partner's mistakes will affect the other organization's reputation and income. Generally, a partner performance measure is directly affected by selecting a suitable partner.

The major partnering motivations identified from the respondents were (1) improvement in construction quality, (2) cost reduction, (3) willingness to enter new markets and gain market advantages, (4) cover the weaknesses of the organization and enhance strengths and the knowledge of engineering, (5) risk sharing and (6) innovation.

The major problems with implementing partnering were perceived to be (1) dealing with large bureaucratic organizations resulting in slow decision-making; (2) difference in partners' cultures; (3) stakeholders not developing a win-win attitude; (4) lack of training and guidance in the project partnering; (5) little experience with the partnering approach and (6) risks or rewards were not shared directly.

7.5 Case Analysis

Case analysis was done to investigate the unique patterns of each case (Eisenhardt, 1989). The analysis focused on how each project managed CRM practices, while answering similar questions asked to all interviewees, with further probes. An analysis of the sources of design risk, project risk management process, collaborative activities and the design process results were achieved. Second, cross-case analysis was performed to examine similarities and differences in the projects. Based on the categories presented by Burns and Stalker (1961) and Geraldi (2008), comparisons on how different risk management systems were used in the completed or design phased projects affected CRM.

7.5.1 Characteristics of case studies

Setting up and maintaining a team collaboration environment is a very important task in collaborative design processes (Alreshidi *et al.*, 2018). The use of integrated patterns in a collaborative work environment enabled teams to bring multi-disciplinary knowledge and skills. This is a requirement of sustainability which usually needs the expertise of stakeholders in risk management due to the unique problems associated with green constructions. These engagements facilitated collaborative decision making by providing transparent information to stakeholders and increasing the number of options to be considered. This is particularly motivating as green projects always seek a near-optimal building performance related solution (Owoha *et al.*, 2021).

Flexibility has been increased in green buildings as it allows the use of model data to iteratively run various and more detailed sustainability analyses in different design alternatives without overly compromising setup time, thus contributing to a better design in terms of performance and environment impacts (Liu *et al.*, 2017). To accelerate CRM activities, additional arrangements had to be implemented, such as the collaborative pre-project meetings, CRM workshops, and performance benchmarking and shared bonuses.

Experienced personnel to overlook the collaborative applications in the projects facilitated these meetings and workshops. Another step to implementing an integrated project team was to select an experienced green or BIM consultant or project manager during the project’s feasibility stage. The green consultant could also assist with pricing and developing cost-saving strategies in areas that seem to be lower priorities.

Communication tools were used to facilitate collaboration across the team and to make decisions during the communication process. Emails were the communication tool used most often, followed by mobile phones and then face-to-face meetings. However, as the degree of project complexity rises, it gets harder to ensure the adequacy of the information flow by human-to-human communication.

The current methods of sharing and exchanging data among the project team showed that there is a strong dependency on using email for sharing and exchanging design data; followed by the use of a shared storage drive hosted by a company network. Other projects opted for an information-sharing platform to capture data by more than one person, with the common goal of contributing to joint information processing activities. The use of cloud storage solutions such as Dropbox for these projects was greater than the use of paper and flash storage devices.

The collaboration was mediated by both physical and virtual co-location practices. Teams however, were still more effective at collaborating when physically co-located. This proposed key areas for distributive work, common ground (common language), collaboration readiness, collaboration technology readiness, coupling of work, and organizational management. Depending on the expertise of the team members and their relative comfort level with collaborative technologies, some teams do find virtual co-location effective (Bjørn *et al*. 2014). However, the variety of technological expertise in the AEC industry, lack of common ground among team participants and clients and highly coupled work indicates the AEC industry is not yet able to collaborate effectively with virtual co-location technologies and may be better suited to physical co-location collaboration for certain design tasks.

CRM is an interactive process of strategy formulation, identifying and assessing risks, differentiating risk factors and formulating and implementing appropriate measures (Keers & Fenema, 2018). Collaborative risks are an integral part of the overall design processes; they are tightly coupled and form a domino system where client variations will be a resultant of design variations leading to erroneous cost estimates and eventually to tight project schedules, delays in payments and everybody suffers. Consequently, group decision-makers in the design process should be responsible for their decisions and their consequences. **Table 7.1** is a cross-case analysis to examine similarities and differences in the projects. Adopted from the categories presented by Geraldi (2008); Osipova, and Eriksson, (2013), but amended to suit the case studies and thus compare the different risk management systems used; and how these affected CRM.

Table 7.1: Comparison on case studies from a systematic perspective

Case Study Facets **(Themes from the interviews)**	***Forensic Pathology Facility***	***Retirement Apartments***	***Apartments and Museum***	***Commercial Development***	**Project Characteristics**
Contract- definition of the rights and obligations	✓	✓	✓	✓	Contract obligations were pertinent in all projects
Hierarchical structure of control — the client has a strong control function	✓	✓	-	✓	Whilst the client still has strong control, on one project, the end-user had more control
Collaboration – Stakeholders' understanding	✓	✓	✓	✓	Collaborative design management processes and Co-production
Project manager - provides instructions and decisions	✓	✓	✓	✓	Culture - meeting client expectations
Special knowledge and tasks – contribution to knowledge	✓	✓	✓	✓	Collaboration with Co-production = Efficient exploitation of varies knowledge and expertise

Risk knowledge- understanding the importance	-	✓	✓	✓	Not all project stakeholders understood the need for risk knowledge
The sharing of responsibility - communication structure	✓	✓	✓	✓	Collaborative Management on Communication channels and team well-being
Physical and virtual co-location practices	✓	-	✓	✓	Co-location - Space utilization and flexibility that benefits the design activities
Common knowledge – on risk sharing	-	-	-	-	Stakeholders still do not agree on optimal risk sharing
Technology management – human-to-computer interactions	✓	✓	✓	✓	Effective innovative technology improves processes and incorporates new ideas which generate changes
The emergence of new roles – BIM manager, sustainability specialist, commissioning agent, risk manager	-	✓	-	✓	Other new roles are-partnering facilitator, green building consultant, Big data or Block-chain system designer

Although collaborative teams were more open to sharing information and knowledge to be more effective in foreseeing changes in the highly dynamic design environment, their openness to risk sharing is less so. Collaboration does not always eliminate the underlying adversarial attitude. The beginning of the design phase may have stakeholders agreeing on risk sharing terms, but projects evolve, risks change, and CRM processes may not be revised accordingly (Mendez *et al*. 2016).

Some of the respondents from the case studies (46 %) wanted project managers to be responsible for preparing the project's collaborative environment. Others (28%) wanted the setting up of the collaborative environment to be the risk manager's responsibility as they will know more about risks. Others (16%) wanted a BIM manager to be responsible as they would know about all the data stored. Everyone else (10%) wanted all stakeholders to be responsible.

In terms of technology-focused issues, the effects related to IT capacity and technology management, most of the personnel participating in training programmes are young staff members who have insufficient risk experience. This trend has resulted in young staff members with little experience in risk but skilled with technology tools.

Furthermore, in collaborative ventures, stakeholders come from different industries and have different organizational systems and cultures. As a result, it is difficult to build the relationships spontaneously between them after proposing the risk sharing actions.

7.6 Interviews and Case Studies Data Synthesis

Triangulating the interview replies with the case studies for corroboration of consistent findings on inseparable risks that cannot be avoided by stakeholders in the collaborative design process is the style of enquiry for advancing theory. Based on the interview replies, failure to manage inseparable risks adequately may not only lead to difficulties in meeting project objectives but miscommunications and misunderstandings on roles and responsibilities may also arise.

Table 7.2 shows the types of risks shared in collaborative practices and the views of risk sharing by different stakeholders interacting in a design phases of different projects. The broad themes of the type of risks are constructed from the interviews as they formed the primary source of data for case research. This allows the researcher to modify initial themes with the results from the cases.

Table 7.2: Types of risks shared in collaborative practices

Types of risks shared in collaborative practices (Themes from interviews)	**Results of the Risks**	***Forensic Pathology Facility***	***Retirement Apartments***	***Apartments and Museum***	***Commercial Development***	**Risk Sharing Consequences**
Time and cost	**Delays in time** **Cost overruns** **Cost increases and returns**	Cost risk if budget found to be inadequate	Responsible for ensuring the project is delivered within budget	Additional costs caused by green construction	On-time design, construction and occupation of the building	Stakeholder lacked information, lack of awareness or expertise to achieve a sustainable measure
Quality and technical	**Outcome quality** **Technical barriers** **Material availability**	Reduction of structure aesthetic	Misunderstanding of green technology operations	Responsible for ensuring the project is delivered to green building quality standard	Ensuring construction safety when working on some green features	Waste minimization One sustainability measure was forgone to achieve another
Organization and management	**Organizational structure** **Knowledge management** **Contract management**	Green building promotion and social responsibility	Project contract type and project construction practices	Clients' knowledge and willingness Differences of the know-how between stakeholders	Green products and the final work satisfies green building quality standards	Limited availability of green suppliers and information
Policy and standards	**Regulations and standards**	Need for standardized approval process and	Uncertain governmental policies	Lack of quantitative evaluation	Lack of green regulations/ standards	Tender selection mechanism to choose

	Health and safety **Environmental factors** **Project sustainability**	policy on green building design and implementation		tools for green performance		experienced green building contractor and suppliers
Economic and reputation	**Change in the cash flows - volatility** **Changes in the service demand** **Ethical issues**	Transparent green building assessment standards	Brand publicity Early entry to new market	Conflicts in benefits with competitors	Economic return Exchange rate fluctuations by importing green materials	The maintenance cost should be within budget Green Star achievement
Design	**Scope variation** **Stakeholder coordination** **Failures in the construction** **Unproven engineering techniques** **Inadequate insurance**	Design deficiency Project feasibility Financial viability Delay in regulatory approvals for new green requirements	Apply green building incentives Complex planning approval and permit procedures Changes in weather - durability of green materials	Strict safety and health regulations Inefficient communication and coordination	Use of new construction method and technology Project teams without relevant knowledge Suitability and shortage of green material	Energy-saving from green design Experience in green design and project management Assessment experience and fairness

Risk sharing is a way of handling risk whereby the decision does not go deeply into the method of handling risk itself, but instead discussion is held on the most effective way of handling the risk or selecting for the most economical way of sharing in accordance with the characteristics of the risk. Authors such as Florial and Miller (2001) suggested establishing shared financial safety reserves for mitigating crises when they happen and others such as Zaghloul and Hartman (2003) emphasized adequate risk sharing to be the kind that would give benefits to risks not occurring in all parties during the design processes.

However, according to Banaitine and Banaitis (2012), the achievement of objectives on design processes require of the risks that would face the project being addressed properly. Despite having several risk response strategies, designing construction projects still requires stakeholders to defend their interests actively (Mikapagaro & Germin, 2018). Designing green buildings introduces a level of complexity that requires enhanced stakeholder involvement that can help with managing their needs, decreasing unexpected risk and reducing unconstructive actions or reactions that have a possible impact on project success. With the intention to improve CRM in the design phase of GB, a causal linkage between the proper implementation of risk management and project success is considered.

Therefore, decisions on the appropriate risk sharing between the parties to the contract will be made based on the ability and willingness of the parties to manage risks and bear the associated risk consequences. Ability to manage risks and its associated consequences is determined by the knowledge, resources and experience of the parties to which the risks are transferred. According to Kordas (2015), to minimize contingency costs of building projects, there is a need for the formation of risk sharing agreements between parties to obtain the optimal risk sharing ratios.

7.6.1 Risk and stakeholder management processes

"…In reality, scope changes with time; warranting reconsideration of contracts to adapt to the new conditions"- *"…renegotiating which is mainly related to sharing the financial benefits of projects"* (Project Manager 2).

It is impossible to study risk management without understanding the perceptions of project stakeholders about risk and the risk management process (Hartono *et al*., 2014). Most of the respondents see risk as a negative event that can affect the project and cause problems. Project systems are in essence, risky and their risks are interrelated, meaning that they are dependent events. This causes issues in decision-making when decisions are to be made about the prioritization of risks and the risk mitigation actions.

"…*Everybody must do their own (risk management). We do not have trust among each other"* (Contractor 1).

"…Each stakeholder should determine the amount of risk they are willing to take according to their expected returns" (Structural Engineer 3).

"…When some managers lack formal risk management knowledge, project risks cannot be managed – as anticipated" (Architect 2).

"…Conflicts between stakeholders are when project objectives are not able to reach consensus" (Project Manager 1).

A green building design phase fosters complex relationships between all stakeholders who have to combine their efforts to achieve the overall common objective of the design. While some of the different comments identified above have been discussed in the literature, the stakeholders' interrelations concerning inseparable risks have been less addressed. **Figure 7.1** shows the process of a stakeholder relationship assessment, where interviews were conducted to get views from GB design stakeholders about the strong interrelated actions in their tasks that resulted in the existence of a network of inseparable risks. Existing methods such as the DSM for dependency modelling are employed to evaluate stakeholder interactions and their task interdependencies while identifying inseparable risks and thus, finding mitigation suggestions.

Figure 7.1: Stakeholder relationship assessment

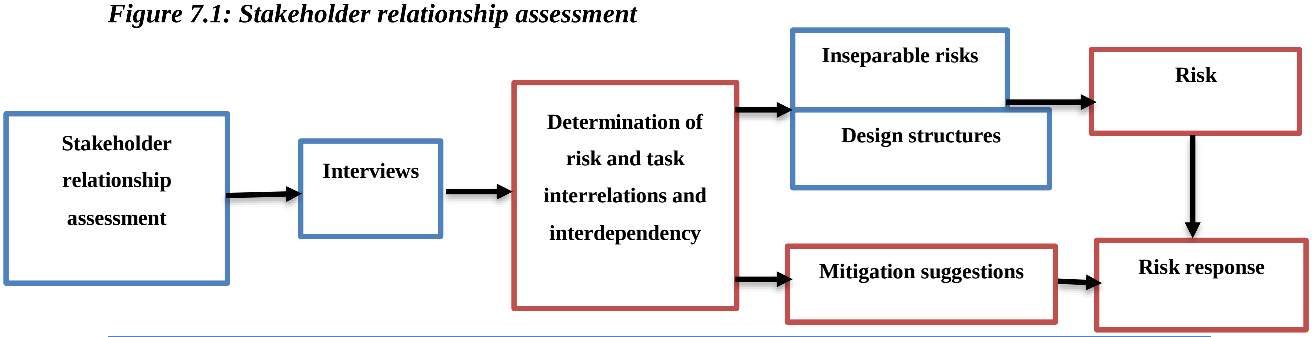


Table 7.3 shows a resulting matrix that determined the dependency relationship between the identified project stakeholders and their risks for a design process. This identification of the stakeholder interactions defines the structure of inseparable risk networks. The interviews were analysed by plotting the information and mapping out interdependencies between the stakeholder and the RM activities. This matrix captured the interrelationships among various stakeholders on specific RM tasks. The purpose of this matrix is to illustrate the interactions capturing procedure, which can be adopted when using DMM and its useful contribution in the process of uncertainty reduction and management.

Table 7.3: Collaborative activities

Collaborative activities	Owner	Architect	Quantity Surveyor	Structural designer	Electrical designer	Mechanical and plumbing designer	Fire protection designer	Main contractor	Sub-contractors (Mechanical, Plumbing, Electrical, Fire)	Process and technology manager
Determine reciprocal responsibility of stakeholders	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Determine how to allocate benefits and risks	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Establish mechanism of conflict coordination	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Analyze functional requirements of the design		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
Determine design criteria for each specialty		**x**	**x**	**x**	**x**	**x**	**x**	**x**		
Determine standards for exchanging BIM data	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**
Determine time control points for design tasks	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Examine the schedule jointly	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**

Examine the site design jointly	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
Considerations of environmentally safe methods of construction		**x**	**x**	**x**			**x**	**x**		**x**

Interdependencies of varying strengths are identified across activities and by clustering; this DMM identifies areas between tasks and stakeholders that require a high level of coordination and integration. Interfaces between these activities indicate the stakeholders who must communicate to transfer information. However, inseparable risks still need to be allocated to design processes.

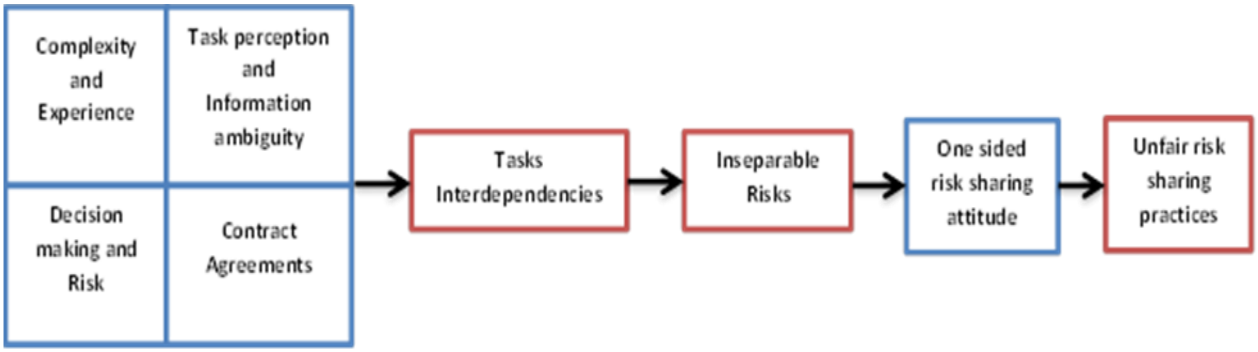
Moreover, it is important to ensure that the positive outcomes of these collaborations are maximized to enable all stakeholders to increase value in their tasks rather than endless disputes due to flawed contracts and misleading estimations.

7.7 Solutions to Remedy the Effects of the Current Risk Allocation Practices in the Construction Industry

Current risk allocation practices have interdependent tasks that have led to inseparable risks, which ultimately result in an unfair risk-sharing situation.

Figure 7.2 shows that inappropriate risk sharing has led to adversarial relationships between contracting stakeholders. Contracts are all-powerful in defining the relationships between stakeholders and in governing their future interactions with one another, if they are drafted and negotiated by parties who understand the design processes and how contracts may be used to facilitate the resolution of disputes or to avoid the occurrence of disputes in the first place.

Figure 7.2: Interdependent tasks and risks can leads to an unfair risk sharing situations



"…It happens very often that people, who are not involved at the inception of a project, do not see the overall picture of collaborative risk management" (Project Manager 1).

"…In light of the myriad of stakeholders involved, it is prudent that from the outset of the project all parties are made to know their roles and responsibilities as far as risk allocation and its management are concerned" (Quantity Surveyor 3).

Thus the need for CRM to improve the working relationships. On the other hand, to achieve good collaboration in risk management and an open discussion of design risks and risk sharing, the following factors are considered important:

Active participation of all project stakeholders in discussions on risks: "…acceptance to joint responsibility and shared objectives" (Project Manager 1); *"…effective negotiation and communication between contracting parties at all times"* (Architect 2).

Open and effective communication and information exchange: *"…all risks are placed on the table"* (Risk Manager 1)*;*
"…any choice of a procurement route should be made in cognizance of the terms of agreements that will be used in the contract" (Quantity Surveyor 1)*;*
"…standard forms of contracts should only be edited where necessary to suit the interests of all parties in the contract" (Contractor 1)*;*

"…a clear unambiguous language should be used in writing contract terms" (Development Manager).

Project stakeholders' ability to raise the problems as soon as they appear; "…*dare to ask questions and work without prestige"* (Client 1)*; "…be aware of cultural differences and have the no blame philosophy"* (Contractor 1).

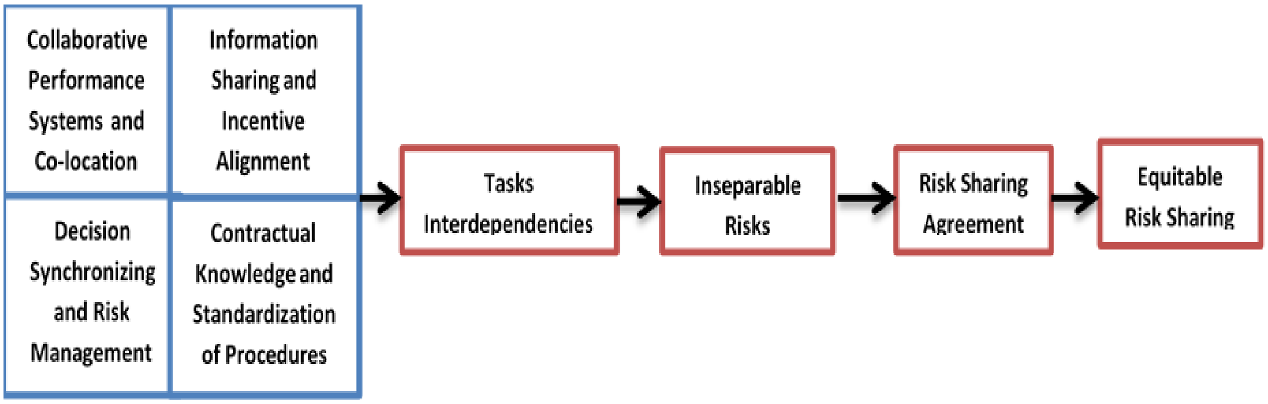
Building trust and teamwork: "…*personal commitment, motivation and responsibility"* (Green Design Engineer 1)*; "…respect for each other's' roles and competence"* (Architect 4)*; "…have equal design inputs and cost-saving mechanisms"* (Architect 2)*; "…development of training programs for team members"* (Structural Engineer 3).

Fair distribution of opportunities: "…*allocation of risk to the party that have the resource and expertise to manage them"* (Project Manager 1)*; "…owners should make a shift from allocating risk by aversion to risk sharing"* (Contractor 1)*; "…assess risks and plan adequately for them"* (Risk Manager 1)*; "…purchase of insurance at risk allocation"* (Quantity Surveyor 2).

Utilizing integrated design processes: "…*understanding client's goal in green building projects"* (Development Manager)*; "…improving communication and coordination among stakeholders"* (Structural Engineer 2)*; "…effective management system for design changes"* (Project Manager 1).

According to the responses, project teams with shared responsibility, should regularly evaluate each other's roles and responsibilities and accept joint responsibilities for the team's achievement. To ensure such shared responsibility, all stakeholders should embrace collaborative attitudes such as decision-synchronizing that focus on finding solutions when problems occur, risk management practices that are open to risk sharing agreements that can lead to equitable risk sharing as in **Figure 7.3.**

Figure 7.3: Interdependent tasks and risks can have an equitable risk sharing solution



In addition, respondents maintained that improving communication and coordination among stakeholders is important to assure the flow of information throughout the design development process and in reducing design defects. This is particularly practical where some parties may be new to green building. Measures to assure information flow include:

Holding meetings with the design team to review project requirements and goals; clarifying additional documentation and other certification-related requirements particularly with specialized contractors and attorneys; holding meetings with general contractors and subcontractors to ensure they understand the purpose of green-related requirements; and providing additional training and materials to subcontractors where necessary.

"…The greatest risk management tool in green buildings is reaching understanding and clear communication between all stakeholders" (Risk Manager 1).

Such mutual understanding requires in-depth collaboration between stakeholders to minimize the potential risks associated with new practices of innovative technologies and materials applied in the green building design.

The outcome of a green building depends on how well risks are managed on that project. The design workflow of interacting tasks and risks entail various requirements that may assess the features and limitations of the current design elements. However, not all designs fulfil all requirements; even so, this is the desired basis.

Knowledge base that represents the starting and finishing point for each task. This facilitates generation, consistency and collection of experience.

Baseline is a swift set up by integration of stakeholders' inputs, a combination of risks and suitable technology interoperability.

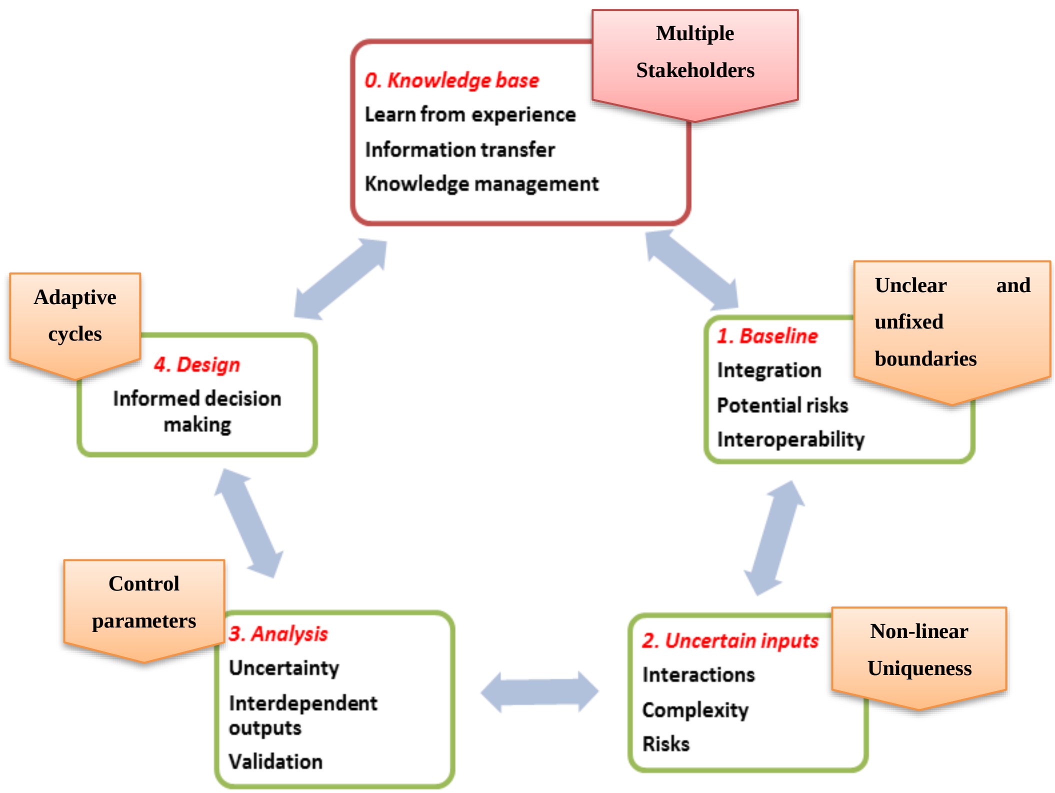
Uncertainties are assigned to inputs and within interactions, where a sampling strategy is applied to explore the design space and facilitate uncertainty and sensitivity analysis.

Analysis and simulations are run using a validated and detailed software engine(s) that evaluate important, interdependent design objectives.

On designs, attention is drawn to the most important design parameters and the design team is informed of the benefits and consequences of various design strategies.

Informed decision-making allows for interaction where different stakeholders preferences maybe explored.

Figure 7.4: Design workflow of interacting tasks and risks



The design workflow of interacting tasks and risks need an efficient RM to reduce the impact of risk on the overall project objective, time, cost and quality. Moreover, an efficient CRM to provide all stakeholders with a mechanism that will provide an alternative option to the traditional allocation of risk and will aid them in making rational and economical decisions that could minimize disputes, delays, adversarial relationships and project cost and increase project efficiency and overall quality.

There is currently a growing interest in the alignment of BIM technologies and risk management philosophy, but most stakeholders are still at the beginning of the learning curve. Their parallel adoption seems to be quite promising, providing better visualization of processes, clear communication and fast information flow, minimization of risks, maintenance and human error and helping in decision making.

Although BIM can facilitate risk management practices, most of its principles have parallel functionalities.

BIM-based risk tools require experienced, trained and engaged stakeholders, integrated and constantly up-to-date interoperable information systems, investment in equipment and technologies, and user-friendly interfaces. Most organizations and design teams should invest in knowledge management by holistic education, training, research and innovation, leading to building soft, technical and technological skills respectively about green, lean and BIM.

Although this study does not aim to be generalizable across the industry, the research findings provide a deeper understanding of the complexity of the green building project environment.

7.8 Summary of Key Points

The fundamental goal of case study research was to conduct an in-depth analysis of an issue, within its context to understand the issue from the perspective of respondents and further validated the information from the interviews to ensure congruency with both the empirical data and the existing literature. The cases were selected based on the research purpose and question, the aim being to provide a detailed holistic description that clarifies the understanding of CRM and inseparable risks. The holistic understanding from the case studies contributed unique insight on partnering concepts that demands high professionalism and very good knowledge of the design principles on the part of the stakeholders. Also, effective collaboration was claimed to lead to fewer disputes, lower design task iterations and to give a better quality building environment.

Existing methods such as the DSM for dependency modelling were employed to evaluate stakeholder interactions and their task interdependencies, while identifying inseparable risks and thus, finding mitigation suggestions. To achieve equitable risk sharing, the DSM is a straightforward discrete modelling method to model the structure of complex systems, to perform system analysis, project planning and design. It is a highly flexible method with extensive applications in management and design of complex systems, as seen in the next chapter. Advantages derived from this method may include complexity management, visualization and understanding of complex systems, enabling decomposition and segmentation of a structure and facilitating collaborative risk management and design.

8. Application of Dependency Analysis Matrices

8.1 Preface

In seeking the essence that makes collaboration work, this research focused on the Dependency and Structure Modelling techniques such as the DSM and the DMM to support, the management of complexity by focusing on the elements of a design process, capture dependencies and risks. The congruence of with both the empirical data and the existing literature is an iterative process of building and refining theories of effective RM.

This chapter applies DSM and develops DMM and the MDM, which have broadened the capabilities and applications of matrix-based models of complex designs. Such capabilities have become recognized as increasingly beneficial and can be traced anytime during the design progress among design teams, tasks, processes, and risks.

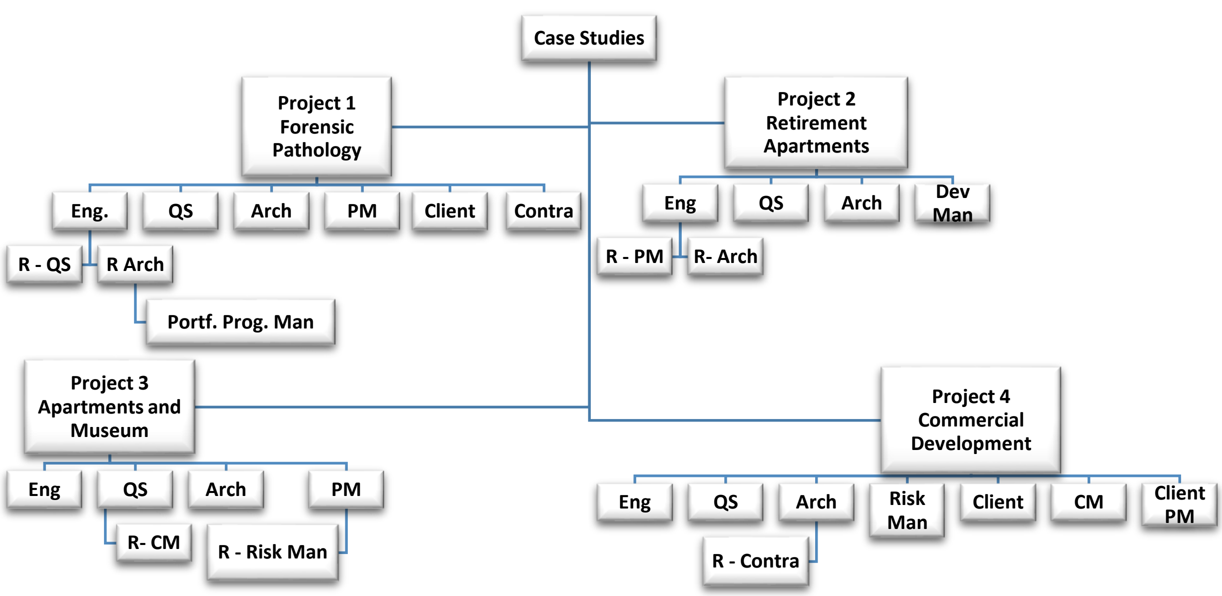
8.2 Design Structure Matrices for Risk Networks

The interdisciplinary dependency of stakeholders on design processes is an important facet and requirement, linked to complexity. With respect to complex theory attributes and interdependency structures, the multiple case study method contributed to theory building on how inseparable risks are managed in collaborative circumstances. The interdependency links different objects such as tasks, information or people (Lindemann, 2009) require a matrix-based approach that comprises of three different types, DSM, DMM and MDM. Application of these matrices assists in analysing team relationships, communication patterns, information exchanges, organizational ranking, construction scheduling, and task allocation (Chinowsky et al., 2009).

The interconnectedness of stakeholders within the case studies, emphasized on the concepts of interdependence and complexity in a project environment. Rather than prioritizing project risks/stakeholders independently with respect to their attributes (impact and probability for risks; power, legitimacy, and urgency for project stakeholders), in these projects - complexity was from analysing the interfaces between individual risks and stakeholders, and reflecting the roles of each stakeholder Herrera, 2021). The interactions among project risks and stakeholders are further modelled and represented in terms of a project risk-stakeholder networks.

Figure **8.1** shows people and their relationships with each other. It maps and measures formal and informal relationships to understand, what facilitates or impedes the knowledge flows; for example, who knows whom, who shares what information/knowledge with whom by what media (Welege et al., 2021).

Figure 8.1: The interactions of Stakeholders from different Projects



This figure provides starting point information, which could be analysed to improve knowledge flows, i.e., social connections with increased productivity.

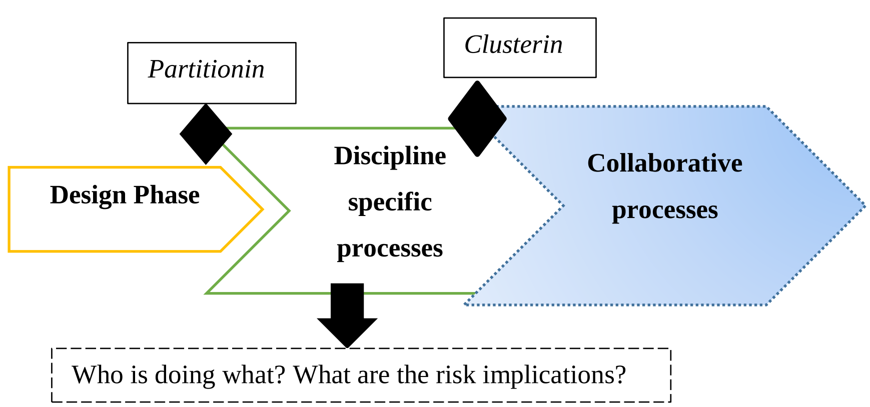
A DSM is an intra-domain matrix, which is squared and maps elements in one domain. The MDM is an inter-domain matrix, which links elements from two different domains, and, therefore, the number of rows and columns is not always the same (Wilberg et al., 2016). The MDM is based on DSMs and DMMs.

The DSM is useful for dealing with large amounts of data obtained between interrelations of tasks, stakeholders and risks in the design phase. However, DSM maps elements in one domain; for instance, information can be about task-task sequence relationships or risk-risk relationships. This helps to identify the correlation between risks within the tasks.

The close interplay between risk, task and stakeholders needs a general underlying question that, of these three systems, which is the dominant one for collaborative risk management in the design process? In theory, both the tasks and risks have to adapt by generating new cross-team interactions and processes (Sinha *et al.*, 2012). However, in practice, when solving design problems in green buildings because of the holistic approach due to their integration in design, different stakeholders face complexities and task interdependencies, which have resulted in inseparable risks.

These risks have ultimately resulted in an unfair risk-sharing situation, which extent leads to a lack of transparency about who is doing what and who needs to interact with whom (necessary co-ordination), especially when considering interdisciplinary co-ordination (**Figure 8. 2**).

Figure 8.2: Necessary interdisciplinary co-ordination



The process of developing the unfair risk-sharing situation is as useful as the need for clarity of design tasks and goals, for stakeholders to enhance their creativity and synergistic actions that will improve risk interdependencies. There are different types of risk associated with a design phase, and the degree of impact in these risks is described as risk importance. This importance is then partitioned during the design stage. Partitioning aims to manage the complexity of inappropriate risk sharing that has led to adversarial relationships between contracting stakeholders in the design processes. Partitioning a DSM aims to find the optimal order of activities and eliminate the feedback marks (Yassine, 2004).

To do so, the first thing is to understand what components the project consists of and then list all the activities that make up each component. When this is completed, one can start looking at who does what task, what is the duration and what are the risk implications. The time each stakeholder spends on a task must also be anticipated, as the workload. (Danilovic, 2005). This then may support the focus on interdependencies, inseparable risks and the need for information exchange between stakeholders in the design phase to evolve.

Where there is risk importance, there is risk responsibility. This responsibility clusters risks according to their attributes their nature, domain or class (Marle *et al.* 2013). Clustering in this order manages risks properly, that is, which risks are interdependent. Then again, the phenomenon of the study was the implementation of CRM within the design phase of GBs. While the phenomenon itself may be relatively studied in the RM literature, it is rarely examined from the perspective of interconnected stakeholders, interdependent tasks and inseparable risks. Further probing into the multiple case studies perspective raised these questions:

How can risk sharing be organized systematically and how does this affect discipline-specific design tasks? How can inseparable risks be allocated systematically based on a design concept at the end of the design phase?

To handle the dynamics of CRM, a binary matrix representing interdependence risks in tasks is built. This binary matrix can be transformed into a numerical one to assess the strength of risk interdependence. A DSM for risk is a binary and square matrix with $DSM_{ij} = 1$, and there is a link from R_i to R_j.

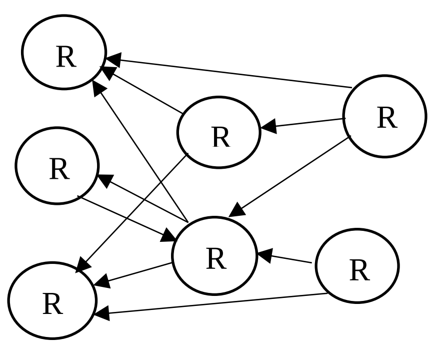
Where:

R_i and R_j = *Risk*

DSM_{ij} = *(i, j)-th element in the design structure matrix of risks*

The risk interdependence is defined as the existence of a possible precedence relationship between two risks R_i and R_j. **Figure 8.3** gives an example to show the use of a DSM to represent the structure of the risk network.

Figure 8.3: Illustration of a risk DSM



Risks	R1	R2	R3	R4	R5	R6	R7
R1				X	X	X	
R2				X			X
R3				X		X	
R4			X		X	X	X
R5							
R6					X		
R7							

Practitioners are required to analyze risk interdependences for all new projects because all projects are unique, and with GBs, there is no previous data. The analysis needs to judge the existence of risk interdependences between any two risks, determine if they are favourable or unfavourable. And then evaluate the strength of the risk interdependences. Commonly, the purpose of design processes is to provide flexibility, robustness, and adaptability; therefore, any changes to the design tasks must be managed to minimize the risks. (Konig *et al*., 2008). Minimizing the risks includes reducing the cost of implementing risk-sharing strategies, and the constraints include combinations of these strategies from different stakeholders, the acceptable level of the loss of risks, the budget of implementing the strategies and so on (Soofifard & Gharibb, 2017).

It is necessary to consider the interactions between design risks, to build a DSM. Classically, the DSM is restricted to one domain which shows first level blocks using the well-established partitioning process. However, there is a need to combine interdependencies, and a DMM can be used to note the relationships between different domains. DMM analysis enables the synchronization of activities by mapping information from one domain to another and helping analyze its implications. However, neither DSM nor DMM are capable of dealing with complex systems if they stand alone. As presented by Lindemann *et al*. (2008), MDM is the combination of all DSMs and DMMs in a system.

The DSM/DMM approaches are complementary to each other. While one focuses on one domain, the other focuses on interactions between domains. This research aims to combine the content analysis method with the use of DSM and DMMs to structure results of analyses composed by numerous elements to identify the fundamental ones.

In real life, practitioners are dealing simultaneously with risks in several dimensions. These risks are about issues of how to organize people in different simultaneous design processes. Moreover, how to manage the process of inseparable risks? How to organize the interdisciplinary environment? And, how to coordinate people and integrate their tasks in many interrelated processes. To manage all these dimensions, this research introduces the synchronization of domains between DSM and DMM analysis.

8.3 Multiple Domain Matrices

According to Danilovic and Browning (2007), the main advantage of these matrices is to indicate four types of person-to-task relationships, responsibility, accountability, consultation and information, as shown in **Figure 8.4**.

Figure 8.4: MDM Mapping System for capturing the design process interfaces in various domains

	Stakeholders	Design Tasks	Design Components
Stakeholders	People DSM	People-Activity DMM	People-Design-Components DMM
Design Tasks		Activity DSM	Activity-Design-Components DMM
Design Components			Component DSM

With complexity playing a major role in design management, the presented MDM approach allows for the integrated management of variants, i.e. the relations between nodes. This then aims to handle inseparable risks during the design phase by identifying interdependencies. Stakeholders will manage the communication plans on people-activities and people-components for identified inseparable risks. Based on the information from the respondents and the analysed data, this will then enable constraints to be formulated, not only on the risks but also on the stakeholders who manage the risks.

Table 8.1 lists the different inseparable risks given by respondents from their interviews about their interdependent design tasks. To further develop the theoretical categories, inseparable risks were explained, as it attempts to structure the indivisible risks affecting project stakeholders in their tasks. Classifying these risks was a significant step for the CRM process, as it challenges risk responsiveness and provides an alternative approach to effective RM processes.

Table 8.1: Classified inseparable risks

Risk Classification listed by respondents	Inseparable Risks – explained by respondents	Categories from the Literature
Lack of green competencies	**R1** - Sub-minimal information to proceed with task because of lack of qualified and experienced green designers **R2** - Inexperienced stakeholder on green and risk concepts because of company budget **R3** - Poor interdisciplinary information processing skills	**People focus (Stakeholder Interconnectedness)** *Osipova (2015) Establishing Cooperative Relationships*
Design variations	**R4** - Lack of information on the side of the client and rework on designs **R5** - No unified design codes and standardized green application process **R6** - Excessive and complicated governmental approvals	
Variations by the client	**R7** - Incomplete or inaccurate cost estimate due to wasteful modifications to cover GB works **R8** - Failure to meet green code or green certification requirements	
IT capacity and Knowledge management techniques	**R9** - Insufficient communicated design information resulting in incorrect models **R10** - Some information is lost when captured in digital models **R11** - Technology Management: human-to-human or human-to-technology interaction **R12** - Limited GB benchmarks to guide new projects and lack of green technology databases and GB management systems **R13** - No trained professionals on latest computer programs	**Technology focus (Interdependent Tasks)** *Doloi (2009) Importance of communication, trust and confidence*

Potential conflict of interests	**R14** - Complex contractual clauses **R15** - Ineffective communication among project stakeholders **R16** - Unequal distribution of profits and expenses between stakeholders	**Process focus (Interdependent Risks)** (Lehtiranta, 2013) *Improved RM performed by multiple stakeholders*
Unclear allocation of the risks	**R17** - Different stakeholders with different outlooks on risk management **R18** - Lack of understanding regarding collaborative risk management **R19** - Static risk allocation for a dynamic construction industry	
Shared insurance	**R20** - Delayed compensations after the risk has occurred **R21** - Poor service offered by insurance companies because of lack of insurance products to cover GB aspect	

To address these risks, more domains are added to the existing MDM Mapping System. These added domains include requirements and functions to improve design process understanding and communication. The domains are illustrated in the MDM in **Figure 8.5.**

Figure 8.5: MDM mapping system for capturing the design process with added domains

	Stakeholders	Design Tasks	Design Components	Requirements	Functions
Stakeholders	People DSM	People-Activity DMM	People-Component DMM	People-Requirements DMM	People-Function DMM
Design Tasks		Activity DSM	Activity-Component DMM	Activity-Requirements DMM	Activity-Functions DMM
Design Components			Component DSM	Component-Requirements DMM	Component-Functions DMM

Requirements				Requirements DSM	Requirements-Functions DMM
Functions					Functions DSM

This MDM already has domains with people for stakeholder centricity and tasks to establish an interface with risk management. Furthermore, to illustrate the domains and their relationships, **Figure 8.6** will clarify.

Figure 8.6: MDM as an overview of the added domains and their relationships

	Stakeholders	Design Tasks	Design Components	Requirements	Functions
Stakeholders	Connect to	Initiate task	Initiate changes to	Initiate changes to	Complete task
Design Tasks		Commence task	Realized by	Complete task	
Design Components			Connect to	Complete task	
Requirements				Fulfilled by	Implemented by
Functions					Flow of Process

As shown in **Figure 8.6**, no matter how organized the design processes, there are intersections between stakeholders that are interdependent and need their risks to be shared. Both empirical data analysis highlighted continuous communication is an essential tool for maintaining the support and commitment of all stakeholders, when doing the design reviews and coordination. Effective, regular, and planned communication with all members of the design community is necessary to reduce the levels of uncertainty and resolve any challenges; promote collective thinking and collaboration that necessitates the colocation of the design team.

Further analysis on the classification of inseparable risks listed on Table 8.1 shows the interdependencies as defined in terms of the need for knowledge management processes to improve the capacity of stakeholders, enhancing the way they share knowledge and use the different tools in order to fulfil tasks. Often, questions such: who needs to communicate to whom in order to solve their tasks? What kind of information is needed and when should it be exchanged, requires a communication plan that contributes to effective decision-making. **Figure 8.7** shows the causes of inseparable risks within the focus of stakeholders, technology and processes.

Figure 8.7: Mapping matrix for inseparable risk networks

Classified Inseparable Risks	Stakeholder participation	Design tasks completion	Efficient knowledge managenent	Technology implementation	Collaborative risk management
Stakeholder Variations	X	X	X	X	X
Design tasks variations		X	X	X	X
Knowledge management techniques			X	X	X
Technology capacity				X	X
Risk Management					X

To handle dynamics of complexity, after mapping interdependencies in the matrix, rows and columns are then altered in order to find clusters that are highly related to each other, to enable coordination.

Stakeholder knowledge and perception of inseparable risks can be further mapped-out to focus on what matters most, to promote mutual understanding and communication based on completed projects and projects still in the design phase as shown in **Figure 8.8.** Practitioners highlighted dependency-culling workshops where time is spent to understand the dependencies between tasks and try to eliminate as many dependencies as possible. The workshops resulted in a baseline design interdependency map, which stresses structure and quality communication systems.

Figure 8.8: MDM for inseparable risk networks

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21
R1	0								1												
R2		0									1			1							
R3			0																	1	
R4				0																	
R5					0							1			1						
R6						0															
R7							0												1		
R8								0					1								
R9									0								1				
R10										0											
R11											0									1	
R12												0			1						
R13													0								
R14														0							1
R15															0				1		
R16																0					
R17																	0				
R18																		0			
R19																			0		
R20																				0	
R21																					0

8.4 Managing Inseparable Risks

The case studies revealed that, to manage inseparable design risks, stakeholders suggested co-location, improved co-ordination between disciplines, as well as getting GB accreditation training where attendees have the opportunity to discuss and become familiar with suitable practices of design and risk. However, what impedes risk sharing? In seeking a new dimension for the study of collaborative risk management, GB design processes are chosen as a focus application area for exploration because of their strong influence on risk sharing agreements.

Risk sharing should be balanced, and appropriate risks should be distributed to the appropriate party (Khazaeni *et al*. 2012). In spite of this, sharing risk is still influenced by many other factors, such as bargaining power or power imbalances (Loosemore 1999; Xu *et al.* 2010). Ironically, in practice, risks are often allocated to the party that is least able to control them due to their limitations of bargaining power (Chen & Hubbard 2012).

Nonetheless, how to manage risk sharing efficiently should be placed in the centre of all contractual agreements. In current construction practice, three types of means are commonly employed to manage interdependent stakeholders, tasks and risks. Organizationally, the choice of delivery systems can change the intensity of behavioural uncertainty (Ive & Chang, 2007). Contractually, the choice of contract forms can shift risk exposure between parties (Smith *et al*., 2006). Financially, the use of financial protection can reduce a project's overall risk exposure (Chang, 2015). How to efficiently manage risk sharing by these three means is the overarching issue in the design phase.

Although collaborative risk management has gained acceptance in recent years, it is still not well understood by the AEC industry. While a lack of knowledge and understanding hinders the adoption of CRM, it is not the only obstacle to adoption of the practice. **Figure 8.9** show what impedes the risk sharing method.

Figure 8.9: A matrix on what impedes risk-sharing implementation

What impedes Risk Sharing	Contract Negotiation	Communication	Stakeholder Management	Green Building Development	Continuous Training	Mandatory GB Assessment Tools	Regular team meetings	Unified design codes	Collaborative engagements	Shared insurance	Risk sharing capacity
Restrictive contractual clauses	x	x	x		x	x	x		x	x	x
Clarity of roles		x	x		x		x		x		x
Differing risk attitudes			x		x		x		x		x
Client knowledge				x	x		x		x	x	x
Green building skills					x	x	x	x	x		x
Standardize application processes		x				x	x	x	x		x
Information sharing		x					x	x	x		x
Design Variations		x						x	x		
Government bureaucracy									x		
GB specific insurance		x								x	
Unfair risk sharing		x					x				x

The obstacles for CRM implementation are shown in the MDM, including the structure for facilitation because the client usually chooses the delivery method without consideration of the entire project team, the involvement of people with little or no experience in CRM or any form of a collaborative arrangement. The other obstacle is contracts. Traditional contacts are set up to define a single entity's role in a project. They are not written for teamwork and collaboration, and thus they do not work with multi-party agreements. To further complicate matters, the multi-party contracts used remain untested over time and in the courts, as the risks and shifting regulatory requirements remain unaddressed in these contracts.

Lastly, there is the use of insurance. Most stakeholders and even insurance firms are using the same liability insurance they use on traditional projects to cover green buildings, and they do not provide significant coverage. Each new collaborative project requires an insurance firm that can underwrite a newly tailored insurance product specific to collaborative projects with less standard limitations. Giving different stakeholders professional indemnity insurance that caters for collaborative facets.

8.5 Collaborative Risk Management Processes

Adoption of the collaborative risk management process by the industry remains rare. Discussions with practitioners revealed different issues that hinder the rapid adoption of CRM. These include: the client's lack of understanding of his role in this new risk management process; the lack of incentives for different professionals to change their practices; the nature and fragmentation of procurement within the traditional processes and the absence of a recognized code of practice or body of knowledge to support this new form of collaborative work.

Collaborative designing is cyclic, repetitive and evolutionary involving designers from various design teams who exchange information with each other often. Habitually, designers perceive their design tasks with a unique and independent visualization neglecting, the holistic view of the project. This causes them to fail to even consider or address the socio-technical problems affecting the performance of multidisciplinary teams. This alters the priority and sequence of the complete design process leading to design risks that have been informally managed and allocation of risk that has been improperly done (Yirenkye-Fianko & Chileshe, 2015; Mujumdar & Maheswari, 2018).

CRM aims to deliver superior value by assembling, integrating and harnessing the collective skills and capabilities of all stakeholders by effective utilization of technology, unique leadership and communication. The cardinal quality of the CRM approach is its ability to collaborate the decisions of three means quantitatively, organizational, contractual and financial. The choice of the delivery system can greatly affect the riskiness of the project along with the contractual arrangements that can fundamentally change the risk impact a project can withstand combined with the evident use of financial instruments that can raise a project's risk sharing capacity.

In addition, risk-sharing practices in a CRM arrangement cannot be considered individually but must be correlated. The interaction between these practices means there are different constraints considered to create a balance among the selected practices. These constraints attempt to consider prerequisites between risk-sharing practices and further prevent the selection of antithetical practices.

However, risk sharing in practice too often favours the owner along with improper risk sharing practices that increase the risk exposure of all the stakeholders (Jin & Doloi 2008; Jin 2010; Peckiene *et al*., 2013). Cooperative or uncooperative behaviour can be explained from an economic perspective (Aibinu *et al.*, 2011). From this perspective, a choice to be cooperative or uncooperative depends on the expected costs and benefits because people are considered rational (Aibinu *et al.*, 2011).

Obtaining an optimal risk sharing practice is demonstrated using a mathematical equation determined by Chang (2015) that allows the choice of optimal risk-sharing ratio and insurance decisions to be determined simultaneously using the equation below:

$$\boldsymbol{5 + b\ (B\text{-}L)\ 40b^{4} = 0}$$

This equation is a derivation of the relationship between risk-sharing ratio and insurance cover. It has two parameters, contract breakup loss (***L***) and insurance cover (***B***).

Table 8.2 shows the optimal risk-sharing ratios in cases where each of the two parameters takes a low, medium or high value with risk premiums (λB).

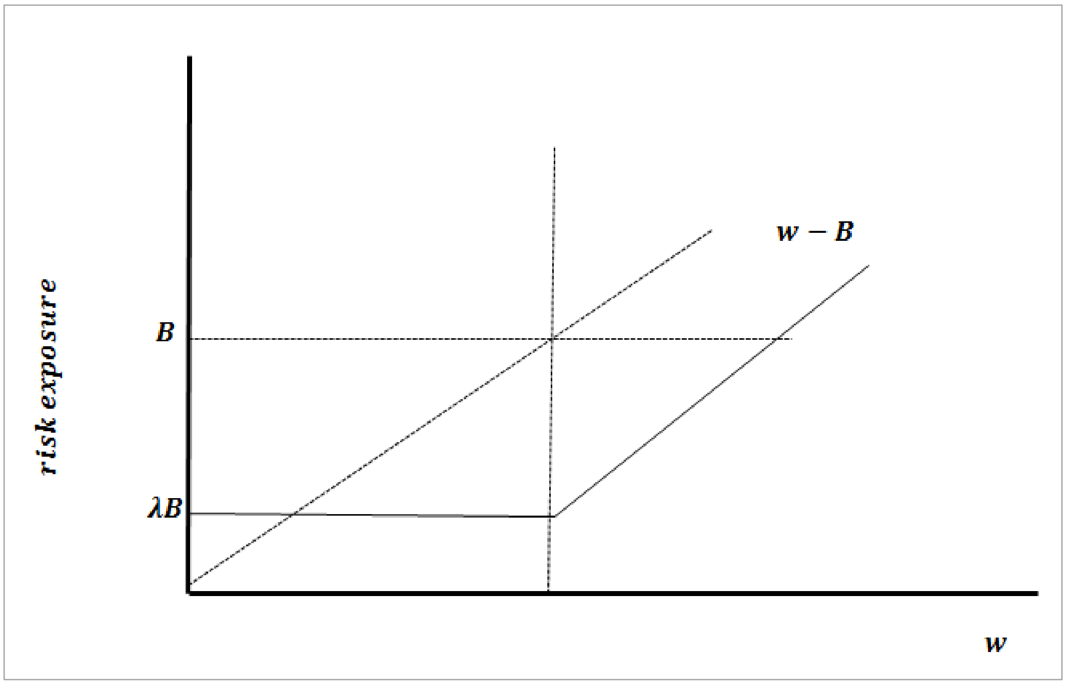
Table 8.2: Optimal risk-sharing ratios when stakeholders have different risk attitudes, contract breakup cost and insurance cover

Design attributes	Insurance cover	Optimal risk-sharing ration (*b*)
Low specificity (L = R10 m)	No cover (B = 0)	−0.40
	Medium cover (B = R10 m)	−0.60
	High cover (B = R20 m)	−0.75
Medium specificity (L = R15 m)	No cover (B = 0)	−0.31
	Medium cover (B = R10 m)	−0.50
	High cover (B = R20 m)	−0.68
High specificity (L = R20 m)	No cover (B = 0)	−0.25
	Medium cover (B = R10 m)	−0.40
	High cover (B = R20 m)	−0.60

(Adapted from Chang, 2015)

When the breakup loss is held constant, greater insurance cover will reduce the optimal risk sharing ratio (closer to −1), meaning that the availability of insurance options for GBs will reduce the stakeholders' methods of shifting risks to other stakeholders with less bargaining power. By contrast, under the same insurance cover, a large breakup cost (mostly caused by task specificity) will lead to an increase in the incentive contracts (b closer to 0) being employed. Whereas offloading more risk to the stakeholders such as the contractor or sub-contractors could increase the expected breakup costs, which can also yield benefit by strengthening the contractor's incentives to cut cost. Under this equation, the benefit from cost savings outweighs the additional breakup cost, if w does not eventuate to affect the total surplus yielded, as shown in **Figure 8.10.**

Figure 8.10: The relationship between cost savings and the breakup cost borne



The design phase uses a mix of organizational, contractual and financial means, which jointly determine how much random shock a GB project can withstand. With this approach, stakeholders can determine how design tasks can influence expected risk exposure by choosing the optimal mix of three means. Currently, these means are studied as different topics (organizational means - delivery system/procurement route, contractual means - risk management, risk allocation, financial means - risk management, insurance, bonding). Breaking the false line between these means can allow the cost/benefit of them to be evaluated jointly and prevent over-protection (as it is too costly) or under-protection (as it exposes the design processes to too much risk).

This approach can establish itself as a positive theory for understanding the design processes in green buildings. The key prediction is that the employment of three means is a reflection of their relative costs. For example, a significant change to insurance premiums could prompt a systematic shift to contractual risk-sharing patterns in collaborative arrangements.

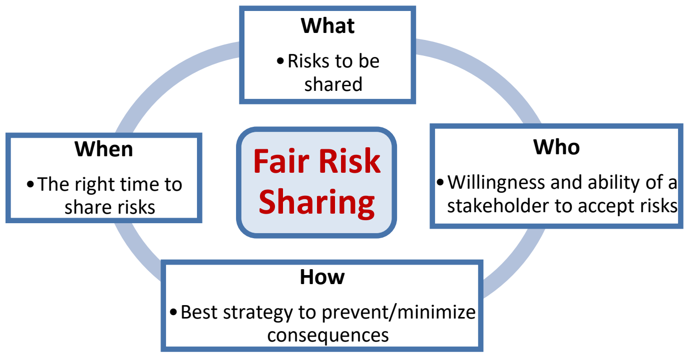
8.6 Risk Sharing Processes

Risk sharing is a process of distributing risks among stakeholders with an intention to implement collaboration strategies, where a suitable risk distribution strategy is crucial for promoting negotiations between stakeholders (Sastoque et al., 2016).

Risk sharing is expected to be symmetrical with risk control abilities, and with all stakeholders bearing the risks arising from the relative benefits. However, sharing risks will always be a difficult problem to solve, due to the one-sided attitude of risk allocation. A fair risk sharing practice involves the appropriate and timely involvement of stakeholders, as well as decision-makers that will ensure that risk management remains relevant and up-to-date. Involvement also allows stakeholders to be properly represented and to have their views taken into account in determining risk criteria. However, in practice, the unfair transfer of risks has made stakeholders to adopt defensive strategies such as lowering the work quality, imposing extensive contingency charges, conservative design and eventually resorting to claims, disputes and litigation. Such defensive strategies have led to project delays and project cost overruns.

Moreover, risk sharing has turned out to be a platform of designing and integrating sharing rules in contractual project forms rather than implementing the approach. CRM assumes that the stakeholders search jointly for a mutually acceptable agreement. It requires fairness and cooperation between stakeholders when allocating risks. Therefore, besides just determining which stakeholder (who) has the best capabilities to accept the risk (what), the when and how factors should be considered to ensure fair risk sharing **(Figure 8.11)**.

Figure 8.11: Concept of fair risk sharing



(Adapted from Abednego and Ogunlana, 2006)

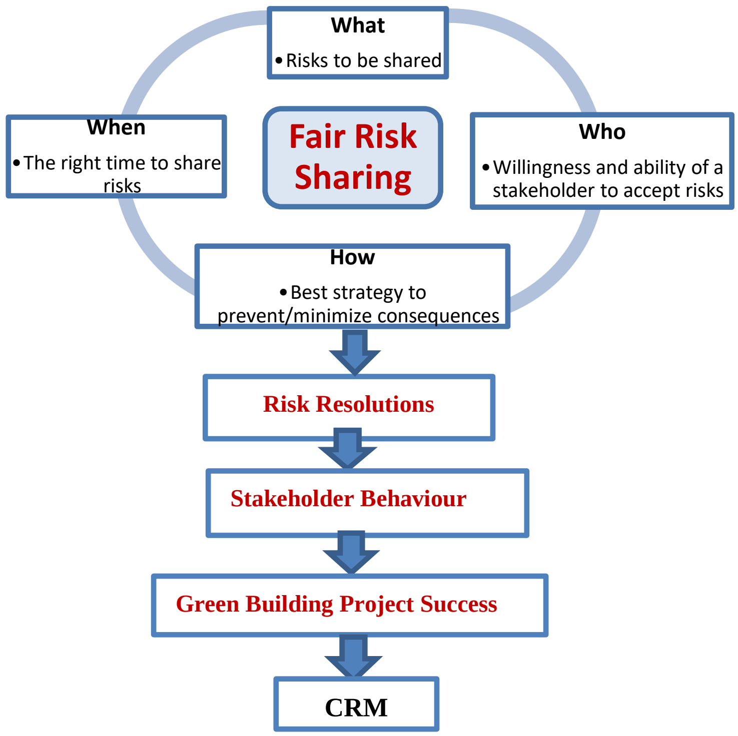
Fair risk sharing enforces fair legal frameworks and transparency (Abednego & Ogunlana, 2006). This means information must be freely available and directly accessible to those who will be affected by the decisions and the risks implicated.

In a fair risk arrangement, stakeholders need to be accountable and have reasonable responsiveness because an important benefit of shared risk is that stakeholders consider and conceive new ways to brainstorm so that requirements are identified and explained proactively. One-sided risk sharing is stopped because stakeholders are trying to safeguard against possible deception and self-interest seeking with guile (Wang et al., 2018). Given the nature of GBs, which include high-technology development and project teams operating in a concentrated risk contract environment, there are difficulties in anticipating the intentions and future actions of all stakeholders.

Contract fairness and equality between all stakeholders creates a collaborative environment where risks are properly identified, understood and evaluated (Abednego & Ogunlana, 2006). CRM embraces all these collaborative efforts to improve risk and stakeholder management effectiveness on design processes where cooperation benefits are greater than the sum of individual returns (Teng *et al.*, 2019). Achieving project and stakeholder goals require an effective distribution system, which considers the marginal contribution of the stakeholder to the potential coalition that will be formed.

All stakeholders have incentives to collaborate as an alliance because this will result in reduced costs and consequently lead to increased profits, as illustrated in **Figure 8.12.**

Figure 8.12: Fair Risk Sharing that leads to successful green building projects



8.8 Key Summary

The focus on the Dependency Structure Modelling techniques such as the DSM and the DMM to support, the management of complexity on elements of the design process captures dependencies of tasks, stakeholders and risks. The close interplay between risk, task and stakeholders leads to the underlying question of which of these three systems is the dominant one for collaborative risk management of the design process. In theory, both the tasks and risks have to adapt by generating new cross-team interactions and processes. However, in practice, when solving design problems in green buildings because of the holistic approach due to their integration in design, different stakeholders face complexities and task interdependencies, which have resulted in inseparable risks.

Practitioners are required to analyze risk interdependences for all new projects because all projects are unique, and with GBs, there is no previous data. The analysis needs to judge the existence of risk interdependences between any two risks and determine if they favourable or unfavourable and then evaluate the strength of the risk interdependences. This will assist in reducing the cost of implementing risk-sharing strategies and the constraints that include combinations of strategies from different stakeholders.

The obstacles to CRM implementation are shown in the MDM, these include contracts. Traditional contacts are set up to define a single entity's role in a project. They are not written for teamwork and collaboration and thus they do not work with multi-party agreements. To further complicate matters, the multi-party contracts used remain untested over time and in the courts. The use of insurance is another problem. Most stakeholders and even insurance firms are using the same liability insurance they use on traditional projects to cover green buildings, and these do not provide significant coverage. Each new collaborative project requires the insurance firm to underwrite a newly tailored insurance product specific to that project. CRM aims to deliver superior value by assembling, integrating, and harnessing all the collective skills and capabilities of all stakeholders, by effective utilization of technology, unique leadership and communication.

In addition, risk-sharing practices in a CRM arrangement cannot be considered individually but should be correlated. The interaction between these practices means there are different constraints considered to create a balance among the selected practices. These constraints attempt to consider prerequisites between risk sharing practices and further prevent the selection of antithetical practices.

9. CONCLUSION

9.1 Preface

Complexity appears to be one of the main reasons for the unpredictability of projects, particularly in terms of problems and failures. In GBs, this complexity is added by the reciprocal interdependencies between different stakeholders. There are a large number and diversity of interdependent elements to manage and a lot of diverse parameters that characterize them. The amount and diversity of these interactions are huge such that projects rapidly become unmanageable due to the sole use of traditional risk management tools.

The progression in constructing GBs with their related technologies requires collaboration. Team-based decision-making and solution-finding enable different stakeholders to communicate, coordinate and create routines to structure and solve design problems, improve current processes and routines, and achieve efficient design operations. Both the complexity of the evolving environment and the internal complexity of the project justify the need for a new approach.

9.2 Need for Collaboration

In a design phase, a collaborative way of managing risks is needed to take advantage of the various views from the different stakeholders involved and identifying risks that cannot be shifted to one stakeholder but have to be collaboratively managed. It has become increasingly clear that traditional risk management approaches do not holistically identify, evaluate and manage unknown risks and it is now unavoidable to use CRM. CRM is a solution that emphasizes equitable and balanced risk sharing among contracting stakeholders (Osipova & Eriksson, 2013) and would eliminate improper or unfavourable risk sharing outcomes which result in cost and time overruns and, undoubtedly, in legal disputes.

In light of collaboration, stakeholders are increasingly looking for alternative ways of working with each other. The result has been the development of formal collaborative working arrangements known as partnering and alliancing, both of which are intended to align project objectives with common business goals to create a more cooperative and productive working atmosphere (Rahman & Kumaraswamy, 2005; Xue *et al*., 2010). However, despite the increasing ways of working with each other, case studies show that even though formal collaboration arrangements had been adopted, project stakeholders often encountered practical problems, such as a lack of collaborative mind-set and insufficient initial effort to establish a shared culture (Chan *et al*., 2012).

Although a significant adoption of collaborative working arrangements has been observed, a lack of attention to the underlying factors and mechanisms that makes people in project-based collaboration teams emphasize on formal mechanisms (such as contracts, procedures, and techniques) have been substantial too. Such formalization often underplays the important social dimension of collaboration in practice, and the dynamics of relationships among different people within and between different organizations (Bresnen & Marshall, 2002).

In seeking the essence that makes collaboration work, this paper focused on the amplified complexity by the interdependencies of stakeholders and their tasks, which require a collaborative approach to ensure the consistency and efficient RM decisions, enabling stakeholders to apportion their risks fairly. The collaborative interdependencies have resulted in highly intertwined tasks which in turn result in inseparable risks that are difficult to uncouple.

9.3 Adoption of Collaborative Risk Management

Over the years, it has been seen that design risks have been managed informally and allocation of risk has been improperly done (Yirenkye-Fianko & Chileshe, 2015). As a result, there are no known records that stakeholders can rely on, to improve their performance concerning handling risk collaboratively. Project stakeholders have realized that, while there may be good RM methods which provide a critically important toolset for risk management, it takes collective thinking and collaboration of all the stakeholders to identify and deal with the complexity of inseparable risks in today's green projects (Thamain, 2013). However, risk sharing among stakeholders appears to be a relevant problem currently explored by many researchers from all over the world. This predetermines improper or unfavourable risk allocation outcomes which results in cost and time overrun and, undoubtedly, in legal disputes. Therefore, it was necessary to consider the critical risk sharing principles comprehensively and influencing factors to share the risk equitably.

The adoption of CRM and the use of CDM by the industry is still rare. Discussions with practitioners revealed some issues that hinder rapid adoption: (1) The clients lack of understanding of his role in this new design process. (2) The lack of incentives for design professionals to change their practice; (3) the nature and fragmentation of procurement within the different design-build processes; and (4) the absence of a recognized code of practice or body of knowledge to support this new form of collaborative work.

CDM is considered as an approach that establishes design as the common thread linking organizations (Jansson *et al.*, 2016). The interdisciplinary and iterative trends in design processes have resulted in a CRM that requires synchronization in contracts for future adjustments of changing situations, with the combined efforts of all related stakeholders to manage unforeseen risks at the post-contract stage and use the best holistic options to accommodate a collaborative design environment.

Understanding the adoption of CRM and the use of CDM by information, communication, knowledge, and collaboration are fundamental. The existence of knowledge boundaries among diverse disciplines during communication is complex (Whyte *et al*., 2016). Therefore, reaching a common understanding among stakeholders is crucial for communication. It develops effective collaboration as a process that leverages the different expertise among stakeholders to create innovative, synergistic solutions beyond their individual goals. As a result, there is a need to broaden the RM discipline to include both tool-oriented approaches for assisting with the execution of processes as well as an aligning process with behaviourally driven considerations.

9.4 Research Approach Applied

Yuan (2011) reiterates that most researchers do not see the distinction between methodology and method. According to Rajasekar *et al*. (2013), a methodology is "…the procedures by which researchers go about their work of describing, explaining, and predicting phenomena". In contrast, a method is a procedure that the researcher will follow when conducting the research (Yuan, 2011).

For this research, the procedural framework in which the research was conducted highlights collaboration as an advantage for knowledge management, but also results in risks that may not be separable and thus not be transferred or allocated to an individual, but would have to be shared. Inappropriate risk sharing has led to adversarial relationships between contracting stakeholders and how risk sharing could be organized under a systematic, CRM scope is what was researched.

Multiple case studies were analysed using empirical data from the interviews to further develop theoretical explanations for effective RM. To bridge the current research gap, this research provided a detailed holistic description that clarifies the respondents' understanding of the CRM as a practical solution. The primary data was collected using semi-structured interviews containing a mixture of open and closed-ended questions, where participants were asked about stakeholder techniques on carrying out inseparable tasks, as well as their options and suggestions on CRM processes of green projects. The use of interviews was a highly flexible method that could produce data of great depth and experiences related to the case study (Zainal, 2007). The goal was to see the research topic from the perspective of the interviewee and to understand how and why they came to have that particular perspective. To avoid impression management and perceptions of individual subjects, such as only managers, employees from various hierarchical levels were interviewed. The participants were selected based on their role in the project and familiarity with green building construction and the use of CRM in these projects.

A non-probability, snowballing or chain referral sampling technique was used to identify the right respondents (Saunders *et al*., 2016). The interviews were done before covid-19 restrictions and they allowed the researcher to gather rich insights. Before the interviews, all interviewees had the same information about the study goals and the interview, for example implications of CRM during the design phase of green buildings, whether the respondent has experienced inseparable risks in the projects they have worked on, and how they manage inseparable risks (the type of risk methodology used). With their permission, the interviewees were recorded to aid the transcription. In addition to knowledge and experience, the importance of availability and willingness to participate; and the ability to communicate experiences and opinions reflectively was also important.

The transcripts were analysed with qualitative analysis software (Nvivo Pro 11), using both deductive and inductive codes, around collaboration, interdependencies, risk sharing and tasks. The synthesis was developed, and the data is presented in the form of quotations. All quotations included are translated direct quotations, improved for readability. The interviewees agreed on using their input for research, under anonymity to protect their organizations and commercial interests.

A process of a stakeholder relationship assessment, where interviews were conducted to get views from GB design stakeholders about their strong interrelated actions in their tasks that resulted in the existence of a network of inseparable risks was determined. Case studies further explored the insights of empirical data, providing unique means of developing theory by utilizing in-depth perceptions about CRM in their contexts. Direction and redirection of the study was an important feature for achieving a systematic combining process of different sources of data and methods of data collection. Methods such as the DSM for dependency modelling were employed to evaluate stakeholder interactions and their task interdependencies, while identifying inseparable risks and thus, finding mitigation suggestions.

DSM is a square matrix that focuses on dependencies between elements of one domain such as task-task sequence relationships (Eppinger & Browning, 2012). The DMM was then used as it examines the interactions across domains to represent enriched analysis results that provide an expanded view of the complex system (Yang *et al*., 2014). When applied, DMM was constructed to map out the interdependencies, interactions and exchange of information from design tasks and risks, identifying the optimal sequence of tasks, risk interactions and iterations across domains. The combination of square DSM and rectangular DMM is called Multiple Domain Matrix (MDM) where useful information is provided using intra- and inter-domain networks to identify and examine interfaces between the clusters and keep iterations at a minimum; minimizing the number of task dependencies (Browning, 2015).

9.5 Research Progression

The general objective of the study was to determine the optimal way of risk sharing in a collaborative risk management approach. To meet the general objectives, the study focused on exploring the implications of CRM during the design phase, identified how inseparable risk are managed in collaborative circumstances and explored the current risk practices and design problems which can only be dealt with collaboratively. As a result, a mixed-method approach was applied to seek practical solutions for creating a complete picture of real-world problems (Creswell, 2014).

The advantages of choosing a mixed-method approach was that, it connected qualitative and quantitative data and provided the researcher with the opportunity to communicate closely with participants and get in-depth insight (Onwuegbuzie & Leech, 2004a). It further revealed complementarity, convergence and dissonance among the findings. Enabling a theory, which provides an explanation about the main problem area and how the problem area will be processed and how it could be resolved.

As Simmons (2006) stated, the researcher should not predetermine a thesis about what they will find but rather what and how the problem area in question should be viewed.

The effective collaboration was claimed to lead to fewer disputes, lower design task iterations and give a better quality building. The case studies showed that it is important to note that the partnering concept demands high professionalism and very good knowledge of the design principles on the part of the stakeholders.

Some respondents do not consider formal partnering or collaborative arrangement as necessary condition as long as its principles can be put into operation. Overall, views of collaborative relationships were seen as a winner as times are evolving. Risk sharing in these situations would be through, the stakeholders' decision on appropriate risk sharing based on the ability (efficiency) and willingness (fairness) of the stakeholders to manage risks and bear the associated risk consequences.

The need for the formation of risk sharing, ability to manage inseparable risks and its associated consequences is determined by the knowledge, resources and experience of all stakeholders between whom the risks are shared to attain the optimal risk sharing ratios.

9.5.1 The Implications of CRM during the Design Phase

The complexity of the projects has led to the existence of inseparable risks; this complex phenomenon is hard to anticipate and difficult to keep under control (Fang & Marle 2012). Many risk management methods and associated tools do not take into account the interrelationships and interactions among different risks and tasks. CRM tries to simplify the process by requiring a joint understanding among all stakeholders engaged and interacting with it. According to Levina and Vaast (2005), this joint understanding of CRM emerges after all stakeholders assign a collectively-created meaning to it.

Its implications required a mental shift and a sharing behaviour to help a team to develop a shared understanding before it can perform a joint sense-and-decision-making process collectively to resolve any design problems. This approach encouraged stakeholders to meet, communicate and coordinate better, to manage potential interactions and propagations. It underlined the need for cooperation and transversal communication in the design teams, suggesting the need for identification of responsibility and accountability, fair allocation of resources and conducting actions on key interactions.

Successful CRM requires the creation and utilization of new knowledge. This knowledge needs to be explored continuously, both internally and externally, by all stakeholders and should be used for enhancing design task performances. Integrating different design tasks and knowledge, is central to the functioning of an effective CRM and in building mutual trust among design teams. Trust in a complex project setting is regarded as a valuable component as it can also reduce risks associated with partnering, relationship development, and increasing commitment to such relationships (Morgan & Hunt, 1994).

CRM has decentralized power, by fostering a co-operative culture. This acknowledges relevant knowledge, information and competence rather than a formal position. This implication motivates design teams to share information timeously and facilitate knowledge-sharing.

9.5.2 How inseparable risk can be managed in collaborative circumstances

Mattessich and Monsey (1992) defined collaboration as a dynamic and mutually beneficial and well-defined relationship entered into by two or more organizations to achieve common goals. However, in reality, not all collaborative relationships are well-defined, well-structured and truly mutual, or indeed working towards the same goals. Effective collaboration among various stakeholders allows temporary-based organizations to utilize multivariate expertise and produce new competences to the design teams. CRM is seen as a process that motivates different expertise among stakeholders to create innovative, synergistic solutions beyond their individual goals. In the light of design digitalization and BIM, the digital capabilities of teams that affect information flows, also affect collaboration and the degree to which people work synergistically.

The interplay between technology and processes has become more dynamic and difficult to separate, as the communication capabilities are being shaped by appropriate digital processes. This has resulted into complexity in design processes where tasks and risk are interdependent. Inseparable risks are risks that occur to trigger another one within the design-risk network (Marle &Vidal, 2014).

With a view to exploring the interrelationships among design risks, a matrix-based approach for building the design process, risk network methods such as the DSM and the DMM for dependency modelling were employed to identify and evaluate risk interactions. The combination of the two matrices, MDM, was also used, to identifying risk interactions across different domains. The intention was to provide stakeholders with an improved quantitative risk analysis method and to thus support them in making more reliable risk response planning decisions.

Effective risk management requires the complete examination of all alternatives and factors that may be subject to change and the formulation of a mechanism for risk quantification. Rahman and Kumaraswamy (2002b) characterized unforeseen risks as needing CRM strategy at the post-contract stage, with the combined efforts of all related stakeholders, under flexible contract conditions and using the best available options at the time of their occurrences. Inseparable risks needs non-adversarial teamwork where better relations, mutual understanding, strong cooperation among all stakeholders and an appreciation of the situation are preconditions. They also require co-located teams to improve communication, productivity, and team relationships.

Effective collaboration is claimed to lead to fewer disputes, lower design task iterations and a better quality building (Ayegba *et al.*, 2018). The case studies showed that, it is important to note that the partnering concept demands high professionalism and very good knowledge of the design principles on the part of the stakeholders.

9.5.3 Exploring the current risk practices and design problems which can only be dealt with collaboratively

Collaboration has become common in building design projects, but traditional RM processes tend to constrain it. The usual linear and chronological development of projects has disconnected RM from collaboration because of the growing complexity due to the involvement of numerous, diverse and strongly interrelated elements. RM is indispensable for the successful realization of projects. The traditional steps of determining risk involve: risk identification, analysis, response planning, monitoring and control and lessons learned (Fang, 2016). However, projects are facing increased interdependent tasks and risks, which must be taken into account in order to share risks fairly.

Generally, current risk practices operate to manage risk and minimize the chance of failure, as its costs can be substantial. Aversion to risk naturally encourages stakeholders to resist innovation and persevere with existing unsuccessful methods, even if they deliver a less than optimal performance. The increasing amount and diversity of task interactions have resulted in design processes becoming unmanageable due to the sole use of traditional risk management tools. The complexity in cross-team interactions and design processes justified the need for a new approach, as it involved interrelations between tasks, stakeholders and risks. However, risk and new approaches to its management are influenced by the effective adoption of its outcomes by innovation in professional practices.

In the interviews, the industry practitioners set the scene of traditional RM weaknesses and discussed their experiences with the collaborative approach of CRM. In detail, the interviewees backed the view that traditional RM practices involve limited accuracy and efficiency and entail potential conflicts in risk sharing and transference. The benefits of CRM were acknowledged with references made not only to the enhanced risk mitigation effectiveness but also to increased schedule observance, conflict reduction as well as to share risks fairly.

Introducing a systematic approach for exploring, designing and improving the current risk practices integrated diverse tools to understand the current problems better and find ways to improve analysis and optimization of the design processes while bettering the RM. By modelling these interdependencies in a risk-matrix, it enabled decision-makers to filter out the complexity of the real world, so that efforts could be directed to proper risk sharing and analysing important parts of design processes.

CRM is the creation of new knowledge or the use of existing knowledge in a new and creative way to generate new concepts, methodologies and understandings.

9.6 Attaining an Optimal Way of Risk Sharing within a Collaborative Risk Management Approach

The increasing attention to 'go-green' has led the construction industry and its professionals to search for innovative and collaborative RM methods. Both academics and practitioners have noted that the traditional silo-type, linear and fragmented design process creates a significant barrier to collaboration. Thus, there is an emphasis on the need for a more collaborative and integrated approach in order to address the increasing complexity of design problems.

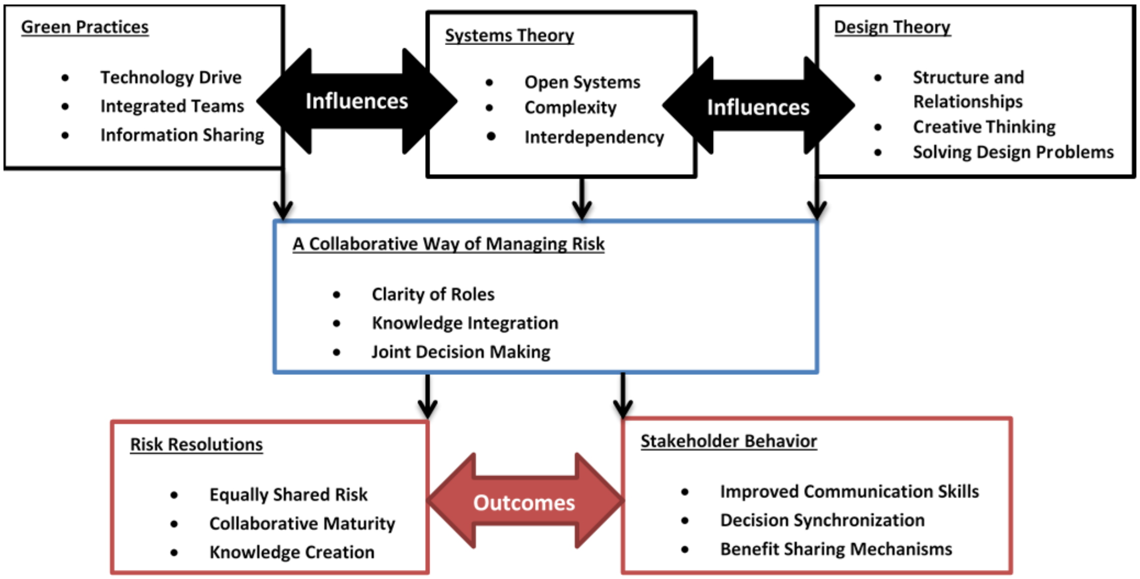
The synthesis of the three knowledge areas identify the interconnected stakeholders and interdependent tasks as well as their effects but, noticed how most RM methods still concentrate on individual risks for simplifying the problem. How these methods have limitations for modelling the complexities of inseparable risks. A good number of existing risk analysis methods are restricted to one of the two dimensions, which also can reduce the results of risk management. But, a matrix-based approach of using DSM to integrate the stakeholder dimension and the task dimension to solve for inseparable risks, using a CRM method to improve the accuracy of risk analysis and the effectiveness of risk management can be effective.

Bringing together these theories referred to the research's theoretical framework where a collaborative way of managing risks, which could take advantage of various views from different stakeholders, involved in designing GBs and identify risks that cannot just be shifted to one stakeholder, but are, managed collaboratively.

Figure 9.1: Synthesis of the Three Knowledge Areas

The research's theoretical framework further shows critical outcome for collaborative practices, where a shared perspective of integrated teams and technology drive will enable interdependencies and complexity to model stakeholder benefits. For each design, this collaboration will enhance stakeholder behaviour and achieve better risk resolutions, leading to better-informed decisions and cooperation. Making the process of risk sharing more efficient through planning and coordination by mutual adjustment of stakeholders (Fundli & Drevland, 2014). These practices will allow CRM to achieve optimal risk sharing.

Figure 9.2: Research Theoretical Framework

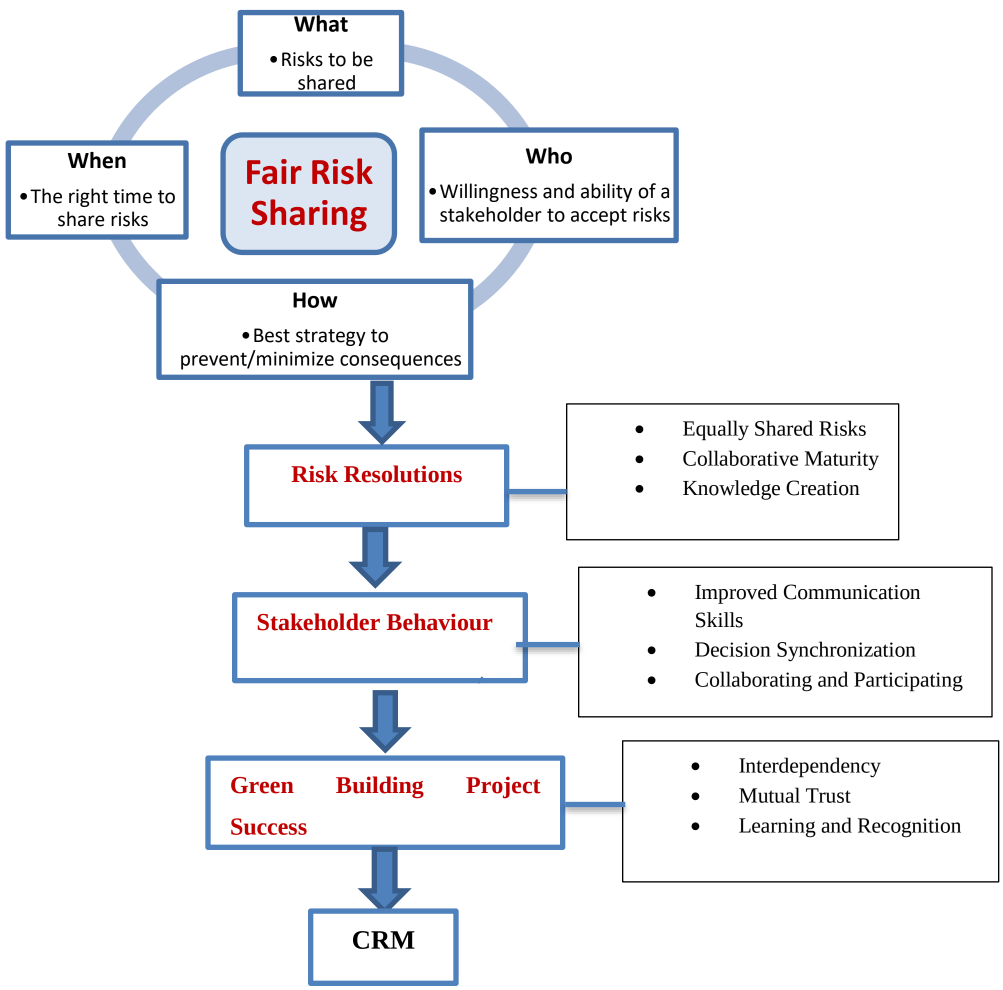


Given that a comprehensive contract is impossible to achieve, while even the more comprehensive ones are expensive and time-consuming to formulate (Rahman & Kumaraswamy, 2002b), CRM is the culmination of the long-awaited paradigmatic cultural shift required for the effective collaborative management of inseparable risks (Rahman & Kumaraswamy, 2004). CRM entails making provision for some gaps in the contract provisions and provides adequate procedures to address them, as and when those risks materialize during the process of designing.

Successful CRM is a mix of control and flexibility expressed as a combination of formal and informal collaborative processes. Informal practices such as team building activities and co-location, interactive workshops where statements for a common goal are formulated and a joint design database is discussed; demonstrating a significant positive effect on CRM, compared to formally implemented approaches. Respondents also highlighted the facilitating role of risk workshops and multidirectional performance feedback systems as a positive means to improve risk communication and allow flexible risk sharing in the design processes. CRM sets-up relationships of trust and confidence rather than mandatory contractual obligations; and is a very important ingredient for the capability and willingness for sharing risks among stakeholders.

Traditional RM practices serve as motives for the use of CRM and confirm that the lack of collaborative values and understanding of risk sharing are the most important barriers for CRM success. These conventional practices neither enhances stability nor provides protection against risk, and are responsible for unfair risk allocations. It is important that the mechanism for risk sharing is consistent in incentivizing stakeholders to achieve the goal of the common project, while also allowing each party to realize their additional objectives, as shown in **Figure 9.3**.

Figure 9.3: Fair risk sharing that leads to successful green building projects



Risk sharing aims for an optimum way of managing risk with benefits, as it helps to allocate resources more efficiently and improve project efficiencies. It has led to design teams to not only fulfil their functional roles, which is supplying the requisite technical skills and operational knowledge but also having team role behaviour which includes a tendency to behave, contribute and interrelate with others in certain distinctive ways (Senaratne & Gunawardane, 2013). To achieve CRM, the outcomes mentioned in the theoretical framework were necessary. Risk resolution and stakeholder behaviour ensured GB success when the CRM approach was used to come to decide on an equitable risk sharing way.

The DSM method used identified interdependencies and relations between items such as tasks, activities, risks and among people and teams. The parameters in inseparable risk networks were considered to give priority to certain risks and design more effective response actions. Mapping this information dependence revealed the underlying structure for design processes and the design teams setting was designed on the basis of this structure. However, tasks, specifications, and processes changed when new information was introduced. While the design process can be dynamic, the application of DSM, DMM or both is instant. To handle the dynamics of CDM, DSM and DMM analyses have to be done repeatedly. This then can support stakeholders in making decisions, such as risk response planning and allocating available budget or resources. CRM encourages people to meet, communicate and coordinate better, to manage potential interactions. It underlines the need for cooperation and transversal communication in the design teams. Interviews prove that, it does indeed improve communication between stakeholders and the understanding of responsibility and accountability.

This change of paradigm does not take place naturally or without criticism. Findings show that some professionals see CRM as an extreme alternative as it involves risk sharing. Future developments in collaboration will lead to the widespread use of CRM principles in project management. Direction for actions of people will come from the intensive interaction and understanding of the design context, not from orders of the hierarchy structure bur rather from the knowledge of the end user's needs.

9.7 Collaborative Risk Management Practices

Information from the multiple case studies linked the methodologies to provide more insight for theory development and understandings for the need to use CRM. The different points of view allowed the researcher to take a deeper look on stakeholder and tasks interdependencies. This holistic understanding contributed unique insight on effective RM concepts that demands high professionalism and very good knowledge of the design principles on the part of the stakeholders. These viewpoints worked and made stakeholders to adopt CRM practices.

9.7.1 Contractual arrangements

Risks are often underestimated and misallocated for a party that is not in the best position to control them (Ng & Loosemore, 2007). Although most contractual arrangements can be considered to involve risk sharing, the increased potential for involving multiple parties in RM will most likely be observed in partnering arrangements. The development of CRM mechanisms would significantly improve multi-stakeholder RM because the risks are common to several participants.

In a GB design phase, this development is ongoing. Management and incentives beyond traditional contracting have been utilized to improve CRM. For example, Osipova and Eriksson (2011) have found that partnering improves the efficiency of CRM in construction projects. The respondents in this study did not identify the need for additional collaboration. However, they did address the need for aligning contractual incentives by providing liability insurance that supports GB objectives.

Finally, adequate training is an integral part of the success of any management structure. The use of CRM requires that all stakeholders understand its principles, have appropriate access to the related tools and are committed to systematic RM.

9.7.2 Contractor risk integration

This is good to trigger the contractors' risk awareness and self-management by sharing project-specific risk information in the design phase and by asking them to develop contract specific risk identification and response planning documents (Rostami & Oduoza, 2017).

The contractor integration process is deemed to promote better risk awareness and help to even out the complexity of collaborative relationships by increasing risk communication and opportunities for flexible approaches to inseparable risks.

9.7.3 Risk workshop

CRM practices help in triggering thoughtful, risk-based project planning. Continuous RM workshops assist in reaching the common goal of the project by sharing information on the project’s focal success factors and in discussing management processes. This practice increased the levels of risk knowledge, communication, motivation, and opportunity. It also ensured that all stakeholders know their roles in the project and its RM process.

Lehtirant (2014) indicated that risk workshops are found to serve the purpose of addressing a wide variety of multi-stakeholder expert insights for collaborative risk identification and response planning. Further, the workshop concept has the potential to initiate CRM more efficiently if stakeholders are carefully briefed on the overall project RM processes.

A series of workshops as a future enhancement will provide a systematic method to share and gather dispersed risk knowledge in multi-disciplinary teams, which is often recommended but, not explained in research.

9.7.4 Performance feedback

This helps in identifying strengths and weaknesses in collaborative relationships by collecting and responding to multi-directional performance feedback from stakeholders. The guideline had two main purposes. First, it was meant to serve as a structured quality risk identification system that utilized the project stakeholders' observations. Second, it functioned as a development (learning) system, the stakeholders' receiving useful feedback on their own performance from the perspectives of others.

This performance feedback responds to the opportunity of utilizing multiple perspectives of project performance to the benefit of performance improvement and CRM.

9.8 Research Contribution

9.8.1 Theoretical contributions

Traditional RM approaches represent the widest accepted body of knowledge on construction project RM. However, in practice, they do not correspond well to the complexity of green projects. This research hopes to contribute to the theory of complex, green project RM by exploring and guiding CRM processes in some of the multi-stakeholders' collaborative relationships.

The research is grounded on and has implications for, complexity theory on design management. Practical responses to design complexity need to address the relational and communicative nature of planning and control. This research provides an important building block for RM response decisions. It includes the development of a body of knowledge in collaboration and its evolution in risk management. CRM on design processes drives the need to understand the full extent and breadth of collaboration in context, which is very challenging in a project-based domain such as that of the AEC sector.

The proposed approach of measuring risk interdependencies make it promising for practical application to improve the effectiveness of RM in GB projects. The complexity approach is visible in the analysis and interpretation of the CDM as the context of CRM and in the recommended management approach. When design processes are analysed as a complex, open system, potential for integration can be found in the system parts (Walker, 2007).

The proposed methodology of DSM and DMM is developed to respond to the inseparable risks caused by design tasks. This methodology responds to the complexity of collaborative design processes and CRM by increasing the opportunity for risk communication, response innovation, and flexibility in risk sharing systematically. This approach also assists in adapting to high levels of uncertainty, including the consequent inseparable risks and design goals.

The results of this dissertation provide complementary CRM processes to broaden standard RM processes beyond discipline-specific boundaries. Allowing future built environment professionals to challenge the traditional practices and use their creative and innovative capacities to embrace new collaboration models that change the paradigms in fundamental ways.

9.8.2 Practical implications

The knowledge developed will be reintegrated into future curricula, which will reinitiate a new cycle of reconditioning the core entities of collaboration, prompting an evolution in RM. This will be useful and beneficial for bridging the gaps that have been identified in the scope of traditional RM standards and the needs of GB projects. The success of green projects depends increasingly on the multidisciplinary team's collaborative and coordinative competences, to mobilize their team's expertise for the best of the project. The strategic and contractual levels involve early engagement of stakeholders around collective objectives and interests through a suitable contract. This research is beneficial for the industry and academia as it enlightens the essential strategic, practical and behavioral aspects that are necessary for CRM processes to broaden standard RM. Collaboration and meaningful contributions are naturally more likely when risk and reward are divided equally.

9.9 Limitations and Suggestions for Future Research

With the growing complexity of projects, the phenomenon of risk interdependence has become universal. Though progress is being made in the RM research frontier, there is stillroom for improvement, as some facets have not received exhaustive research, such as the inclusion of CRM in most projects. Because the case project respondents' openness to adopting new practices is likely to be above average the application of CRM in other projects may encounter more resistance. Additionally, there are many new risks in GBs related to different stakeholders, which might limit them in developing a common risk response strategy because they all deal with risks differently. This limitation may influence CRM practice.

Moreover, the size of the sample does provide insight into the perceptions of the design professionals; however, further research with a larger sample may be required for the data interpretation to be confirmed. Further research could also be conducted to the clarification of the essential CRM requirements and associated challenges in terms of the life-cycle of the project. In addition, traditional efforts for improving risk and stakeholder management are largely undertaken in isolation.

Furthermore, since CRM involves insurance as part of a solution to risk mitigation, how do stakeholders claim for professional indemnity in collaborative circumstances of interdependent tasks? How can CRM solve this problem? Professionals should re-evaluate their professional liability policies to ensure they are covered for services associated with green projects. This means that their professional liability coverage should be worded broadly to protect against errors and omissions associated with the rendering of collaborative services.

9.10 Recommendations

Researchers and practitioners alike are encouraged to take advantage of the CRM approach to CDM and advance the standard applications to the needs of interconnected stakeholders and interdependent tasks. The advancement of RM research and standards would benefit from adopting the collaborative structure as a starting point for RM process development, not only as a source of risk but also as an opportunity to be mobilized for effective CRM.

There are many risk management tools commercially available to support PM but, they tend to address either a limited scope of application or limited processes in RM. Future research may involve the advancement of CRM tools and promote CRM as an optimal way of risk sharing in the design phase of GBs. Although CRM has been beneficial in developed countries and is still being improved, developing countries have not fully utilized the effective RM process.

When incentive contracts are prepared, less attention is paid to stakeholders' opportunistic behaviour, which makes it necessary to explore the challenges associated with using the CRM approach in other construction projects. The optimal risk sharing proposed in this thesis is important for coordinating the conduct of all parties to ensure they all choose high levels of effort in seeking to maximize their profits. This creates opportunities for further research studies in the possibilities and strategies to utilize CRM with ease in South Africa.

The research also recommends that future studies should concentrate on the use of DSM in CRM practice, with attention to risk clustering to take into account the synergy or co-effects of risks with respect to mitigation actions planning.

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Website: http://pmbook.ce.cmu.edu/03_The_Design_And_Construction_Process.html

Appendix 1

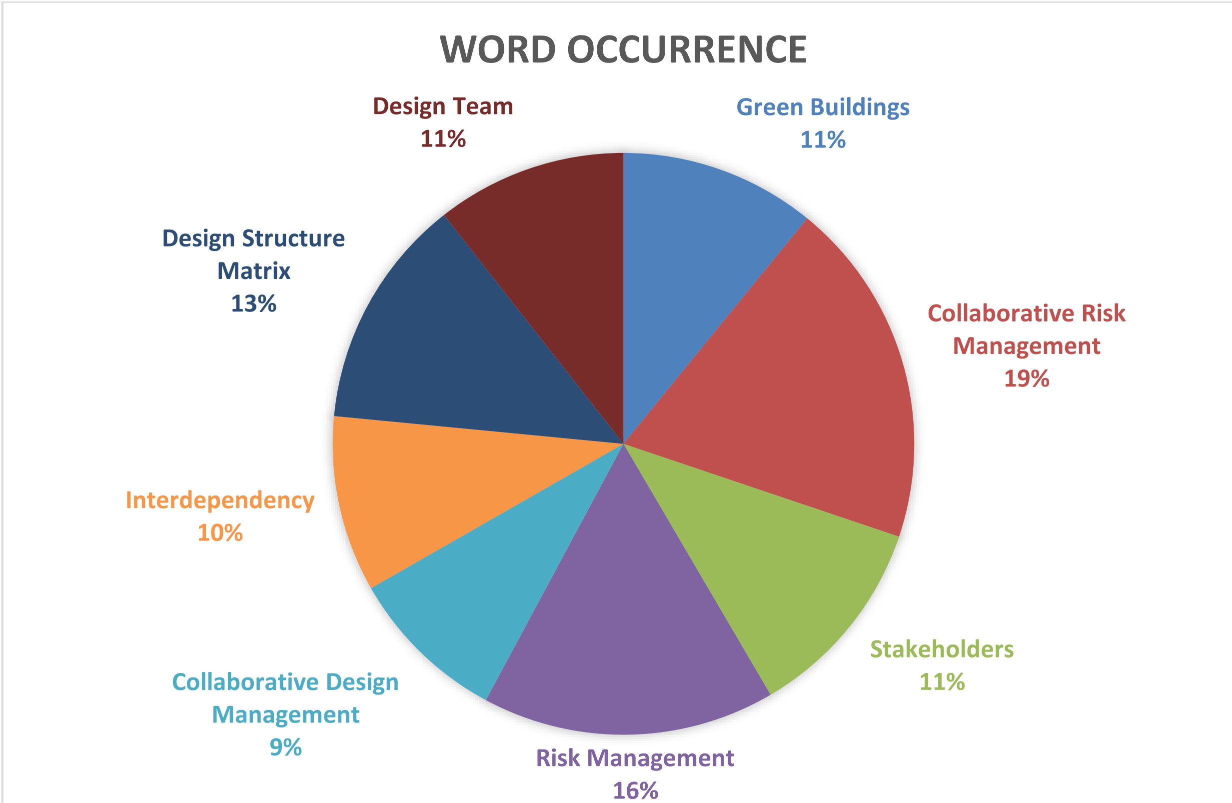
Glossary of Terms

1. **Risk:** An uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost, scope, or quality.
2. **Uncertainty:** A lack of certainty, involving variability and ambiguity when the likelihood of future events is indefinite or incalculable.
3. **Pure Risks:** Are uncertainties as to whether some unpredictable event that can result in loss will occur. Pure risk can result only in loss, never in gain and the extent of the possible loss is unknown. This kind of risk consists of hazards such as a fire or a hurricane, death of key employees, or customer injuries on the premises of the business.
4. **Unknown Risks:** An unexpected or unforeseeable condition which poses a potentially greater risk simply because they cannot be anticipated based on past experience or investigation. A potential loss that is completely unknown, this includes any risk that is not identified and managed.
5. **Risk Assessment:** Evaluation, review and appraisal of the possibility of loss, injury, disadvantage, damage or destruction.
6. **Risk Assumption:** Also known as risk absorption or risk retention, involves the planned acceptance of the risk of loss. Generally, the small business owner will assume risks in which losses that occur will not produce significant financial consequences to the business.
7. **Risk Avoidance**: Eliminating the risk is abandoning or refusing to undertake an activity in which the risk seems too costly.

8. **Risk Reduction:** Minimizing the risk consists of using various methods to reduce the probability that a given event will occur. Although some risks cannot be avoided, most can be appreciably reduced.
9. **Risk Transfer:** Shifting the consequences of a risk to persons. The best known form of risk transfer is insurance, which is the process by which an insurance company agrees to pay an individual or organization an agreed upon sum of money for a prospective future loss.
10. **Risk Averse:** Where decision makers prefer a sure cash payment to a risky venture with a known expected value greater than the sure cash payment.
11. **Risk Neutral:** Where decision makers are indifferent between a sure cash payment and a risky venture with an expected value equals to the sure cash payment and therefore accept a fair gamble
12. **Optimal Risk Allocation:** The decision to allocate risk to parties (shared) such that the allocation minimizes the negative impacts, best able to evaluate, control, manage, and assume that risk at a minimum cost to the project.
13. **Risk Sharing:** Sharing responsibility for dealing with the consequences of each risk, or agreeing to share the risk
14. **Risk Management:** A systematic and iterative process of identifying and analyzing risks, determining the most appropriate techniques for handling those risks, implementing the techniques, and monitoring the results.
15. **Collaborative Risk Management:** An approach that highlights the importance of collaboration between the project stakeholders in managing risk that cannot be identified at the outset of the project.
16. **Effective Risk Management**: Providing reasonable assurance that performance will be optimized, objectives achieved, and desired levels of value will be delivered to all stakeholders.
17. **Risk Analysis:** A number of approaches to dealing with the problems created by uncertainty which includes identification, evaluation, control and management of risk.

18. **Risk Engineering:** An integrated approach to all aspects of risk analysis aiming to identify and measure uncertainty as appropriate, and to develop the insight necessary to change associated risks through effective and efficient decisions.
19. **Barrier:** Barriers imply that there are some of known conditions that might prevent progress or make it difficult to achieve something.
20. **Wicked Problems:** A problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. It has no clear stopping rule, there is no single right answer and every attempt can matter because it affects the things people depend upon.
21. **Collaborative Management:** A collection of various management techniques that enlighten a sense of unity and teamwork amongst all stakeholders.
22. **Knowledge Management:** The process of creating, sharing, using and managing the knowledge and information by multidisciplinary stakeholders.
23. **Stakeholder Management**: A critical component to the successful delivery of any project or activity. The process of forming, monitoring and maintaining constructive relationships; in a responsible and ethical way
24. **Project:** A unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including the constrains of time, cost and resources
25. **Project phases:** Parts of the project that are marked by completion of one or more deliverables
26. **Tasks**: The elements of action comprising of a process, which in various contexts may be tasks to execute, information to generate, decisions to make, or design parameters to determine. Each task transforms one or more inputs into one or more outputs. Complex processes are generally broken into phases, stages, or sub-processes, which are further decomposed into activities
27. **Process**: A system of activities and their interactions comprising a project, such as a design and development of a project

28. **Interactions**: The output-to-input relationships between activities. We are especially interested in work products, deliverables, and information flows, where the outputs of activities enable the execution of others
29. **Iteration**: The repetition of activities, also known as rework. Iterations may be planned (due to coupling or uncertainty) or unplanned (due to discovery of errors or arrival of new information)
30. **Partnering:** A structured management approach to facilitate team working across contractual boundaries
31. **Contract:** A mutually binding agreement that obligates the contractor to provide the specified product and obligates the end user to pay for it a written or spoken agreement, especially one concerning employment, sales, or tenancy that is intended to be enforceable by law.
32. **Contractual flexibility**: The ability of contracting parties to make adjustments that achieve expected outcomes when faced with project uncertainties.
33. **DSM**: Dependency Structure Matrix or Design Structure Matrix - a matrix representation of a design where information flow dependencies are considered. Reading across a row, a dependency mark reveals the flows to that element from the column activities. Reading down a column reveals the output information flows from the activity represented by that column to other activities.
34. **DMM**: Domain Mapping Matrix - examines the interactions across domains: the rows represent nodes of one domain, while the columns represent nodes of another domain. Unlike the DSM, the DMM is an m x n rectangular matrix since the rows and columns are not identical
35. **MDM:** Multi Domain Matrix – a combination of DSM and DMM methodologies, to enrich the analyzed results, providing an expanded view of the system. It also helps to focus the analysis results on interdependencies, interactions, and the exchange of information within and across domains.


WORD OCCURRENCE
Design Team
11%
Green Buildings
11%
Design Structure
Matrix
13%
Collaborative Risk
Management
19%
Interdependency
10%
Stakeholders
11%
Collaborative Design
Management
9%
Risk Management
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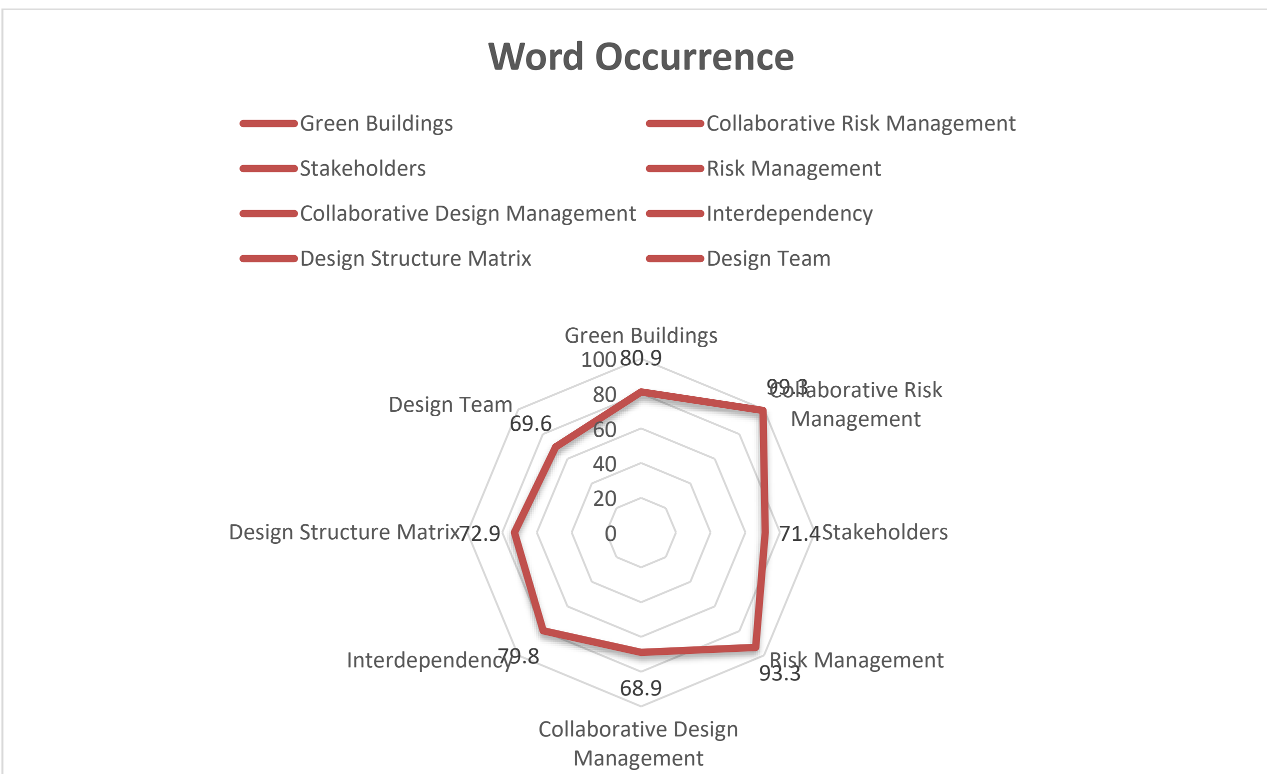
Word Occurrence
Green Buildings
Collaborative Risk Management
Stakeholders
Risk Management
Collaborative Design Management
Interdependency
Design Structure Matrix
Design Team
Green Buildings
100
80.9
80
60
40
20
0
Collaborative Risk
Management
99.3
Design Team
69.6
Design Structure Matrix
72.9
71.4
Stakeholders
Interdependency
79.8
Risk Management
93.3
68.9
Collaborative Design
Management

Appendix II [A]   Letter to Respondents

UNIVERSITY OF WITWATERSRAND

School of Construction Economics and Management

RESEARCH TOPIC–Collaborative Risk Management within a design phase of Green Buildings

Dear Sir/Madam,

TO WHOM IT MAY CONCERN

The integrated nature of green building design does not map well against traditional risk management practices such as allocation of design risk to single parties. Collaborative risk management appears to be a relevant problem as it emphasizes equitable and balanced risk sharing among contracting stakeholders and wants to eliminate improper or unfavorable risk sharing outcomes which result in cost and time overrun and, undoubtedly, in legal disputes. For this reason there is the need to find a proper way to efficiently allocate risk among contracting parties.

This research work is therefore being carried out to find answers to the problems with the current risk allocation practices and how stakeholders in collaborative teams deal with inseparable risks within their different design tasks? The research has the following objectives:

- Explore the implications of Collaborative Risk Management during the design phase of complex buildings
- Identify how inseparable risk will be managed in collaborative circumstances
- Explore the current risk practices and how we can identify in advance design problems which can only be dealt with collaboratively

- Understand how different stakeholders interact within complex green constructions
- Provide solutions to remedy the effects of the current CRM practices

This study is for academic purposes, therefore all the information you provide will be kept in strict confidentiality and only used for the research.

I value your participation and appreciate your commitment of time and effort. If you have any further questions or suggestions you may contact me on the email address provided below.

Sincerely,

Lungie Maseko (PhD Candidate)
Email: lungie.maseko@wits.ac.za
Mobile: +27716290992

Appendix II [B] Questionnaire

SECTION A: Demographics

Kindly respond to the questions by ticking (√) in the appropriate item(s).

1. Please state the number of years you have been involved in green building construction?

- ☐ 1 – 5 years
- ☐ 6 – 10 years
- ☐ 10 years ≤
- ☐ 20 years ≤

2. Please indicate your position in your firm.

- ☐ Engineer
- ☐ Quantity Surveyor
- ☐ Architect
- ☐ Contractor
- ☐ Project Manager
- ☐ Risk Manager
- ☐ Other ………………………………. (please explain further)

3. Please indicate the number of green buildings executed the last three (3) years:

- ☐ 1 - 2
- ☐ 3 - 5
- ☐ 6 - 10
- ☐ 10 ≤

4. Which province(s) are you mainly working in?

- ☐ Gauteng
- ☐ Kwa-Zulu Natal
- ☐ Western Cape
- ☐ Eastern Cape
- ☐ Limpopo
- ☐ Others...

- ☐ Internationally……………………………………….

5. **Risk Attitude:** Choose one of the bold characteristics of a decision maker

- ☐ Dare to make mistakes
- ☐ Strong personality
- ☐ Have a high position
- ☐ Others...

6. **Risk Attitude**: Based on the priority, please put in order for the following steps that you will take when you face a risky problem.

- ☐ To avoid taking the risk
- ☐ To gather more information
- ☐ To determine some aspects related with the problem
- ☐ To directly address the problem to reduce risks
- ☐ To postpone the decision
- ☐ To pass the authority to others
- ☐ Others……………………………………………………….

SECTION B

Part 1- The following have been identified as effects of current risk practices by stakeholders.

Kindly indicate in your experience these effects on parties based on the ranking/rating:

(5= strongly agree, 4= agree, 3= neutral, 2= disagree, 1= strongly disagree)

Effects of current risk allocation	**Magnitude of agreement**				
	5	**4**	**3**	**2**	**1**
Lack of defined roles and poor communication					
Adversarial project environment					
Lack of proper experience					
Unfair allocation of risk among project stakeholders because of unscrupulous behavior					
Disputes because of contractual clauses and competing attitude of stakeholders					
Client constant changes					

Static risk allocation for dynamic projects					

Please indicate in the spaces provided below any other effect of risk allocation on contracting parties and project objectives that has not been captured above.

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…………………………………………………………………………………………
……………………………………

Part 2: Questions related to how different stakeholders interact within a Green Building's design phase

The following is a list perceived to be the stakeholders' interactions and attitudes. Kindly rank them: (5= strongly agree, 4= agree, 3= neutral, 2= disagree, 1= strongly disagree)

Obstacles to optimal risk allocation	5	4	3	2	1
Different stakeholders with different outlooks on risk management					
Choosing risk by aversion					
Ineffective risk management communication among project stakeholders					
Inexperienced stakeholder of green and risk concepts because of company budget					
Complex contractual clauses					

Static risk allocation for a dynamic construction industry					
Lack of understanding regarding Collaborative Risk Management					

Please indicate in the spaces provided below any other difficulties that affect stakeholders' interactions and attitudes in Green Buildings.

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Part 3:

Please indicate in the spaces provided below the implications of Collaborative Risk Management during the design phase of green buildings

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In the spaces below, please pinpoint 2 inseparable risks you have experienced

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In the spaces below please identify 3 ways on how inseparable risk can be managed in collaborative circumstances (type of risk methodology used)

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Part 4: Solutions to remedy the effects of the current risk allocation practices in the construction industry

Please rank them: (5= strongly agree, 4= agree, 3= neutral, 2= disagree, 1= strongly disagree)

Remedies to the effects of current risk allocation	**5**	**4**	**3**	**2**	**1**
Effective negotiation and communication between contracting parties at all times					
Building trust and teamwork among contracting parties					
Allocation of risk to the party that have the resource and expertise to manage them					
Any choice of a procurement route should be made in cognizance of the terms of agreements that will be used in the contract					
Standard forms of contracts should only be edited where necessary to suit the interests of all parties in the contract					
A clear unambiguous language should be used in writing contract terms					

Owners should make a shift from allocating risk by aversion to risk sharing					
Ample time should be allowed at the inception stage of projects for contracting parties to assess risk and plan adequately for them					
Equal design inputs and cost saving mechanisms					

Please indicate in the spaces provided below any other remedy to the effect of current risk allocation that has not been captured above

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Appendix III Interview Guide Questions

POSSIBLE QUESTIONS

Study Title: Collaborative Risk Management within a design phase of Green Buildings

SECTION A: Demographics

1. Please state the number of years of experience in building construction?

- ☐ 1 – 5 years
- ☐ 6 – 10 years
- ☐ 10 years ≤
- ☐ 20 years ≤

2. Please state the number of years you have been involved in green building construction?

- ☐ 1 – 5 years
- ☐ 6 – 10 years
- ☐ 10 years ≤
- ☐ 20 years ≤

3. Please indicate your position in your firm.

- ☐ Engineer
- ☐ Quantity Surveyor
- ☐ Architect
- ☐ Contractor
- ☐ Project Manager
- ☐ Risk Manager
- ☐ Other ………………………………. (please explain further)

4. Please indicate the number of green buildings executed the last three (3) years:

- □ 1 - 2
- □ 3 - 5
- □ 6 - 10
- □ 10 ≤

SECTION A: Questions

What does the term risk mean to you and how do you understand the term risk management?

How does the current risk management practice affect the contractual arrangement and how do stakeholders handle disputes? (If they occur)

Risk means different things to different stakeholders and risk management of Green Buildings should go beyond traditional analytical methods to deal with unknown risks. What risk approaches do these different stakeholders have and how are they managing the new approaches?

What are the implications of Collaborative Risk Management during the design phase of green buildings and how do they foster creativity and collaboration?

Interdependency and interdisciplinary is pushing boundaries, and often requires collaboration that aligns flow processes with task dependencies. As a stakeholder within the design phase of Green Buildings, can you personally pinpoint inseparable risks you have experienced?

How risks are shared among stakeholders in the design phase is to a large extent governed by the dynamic evolution of management. How can inseparable risks be managed in collaborative circumstances because, even risks that have been identified and shared change in scope? (Type of risk methodology used) And, what are the different types of responses to such risks?

The general principle is to allocate risk to the party best positioned to control the risk. How is risk allocated in Green Building projects?

Effective risk management contends with a broad spectrum of risks that may be dynamically distributed throughout the project life. What are the obstacles to optimal risk allocation?

Collaborative Risk Management in South Africa needs to identify inseparable risks and their adverse impact on Green Buildings. As part of the strategy, what could be the solutions to remedy the effects of the current risk allocation practices in the construction industry?

Thank you for your contribution.

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Phone: 0716290992 Phone: 011 717 4663

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.

Yes	No

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.

Yes	No

3. I agree to take part in the above study and to being interviewed.

Yes	No

4. I agree to the interview / consultation being audio recorded.

Yes	No

5. I agree to the use of anonymous quotes in publications.

Yes	No

6. I agree to taking part in a follow up interview if requested.

Yes	No

7. I agree to provide access to relevant documents as may support this study, if needed. (eg: Drawings, Site Meeting Minutes, Contracts)

Yes	No

8. I agree to asking for organizational consent before giving private information.

Yes	No

……………………….. ………………….. ……………………….

Name of Participant Date Signature