Exploring Interdisciplinary Collaboration in Construction: Phases and patterns of interaction in detailed design meetings

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under the supervision of:

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Certificate of Original Authorship

I, Mona Abd Al-Salam declare that this thesis, is submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy, in the School of Built Environment at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Note on the Thesis Format

This thesis was prepared to fulfil the criteria for Doctor of Philosophy and is in the format of a conventional thesis. It adheres to the guidelines set forth in “Procedures for Preparation and Submission of Thesis for High Degrees - University of Technology, Sydney: Policies and Procedures of the University”. This thesis used a form of intext referencing named UTS Harvard that is an adapted version of the standard Harvard referencing style.

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List of Abbreviations

AEC	Architectural, Engineering and Construction
BIM	Building information Modelling
CBA	Choosing by advantages
CPDD	Collaboration phases in detailed design
CCF	Closed cavity façade
CM	Construction management
DBB	Design, bid and build
D&C	Design and construct
DC& M	Design construct and maintenance
DGU	Double glazed unit
DIP	Design intent principles
EMP	Estimated maximum price
GMP	Guaranteed maximum price
IFOA	Integrated form of agreements
IPA	Interaction Process Analysis
IPD	Integrated project delivery
RFI	Request for information
SBD	Set based design
SDP	Shop drawing phase
TVD	Target value design

List of Abbreviations for Bales (1950) modified categories

SS	Shows solidarity
TR	Shows tension release
AE	Agrees
GS	Gives suggestion
GO	Gives opinion
GC	Gives confirmation
GI	Gives information
AI	Asks for information
AC	Asks for confirmation
AO	Asks for opinion
AS	Asks for suggestion
DE	Disagrees
ST	Shows tension
SA	Shows antagonism

Abstract

The research adopts a practice-based inter-organisational perspective to study interdisciplinary collaboration in the detailed design phase in construction projects. The detailed design phase is critical due to the large number of important decisions made to develop the conceptual design into a set of construction documents. It requires input from diverse participants such as contractors, architects, design consultants, and project managers in order to improve value for the client. These participants each bring different backgrounds, skills and expertise and also have differing perspectives that can make the collaborative process problematic. The detailed design phase involves confidential discussions of design tasks and monetary issues, which makes it difficult to gain access to study this environment, and there is little in-depth research in this area. The aim of this research is to understand interdisciplinary collaboration in the detailed design meetings of construction projects and develop insights that guide organisations in improving collaboration in such environments and how it is managed.

This study proposed and refined a model of collaboration phases incorporating two theoretical perspectives: an inter-organisational practice-based approach and a framework for group interaction. The model underpinned the design of a novel data collection approach including non-participant observations and other complementary methods that allowed capturing a broad range of contextual and complex views reflecting multiple realities about interdisciplinary collaboration. The results demonstrate that participants have different ways of viewing their collaboration and reveal patterns of interactions that are associated with positive and negative collaboration. The findings also highlight a range of process and social-reaction factors that may be relevant to the success of the collaboration and provide examples

of management approaches to resolve collaboration problems. These findings suggest a need for a holistic and systematic approach to monitor and evaluate both processes and social reactions to enhance interdisciplinary collaboration in detailed design meetings.

Chapter 1 Introduction

The foundation for successful collaboration in the detailed design phase of construction projects is aligning the knowledge and views of interdisciplinary team members to improve value for the client. Members of teams represent multiple disciplines and organisations, such as the client, architects, designers, contractors and subcontractors. In detailed design meetings, interdisciplinary teams face several challenges in bringing together their interests when developing conceptual designs into a documented set of shop drawings. Collaboration is not a straightforward process in this setting due to the diverse backgrounds, attitudes and goals that affect interactions and the ability to resolve conflicts, communicate effectively and exchange knowledge.

Collaboration research in the design and construction literature often focuses on factors related to the pre-conditions environment and desired outcomes, leaving the interaction processes the least understood. However, an understanding of the interaction is necessary for a systematic approach to examining collaboration at a project level. This study adopts an inter-organisational theoretical perspective to address the need for deeper understanding of collaboration processes through a longitudinal study involving non-participant observations, short surveys, interviews and project documents to support an in-depth study of collaboration. The research questions guide this study to investigate how interdisciplinary collaboration occurs and how it is managed in the detailed design phase of construction projects.

This chapter provides an introduction of the background and justification for the research. It explains how inter-organisational theory presents a new perspective that can provide a systematic approach to conceptualise interdisciplinary face-to-face collaboration in construction projects. The chapter reviews the literature on interdisciplinary collaboration in the design phase, then exposes the importance of the dynamic interactions taking place between the client, architects, designers and constructors in the transition between the design and construction phases. This chapter shows that inter-organisational theory can potentially provide new insights into this under-researched area. The chapter concludes by introducing the research questions followed by the research method and the structure of the thesis.

1.1 Defining collaboration in the construction industry

Collaboration is a very broad theme that involves a number of interrelated features. It is not just about the sharing of information and communication, which is commonly mistaken for a collaborative approach (Jørgensen & Emmitt 2009; Thomson 2003). Communication is considered a prerequisite for collaboration as it involves leveraging information and the synergy of ideas amongst team members to reach a specific goal or objective (Natter, Ockerman & Baumgart 2010). Collaborative efforts are also different from other interactive forms such as cooperation and coordination. Inter-organisational cooperation is not commonly related to aligning a vision or goal and information is only shared when needed (Mattessich & Monsey 1992). Coordination requires a more formal planning approach than cooperation because it focuses on the alignment of goals and sharing of some risks among groups (Schöttle 2014). These interactive forms refer to static patterns of inter-organisational relations and do not capture the dynamic nature of collaboration (Gray 1989). The relationship between participants is more intense and stronger in collaboration. It involves achieving a mutual understanding by exchanging knowledge to achieve a shared goal in a culture based on trust among participants (Carrara & Fioravanti 2007) and, in an atmosphere of trust and mutual respect, to jointly deliver the best solution that best meets a common goal (Wilkinson 2005).

Several definitions of collaboration have emerged in the Architectural, Engineering and Construction (AEC) industry representing different perspectives in design, construction and management. For instance, the design perspective often focuses on the client's relationship as the designers, especially the architects, are the first organisation to interact with the client to understand the project requirements. For instance, Mohsini (as cited in Kalay 2001, p. 741) describes collaboration as "an agreement among specialists to share their abilities in a particular process, to achieve the larger objectives of the project as a whole, as defined by a client, a community, or a society at large". Another design view focuses on the attitude and social aspects of collaboration when discussing design solutions as collaboration was described by Hamid et al. (2006, p. 92) "as a social setting, rather than a problem of communication as it involves, and is impacted by non-technical aspects, such as lack of understanding, conflict, conflict resolution methods, availability and motivation of the participants, their social stature, charisma, and other factors that can facilitate or impede the goals of the collaborative enterprise". A different design view is concerned with the interdependent nature of designers' working practices, which is seen in Carrara and Fioravanti 's (2007, p. 146) definition of collaboration "as the highest form of interaction in design as it implies that actors can help each other to better understand how their work is going to match that of the others and to better perform their tasks, it requires that the actors involved in any stage of the process exchange information and knowledge, thus activating mutual understanding".

From the construction perspective, sharing information and resources, and mutual respect were common themes in collaboration definitions. For example, Wilkinson

(2005, p. 5) focused on the role of technology in collaboration and defines it as “a creative process undertaken by two or more interested individuals, sharing their collective skills, expertise, understanding and knowledge in an atmosphere of openness, honesty, trust and mutual respect, to jointly deliver the best solution that meets their common goal”. Along the lines of this definition is Baiden et al.’s (2006, p. 14) focus on the need for aligning working practices at the project level to foster collaboration as “individuals from various organisations work together to achieve common attainable project goals through the sharing of information, which means that different company processes and organisational cultures have to be aligned in a collaborative manner”.

From the management perspective, collaboration involves leveraging information and the synergy of ideas amongst team members to reach a specific goal or objective (Dietrich et al. 2010). It is regarded as the highest form of interaction between participants working towards achieving mutual understanding in an atmosphere of trust and respect (Alarcon et al. 2001). Collaboration is highly dependent on the willingness of organisations to work together in terms of having a mutual understanding, common vision, shared resources and collective goals (Dietrich et al. 2010; Kahn & Mentzer 1996; Patel, Pettitt & Wilson 2012). At a project level, it involves resolving conflict, motivating participants and aligning views to collective decisions (Dyer 2000). Collaboration is when “autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain” (Wood & Gray 1991, p. 146). Collaboration includes a self-interested process that will occur as long as participants can satisfy one another’s differing objectives without loss to themselves (Gray 1989).

In summary, these definitions, in particular the management definitions, recognise the social and attitudinal aspects of collaboration, the aspects of interactions among participants who have different views and objectives, and the need for alignment in working practices. Therefore, the research adopts Gray's (1989) view of defining collaboration as "the process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their limited vision of what is possible" (p. 5). This definition is useful for this study because it focuses on the interactive processes between participants involved in design discussions in detailed design meetings.

1.2 Importance of the detailed design phase in construction projects

In construction, the design is developed through different stages, including conceptual design, detailed design and construction documentation. In the conceptual design phase, the architects work closely with the client to understand the project purpose and conduct site analysis to offer a number of design options (Australian Insitiute of Architects 2019). At this stage, several design iterations take place to refine these alternatives and conduct budget analysis to meet the client's requirements (Emmitt 2010). These are regarded as positive design iterations because they add value to the client in terms of quality, functionality and aesthetic features (Ballard 2008). Based on the client's feedback, the design is developed further to include architectural and interior floor plans, preliminary cost estimates and materials schedules (Evbuomwan & Anumba 1998). After completing the conceptual documents, designers proceed to develop the detailed drawings and technical specifications (Merritt & Ricketts 2001).

The detailed design phase is defined as the stage at which the preliminary design is refined, the scope of alternatives is reduced, the level of detail is higher, and design documents, specifications and cost estimates are created (Baldwin, Bordoli & Magee 2014; Bravoco & Yadav 1985). In the detailed design meetings, representatives of the client, architects, design consultants, main contractor and subcontractors need to align their views when discussing the design solutions to develop the conceptual design to a documented set of shop drawings needed for the subsequent phase, the construction and fabrication documents (Kalsaas & Moum 2016). Thus, the detailed design phase is critical as it represents the change point between the design and construction phases. Collaboration in the detailed design phase allows construction teams, especially the subcontractors, to have an input in the design discussions to evaluate the proposed design options (Gil et al. 2000). Their input enhances constructability and facilitates the work of construction teams on site (Pulaski & Horman 2005).

However, some of the design changes occurring at later stages of the detailed design phase are considered the leading cause of rework in the construction phase (Love et al. 2002). A survey of 139 projects in Australia showed that the average cost of design changes was as much as 14.2% of the construction cost (Lopez & Love 2011). For instance, changes in the architectural set-out cause negative design iterations for other design consultants such as structural engineers to adjust the alignment of the supporting systems, which in turn could impact the work of the mechanical and electrical engineers and relevant contractors (Smith 2010). Managing the design phase should allow for positive design iterations at early stages of the design such as the conceptual phase that add value to the client and minimise late changes at the detailed design phase that have cost and time implications (Jørgensen & Emmitt 2009). Figure 1-1 below demonstrates the design stages, participants involved and related design documentation, and highlights the focus of this research on the detailed design phase.

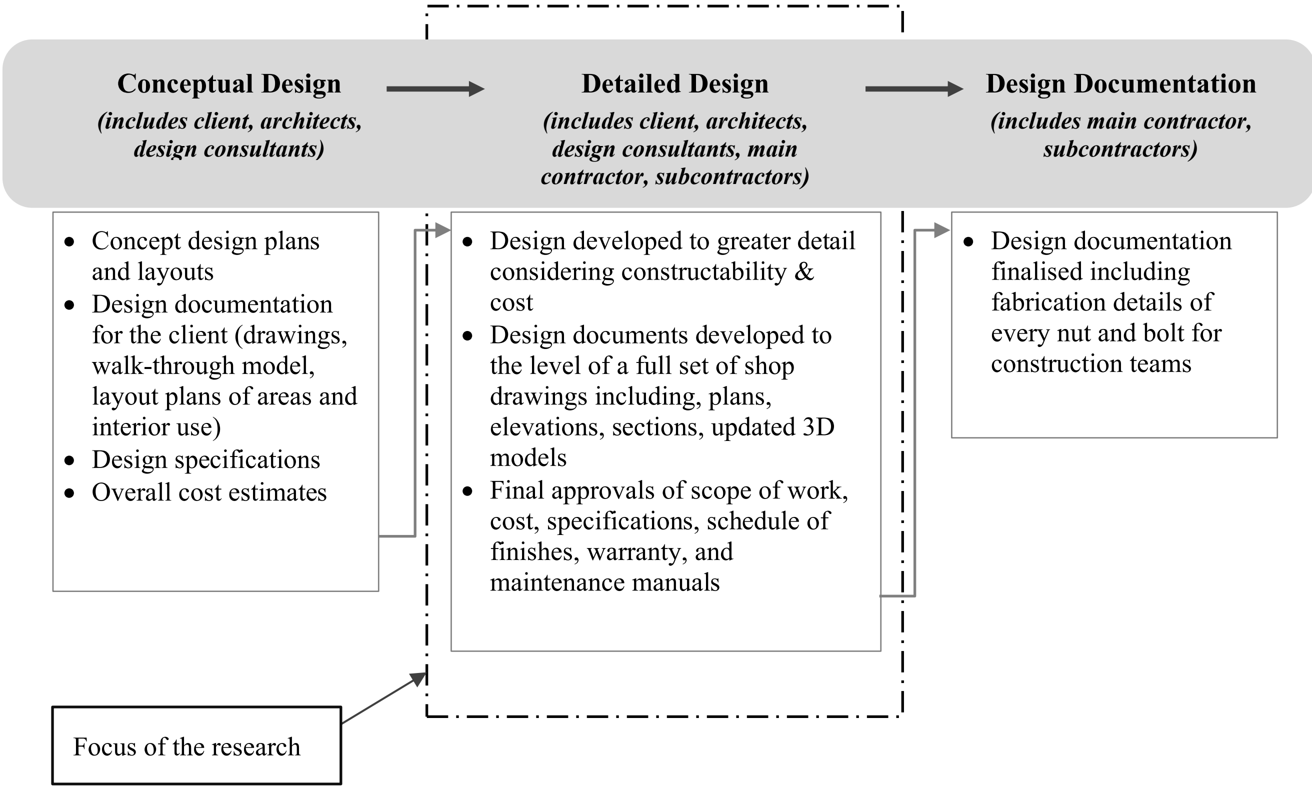

Figure 1-1 Demonstration of the design stages in a construction project

Collaboration varies throughout the whole design phase because of opposing interests between the designers and contractors. At the conceptual design phase, contractors' constructability information allows the designers to be more informed about the cost ramifications of their design options (Alderman & Ivory 2007). However, there is a point as the design progresses through the detailed design phase where the contractors' focus becomes cost and schedule centric, which conflicts with the creative and innovative nature of architects' work (Forbes & Ahmed 2011). As shown in Figure 1-1, in the detailed design phase several decisions need to be taken to finalise the scope of work, develop design details in plans, elevations and sections, approve the cost, finishes and materials samples, and prepare warranty and maintenance documents for facility operation. In addition to being the peak of interaction between the client, designers and contractors to develop the design intent to be a physically achievable reality, the detailed design phase is also a period that tests the suitability and robustness of earlier design decisions.

The long duration of the whole design process makes it unrealistic to study all the design phases in detail. The detailed design phase is important as it involves the peak of interactions between interdisciplinary teams where aligning their knowledge and views is needed to develop the design documentation. Therefore, the detailed design phase represents an ideal setting to study collaboration and is why it has been chosen as the central focus of this research to study what interdisciplinary collaboration is and how it unfolds.

1.3 The growing need for interdisciplinary collaboration in construction projects

Interdisciplinary collaboration has been linked to improved performance in construction projects since the early reports of Egan (1998) and Latham (1994) and later in the review by Farmer (2016). Construction projects are known to be complex and multifarious, with competitive collaborations (Winch 2009). Complexity refers to the involvement of multiple organisations and skilled professionals such as the client, architects, design consultants, project managers, contractors and subcontractors. These stakeholders form an interdisciplinary team that exists temporarily to deliver a specific project (Emmitt 2010). Their discussions include exploring and refining design solutions, explaining and reflecting on each other's ideas and concerns, and negotiating design and cost decisions. Participants involved in these discussions have different values, attitudes, goals and preferred working practices, which affect their interactions and their ability to resolve conflicts, communicate effectively and exchange knowledge (Baiden, Price & Dainty 2006) due to the adversarial transactional interface between members (Ahmed, Pasquire & Manu 2019; Farmer 2016). Despite these differences, they are expected to work closely in a collaborative manner to achieve value for the client.

More specifically, collaboration between designers and contractors is not a straightforward process. They face several challenges that affect their ability to collaborate effectively, such as problems of poor communication, deficient or missing information for making timely decisions, and excessive coordination tasks to approve design reviews (Deep, Gajendran & Jefferies 2019; Dossick et al. 2013; El.Reifi, Emmitt & Ruikar 2013; Emmitt, Sander & Christoffersen 2004; Jørgensen 2006; Love et al. 2018; Osmani, Glass & Price 2006). These process problems are reflected in the poor quality of design documents produced (Formoso et al. 1998; Lopez & Love 2011; Love & Li 2000; Love et al. 2018; Mryyian & Tzortzopoulos 2013; Tilley & Barton 1997), and cause unnecessary design iterations that do not add value to clients or subsequent disciplines in the supply chain (Ballard 2000; Ballard & Koskela 1998; Mujumdar & Maheswari 2018; O’Connor James & Koo Hyun 2020).

Such design documentation problems are often demonstrated in major trade packages such as steel and concrete because of the associated delays on site and the cost implications. For instance, some of the common problems are related to missing information on the exact location of penetrations in steel beams to accommodate mechanical, electrical and plumbing services (Smith 2010) and congested rebar areas (Luth 2011). The location of such penetrations is not realised until the design coordination effort in the detailed design phase has made substantial progress. From the contractor’s point of view, it is more convenient, safe and cost effective to prepare the beam penetrations in a more controlled environment such as the fabrication shop and then transport them to the site ready for erection. The lack of such details in design documents is critical because these problems are usually discovered during construction, with associated cost and schedule implications (Ke et al. 2012). As a result, compromises occur in the construction phase because of poorly resolved designs including quality problems and time wasted by workers associated with requests for information (RFIs) (Luth 2011; Luth, Schorer & Turkan 2014).

In many cases design documents lack sufficient information to facilitate workflow in the construction phase, which could be resolved if major constructability issues were discussed earlier in the design phase (Formoso et al. 1998). The downstream stakeholders account for the majority of the cost associated with quality problems of the end product (Love, Teo & Morrison 2017). Achieving efficient and smooth workflow on construction sites requires not only appropriate construction planning but also effective design management (Sacks, Radosavljevic & Barak 2010). This is critical because the time between the award of a contract and the start of the construction work is usually short, and the design phase usually takes up two-thirds of the project duration while the construction phase takes up one-third (Simonsson et al. 2012). Despite this, design documents often lack the detailed information required for construction teams. These problems show that designers need to be mindful that the information they create will be used by many other parties such as main contractors, subcontractors and fabrication suppliers.

To reach the required level of synergy, interdisciplinary teams need to work towards achieving a mutual understanding of each other's technical constraints by exchanging knowledge and information to jointly deliver the best solution that meets their common goal of maximising client value (Dyer 2000; Faris, Gaterell & Hutchinson 2019; Hughes, Williams & Ren 2012; Jørgensen & Emmitt 2009; Wilkinson 2005).

These challenges demonstrate the difficulties that managers and practitioners face to foster successful collaboration in construction projects, especially in managing the differences between designers' and contractors' working practices.

1.4 Procurement approaches endorsing interdisciplinary collaboration

There has been a growing interest in enhancing collaboration since the early 1990s through multi-party contractual approaches such as integrated project delivery (IPD), lean project delivery (LPS) and Alliance contracting (Baiden, Price & Dainty 2006; Davis & Love 2011; Dossick et al. 2013; Gomez et al. 2018). These forms of agreements address problems associated with fragmentation and lack of integration between project parties by aligning project deliverables with business goals to create a collaborative working environment (Donato, Ahsan & Shee 2015; Rahman & Kumaraswamy 2005). In addition, they intend to improve the client–contractor relationship by aligning their views and interests in an attempt to replace the ingrained confrontational behaviour when dealing with contract variations (Walker & Hampson 2003). One of the fundamental aspects of these multi-party approaches is the early involvement of contractors in the design process to improve constructability and cost estimation (Ballard 2008; Erik Eriksson 2010; Forbes & Ahmed 2011; Franz & Leicht 2012; Kent & Becerik-Gerber 2010).

Multi-party agreements have been successfully implemented in different countries including Australia, the United States and the United Kingdom (Drexler Jr & Larson 2000; Jefferies, Brewer & Gajendran 2014; Larson 1995; Suprapto et al. 2015; Walker & Hampson 2003). However, a number of recent studies reported practical problems encountered by project teams such as a lack of commitment and trust, conflicting personalities, and incompetence (Ey, Zuo & Han 2014; Manata et al. 2020). Further, multi-party agreements focus on the financial aspect of collaboration, such as contracts, procedures and deliverables, and underrate the social dimension (Alderman & Ivory 2007; Suprapto, Bakker & Mooi 2015). Central to this is the lack of understanding of the social dynamics of interdisciplinary collaboration and the lack of empirical studies that examine working processes at the project level (Bresnen & Marshall 2000b, 2002; Suprapto, Bakker & Mooi 2015), the focus of this research.

Some of the multi-party agreement benefits are still achievable in traditional project delivery methods that can foster successful collaboration (Koolwijk et al. 2018). For example, the early involvement of contractors in the design stage is possible in one of the common types of contracts, design and construct (D&C), where the contractors are procured early to develop the detailed design based on the conceptual design drawings (Errasti et al. 2009; Turner 2017). In D&C contracts, the design and construction phases are integrated allowing for better constructability input into the design and provide value for money; however, the quality of the end product might be comprised for cost reductions (Suratkon, Yunus & Deraman 2020). In a different contract type, the design, bid and build (DBB), the client and designers develop the detailed design documents before procuring the contractors, thus there is full control over the quality of the end product, but the separation between the design and construction phases elongates the project duration and minimises the chances for innovation (Walker & Hampson 2003).

Both of these contract types, D&C and DBB, have benefits and drawbacks. Concurrent engineering tends to bridge the gap between D&C and DBB contracts by shifting the project management focus to the product development and value adding by encouraging open communication and better information flow (Eriksson &

Westerberg 2011; Errasti et al. 2009; Ngowi 2000). For instance, in a construction management (CM) contract approach, the contractor represents the client in the administration work to ensure the project is delivered within budget and time (Davis, Love & Baccarini 2008). This approach allows the early involvement of the main contractor in the detailed design phase to provide constructability advice and construction methods to ensure that the client's objectives of quality and value for money are achieved (Walker & Hampson 2003).

This research focused on studying interdisciplinary collaboration in such commonly used traditional project delivery methods that integrate the design and construction knowledge by including a number of agreements: a managing contractor (CM) contract between the client and main contractor, a design and construct (D&C) contract between the main contractor and subcontractors, and consultancy agreements between the client and each design consultancy organisation. These are explained in more detail in Section 5.3.1.

1.5 Differences in designers' and contractors' working practices

Managing construction projects has been studied from different perspectives including a time-related approach to deal with the interdependence of tasks using the Critical Path method (Fondahl 1962), an authority-related relationship approach influenced by procurement methods to administer the decision-making process (Walker & Hampson 2003) and a production system that focuses on controlling the design and construction processes to improve the flow of information and materials and cope with project uncertainty (Koskela 1999). While these approaches offer different management perspectives, they all present the non-linearity, complexity, iterative and interactive nature of construction projects (Pryke & Smyth 2012).

Eynon (2013) explored the differences between designers' and contractors' working practices by comparing their professional backgrounds, nature of working tasks and working procedures. Eynon (2013, pp. 114-15) defined the opposing traits of designers' and contractors' working practices as 1) iterative versus linear; 2) looking at possibilities for improvement versus looking at cost implications; 3) ambiguity of the design versus focusing on meeting deadlines; 4) focusing on options for improvement versus focusing on schedule timeframe; 5) process is visually driven versus practical; 6) focus on creativity versus focus on certainty; and 7) intuitive versus factual. Eynon introduced the notion of 'tribes' to describe the roles and contributions of these teams, as shown in Table 1-1 below.

Table 1-1 Representation of Eynon's (2013) tribes of design and construct

Tribe of Design	***Tribe of Construct***
Iterative	Linear
Possibilities	Cost-driven
Ambiguous	Deadlines
Options	Schedule
Visual	Practical
Creative	Certainty
Intuitive	Factual

As shown in this comparison, design accounts for the creativity and aesthetic aspects of a proposed building and involves iterations and being open to possibilities to improve the design. This working process is highly iterative and in continuous change because designers seek improvements, which is challenging in terms of implementing control measures because more time and many iterations are needed to investigate design alternatives (Gunasekaran & Love 1998). In contrast, contractors are bound by budget and schedule deadlines that shape their working practices. Thus, their focus is on reducing uncertainty and bringing project processes under control (Ballard & Koskela 1998; Winch 2009).

The cost of the design process is relatively small compared to the overall project cost. In a typical building project, the relative costs of design, construction, maintenance and operation are in the ratio 0.1:1:5:200 (Eynon 2013, p. 31). However, the design phase has a significant impact on the construction, maintenance and operation processes because it is the stage where a large number of important decisions are made (Emmitt, Sander & Christoffersen 2004). Several design reviews and evaluations take place between design and construction teams to arrive at a set of acceptable design solutions, which requires a good understanding of the interdependence relations between these actors who are involved in the subprocesses of the whole project (Farmer 2016; Pryke & Smyth 2012).

These differences in working practices have the potential to create conflicting views and opinions that hinder effective collaboration (Emmitt & Ruikar 2013). In addition, the relationship between organisations involved in a construction project is governed to a great extent by the contractual boundaries, which may result in adversarial behaviour causing negative working practices (Walker & Hampson 2003; Winch 2009). These circumstances put designers and contractors under continuous pressure in the detailed design phase to achieve the design objectives within the project time and budget constraints.

1.6 Interdisciplinary collaboration themes in construction projects

As mentioned earlier, interdisciplinary collaboration is regarded as an essential attribute to facilitate the successful delivery of construction projects (Bresnen & Marshall 2000a; Walker & Lloyd-Walker 2015). As such, it has become an increasingly researched topic in the design and construction literature to study factors relevant to successful collaboration at the organisational level (Black, Akintoye & Fitzgerald 2000; Deep, Gajendran & Jefferies 2019; Faris, Gaterell & Hutchinson 2019; Hughes, Williams & Ren 2012; Rantsatsi, Musonda & Agumba 2020). A number of studies focused on identifying enablers of collaboration at a project level that set up the working procedures, such as co-locating team members in one common space, having a common goal to align participants' objectives towards the project outcome, having common means of sharing information, defining roles and responsibilities of participants to clarify contributions in meetings, and forming interdisciplinary teams including designers and contractors (Aghania, Ramzani & Raju 2019; Baiden, Price & Dainty 2006; Ballard & Howell 2003; Kelly, Schaan & Joncas 2002; Luth 2011; Mattessich & Monsey 1992; Meng 2013). While much effort has been directed to identifying factors and enablers of collaboration, the findings represent a static perspective that does not reflect the highly dynamic nature of the interactions between interdisciplinary teams with different views and objectives.

A less prominent group of themes focused on describing the interactive process in design discussions. The interactive process reflects what participants actually do in their working practices. Interactive processes are highlighted as necessary for collaboration in the literature but are only represented in three themes. The first theme discusses aligning interests in cost related issues by bringing together participants' views when discussing design options to improve value to the client (Boukendour & Bah 2001; Dietrich et al. 2010; Zimina, Ballard & Pasquire 2012). The second theme relates to enhancing collective decision-making by involving participants who possess the required skills and knowledge to address a wider range of potential solutions before agreeing on a specific design solution (Arroyo & Long 2018; Arroyo, Tommelein & Ballard 2012; Schöttle, Arroyo & Christensen 2020). The final theme finds that interactive coordination by engaging downstream stakeholders in discussions can encourage innovative thinking and knowledge integration to pursue improvements in the construction processes on site (Alarcon, Christian & Tommelein 2011; Dietrich et al. 2010; Kapogiannis & Sherratt 2018; Lindgren, Widén & Emmitt 2018; Liu, Rahmawati & Zawawi 2019; Patel, Pettitt & Wilson 2012).

Another set of themes in the literature describes outcomes including achieving value for money, which is achieving the best design for the money being spent, achieving design integrity by ensuring that the design is thoroughly investigated and not comprised because of cost limitation, and staying within the budget and program timeframes while accommodating the design requirements (Denerolle 2013; Johansen et al. 2019; Turner 2017). Lastly, outcomes are discussed related to trust in expertise and capabilities among participants developing after a number of successful collaborative interactions among participants and hence creating a sense of belonging to the team (Baiden, Price & Dainty 2006; Bond-Barnard Taryn, Fletcher & Steyn 2018; Dietrich et al. 2010).

The above themes of collaboration put much emphasis on the enablers that lead to successful outcomes rather than the actual interactive processes. Interdisciplinary teams need to combine their efforts in several activities in the detailed design phase to achieve the desired outcomes, yet empirical research into the interactive process remains scant (Kalsaas, Rullestad & Thorud 2020). While the need for interdisciplinary collaboration has been on the construction management research agenda for many years, research into collaboration at a project level is rare and needs a systematic approach to understand the complexity (Boton & Forgues 2017). This research addresses this important gap in knowledge by adopting an inter-organisational theoretical approach to gain a deeper understanding of what conceptually constitutes interdisciplinary collaboration in the detailed design phase of construction projects.

1.7 Role of the inter-organisational theoretical perspective in understanding collaboration in construction projects

The challenges facing interdisciplinary teams in the detailed design phase, as noted above, call for a systematic approach that re-centres the focus on the process of collaboration. Inter-organisational theory recognises the importance of studying the interactive process of collaboration rather than presenting it as an outcome (Gray 1989; Thomson 2003). The concept of inter-organisational collaboration is not new. It emerged from the normative approach that searches for ways to improve existing organisation networks to cope with increasingly complex problems (Thomson 2003). Theoretical perspectives in the normative stream focus on incorporating collaboration into strategy design, such as organisation networks that advocate sharing skills and resources that cannot be produced internally (Gulati & Gargiulo 1999; Powell 1990). A similar approach is found in collective action to solve problems that potentially enhance learning and adaptive behaviour, which addresses calls for institutional change (Ostrom 1998). This normative approach views collaboration as a strategy for survival to cope with the growing needs for new organisation forms. Thus, collaboration is commonly associated with cooperation strategies that are concerned with what ought to be, with little attention to how the collaborative process takes place (Thomson 2003; Thomson & Perry 2006).

Unlike the normative approach, the inter-organisational practice-based approach recognises that collaboration needs to be examined from three aspects: the antecedents, the interactive process and the outcome of that process (Gray 1989; Huxham 1996; Wood & Gray 1991). The practice-based stream relies on cooperation theory in inter-organisational relationships that recognise consensus while retaining the identities of each organisation (Ring & Van de Ven 1994), where organisations compete at the margin without disturbing the equilibrium of the network (Thomson & Perry 2006). Another view in the practice-based approach focuses on advocating diversity in skills to deal with highly uncertain and complex problems (Gray 1989; Huxham 1996; Huxham & Vangen 2000, 2003, 2013; Thomson & Perry 2006; Wood & Gray 1991), which adds to the concept of stakeholders' interdependence (Thomson 2003). Despite the difference between the normative and practice-based theoretical approaches, what underpins both perspectives is the belief in the concept of stakeholders' interdependence. Table 1-2 below summarises the difference between the two perspectives.

Table 1-2 Representation of inter-organisational theoretical perspectives (Thomson 2003)

	Normative stream	**Practice-based stream**
Theoretical perspective	Network forms of organisation New institutionalism and collective action Multi-organisational implementation	Inter-organisation relationships Network analysis Network performance Cooperation theory Resource dependence Collaboration perspective
Addressing problems related to…	Increasing complexity, new forms of organisations, reconstruction of society	The need for expertise, financial resources, risk sharing, high levels of interdependence
Objectives	Improving existing situations, what ought to be	Focus on antecedents

1.7.1 Implementing the practice-based inter-organisational theoretical perspective in the construction industry

The practice-based perspective is critical in informing the inter-organisational theoretical lens adopted in this research. Gray's (1989) created a model that focused on collaboration processes and differentiate them from the outcomes. It has been useful for this research for several reasons. First, its underlying concepts draw on the holistic practice-based inter-organisation theory of collaboration that focuses on understanding the interactive process of collaboration rather than presenting them as outcomes. These concepts view interdisciplinary collaboration as a mechanism by which negotiated order emerges among a set of stakeholders within an institutional field or from diverse fields that come together to deal with a joint problem, and advocates the need for diversity to solve complex problems (Gray 1989). These concepts are evident in construction projects because participants focus on solving design problems to develop the design from being conceptual to a set of shop drawings documents ready for the construction phase. To achieve this, other design partners, the subcontractors, step in to complete the design, which aligns with the need for diversity concept. In these design discussions, several negotiations occur to refine proposed design options to achieve design integrity within budget limitations.

Second, the holistic view about collaboration adopted in this theoretical perspective differentiated between antecedents of collaboration, such as factors that exist beforehand (the high levels of interdependence and need for sharing resources), the process and the outcomes (Gray 1989; Wood & Gray 1991).

Third, the subjectivity aspect is recognised in considering the presence of different levels of expertise, power and access to information among participants, which often results in unsatisfactory incremental efforts to deal with problems (Gray & Hughes 2001). These differences in participants' discipline, level of expertise and roles within their organisations also exist in interdisciplinary teams in construction projects (Winch 2009). For instance, in detailed design meetings, participants representing the client, design organisations, contractor and subcontractors differ in decision-making power, access to project information such as cost and budget, and in the level of expertise (Emmitt 2010). Gray (1989) advocates that the collaboration processes proceed in a linear fashion through problem setting, direction setting and implementation measures. The linearity of collaboration phases demonstrates participants' efforts in the ongoing discussions to tackle problems and work out suitable solutions. This view of collaboration phases is highly interesting as it dissects the process and retains the dynamics of participants' working patterns (Bedwell et al. 2012), which is important for understanding the process of collaboration in the detailed design phase of construction projects. In such meetings, participants' work is regulated by specific lists of design tasks that need to be resolved through a series of discussions.

The phases of collaboration are shown in Figure 1-2 and involve interactive processes (problem setting and direction setting phases) and outcomes phases representing the objective and subjective implementation measures (Gray 1989). The first part of the interactive process is the problem setting phase that starts with identifying stakeholders then defines the problem by providing comprehensive analysis to improve the quality of solutions, aligning views during negotiation, and taking each participant's interest into account in agreements. This approach is needed in design discussion because participants need to develop a common understanding of each other's concerns regarding the design task they are investigating in terms of design, cost and program constraints. The second interactive process phase is the direction setting that begins when participants evaluate the proposed solutions and align their interest to reach an agreement on the best solution and consequently explore ways to refine and implement it (Gray 1989, p. 74). To achieve this, both design and construction knowledge needs to be integrated to refine design solutions and explore means of improving constructability.

The final two phases are related to outcomes from implementation. These phases represent two types of outcome indicators: the first objective outcome phase documents whether participants reach an agreement and whether it was implemented, while the other subjective phase captures whether participants are satisfied with the collaborative processes. If they are not satisfied, they are unlikely to accept the outcome (Gray 1989, p. 256). The subjective aspect presented as an outcome is relevant in construction because projects usually have an extended timeframe to reach completion. Interdisciplinary teams are expected to maintain their collaboration in meetings throughout the detailed design phase, which can last for more than a year depending on the project complexity (Kalsaas, Rullestad & Thorud 2020). Participants need to experience progressive success in such long timeframes to be motivated to sustain their collaborative efforts (Mattessich & Monsey 1992). Figure 1-2 below demonstrates collaboration phases.

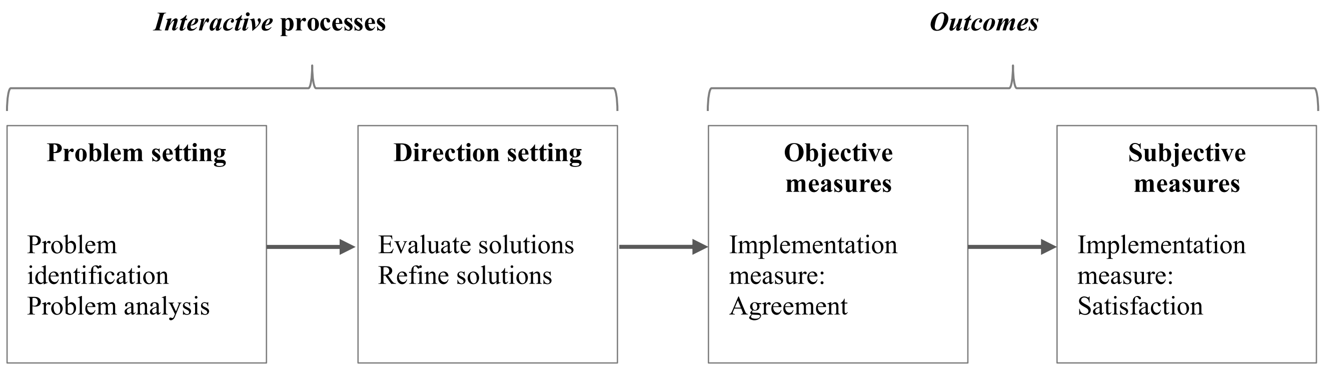

Figure 1-2 Representation of Gray’s collaboration model (1989)

The dynamic interactions between participants in the four phases of collaboration inform this study and the development of an appropriate research methodology that takes into consideration these features:

- Collaboration has a set of defined phases (Gray 1989) that can be studied and investigated further to expand our understanding of its features in construction projects.
- There is a clear distinction between the antecedents of collaboration, the actual processes and the outcomes (Gray 1989).
- Collaboration has a strong subjectivity aspect that defines how participants perceive it to evaluate their performance (Gray 1989; Gray & Purdy 2018). The design process involves people who have different views, attitudes and backgrounds that impact their daily working practices (Emmitt 2010; Eynon 2013).
- Collaboration is an evolving process that changes over time (Gray 1989; Thomson 2003) as it fluctuates between easier and more difficult discussions (Thomson & Perry 2006). Participants in construction projects cannot say in advance that a specific meeting will be collaborative or not. Participants might expect that a particular task will be difficult to resolve due to design complexity or late changes. In these situations, designers are unsure how other design partners, such as subcontractors, will perceive their ideas or design change request, which might affect their collaboration.

Based on the above features, a study of collaboration needs a sufficient timeframe to investigate the long duration of the detailed design phase across different levels of design complexity. A longitudinal study is used in this research to investigate participants' practices in these diverse design discussions.

1.8 Overview of the research methodological framework

A longitudinal methodology is used for this study, as explained in detail in Chapter 5. The method explores detailed design meetings in two cases over the course of a year, through non-participant observations, short surveys, in-depth interviews and project documents. From an ontological perspective, this research is about people and how they perform their working practices in design meetings. These working practices involve various social processes, such as social interaction between participants having different views and backgrounds, collective discussions including evaluating and negotiating design options, and communicating their ideas and solutions. Recognising that interdisciplinary collaboration is a socially constructed phenomenon that involves creating shared meaning and engaging in collective action to deal with complex design problems and project constraints, this research adopts a social constructionist ontology (Denzin & Lincoln 2008).

Past research has been conducted primarily from a positivist perspective, examining collaboration in multi-party projects (Bresnen & Marshall 2002; Eriksson & Westerberg 2011; Meng 2013). While previous studies have provided insights into interdisciplinary collaboration practices, they have not been able to provide empirical findings that examine the dynamics of face-to-face interdisciplinary collaboration at a project level. The case study (Yin 2017) approach selected for this study enabled in-depth understanding and interpretation of the collaboration actions of participants involved in the detailed design meetings. The full research perspective, method and research design are detailed in Chapter 5.

1.9 Research statement and questions

In summary, this chapter has shown that there is an increasing need for interdisciplinary collaboration at a project level in construction research to improve value for clients. The detailed design phase represents the peak of interactions between interdisciplinary teams where aligning their knowledge and views is very much needed when discussing design and construction constraints to develop design documentation. In this design phase, designers need to be mindful that the information they create will be used by several downstream stakeholders such as main contractors and subcontractors. Meanwhile, downstream stakeholders are expected to discuss their technical concerns and cost limitations in an open environment to allow designers to be more informed about their decisions. Collaboration between designers and contractors is achievable in the common traditional project delivery methods, however past studies have focused on examining factors of collaboration in multi-party procurement approaches. Further, the design and construction literature has identified collaboration themes that focus on collaboration enablers and outcomes, leaving the interactive process the least understood. Central to this is the lack of a systematic approach to examine the collaboration processes at a project level. While themes identified in the literature are useful, the practice-based inter-organisational perspective can expand our understanding of how the process of collaboration takes place by considering the interdependent nature of design and construction as well as the importance of participants' views. The practice-based inter-organisational theoretical lens provides an important systematic view of the phases of collaboration, including a clear distinction between the antecedents, the actual processes and the outcomes.

The explicit recognition of collaboration phases can differentiate between a well-managed process and a dysfunctional one in which parties feel dissatisfied and strained (Gray & Purdy 2018). It is often easier for participants involved in interdisciplinary collaborations to agree on acceptable methods for managing their working procedures than to align their views on a current problem that emerges in a meeting and requires a constructive discussion to resolve it (Huxham & Vangen 2000, 2013). Managing interdisciplinary collaboration needs close attention to how the phases unfold and how the patterns of participants' interactions occur over time (Gray 1989). Developing a good understanding of the process and factors which lead to collaborative advantage instead of collaborative inertia can help practitioners manage their working processes (Huxham 1996).

The aim of this research is to understand interdisciplinary collaboration in the detailed design meetings of construction projects and develop insights that guide organisations in improving collaboration in such environments.

Chapters 2, 3 and 4 provide further discussions of the design and construction literature on collaboration and how interdisciplinary teams interact in the detailed design phase in construction projects. Based on the literature findings, the following research questions have been developed to drive the research in this thesis:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.1: Are there different patterns of group interactions in different design environments?

RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?

RQ 2: How do organisations manage interdisciplinary collaboration in detailed design meetings of construction projects?

RQ 2.1: What factors are relevant to the success of interdisciplinary collaboration in detailed design meetings?

RQ 2.2 :What approaches do organisations use to address problems in interdisciplinary collaboration in detailed design meetings?

To meet the aim of this research and develop a deep understanding of interdisciplinary collaboration in the detailed design meetings of construction projects, a longitudinal methodology has been designed to study participants' interactions over time. This methodology enabled allowed in-depth understanding of collaboration processes, the development of an integrative model of collaboration in the detailed design phase, and deeper insights into the factors that affected the collaboration between participants in the detailed design meetings. Together, these findings help advance the practice-based inter-organisational theory (Gray 1989; Gray & Purdy 2018) in understanding and managing the interaction between interdisciplinary teams at a project level in construction projects.

1.10 Structure of the thesis

This thesis is structured in nine chapters.

Chapter 1 has provided an introduction of the research. It draws on the literature to argue that interdisciplinary collaboration is a necessary requirement in the detailed design phase where designers and contractors work closely to improve value for the client. It provided a background of the increasing challenges in the construction industry to improve its performance and associated problems encountered by interdisciplinary teams. This was followed by a rationale for adopting the inter-organisational approach. The chapter concluded by providing the research statement and questions.

Chapter 2 provides a detailed literature review of the collaboration setting that governs the relationship between organisations involved in construction projects and how collaboration is endorsed in different procurement approaches. This is followed by an overview of the contractual setting of the chosen project for this research.

Chapter 3 further adds to the literature review on interdisciplinary collaboration traits in practices of integrating constructability in the design phase in different contexts, such as lean design tools and digital approaches supporting collaboration in different design disciplines.

Chapter 4 presents the initial collaboration model based on the literature review chapters 2 and 3 and informed by the practice-based inter-organisational theory and the methodology of categorising interactions and the research questions. In doing so, it demonstrates how the underlying concepts of a practice-based inter-organisational perspective are an appropriate theoretical lens in conceptualising collaboration phases to investigate the research questions.

Chapter 5 presents the philosophical paradigm adopted as the theoretical framework to investigate this study. It also discusses the methodological approach for conducting the research, including the case study approach and methods for data collection and analysis.

Chapters 6 presents the data analysis, interpretation and discussions of the results for the collaboration model for case study A, a standard design. Chapter 7 presents the data analysis, interpretation and discussions of the results for the collaboration model for case study B, a bespoke design.

Chapter 8 provides analysis and comparison of the findings of the two cases, and links the findings to the literature.

Chapter 9 summarises the research findings and discusses the implications of this research and recommendations for future research.

1.11 Conclusion

This chapter argues that the face-to-face collaboration process in the detailed design phase is an under-researched area from an interdisciplinary perspective. The detailed design phase is a critical stage in realising value to the client because it involves important design decisions, which are challenging due to conflicting views and interests between the contractors. The contractual setting broadly defines the working environment between organisations involved in any construction project, which leads to the next chapter that presents a detailed literature review on collaboration in different procurement approaches to better understand the working practices of participants involved in the detailed design phase.

Chapter 2 Collaboration in Different Procurement Settings

Chapter 1 highlighted the problems that interdisciplinary teams face in collaborating effectively and advocates the need for an inter-organisational perspective to understand the phases of collaboration. The construction industry is governed by legal frameworks that determine the relationships between organisations involved in any construction project. This chapter reviews multi-party and traditional procurement methods to understand how they shape participants' working practices in their face-to-face interactions. This informs the process of collaboration, the core of the proposed collaboration model of this research. The chapter concludes with the suggested contractual setting for this research as it is central to the scope of the empirical study.

2.1 Collaboration traits in multi-party contractual arrangements

Several studies highlighted that the factors hindering interdisciplinary collaboration are associated with two common problems in the construction industry: fragmentation and separation (Ballard & Koskela 1998; Forbes & Ahmed 2011; Olson et al. 1992). Separation exists because designers and construction teams tend to work in silos with open communication channels between them rather than across these disciplines resulting in lack of integration of expertise and knowledge (Alashwal & Fong 2015; Dossick, Neff & Homayouni 2009). Fragmentation exists because of the presence of many subcontracting companies responsible for the execution processes of multiple trade packages who tend to focus on price rather than optimising the client's values through innovation and improvement in their work practices (Jorgensen, Emmitt & Ballard 2005; Mohd Nawi, Baluch & Bahaudin 2014). These problems made clients search for collaborative approaches that align the interests and expertise of organisations involved in construction projects to optimise outcomes (Emmitt 2010).

2.1.1 Joined legal framework in Alliance contracts

The concept of project alliancing was developed on North Sea oil and gas projects by British Petroleum (Thomson 1998). The Alliance contracting method has been implemented in Australian infrastructure projects (Rowlinson et al. 2006; Walker & Lloyd-Walker 2015). In 1994, the first two projects that used alliancing in Australia were the Wandoo project and the East Spar project (Sakal 2005). Other Australian clients and contractors in the heavy civil work sector have also used this collaborative model, especially in projects with higher levels of uncertainty. For instance, alliance contracting was successfully implemented in the National Museum of Australia which was delivered below its estimated maximum price (Hauck et al. 2004; Walker, Hampson & Peters 2002), and in the Port of Brisbane Motorway which was delivered 10% below its estimated maximum price and 30% below industry-standard costs (Ross 2003).

The initial phase in alliance projects includes intense collaboration efforts between the project team of client, designers and contractors to determine the target cost (Lahdenperä 2012). The legal framework adopts a compensation approach based on a pain share/gain share mode, including direct project cost and project overhead, corporate overhead and profit, and predetermined gain/pain share arrangement depending on how the final cost is compared to the target cost (Jefferies, Rowlinson & Cheung 2006; Manley 2002; Sakal 2005). This framework allows parties to form a cohesive entity by tying the profit of all parties to the actual outcome of the project, so decisions are made based on the project's best interest, which develops a sense of ownership among organisations involved in the alliance agreement (Rowlinson et al. 2006; Walker & Hampson 2003).

Alliance contracting has a specific approach to team selection, which is based on a formal process to develop the project cost target and agree on risk and reward sharing arrangements, thus defining participants' roles and responsibilities clearly (Hauck et al. 2004; Kelly, Schaan & Joncas 2002). The main contractor is selected based on their technical expertise, claims and dispute records, insurance claims, safety records, and relationship with subcontractors (Chen et al. 2012). Collaboration between alliance partners is strongly required because parties share resources, including professional expertise, that initiates a higher frequency of ideas needed to expose foreseeable risks at early stages of the project (Cheung & Rowlingson 2005).

The working practices in alliance projects can be grouped into themes describing interdisciplinary collaboration traits, such as aligning cost interests between designers' and contractors' work to achieve value for the client, and defined roles and responsibilities.

2.1.2 Integrated project delivery approach

The integrated project delivery (IPD) approach operates at the project level by integrating teams, working practices and the business structures of organisations involved in a construction project (Thomsen et al. 2009; Walker & Lloyd-Walker 2020). The IPD method represents the adaption of the Australian project alliancing approach in the United States as they both have a similar project delivery approach (Walker & Lloyd-Walker 2015). The IPD method involves forming an interdisciplinary team from different organisations to encourage them to collaborate to cope with their separate objectives and achieve complementary objectives (Baiden, Price & Dainty 2006; Kent & Becerik-Gerber 2010; Thomsen et al. 2009). These organisations pursue and execute work as a team sharing risks and rewards, allowing them to take advantage of opportunities for generating value and improving performance (Franz & Leicht 2012). The fundamental characteristic of IPD involves replacing the series of bilateral agreements with a multiple-party contract that includes at the minimum the client, lead designer professional and main contractor (Thomsen et al. 2009). These participants are given a meaningful voice in decisions that are more likely to affect important matters such as project scope and definition, cost and schedule (Circo 2014). The focus of the project team is then shifted to address project goals, and to share and use information effectively (Baiden, Price & Dainty 2006).

The IPD approach incorporates a reimbursement scheme that awards the project team a percentage of the project cost. In bilateral agreements, a problem occurs when a member of the project team improves collaboration and creates value or savings for the project, and the contracts do not include an incentive for such achievements. For instance, if the designer's fee is based on a percentage of the project cost, the fees may be reduced because of the achieved savings (Hardin & McCool 2015). Economic incentives such as the risk and reward sharing methods of IPD address this issue by working towards the best interest of the project as rewards are based on the project performance as a whole and distributed among all participants (Circo 2014).

Several studies have tested the implementation of IPD in construction projects by developing team performance metrics, including quality, schedule, safety and labour productivity (El Asmar, Hanna & Loh 2013). Another study tested the bi-directional relationships between IPD and building trust throughout the project duration (Pishdad-Bozorgi & Beliveau 2016). A different study compared traditional and integrated delivery timelines and found that the early involvement of contractors in the design phase is essential to better understand the project requirements and constraints, which reduced conflicting opinions and led to a shorter project schedule (Koolwijk et al. 2018).

Research on the collaborative working environment in IPD projects has focused on identifying features of integrated teams in IPD projects (Abdirad & Pishdad-Bozorgi 2014; Baiden, Price & Dainty 2006). Some of these features revolved around a team working towards a single focus and objective for the project and sharing achievements in an atmosphere of respect and a "no blame" environment, and trust in expertise and capabilities of organisations involved in the project. Another set of features focused on working procedures such as a team that operates without boundaries among various organisations to allow them to share information freely without restricting access to specific professions. Features of team formation were also included in these studies, such as the team has a diversity of skills and responsibilities, members have equal opportunities to contribute to the delivery process, and the team has a new identity and is co-located in a common space.

Defining roles and responsibilities is present also in integrated teams. It clarifies participants' contributions in meetings and how the sequence of the design process is expected to unfold (Faris, Gaterell & Hutchinson 2019; Kapogiannis & Sherratt 2018; Kelly, Schaan & Joncas 2002; Mattessich & Monsey 1992; Patel, Pettitt & Wilson 2012). This theme is important in face-to-face interactions because several participants from each organisation are involved where some are key participants who attend regularly, and others are intermittent participants who are present as the design progresses to clarify technical constraints. For instance, a construction manager would be the key participant representing the subcontractor in regular meetings, and others such as the design manager or engineers would join when needed. When participants introduce themselves by name and the company they are representing, this means their specific responsibilities are not always clear, especially to intermittent participants, which might affect team performance (Foley & Macmillan 2005).

Having common means of accessing information is the foundation for coordinating design information (Baiden, Price & Dainty 2006; El Asmar, Hanna & Loh 2013). It is particularly relevant to the detailed design phase because participants need to access the most up-to-date information about design progress to evaluate design solutions and respond to requests for information (RFIs) (Luth 2011). The availability of comprehensive design information has also been associated with the use of Building Information Modelling (BIM) as a platform for accessing and sharing project information (Sacks et al. 2018). For instance, the use of BIM in architectural practice helped in interrogation of designs, minimisation of calculation errors and misinterpretation of design, rapid and accurate updating of changes, and improved communicating with other project stakeholders (Barzegar et al. 2020; Grilo & Jardim-Goncalves 2010; Manning & Messner 2008). The advantages of BIM in clash detection are prominent between building services and structural systems, which improved coordination between designers and contractors (Porwal & Hewage 2013; Staub-French & Khanzode 2007).

These forms of sharing information between designers and contractors can best be described as a common means of accessing passive project information such as design drawings, design specifications, program dates and a schedule of design deliverables that are critical for collaboration and improving performance (Jefferies, Brewer & Gajendran 2014; Rantsatsi, Musonda & Agumba 2020). The active information is different as it relates to another type of information that participants exchange in face-to-face interactions (Bales 1950), for example inquiries about design details, dimensions, structural element locations, or cost of components, and giving feedback or suggestions.

The working practices in IPD projects can be grouped into themes describing interdisciplinary collaboration traits, such as having a common goal, trust in expertise and capabilities, sharing and accessing information, co-locating the team in a common place and defining roles and responsibilities.

2.1.3 Aligning financial interests in relational agreements

Relational agreements, commonly known as integrated form of agreements (IFOA), are another form of the IPD approach that is used in lean construction projects and aligns with the project alliancing approach (Walker & Lloyd-Walker 2015). Relational agreements support collaboration by aligning incentive interests at a project level (Lichtig 2005). Such project delivery methods aim to create a collaborative environment by linking incentives methods to the amount of value created to the client, such as bonuses linked to adding value to the project, rewards for innovation and outstanding performance, and bonuses based on the quality of the end product (Kent & Becerik-Gerber 2010).

The cost arrangements in relational agreements are based on the estimated maximum price (EMP) model in which the owner, designers and main contractors share the risk of cost overruns and use financial incentives to align their interests (Darrington & Lichtig 2010; Forbes & Ahmed 2011). The EMP approach works towards reducing cost overruns because the architects, engineers, prime contractor and speciality contractors collaboratively generate a validation study for the client at the initial stage of the project. The validation study documents design details and the expected cost, which is based on the current market best practice provided by the main contractor (Ballard 2008). Darrington and Lichtig (2010) pointed out that in EMP models, the contractors' risk in cost overrun is reduced because of their contribution in the design process. Thus, there is less need to include high contingencies because any participant is required to justify cost overrun to the rest of the team.

The EMP is different from the guaranteed maximum price (GMP) that is commonly used in traditional procurement methods. The GMP contract encompasses that the client pays the contractor the actual cost to construct the project plus a stated fee and the contractor guarantees that the owner will pay no more than the GMP for the project (Forbes & Ahmed 2011; Walker & Hampson 2003). This type of contract transfers the risks of cost overruns to the contractor, who in return seeks ways to ensure the cost overruns do not exceed the number of contingencies and anticipated profit of the project (Winch 2009). In addition, as in any risk transfer situation, the owner initially pays a premium to transfer the cost overruns to the contractor in the form of higher fees and more contingencies depending on the complexity of the project (Boukendour & Bah 2001). This approach might affect the long-term relationship between the client and contractor due to lack of motivation to be reasonable when addressing potential cost overruns issued by the contractor (Darrington & Lichtig 2010).

Other ways to reduce cost overruns might include pushing subcontractors to reduce costs because their selection is often based on a low-price bidding process (Ballard 2006). This might push subcontractors to seek other ways to increase their profit in terms of change orders, although this does not eliminate the fact that some of the subcontractors' claims are legitimate (Winch 2009). In summary, relational agreements support the need for aligning cost interests in design discussions where designers and contractors work closely to develop a validation study for the client at the initial stage of the project and collectively adjust the cost as they proceed in the project.

The working practices in relational agreement projects describing interdisciplinary collaboration traits focus on aligning cost interests between designers' and contractors' work to achieve value for the client.

Therefore, collaboration traits in the project delivery approaches discussed in this section are summarised as follows:

- *a common goal*: working towards mutually beneficial outcomes by ensuring that all the members support each other
- *co-locating* the team in a common place
- *aligning cost interests*: designers and contractors work closely to achieve value for the client
- *common means of accessing information*: sharing information freely among organisations
- *defined roles and responsibilities*: clear roles and responsibilities are known to all participants
- *trust in expertise and capabilities* of organisations involved in the project to operate in an honest and no blame environment.

The discussion presented in this section on multi-party contractual arrangements presents the successful practices in controlling cost and improving performance. However, a number of recent studies have reported practical problems encountered by project teams in IPD projects such as lack of commitment and trust, inefficient communication, sharing limited financial information, conflicting personalities, incompetence of some stakeholders, and lack of team building activities to rectify goal misalignment (Eriksson 2015; Ey, Zuo & Han 2014; Gomez et al. 2018; Koolwijk et al. 2018; Manata et al. 2020). Further, the multi-party contracting approaches were criticised by putting too much emphasis on the financial aspect of collaboration and underrating its social dimension, which reflects the dynamics of relationships within the project team (Bresnen & Marshall 2000a, 2000b). Formal mechanisms are not sufficient to shift the ingrained adversarial attitude in the construction industry to a fully collaborative mindset (Suprapto et al. 2015). Participants forming such integrated teams have different backgrounds and expertise levels that shape their working practices (Emmitt 2010). There is still a gap between the intentions of multi-party agreements at an organisation level and what happen at the level of individuals (Bresnen & Marshall 2000b, 2002) such as in design meetings.

It is also worth noting that successful collaboration between interdisciplinary teams was documented in the relational contracting method, which is mainly used in the United States in the Sutter Health projects (Alarcon, Christian & Tommelein 2011; Denerolle 2013; Lichtig 2005; Zimina, Ballard & Pasquire 2012). Similarly, the collaborative working environment fostered by the IPD approach is commonly used in the United States (Dossick et al. 2013; El Asmar, Hanna & Loh 2013) and Europe (Baiden, Price & Dainty 2006; Mihic, Sertic & Zavrski 2014). The collaborative model offered by the alliance contracting is common in Australia but in the infrastructure construction sector (Walker & Hampson 2003), where the detailed design phase can extend for years to reach completion, which limits its suitability for this study. However, some of the benefits are achievable in some of the common project delivery methods, for example in the design and construct (D&C) approach (Forbes & Ahmed 2011; Koolwijk et al. 2018), which is used both globally and in

Australia where this research takes place. These common project delivery methods are discussed in the next section.

2.2 Traditional procurement method in construction

Traditional procurement approaches separate the project into discrete phases such as the design development, tender, contract award and construction. This arrangement might create rigid roles making it difficult for participants to collaborate and align their views about design decisions, cost and risks outside the contract boundaries (Eriksson & Westerberg 2011; Francis et al. 1999; Trebbe, Hartmann & Dorée 2015; Walker & Hampson 2003). In these settings, the client usually has the power to make changes such as changes in the design or scope of work. Consequently, the design team may claim extra payments for the time taken to investigate alternative design solutions and update the design documentation (Eynon 2013). Similarly, the contractor controls the work on site, but any slight changes made are subject to the client and designers' approval or rejection. The traditional approach in procurement puts the whole project delivery under the control of individual members who, in many situations, might have different and competing financial interests (Circo 2014).

2.2.1 Separate stages – Design, bid and build approach

The design, bid and build (DBB) procurement method resembles a linear process because it separates the design process from the construction process and deals with them as two separate phases of the project where there is no exchange of information or face-to-face interaction between design teams and the contractor at the design phase (Turner 2003). As a result, each stakeholder tends to focus more on delivering their part of the agreement and maximising their own profit, which often causes many disputes and claims. This type of agreement reflects the adversarial attitude that major project participants may adopt in negotiating agreement terms in an attempt to allocate risks to another participant (Eynon 2013).

Another significant characteristic of DBB is the presence of a series of bilateral contracts with one for the design phase and another for the construction phase (Hardin & McCool 2015). The client might have control over the quality of the end product because the bidding process is based on a complete set of drawings. However, it does not shield the client from bearing the risk of design errors because the design documents would have been approved before the bidding process starts (Eynon 2013). In practice, the design is never fully finalised, which creates opportunities to claim for design variations and extra work (Walker & Hampson 2003). This in turn does not encourage project-wide collaboration and leaves each participant to manage the associated risks with other participants, which causes opportunistic behaviour and does not focus on the best interest of the project (Forbes & Ahmed 2011). The presence of several bilateral contracts in the DBB also adds to the complexity of coordinating and managing the interface between project deliverables, particularly in the detailed design phase (Kalsaas, Rullestad & Thorud 2020).

2.2.2 Combined stages – Design and construct approach

Over recent decades, more project procurement methods have emerged as a way to bridge the gap between design, construction planning and actual construction phases of a project since traditional delivery methods have proven to be inefficient (Mihic, Sertic & Zavrski 2014). Design and construct (D&C) was introduced to link the design and construction phases. In this contractual arrangement, the client appoints a design team to develop the conceptual design to put out for tender, and the main contractor is then appointed to continue the design and construct the project (Walker & Hampson 2003). The client has a single point of responsibility to deal with, and there is no conflict of interest between designers and contractors (Turner 2003). The advantages of this method are seen as supporting innovative solutions, being overall cost effective, combining the expertise of the design and construction professionals, and reducing the administrative work of the client (Ruparathna & Hewage 2015). As for any procurement method, the D&C approach has some shortcomings associated with design changes that are managed and controlled by the contractor, such as inflated cost because the bidding process is based on minimal design data and compromised quality because of cost saving (Forbes & Ahmed 2011).

2.2.3 Contractor involvement in the design development

The construction management (CM) procurement method allows the contractor to represent the owner in being responsible for all of the administration work and delivering the project within budget and time (Davis, Love & Baccarini 2008). A key benefit of this method is allowing the early involvement of the main contractor in the detailed design phase to provide advice on the practicality of the design and construction methods and ensure that the client's objectives of quality and value for money are achieved (Forbes & Ahmed 2011). CM tasks also include providing construction planning, cost control and coordination of the work of all designers, which helps reduce confrontation between designers and subcontractor teams (Walker & Hampson 2003). However, some problems might exist because of the main contractor's management role as there is no direct contractual agreement with the designers. Under this arrangement, the main contractor's role is limited to being an advisor who relies on persuasion and providing expert knowledge to influence design decisions, which might create adversarial practices (Oyegoke Adekunle et al. 2009).

The contractual agreement between the client and the main contractor in the CM approach can take two forms. The first is a consultancy fee for providing constructability advice and coordinating the construction processes. The second form is based on a guaranteed maximum price (GMP) contract in which the client pays the contractor the actual cost to construct the project plus a stated fee and the contractor guarantees that the owner will pay no more than this guaranteed maximum price for the project (Walker & Hampson 2003). This type of contract transfers the risks of cost overruns to the contractor, who in return seeks ways to achieve the anticipated profit of the project. The main contractor might shift the risk further down the supply chain to reduce cost overruns because the selection of subcontractors is often based on a low-price bidding process (Walker & Hampson 2003). This practice pushes the subcontractors to seek other ways to increase their profit in the form of design changes and variations, and many of the subcontractors' claims may be legitimate (Do et al. 2014). The rework resulting from design changes and contract variations represents a significant share of cost overruns encountered in construction projects (Love et al. 2018; Love et al. 2002). This means risk-shifting to contractors might not be the optimal solution because, ultimately, the client suffers the consequences (Zimina, Ballard & Pasquire 2012).

The procurement scenarios discussed in this section show the difference in participants' objectives in discussing design rework and cost implications that occur in the detailed design phase. The contractor's involvement in this design phase differs in the three traditional procurement methods. It is minimal in design, bid and build and is present in the design and construct and managing contractor approaches. As mentioned earlier in Section 2.1 in the multi-party contractual agreements discussion, these forms of project delivery methods are not suitable for studying the whole detailed design phase. Therefore, this study examines collaboration in a contracting setting that is relevant to Australia using traditional procurement approaches that allow the integration of the design and construction phases. A detailed account of the contractual setting of the chosen construction project is provided in Chapter 5. Figure 2-1 below illustrates the different procurement approaches and highlights the chosen contracting setting for conducting the empirical part of this study.

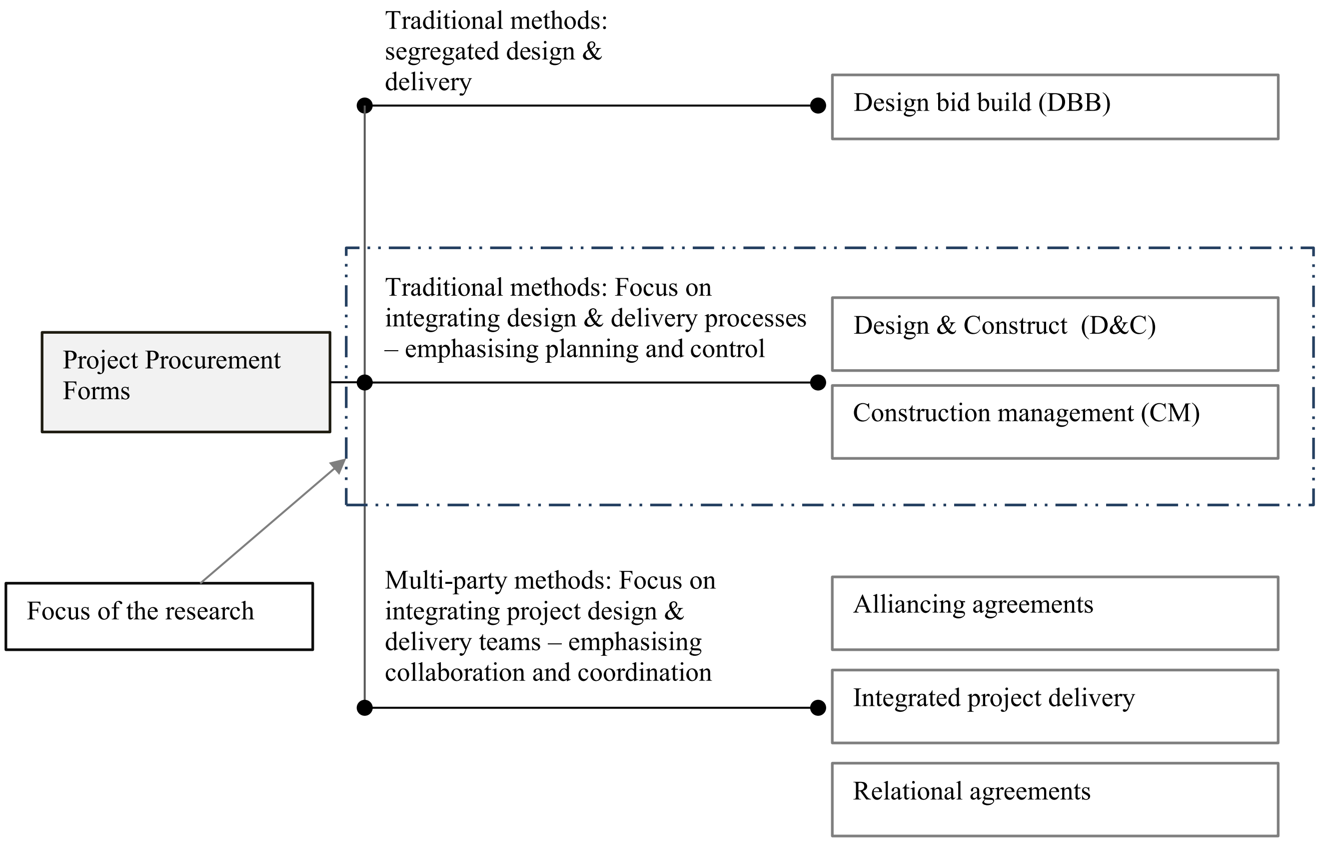

Figure 2-1 Representation of project procurement forms, adapted from (Walker & Lloyd-Walker 2015)

2.3 Conclusion

The chapter has shown that while much literature focuses on the legal frameworks that support collaboration, the expressed intentions of these agreements to enhance the process of collaboration are not yet being realised. Collaboration traits extracted from the multi-party procurement literature included a *common goal, aligning cost interests, common means of accessing information, defined roles and responsibilities,* and *trust in expertise and capabilities*. These traits revolve around regulating participants' working practices, not the process of collaboration. Given the central importance of understanding the collaboration process, the next chapter explores practices of integrating design and construction knowledge in more detail.

Chapter 3 Integrating Design and Construction Knowledge

The multi-party procurement methods discussed in Chapter 2 tend to advocate interdisciplinary collaboration at an organisation level rather than focusing on regulating working practices at a project level. This chapter builds on this argument with a general overview of the work done to enhance the integration of design and construction practices in the design phase. It discusses collaborative practices in the design phase that foster collaboration and concludes with a classification of collaboration themes describing the working practices of interdisciplinary teams in the detailed design phase.

3.1 Nature of interdisciplinary groups in construction projects

There are several definitions of the term 'group' available in the literature. For instance, a group is a number of persons engaged in discussion with each other in a face-to-face meeting or series of meetings (Bales 1950). These participants are committed to a set of values that define the overall pattern of their overall interaction (Hare 1992). A group includes autonomous stakeholders who are engaged in an interactive process, using shared rules, norms and structures to solve a problem (Gray 1989, 2003; Wood & Gray 1991). Tuckman (1965) explained that groups pass through a number of steps to develop, starting from where participants get to know each other's roles and try to avoid early negative impressions until they feel secure enough to express their opinions assertively, then they begin to develop their norms to perform tasks and interaction patterns begin to emerge.

Although it seems that the process of developing groups is theoretically straightforward, the dynamic nature of construction projects is much more complicated. The interaction may be problematic, in particular due to participants such as designers and contractors having different professional backgrounds and working procedures (Dainty, Moore & Murray 2007; Thunberg & Fredriksson 2018; Yap & Skitmore 2018). The interdisciplinary group, the focus of this research, has another distinct feature: it is inter-organisational as well as interdisciplinary, and temporarily formed for a specific project. Organisations involved in a construction project form a group of their representatives who contribute towards the completion of the project, and then the relationship comes to an end (Baiden, Price & Dainty 2006; Dietrich et al. 2010; Gorse & Emmitt 2003). Even if the same organisations are involved in future projects, there is a low chance that the same participants will work together again (Suprapto, Bakker & Mooi 2015). Dainty et al. (2007) argue that relationships between such participants are formed, developed and disbanded throughout the project lifecycle. The temporary nature of relationships makes the interactive process between participants problematic to develop the required level of synergy that allows them to constructively explore their differences. Nevertheless, their collaboration is critical to improving project outcomes.

The need for interdisciplinary collaboration in construction projects is not new, and it has been an ongoing research topic in the design and construction literature to improve the supply chain performance (Baiden, Price & Dainty 2006; Bedwell et al. 2012; Dainty, Moore & Murray 2007; Forgues & Koskela 2009). The collaborative working of interdisciplinary teams has been regarded as a solution to the increasing complexity of construction projects that made clients search for better ways to create a suitable working environment between organisations involved in projects to improve outcomes (Emmitt 2010; Jørgensen & Emmitt 2009).

Interdisciplinary collaboration was regarded as an objective to bring various professionals in construction projects to work together towards a common goal across organisation boundaries (Baiden, Price & Dainty 2006; Love, Gunasekaran & Li 1998). Scholars examined the extensive literature reviews and identified factors relevant to successful collaboration at the organisational level (For ex. Black, Akintoye & Fitzgerald 2000; Deep, Gajendran & Jefferies 2019; Eriksson 2015; Faris, Gaterell & Hutchinson 2019; Patel, Pettitt & Wilson 2012; Rantsatsi, Musonda & Agumba 2020). These studies emphasise that common success factors of interdisciplinary collaboration include trust, commitment, open communication channels, information sharing, clear understanding of roles and a flexible attitude. Despite the widespread attention of research understanding, the literature related to the practices of interdisciplinary teams – the collaboration process – in the detailed design phase still remains limited. Further, there is no consolidated information on the classification of collaboration themes describing the working practices in the detailed design phase. To enhance the understanding and insights into what constitutes collaboration, the remainder of this chapter focuses on reviewing the working practices between designers and contractors at a project level in construction projects to identify relevant patterns to better understand collaboration processes.

3.2 Practices of integrating constructability knowledge in the design phase

Constructability is regarded as the optimum use of construction knowledge and experience in design and planning site operations to achieve overall project objectives (Russell et al. 1994). Constructability information comprises two knowledge groups: the product (design) knowledge, and process (sequencing and plans) knowledge that is provided by the contractors (Pulaski & Horman 2005). Addressing constructability in the design process is often considered after possible designs have already been developed rather than being integrated into the design process (Ballard & Koskela 1998), where it is needed to minimise the effects of design complexity and uncertainty that lead to the delivery of insufficient information in construction documents (Eldin 1999; Formoso et al. 1998).

There are common practices in the industry for conducting constructability reviews. For instance, the review could be conducted by someone in the design organisation with a construction background, a construction expert who is assigned to be part of the design process, peer reviews, or by using specifications and manuals of practice (Francis et al. 1999; Pocock et al. 2006). These forms of integrating design and construction knowledge aim to improve coordination of design documentation. Another form revolves around information systems, for instance, incorporating constructability reviews into the design process linked to the design schedule by using 3D models (Hartmann & Fischer 2007). Similarly, digital approaches are used to attach assembly instructions to the structural elements in design models to facilitate communicating constructability information to designers, contractors and manufacturers (Grilo & Jardim-Goncalves 2010). A different approach incorporates the use of boundary objects as full-scale mock-ups of the proposed building to thoroughly test constructability, which helps understand the complexity of the design intent and enhances inter-organisation cooperation (Naar, Nikolova & Forsythe 2016). These forms of integrating design and construction knowledge are regarded as best practices that enhance interdisciplinary collaboration, however they do not follow a specific management approach.

3.3 Tools integrating design and construction practices

Most of the tools used to integrate design and construction knowledge were found in the lean construction literature. Lean construction has been an evolving field in some countries as a means of improving the performance of the construction supply chain by integrating design and construction activities (For ex. Barth et al. 2020; Bhat, Trivedi & Dave 2018; Jorgensen, Emmitt & Ballard 2005; Tezel et al. 2020). The lean philosophy adopted in the construction industry originated in Toyota in the 1950s as a new management approach that reformed the car manufacturing industry (Ohno 1987; Ōno 1988; Shingo 1981). The lean management system focuses on adding value to the client and reducing waste from production processes by improving productivity, quality, delivery system and product development (Womack & Jones 1990).

These lean management principles were transferred to the construction industry through (Koskela 1992)'s report on the application of the new production philosophy in construction. The lean construction management approach focuses on the way work is done to cope with uncertainty and to bring project processes under control to deliver value to the client (Koskela & Howell 2002). The aim is to reduce process waste and improve workflow by adopting some changes to convert the construction process from being a set of discrete stages to a linked sequence of work tasks (Koskela et al. 2002).

3.3.1 Integrating construction knowledge into the process of selecting design solutions

Set-based design (SBD) is one of the lean construction tools that supports the investigation of different design solutions to be done collectively with contractors to agree on the best solution. It emphasises that time should be spent upfront in the design process because once construction has begun, it is expensive to change the design (Ballard 2008; Forbes & Ahmed 2011). The SBD strategy seeks to align views about design concepts and criteria when evaluating the proposed design options from the outset of design and defers commitment to avoid premature decisions, thus reducing negative design iterations (Ballard 2002). Designers can then move forward within the limits of the defined sets of alternatives and, as the design progresses, they gradually narrow these sets based on continuous information from the construction team (Sobek, Ward & Liker 1999).

The SBD strategy was implemented in a few studies illustrating the interactive coordination between designers and contractors that promoted collaboration. For example, the SBD approach was applied in investigating relevant factors needed to evaluate façade framing systems, and the contractors' input helped in choosing the most suitable option that satisfied design criteria and constructability constraints (Lee, Bae & Cho 2012). In another example, the SBD strategy allowed designers and contractors to collectively explore innovative design ideas in testing the main structural systems that satisfy seismic resistance and identifying factors affecting structural performance (Parrish et al. 2007, 2008; Parrish 2009).

Another concept discussed in the SBD is the cross-functional team, which involves clustering designers and contractors for major trade packages of the proposed building (Ballard 2008; Ballard & Koskela 1998). The cross-functional team is the term used in lean construction literature for an interdisciplinary team that has a similar setting, including the client, designers and contractors (Emmitt 2010; Jørgensen & Emmitt 2009). Forming an interdisciplinary team is a fundamental aspect in projects applying lean tools (Arroyo, Tommelein & Ballard 2012; Mikati et al. 2007; Nguyen, Lostuvali & Tommelein 2009; Parrish et al. 2007). The aim of including main contractors and specialty subcontractors in design discussions at an early stage is to merge experiences and speed up responses to technical inquiries (Denerolle 2013). The lean studies involved multi-party procurement approaches, which foster the early involvement of contractors in the design phase.

Recent studies that focused on the detailed design phase found that many designers are concerned about delays in the design process due to uncertainty of receiving feedback from the contractors early enough to reduce the time taken to decide on a suitable design option (Kalsaas, Nwajei & Bydall 2020; Kalsaas, Rullestad & Thorud 2020). These authors also highlighted other issues, such as late changes requested from end users and the difficulties of connecting different technological tool used in discussing the interface between the building elements.

The above section illustrates the collaboration process theme of *interactive coordination* in discussing the proposed design solutions and integrating real-time cost and constructability input from contractors, and the need to form *interdisciplinary teams* that involves clustering design teams and contractors to make use of their knowledge in construction and fabrication processes to enhance constructability.

3.3.2 Integrating construction knowledge into the design decision-making process

The decision-making process is addressed in lean construction by adopting the choosing by advantages (CBA) method. CBA is a structured multi-criteria decision-making method that provides a context-based analysis that focuses on differentiating between alternatives and defers judgements until late in the decision-making process (Arroyo, Tommelein & Ballard 2013; Schöttle, Arroyo & Haas Georgiev 2017). Decisions are based on the importance of the advantages of alternatives (Suhr 1993).

The implementation of the CBA was seen in a case study of beam–column joints that showed how designers, the contractor and relevant subcontractors, such as steel fabricators and placers, worked together to conduct a rigorous analysis to explore design alternatives, illustrating another theme related to collaboration processes: *collective decision making* (Parrish & Tommelein 2009).

Forgues and Koskela (2009) stated that in collective decision making all team members are involved by having their voices heard and ideas discussed in an open manner. To reach this level of collective understanding of each other's ideas and concerns, there is a need for continuous alignment of goals through sharing information at any stage of the process (Baiden, Price & Dainty 2003). However, successful collective decision making is not a straightforward process even in interdisciplinary teams due to problems related to goal misalignment and miscommunication. These undesirable practices can occur during the interactive process between team members, which can be addressed by team building activities and workshops (Manata et al. 2020).

3.3.3 Integrating design and construction knowledge to control cost in the design phase

Aligning the designers' and contractors' knowledge to control project cost was proposed in lean construction by adopting the target value design (TVD) method as one of the key lean concepts in manufacturing introduced to the construction industry (Ballard 2008; Darrington & Lichtig 2010). The TVD concept encompasses a number of lean approaches such as set-based design and co-locating the project team in one common space, and expanded to cover constructability issues (Namadi, Pasquire & Manu 2017; Nguyen, Lostuvali & Tommelein 2009; Smoge, Torp & Johansen 2020). It is a collaborative strategy and process that aims to make the client's value (specific design criteria, cost, schedule or constructability) a driver of design, so the design is based on detailed estimates, rather than estimates that need to be adjusted later in the design process (Zimina, Ballard & Pasquire 2012).

Co-locating team members in one common space is one of the practices in lean projects, and it is sometimes used interchangeably with the use of a “big room” that is equipped with tables and screens to project 2D drawings and 3D models. The aim is to maximise the opportunities for face-to-face interaction in solving problems that occur throughout the design phase and increase the desire to discuss project issues in real-time (Alarcon, Christian & Tommelein 2011; Denerolle 2013; Gomez et al. 2018). However, physically co-locating designers and main contractor staff in a temporary shared office on the building site might not be a feasible solution for all organisations. An alternative approach is to partially implement it by including designers and contractors every other week and, when needed, for continuous periods of 3–5 days at regular intervals throughout the detailed design phase, or in regular workshops (Denerolle 2013; Zimina, Ballard & Pasquire 2012). These approaches serve the same purpose of face-to-face collaboration by bringing together designers and contractors to share knowledge and provide real-time feedback on the feasibility of the proposed design solutions (Fischer et al. 2017).

Another benefit of forming an interdisciplinary team is seen in TVD in the involvement of client, designers, contractors and relevant subcontractors in the design phase to collectively manage and control target cost by moving money across trade packages throughout the design and construction phases to optimise the project as a whole (Ballard & Pennanen 2013; Nguyen 2010). To achieve this change in mindset, TVD meetings are conducted weekly in lean projects to align ends and constraints, so the design can create means to match these ends by exploring design problems of mutual interest and searching for better solutions (Denerolle 2013). The TVD meetings enable face-to-face interaction when discussing design problems in the weekly meetings, which helped in getting instant feedback on proposed design solutions and real-time cost and constructability input from contractors (Nguyen 2010).

A study conducted in healthcare facilities to compare cost overruns in TVD projects (sample size of 47) and other project delivery methods such as D&C and DBB projects (sample size of 168) found that TVD reduced the likelihood of cost overruns and the contingencies percentage in the project budget (Do et al. 2014). However, these authors reported some limitations of their study, such as differences in budget size, complexity and the effect of other lean tools, that could impact the results. It is worth noting that there is a low number of cases implementing TVD compared to other project delivery methods to get consolidated information about financial integration practices. For instance, a recent study argued that the D&C project delivery method showed similar practices of financial integration when compared to findings of multi-party projects related to collective decision making and sharing information practices, however these findings still need further research to validate them (Koolwijk et al. 2018).

This section reinforced findings from the previous chapter about the collaboration theme of *aligning cost interests* in multi-party contractual approaches. Also, TVD provided additional themes revolving around *achieving value for money, achieving design integrity, and cost and time efficiencies* to address the client, designers and contractors' requirements and objectives of the proposed project.

A key feature in the above discussion about studies documenting lean tools appears to be following the pattern of integrating design and construction knowledge by using structured methods for documenting views, constraints and solutions. Interdisciplinary collaboration traits highlighted in this section included:

- *co-locating* the project team to a common place to enable face-to-face interaction when discussing design problems
- *an interdisciplinary* team including design teams and contractors to make use of their knowledge in construction and fabrication processes to enhance constructability
- *interactive coordination* by providing real-time cost and constructability input from contractors and being committed to improving flow of information to accelerate design decisions
- *collective decision making* by including designers and contractors to align views about design concepts and criteria when evaluating the proposed design options to add value to the client
- *achieving value for money* for the client by aligning designers and contractors' technical views when evaluating the design options
- *achieving design integrity* by making the client's value (specific design criteria, cost, schedule or constructability) a driver of design
- *cost and time efficiencies* where contractors are looking for better performance by being involved early in the design process to give constructability feedback.

Moreover, the traits reinforced and elaborated on the previous theme around:

- *aligning cost interests* when discussing design options to improve value to the client by getting feedback on cost and constructability from contractors.

3.4 Classification of collaboration themes describing working practices in the detailed design phase

A number of themes have been identified in this chapter and the previous chapter describing the working practices of interdisciplinary teams in the detailed design phase. There is a clear distinction in the themes. Some are about enabling collaboration to occur, in that they have to exist before collaboration takes place. In contrast, others describe the interactive collaboration process between designers and construction teams. Another set of themes is about the outcomes of collaboration. These groups are presented below.

1. The first group of themes is clustered around setting out the working environment to facilitate collaboration, which is the preparatory phase. These themes are *co-location, agreeing on a common goal, common means of accessing information, defined roles and responsibilities,* and *forming an interdisciplinary team*. These themes of collaboration inform and support the development of the model as they represent the agreed rules and guidelines that will regulate the working procedures in the detailed design phase. The presence of these themes before the interactive process takes place aligns with the inter-organisational practice-based stream that acknowledges the presence of factors that are likely to enhance collaboration (Gray 1989; Thomson 2003).

2. The second group of themes explains the interactive process, which is concerned with the interaction between the interdisciplinary team at a project level. The interactive process themes included *aligning cost interests, collective decision making* and *interactive coordination*. These themes provide useful input for developing the collaboration model; however, they are not detailed enough to represent the interactive process and cover the extended

discussions between participants throughout the detailed design phase. The fact that the literature only presents a limited number of themes related to the interactive process supports arguments that the collaboration process is often presented in the literature as outcomes and the interactive aspect is the least understood (Wood & Gray 1991).

3. The last group of themes describes collaboration outcomes, which is the achieved goals that will dictate the level of success of the interactive process and satisfaction. As such, the outcome themes represent the assessment and evaluation of construction projects (Winch 2009) including *achieving value for money, achieving design integrity, cost and time efficiencies*. Lastly, the *trust in expertise and capabilities among participants* theme is considered an outcome because it develops after a number of successful collaborative interactions among participants and hence creating a sense of belonging to the team (Bond-Barnard Taryn, Fletcher & Steyn 2018; Dietrich et al. 2010).

Table 3-1 below summarises the identified collaboration themes and their classification.

Table 3-1 Classification of collaboration themes on working practices in the detailed design phase

Themes	Type	Defining elements
Co-location	Enabler	Co-locating team members in one common space to enhance face-to-face collaboration by bringing together designers and contractors to share knowledge and provide real-time feedback on the feasibility of the proposed design solutions or use a "big room" equipped with tables and screens to project 2D drawings and 3D models, An alternative is to partially implement it by including designers and contractors every other week and when needed, or regular workshops.
Common goal	Enabler	Having a common goal is fostered by multi-party agreements to align participants' objectives towards the project common goal to reduce adversarial attitudes, Aligning participants' common goal was also found in the lean tools as they advocate improving value for the client and reducing process waste as clear goals for all participants at the outset of the project.
Common means of sharing information	Enabler	Having common means of sharing and accessing passive project information such as design drawings, design specifications, program dates and schedule of design deliverables, Making comprehensive design information available has also been associated with the use of BIM as a platform for accessing and sharing information.
Defined roles and responsibilities	Enabler	Clarifying participants' contributions in meetings and how the sequence of the design process is expected to unfold, It is important in face-to-face interactions because several participants from each organisation are involved where some are key participants who attend regularly, and other intermittent participants who are present as the design progresses to clarify technical constraints.
Forming interdisciplinary team	Enabler	Clustering designers and contractors for major trade packages of the proposed building to form an interdisciplinary team to merge experiences and speed up responses to technical inquiries, Encouraging exploring design alternatives by conducting a rigorous analysis of proposed options carried out collectively by designers, contractor and relevant subcontractors.
Interactive coordination	Interactive process	Discussing the proposed design solutions and integrating real-time cost and constructability input from contractors, Being committed to improving flow of information to accelerate design decisions.
Collective decision making	Interactive process	Involving designers and contractors and alignment of views about design concepts and criteria when analysing and evaluating the proposed design options to add value to the client.
Aligning cost interests	Interactive process	Collectively discussing design options to improve value to the client by getting real-time feedback on cost and constructability from contractors, Making the design based on detailed estimates, rather than estimates that need to be adjusted later in the design process, Collectively managing and controlling target cost by moving money across trade packages throughout the design phase.
Achieve value for money	Outcome	Aligning designers' and contractors' technical views when evaluating the design options to choose the best option that meets the client's requirements.
Achieve design integrity	Outcome	Making the client's value (specific design criteria, cost, schedule or constructability) a driver of design.
Cost and time efficiencies	Outcome	Involving contractors early in the design process to give constructability feedback to improve performance in the construction phase.
Trust in expertise and capabilities	Outcome	In interdisciplinary teams, it develops over time after successful collaboration process, In multi-party agreements, selecting contractors based on past experiences and a good record of working in an honest and no blame culture.

3.5 Conclusion

This chapter concludes the review of collaboration themes in the design and construction literature. The lean construction tools and studies were found useful to describe the collaboration process between designers and contractors. These themes focused on incorporating cost and constructability knowledge in the design phase, which makes the designers more informed about the feasibility of their design decisions. The chapter concluded by classifying the identified themes into three groups: enablers of collaboration, interactive process, and outcomes. Chapter 4 examines these themes from the inter-organisational theoretical lens and concludes by drawing together the literature to develop an initial model of collaboration in the detailed design phase.

Chapter 4 Collaboration Model

The purpose of this chapter is to draw together the discussions on collaboration from previous chapters into a new model of collaboration phases based on the literature review and informed by the practice-based inter-organisational theoretical perspective presented in Section 1.5 as well as the group interaction theories discussed in this chapter. This chapter concludes with the presentation of an initial model of interdisciplinary collaboration tailored for the detailed design phase of construction projects and a discussion on the research questions that guide this study.

4.1 Inter-organisational theoretical perspective

The practice-based stream of inter-organisational theory presented earlier in Chapter 1 recognises the long-term nature of the collaboration process. The long-term perspective is needed to solve complex problems because aligning views and interests does not happen spontaneously and time is needed to develop a better understanding of the problem domain (Bedwell et al. 2012; Gray 1989; Gray & Purdy 2018; Ring & Van de Ven 1994; Thomson 2003; Wood & Gray 1991). This theoretical perspective provides a number of frameworks that offer different methods of structuring collaboration. For example, Ring and Van (1994) proposed the interactive and cyclic view about the collaboration process that evolves through four stages: negotiation, commitment, implementation and assessment. Participants start by negotiating solutions, then commit to an initial solution, and proceed to implementation if they reach a collective commitment. The assessment is applied if any organisation did not commit to the chosen solution, then corrective measures are applied to the initial solution to reach an agreement. This interactive and cyclic view consolidates the non-linearity of the collaboration process.

Thomson and Perry (2006) build on the cyclic framework of Ring and Van (1994) to identify a systematic approach to administer the interactive process of collaboration, so managers know beforehand how to manage the tension inherited in negotiations among participants. In these authors' study, five variables were identified that tackle the collaboration process by (i) governing the structure, behaviour and relationships in the process of decision making, (ii) administering communication and coordination of information, (iii) reconciling individual and collective interests, (iv) building mutually beneficial relationships through the interdependence of members, and (v) building mutual trust. This view recognises the differences between organisations' interest and a collective goal, which could result in tough negotiations and competing perceptions of value that need to be managed.

Gray's (1989) model provides an integrative view of the collaboration process, defining collaboration as "the process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their limited vision of what is possible" (p. 5). As mentioned in Chapter 1, the thesis adopts this definition of collaboration for a number of reasons. This collaboration definition is based on a number of key concepts: it recognises the presence of stakeholders' interdependence, solutions are generated by dealing constructively with differences, there is joint ownership of decisions and collective responsibility of the future direction of the domain, and it recognises that collaboration is an emergent process (Gray 1989). Each feature is discussed and described below and then related to the context of detailed design meetings.

- **Collaboration implies interdependence of stakeholders**

  Interdependence of stakeholders is one of the ingredients of collaboration. Collaboration is designed to produce solutions that are not expected to be achieved by one party. Special attention is needed at initial stages of collaboration to raise awareness of stakeholders' intertwined concerns, which might be forgotten in conflicts (Gray 1989). This point might be important in macro-level collaborations because they involve, for example, organisations working with councils, government entities or communities (Gray & Purdy 2018; Thomson 2003). However, in the detailed design phase, the concept of interdependence between organisations involved in any construction project is well established, and there is a need for collaboration to be managed effectively to achieve better value for the client (Emmitt 2010; Emmitt & Ruikar 2013). Collaboration in this setting seeks to make use of the diversity of participants' skills to solve complex design problems and produce better solutions.

- **Solutions emerge by dealing constructively with differences**
  Gray notes that "respect for differences is an easy virtue to champion verbally and much more difficult to put in practice in our day-to-day affairs" (1989, p. 11). Gray (2018) explains further that different interpretations of a problem do not mean, by definition, that they are opposing views. On the contrary, different interpretations and interests in a problem enhance creativity and innovation, which can be mutually beneficial. However, in conflicting situations, participants articulate these interpretations as opposing because of the way they were framed or described. Participants tend to forget that their underlying concerns are initially intertwined and need their interdependence (Gray 1989; Gray & Purdy 2018). The same concept exists in the detailed design phase because of its long duration where conflicts are expected to occur between designers and contractors due to the inherent differences in their

working practices (Eynon 2013; Forbes & Ahmed 2011).

- **Collaboration involves ownership of decisions**

  Ownership of decisions is concerned with clarifying that participants in a collaboration setting need to reach an agreement on the solutions they discussed without external interventions such as mediation or litigation actions (Gray 1989). This concept is related to directing participants to find ways of implementing solutions by refining them through further investigations taking into account the different interpretations of the problem. In construction environments, this feature is important for understanding how designers and contractors work closely to refine the proposed solutions to deliver better value for the client (Ballard & Koskela 1998; Forgues & Koskela 2009).

- **Stakeholders assume collective responsibility for future direction of the domain**

  Responsibility for future direction of the domain is related to one outcome of collaboration that often affects future actions in the problem domain (Gray 1989). For instance, this outcome might include restructuring ways of addressing similar problems that participants need to be committed to following in the future. This concept is seen in construction projects as participants use their experience in addressing a current design problem by sharing previous design or construction concerns (Patel, Pettitt & Wilson 2012). For example, responsibility for future direction of the domain is demonstrated when a designer points out that a beam–column connection was aesthetically unpleasant because of the crowded joint, and recommends a prefabricated solution. Similarly, contractors may raise awareness of the tight space in formwork because of a small tolerance, and ask to rethink the proposed design solution.

- **Collaboration is an emerging process**

  Recognising "collaboration as an emergent process" makes it possible to describe its development and change over time (Gray 1989, p. 15). This view is important in understanding that collaboration is an evolving process that is expected to change throughout the detailed design phase. This feature informs the research methodology of this study as explained in detail in Chapter 5.

It is worth noting that despite the lack of a formal selection process between the frameworks that guides organisations' decisions and matches their activities (Guo & Acar 2005), the practice-based theoretical approaches of inter-organisational collaboration have generated much interest across many disciplines. For instance, Gray's (1989) work was studied further in several literature domains focusing on multi-organisation collaboration and stakeholders' interest (Bryson, Crosby & Stone 2006; Loorbach et al. 2010; Wood & Gray 1991), investigating determinants for collaboration between environmental groups and construction organisations (Fiedler & Deegan 2007), defining the characteristics of multi-organisational collaboration teams (Franco 2008) and conceptualising collaborative behaviours to inform human resource managers during the process of recruitment, selection and placement of individuals to take part in collaborative activities (Bedwell et al. 2012). However, the practice-based theoretical approach rooted in Gray's (1989) model has never been applied at a project level in the design and construction management literature. This study seeks to address this deficiency by examining interdisciplinary collaboration in the detailed design phase at a project level, drawing on Gray's (1989) practice-based theoretical approach.

4.1.1 Conceptualising collaboration in the detailed design phase

This section draws together the literature findings and the definition of collaboration detailed above to develop an initial model of collaboration tailored for the detailed design phase of construction projects. The first step in the creation of a new model to assist with the study of collaboration in the detailed design phase involved arranging the identified themes presented in Table 3-1 to fit with Gray's (1989) model of the collaboration process (Figure 1-2). In Gray's model, there is a clear distinction between antecedents of collaboration and where the collaboration efforts begin. The antecedents of collaboration are present in the preparatory phase, which will be referred to as enablers of collaboration. Themes in Table 3-1 that match this description are: *co-location, common goal, common means of accessing information, defined roles and responsibilities, and forming interdisciplinary teams*.

Collaboration efforts proceed in a linear fashion: problem setting, direction setting and outcomes measures (Gray 1989). The interactive process starts in the problem setting phase. In this phase, participants define the problem by conducting a rigorous analysis to develop a common understanding of each other's concerns regarding the design task they are investigating in terms of design, cost and program constraint. Two of the interactive process themes identified in Table 3-1 fit with this description: *interactive coordination* and *aligning cost interests*. Moving to the second phase in Gray's (1989) model, the *collective decision making* theme resembles the direction setting phase as participants work towards refining design solutions and collectively reaching an agreement on the best design solution that satisfies their technical concerns. Lastly, the outcomes themes identified in Table 3-1 are split into objective themes reflecting what participants achieved, such as *value for money, design integrity* and *cost and time efficiencies* and the subjective social reaction theme that is represented by the developed *trust in expertise and capabilities.* The arrangement of the identified themes under each phase of Gray's (1989) model is presented in Figure 4-1 below, which shows the first step in developing the collaboration model. The enablers of collaboration are shaded in Figure 4-1 because the active processes and the associated outcomes are the focus of this research.

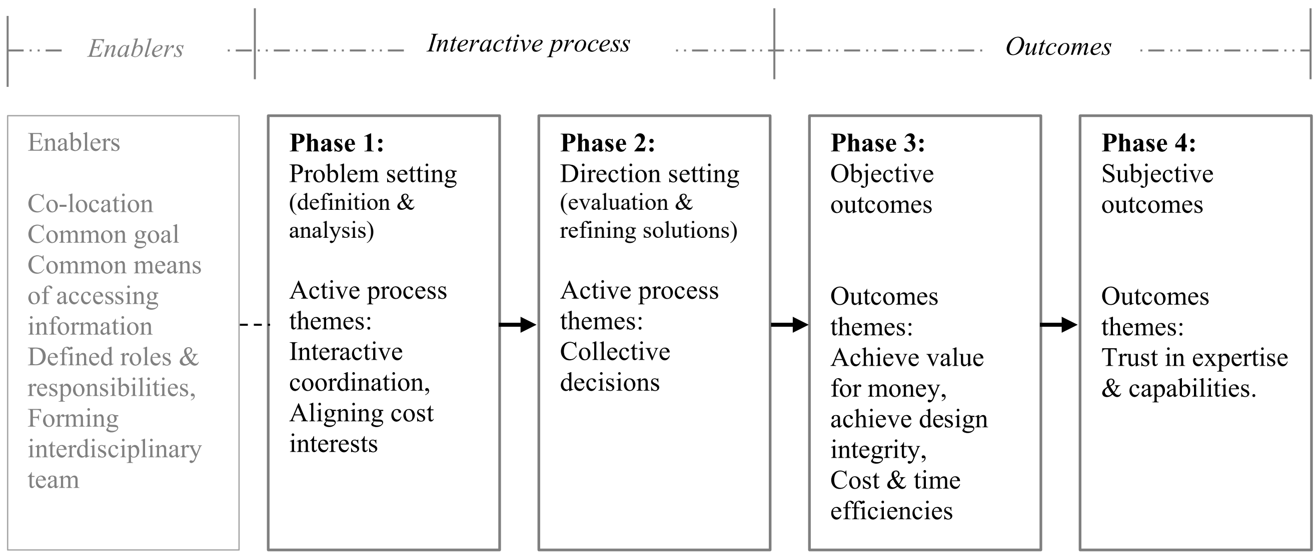

Figure 4-1 Alignment of collaboration themes in the literature with the four phases of Gray's model (1989)

Figure 4-1 highlights that the important area of interactive collaboration processes is somewhat neglected, with only a few themes identified in the research to explain what participants actually do in these discussions. As discussed in the previous chapter, there is limited information about the interactive processes. The literature also highlighted that a variety of collaboration perspectives are expected to emerge due to the diversity of participants involved in the detailed design phase. The construction industry relies heavily on people compared to other industries such as manufacturing, and subjective social reactions are important components of the collaboration process. Thus, there is a need to examine participants' interactions at a project level. To do so, the following section discusses the existing theoretical perspectives on group interaction to inform the interactive process.

4.2 Theoretical perspectives on group interaction

The theoretical interest in group interaction can be traced back more than half a century. In this time, this discipline has attracted researchers to investigate different conceptual frameworks and methodological practices. The dramaturgical perspective is a highly cited work in social science that focused on exploring interpersonal and intrapersonal participants' experience and actions within groups (Goffman 1978, 1983). Goffman argued that individuals often prepare for their roles beforehand to perform a kind of play in front of others. Thus, fieldwork should focus on studying how people interact in face-to-face contact and be able to record every gestural, visual, bodily response to what is going on around them (Goffman 1989). As such, the dramaturgical method is useful in analysing actions and participants' explanation of their action (Travers 2001). The fieldwork can be analysed as themes capturing conflict, objective, attitude, emotion, tactics and subtexts (unspoken thought or expressions) (Miles, Huberman & Saldana 2014). Goffman's (1989) interest in forms of communication within small groups helped in understanding human nature in ethnographic research. The themes identifying interpersonal and intrapersonal actions were used in analysing participants' perceptions and views about their collaboration, as explained in Chapter 5.

The functional perspective is another consolidated approach that adopts an objectivist stance to examine group behaviour and activities in the decision-making process (Poole & Hollingshead 2004). Scholars following the functional perspective identified five distinct steps to be followed by members of the group in the decision-making process: 1) have a clear and accurate understanding of the problem; 2) analyse the requirements of solutions; 3) develop a range of solutions; 4) make accurate assessment of positive consequences of solutions; and 5) make accurate assessment of negative consequences of solutions (Hirokawa 1985, 1990). These steps are concerned with information processing, procedurals and analytical methods of the decision-making process to reduce bias judgements and reveal hidden information (Hackman & Morris 1975; Stasser & Titus 1985).

The psychodynamic perspective is another approach that helps in studying small groups and the relation between the emotional, nonconscious processes and rational processes of interpersonal interaction (Harry 2018). Guntrip (2018) discussed the roots of the psychoanalytic theories of group behaviour in early work in analysing the personal identity of patients suffering from neurosis followed by the introduction of splitting and projection processes that occur in the nonconscious and affect group performance at the interaction level. A member in a group discussion might feel threatened if expressing resentments towards the leader starts to build a negative view about another member in the group and to project this resentment towards this member rather than the leader (Poole & Hollingshead 2004). Poole and Hollingshead explained that the psychodynamic perspective focused on the ego defence mechanism that differentiates between the positive and negative emotions to project them at different people, which required examining group interactions and outcomes over time.

4.2.1 Bales (1950) model of Interaction Process Analysis (IPA)

Bales (1950) built on the functional and psychodynamic perspectives to conceptualise a group as a social system and made a clear distinction between task-based interactions and social reactions. The early work of Bales presented a systematic method of observation and interpersonal rating by recording interaction in small group discussions in 12 categories (six on the task side and six on the social side) known as interaction process analysis (IPA) (Bales 1950) and established the theory of stage movement during interaction (Bales 1953). The interaction categories unfold in an identifiable linear progression as the task-based interactions were grouped as questions and attempted answers that lead to positive or negative social reactions (Bales 1950). The IPA method has been implemented in construction projects in planning field processes (Ghosh 2012), examining interactions in site-based management and design team meetings (Gorse & Emmitt 2003, 2007), and studying communication patterns between different design disciplines (Wallace 1987). Bales' (1950) systematic method of capturing participants' interaction in small groups was found useful for this research because it provides a clear protocol for coding and analysing interaction patterns among participants that can be implemented in the detailed design meetings, discussed next.

Bales' (1953) theoretical approach was chosen as it is the most useful method for coding interactions patterns in detailed design meetings. It provides a clear representation of the task-based interactions and social reactions occurring in discussions. More importantly, this approach has features that support the identification of collaboration patterns using a simple quantitative method and a clear protocol of interaction types that can be followed as shown below in Figure 4-2.

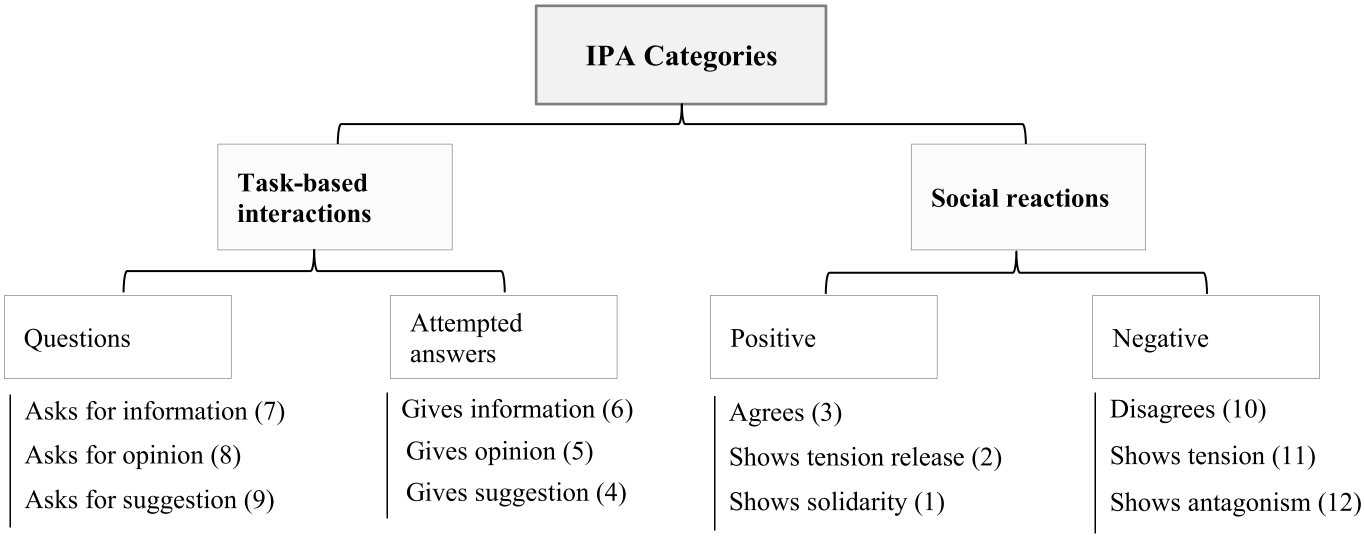

Figure 4-2 Representation of the interaction process analysis method (Bales 1950)

The IPA model shown in Figure 4-2 displays the 12 mutually exclusive categories and groups them into types of problems based on the interaction type (Bales 1950). The IPA method helps in understanding the process of collaboration in a comprehensive way as it provides a guide to categorise and code participants' interactions. In addition, Bales' (1953) approach of stage movement organises the 12 interactions into three groups: question, attempted answers, and positive or negative social reactions as shown in Figure 4-3 below. Task-based categories 7, 8 and 9 represent the questions as part of the interactive process and categories 4, 5 and 6 represent the corresponding attempted answers. Similarly, social reaction categories are divided into positive social reactions (categories 1, 2 and 3) and negative social reactions (categories 10, 11 and 12). Figure 4-3 below presents Bales' (1953) approach of interaction stages.

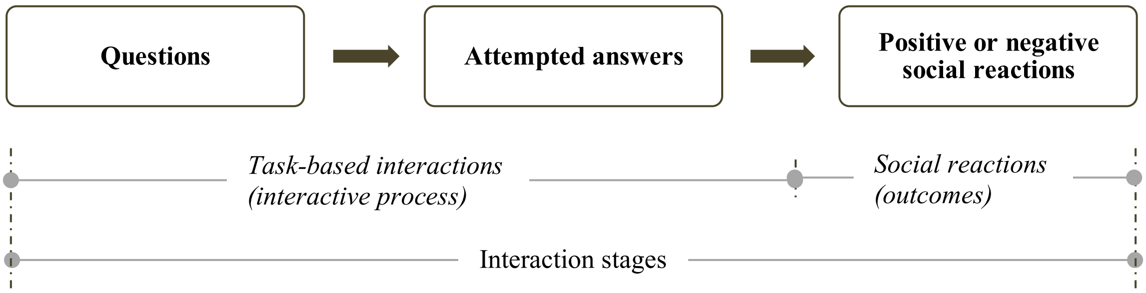

Figure 4-3 Representation of interaction process analysis (Bales 1953) approach of interaction stages

4.3 Model of collaboration phases in the detailed design phase

This section presents the new model of collaboration in the detailed design phase. It was developed by incorporating the interaction process theory of IPA (Bales 1953) with the inter-organisational perspective offered in Gray's (1989) model. Gray's (1989) model and the revised model incorporating the interactive process and outcome themes (Figure 4-1) are useful to understand the interactive process of collaboration and how it unfolds through four phases: problem setting, direction setting, objective outcomes and subjective outcomes. However, the model is limited in explaining face-to-face interactions in ongoing design meetings. Hence, theoretical perspectives on group interaction were investigated and Bales' (1953) approach of stage movement (Figure 4-3) was chosen to provide a perspective to guide the difficult task of measuring face-to-face interactions. This study combined both inter-organisational and interaction process theories as shown in Figure 4-4 below.

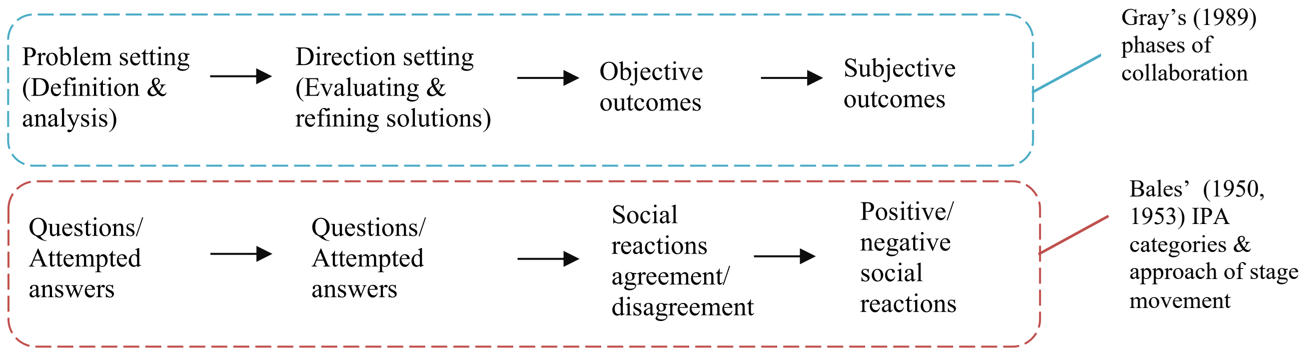

Figure 4-4 Combining inter-organisational and interaction process theories

Gray's (1989) inter-organisational process theory is represented by the four main phases of collaboration in the top row of Figure 4-4, and Bales' (1950, 1953) relevant categories of interactions and their stages are shown in the bottom row. By aligning the types of task-based interactions and social reactions (Figure 4-2) with the relevant phases of collaboration, this model provides structure for observing and coding interactions that occur in the ongoing discussions in the detailed design phase.

Therefore, a new model of collaboration in the detailed design phase is presented that combines inter-organisational and interactive process theories, and themes in the design and construction literature. The four-phase model is tailored for the detailed design phase of construction projects. The model is able to differentiate between the processes of collaboration and its outcomes, and provides a guide for measuring face-to-face interactions in detailed design meetings. The first and second phases of the problem setting and direction setting are aligned with the task-based interactions involving questions and attempted answers. The third phase represents the objective outcomes and is aligned with the social reactions of agreement and disagreement. The last phase represents the subjective outcomes, and is aligned with the positive and negative social reactions. This new model is called Collaboration Phases in Detailed Design (CPDD) presented in Figure 4-5. This initial model is used as a guiding frame for the research questions and for designing the methodology for the empirical study of this research.

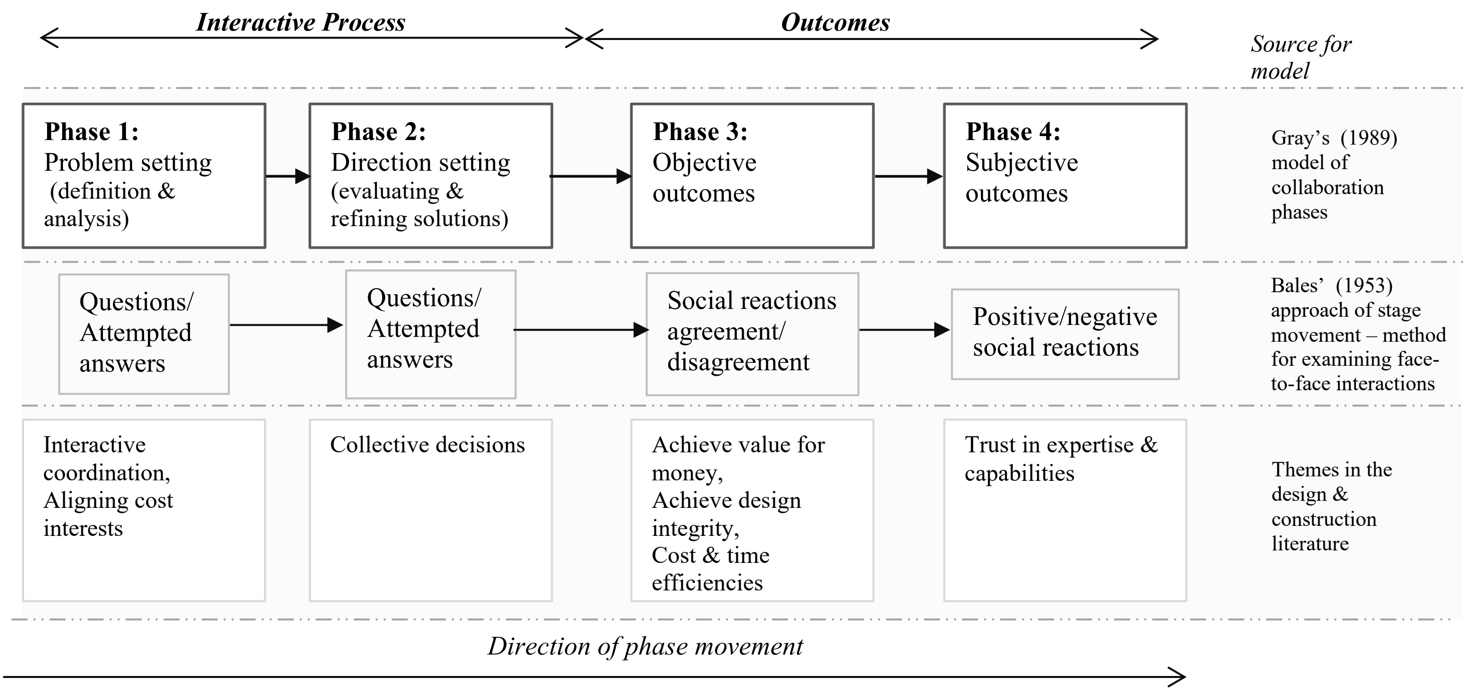

Figure 4-5 Proposed collaboration phases in detailed design (CPDD) model

4.3.1 Phase 1 – Problem setting

The problem setting in the first phase represents the beginning of the interactive process, where participants start exploring the problem from different perspectives to get a good understanding of the technical constraints. In this phase, the interactive coordination between participants includes engaging contractors in discussions to encourage innovative thinking to pursue improvements in the construction processes on site. Contractors can contribute to the discussion by providing their input on constructability, which allows designers to make better decisions with fewer design iterations. Participants' interactions also involve aligning incentive interests to bring together their views when discussing design options to improve value to the client. Participants' discussions in this phase primarily involve task-based interactions in the form of questions and attempted answers, following Bales' categories in Figure 4-2. These interactions involve the analysis of design problems, such as exchanging information, opinions and suggestions. The designers' questions reflect their need to know the contractors' constraints so that they understand the design limitations. At the same time, the contractors have several questions about the design to get a better understanding of the conceptual design to enable them to think about possible design solutions. These task-based interactions are represented in the problem setting phase 1 in the CPDD model (Figure 4-5) by categories 6 and 7 ('asks for information' and 'gives information') demonstrating patterns of communication, by categories 5 and 8 ('asks for opinion' and 'gives opinion') illustrating evaluation of design issues, and by categories 4 and 9 ('asks for suggestion' and 'gives suggestion') representing direction on how to solve a task (Bales 1950).

4.3.2 Phase 2 – Direction setting

Direction setting relates to finding ways to refine the design solutions proposed in the problem setting phase by collectively deciding on a set of solutions that are feasible for conducting more investigations. In the direction setting phase, participants begin to evaluate a wider range of potential solutions before agreeing on a specific design solution based on their skills and knowledge. Decisions are more accurate and rational if participants who have the decision-making authority – the client representatives –

engage constructively in the discussions to give directions (Alderman & Ivory 2007; Gray & Hughes 2001). Similar to the problem setting phase, participants' discussions in the direction setting phase include the same IPA categories – the task-based questions and attempted answers – to evaluate and refine the proposed solutions through exchanging information, opinions and suggestions.

4.3.3 Phase 3 – Objective measures

Much of the collaboration during the earlier phases (problem setting and direction setting in phases 1 and 2) aims to set the scene for either positive or negative social reactions in the form of the social reaction represented by the agreements or disagreements, which represent phase 3 – the objective outcomes. The objective outcomes in the detailed design setting are identified in the literature as themes focusing on achieving value for money for the client, which is achieving the best design for the money being spent (Winch 2009). This concept is present in any procurement type because the client is the principal who brings participants together in construction projects. The clients' objectives such as design criteria and functional requirements of the proposed building should be clear to the designers and contractors (Ballard 2008; Ballard et al. 2001).

Achieving design integrity is also important to the designers as their working process involves creativity and continuously looking for possibilities and options to improve the design (Lawson 2006). The design process is an intellectual activity where designers use various strategies to understand and represent the problem as an artefact that aligns with the client's objectives (Gero & Mc Neill 1998). After the client approves the conceptual design, it becomes one of the project deliverables in the form of a series of submissions in the design phases (Eynon 2013). The designers establish deadline dates for releasing the information required for design deliverables, forecasting their resources, and coordinating their working tasks (Abdirad et al. 2021; Baldwin, Bordoli & Magee 2014). These activities are required because the designers have a contractual obligation to contribute in the process of developing the design documentation that matches the design intent (Winch 2009), which explains their interest in achieving design integrity.

Similarly, the contractors need to ensure that the design is progressing within the budget and program timeframe limits (Turner 2017). The contractors need to establish the timing of activities and their sequence, evaluate risks and opportunities, monitor and control cash flow, provide information for claims, and identify the required materials (Baldwin, Bordoli & Magee 2014). These activities explain the main contractor's interest in monitoring the budget and project timeframe. Applying Bales' interaction categories, a series of social reactions are expected to emerge in participants' discussions in the form of agreements and disagreements on the proposed design solutions during the detailed design phase. Agreements and disagreements are important parts of the collaboration model as they document whether participants have reached an agreement and whether it is implemented (Gray 1989). These social reactions are represented in the CPDD model (Figure 4-5) by categories 3 and 10 ('agrees' and 'disagrees'), which document problems related to decisions (Bales 1950).

4.3.4 Phase 4 – Subjective measures

The last stage is related to the subjective aspect that documents participants' satisfaction with the collaborative processes and acceptance of the achieved objectives, which can motivate them to sustain their collaborative efforts (Gray 1989,

p. 256; Mattessich & Monsey 1992). The developed trust in expertise and capabilities among participants was identified as one of the collaboration outcomes. Trust is supposed to develop over time after several successful collaborative interactions among participants as it creates a sense of belonging to the team (Baiden, Price & Dainty 2006). However, in construction projects, participants may have insufficient time to develop trust due to time pressures that limit their experience of working together. This might affect negotiations and interactions in meetings. For instance, participants might feel unsure that their concerns were considered or adequately discussed before decisions were made, which could extend negotiations on critical design issues (Emmitt 2010). The social reactions in the IPA method are useful here in capturing participants' satisfaction in the ongoing discussions (Bales 1950). These social reactions include signs of satisfaction, appreciation or dissatisfaction and tension. These social reactions are represented in the CPDD model (Figure 4-5) by categories 2 and 11 ('shows tension release' and 'shows tension') illustrating problems of tension reduction, and by categories 1 and 12 ('shows solidarity' and 'shows antagonism') illustrating satisfaction and problems of re-integration (Bales 1950).

These four phases demonstrate how collaboration in the detailed design phase unfolds in the ongoing iterations of meetings that are going to take place over an extended period to develop the conceptual design into a set of construction drawings. The CPDD provides new insights on how a design discussion unfolds through four linear collaboration phases (phases 1 to 4). The interactions that take place in the interactive process (phases 1 and 2) shape participants' views about their collaborative efforts, which are reflected in the social reactions representing the outcomes (phases 3 and 4) due to the diversity of participants involved in the detailed design meetings.

4.4 Research questions

The CPDD model in Figure 4-5 guided the empirical study by highlighting the important but neglected area of interactive collaboration processes – what participants do in the ongoing discussions. Collaboration is a process that changes over time (Gray 1989) as it fluctuates between easier and more difficult discussions (Thomson & Perry 2006). Given the long duration of the detailed design phase and the different levels of design complexity, it is likely that participants will have different views and practices in these design discussions. Therefore, there is a need to study participants' interactions and views about their collaboration to address the deficiency in the interactive process areas. As such, the developed CPDD model helped in informing the following two research questions:

Research question 1:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.1: Are there different patterns of interactions in different design environments?

RQ 1.2: Are there patterns of interactions aligned with positive or negative outcomes of collaboration?

This research question guides the investigation of the face-to-face interactions in the detailed design meetings to study patterns of group interactions across the four phases of the CPDD model. Participants involved in the detailed design meetings have different backgrounds, views and attitudes that shape their daily working practices (Eynon 2013). Bales' (1950) IPA coding framework provides a systematic approach to capture group interactions and analyse collaboration patterns in the four phases of the CPDD model. The ongoing interactions between these participants influence their perception of collaboration because if participants are not satisfied with the collaborative processes, they are unlikely to accept the outcome (Gray & Purdy 2018; Mattessich & Monsey 1992). Thus, participants need to experience progressive achievements (phases 3 and 4 of the CPDD model) to be motivated to maintain their ongoing collaborative efforts (phases 1 and 2). Therefore, question 1 investigates how patterns of collaboration occur in the four phases and how they differ in an easier design environment and in a more complex design environment.

Research question 2:

RQ 2 : How do organisations manage interdisciplinary collaboration in detailed design meetings of construction projects?

> *RQ 2.1: What factors are relevant to the success of interdisciplinary collaboration in detailed design meetings?*
>
> *RQ 2.2: What approaches do organisations use to address problems in interdisciplinary collaboration in detailed design meetings?*

From the inter-organisational perspective, managing collaboration processes requires a deep understanding of how the phases unfold to differentiate between a well-managed process that leads to a collaborative advantage and a dysfunctional one in which participants feel strained and collaborative inertia occurs (Gray 1989; Gray & Purdy 2018; Huxham 1996). As such, this research question seeks to investigate whether and how collaboration is managed in the detailed design meetings. The question also explores management approaches that were implemented to improve collaboration in the detailed design phase in different design environments.

4.5 Conclusion

The chapter presented the developed four-phase CPDD model that combines two theories: the inter-organisational collaboration (Gray 1989) that explains collaboration, and group interaction theories (Bales 1950) to capture face-to-face interactions in the detailed design phase. The four phases include problem setting, direction setting, objective outcomes and subjective outcomes representing the development of interdisciplinary collaboration efforts. The research questions that were drawn from the literature and informed by the CPDD model have been presented. The CPDD model and the questions guide the research design presented in the following chapter.

Chapter 5 Research Methodology

Having established the research questions derived from themes in the design and construction literature and informed by the initial CPDD model, this chapter details the philosophical paradigms, methodological framework and detailed methods of data collection and analysis underpinning this longitudinal research study. The constructionist ontology adopted is linked to an interpretivist epistemology. Within a case study framework, non-participant observations, quantitative rating tool, interviews and project documents were used to gather multiple types of data to investigate the research questions. The research approach was designed to collect and analyse data on the collaboration interactions during detailed design meetings and the associated outcomes.

5.1 Philosophical position of the research

The philosophical approaches to research inquiry outline the beliefs about the nature of knowledge, the relationship between the investigator and what can be known, and methods of conducting research. Ontology and epistemology are known as the philosophical paradigms, which are the belief systems that shape the nature of inquiry (Bryman 2016; Creswell & Poth 2018). They act as a lens, a set of beliefs that guides the researcher's actions and interpretation in studying a particular discipline (Guba & Lincoln 1994). Paradigms are the ways of thinking, values and assumptions that guide the researchers in developing the methodological framework to conduct the research study (Maxwell 2012). The influence of these paradigms is important in understanding the potential contribution of this research to knowledge because they shape the approaches for data collection and analysis methods.

The earlier chapters highlighted the complex nature of collaboration in the detailed design phase of construction projects. The participation of people in diverse roles and from different organisations adds to the complexity involved in developing a set of shop drawings ready for construction. Understanding collaboration between these participants can be developed by observing their working practices and collecting their impressions through interviews and survey feedback to gather insights into the reality embedded into their views, beliefs and norms and how they interact in tackling the technical problems. Studying these realities necessitates exploring the social processes using different methods to inform the research questions. The next section justifies the research paradigms and methodological framework adopted to investigate this social phenomenon in the context of design meetings.

5.1.1 Ontological position

Ontology is the theory of being that shapes our understanding of the form and nature of reality (Bryman 2016). In social science, there are two main opposing ontological perspectives, positivist and social constructivism, which differ in interpretations of reality and are reflected in how they shape the research methodology and how data is understood and interpreted (Creswell & Poth 2018). The ontological position adopted in this research is social constructivism because collaboration is a social phenomenon that involves participants who have different objectives, background, level of expertise and perceptions that shape how they conceptualise realities. The social constructivism paradigm views realities in the form of multiple, intangible mental constructions and adopts an interpretive methodology to understand phenomena (Lincoln & Denzin 2000). These multiple meanings are formed through interactions with others allowing researchers to investigate the complexity of relative views rather than being limited by few ideas.

Constructivists believe that phenomena are not only produced through social interaction, but they are in a constant state of revision (Bryman 2016). Social research is a study of people that requires the interpretive understanding of people's views and insights. To adopt the constructivist paradigm, the researcher engages in the data collection process using observations and interviews. The more open-ended questions asked in interviews, the better the results obtained as participants will provide useful explanations and reflections (Creswell & Poth 2018). Therefore, the constructivist approach is appropriate for this research aim in understanding how participants interact in collaborative environments and enabling them to expand on their views, thus gaining deeper insights into the collaborative phenomenon.

In contrast, the positivist paradigm believes that reality exists and can be studied, captured and understood (Guba & Lincoln 1994). Positivism is usually associated with quantitative research where theories are well known, such as in scientific research to quantify phenomena by testing the relationship between variables for generalising findings (Creswell & Poth 2018). Another distinct difference between positivism and constructivism is in their approach to theory development through data analysis. The nature of the link between theory and research is necessary for forming the research framework to understand social phenomena and interpret research findings (Bryman 2016). In the positivist approach, the research methods use experiments that start with a theory to deduce hypotheses and design a study to test them (Runeson & Skitmore 1999). The constructivist approach tends to construct a theory inductively developed systematically from the data collected (Robson 1993). Even though positivism and constructivism are seen as the two ends of a spectrum, they are related when theory is not well developed. The inductive approach is needed to frame the problem and define the main variables related to the phenomena, which is achievable through the constructivist lens, and tested on a large set of data using the positivist deductive approach (Creswell & Poth 2018).

5.1.2 Epistemological position

Epistemology refers to the relationship between the researcher and how reality can be interpreted (Guba & Lincoln 1994). The epistemology perspective shapes our understanding of the social world, the way we study it and the best way to generate knowledge (Creswell & Poth 2018; Maxwell 2012). The epistemology adopted in this research is interpretivism, which is closely linked to the ontological position, social constructivism. Interpretivism assumes that the researcher is engaged in a dialogue with participants to understand how they construct knowledge (Creswell & Poth 2018). The interpretivism position is different from the positivist approach that detaches the researcher from the research setting (Bryman 2016). In contrast, interpretivism recognises that researchers cannot be completely detached from the research process as they are engaged in qualitative data collection.

Interpretivists are anti-foundationalists as they believe that there is no universal correct path or particular method to knowledge, as methods or paths are products of a specific group or culture (Willis 1995). Interpretivists do not reject existing methods of understanding phenomena, but simply argue that there are different frameworks or methods that can be used to investigate how people create and construct meaning from their experiences (Bryman 2016). Hence, it is about exploring the depth and richness of the social phenomena through understanding how people experience the world, their interactions and the setting in which they interact (Maxwell 2012).

In the context of this research, collaboration is a socially based phenomenon in the construction industry that is known to rely heavily on people. Participants involved in design meetings create multiple meanings of the collaborative phenomenon as they interact with each other, bringing their own meaning of actions to the world around them. The interpretivist epistemology allows investigating the entire phenomenon for in-depth understanding that requires gathering multiple interpretations (Lincoln & Denzin 2000). Interpretivists use methods of collecting data that are meaning oriented, such as interviews and observations, to understand the researched phenomenon through the people involved in it (Creswell & Poth 2018). This research aims to study these multiple interpretations. Therefore, the interpretivism paradigm is appropriate for this research as it follows a qualitative research method and lends itself to a case study approach by using a variety of data collection methods rather than an experimental approach.

5.1.3 Research method

The ontological and epistemological positions adopted in this research inform the selection of an appropriate method to conduct the empirical study, which involves the actual process of data collection and analysis. Methods can be grouped into two common approaches: qualitative and quantitative. Quantitative research follows the positivist and deductive approach and often adopts experimental methods that separate the researcher from the data and context of the study (Teddlie & Tashakkori 2009). In contrast, the qualitative research follows an interpretivist and inductive approach that requires the researcher to collect data in the social setting in which the research takes place (Bryman 2016). In this regard, the quantitative research seeks explanations of realities and the qualitative research focuses on determining why and how realities occurred from the people involved in the events that created these realities (Maxwell

2012). In doing so, qualitative research attempts to study everyday practices of people in their natural setting (Travers 2001).

Therefore, the qualitative researcher aims to collect multiple types of data about the phenomenon through the people involved in it. This close involvement in the data collection provides better understanding of the phenomenon (Patton 2002). While qualitative research can be criticised for the lack of objectivity and reliability of the methods used in testing relationships between the variables, it is highly valued for its richness in providing deep insights into the phenomenon and validity (Patton 2002). As Merriam (1995) explained, qualitative research focuses on providing rich description of the phenomenon studied, which requires purposeful sampling and multiple methods of gathering the data.

In qualitative research, multiple sources of evidence and analysis are required to capture the phenomenon under investigation (Travers 2001). This method fits with the complexity of interdisciplinary collaboration as a social phenomenon that cannot be studied by a single type of data, but needs multiple approaches to understand its context and the realities constructed by the participants involved in the design meetings. In this regard, qualitative data types include observations, interviews, open-ended questionnaires and documents (Creswell & Poth 2018; Patton 2002; Travers 2001). Aligning with these methods, qualitative data analysis is often presented as narratives incorporating quotes from participants describing their views about the phenomenon and context. Also, in qualitative research, the data collection and data analysis processes are integrated, meaning that as data emerges it is analysed to inform the next data collection process (Travers 2001). The application of methods such as the case study approach offers this level of investigation through multiple sources of evidence to get deep insights into the phenomenon being studied, which aligns with the qualitative research aims (Yin 2017).

5.2 Research design – A case study framework

The research design refers to the whole process of investigating the topic, including framing the problem and research questions, data collection, analysis, interpretation of findings and reporting the results (Creswell & Poth 2018; Denzin & Lincoln 2008). The case study design follows a logical sequence of linking the data collection to research questions to form the conclusions (Yin 2017). In this research, a case study framework is adopted based on the constructivism and interpretivism paradigms, which were identified earlier as suitable for investigating a social and complex phenomenon such as interdisciplinary collaboration. Aligning with these paradigms, this research is concerned with understanding the trends in participants' interactions representing the dynamics of face-to-face collaboration in its natural social setting. To achieve this aim, a case study research approach has been selected as it best suits this research.

To ensure the reliability of results, the case study allows the use of multiple sources of evidence to capture the diverse realities of the research phenomena (Travers 2001). The use of multiple methods of data collection enables the researcher to cross-reference multiple interpretations to produce a reliable picture of the phenomenon under investigation (Creswell & Poth 2018). The case study is particularly suitable for this research as the boundary for face-to-face collaboration extends beyond the design meetings to include participants' perceptions, views and interpretations of their actions (Yin 2017). Lastly, the case study approach allows investigating a case over time through detailed in-depth data collection methods such as observations, interviews and documents (Creswell & Poth 2018). These advantages match the research needs to study the collaborative phenomenon and to capture participants' reflections on its processes, given the variety of disciplines involved in construction projects.

5.2.1 Types of case study and design

The selection of the type of case study is guided by the research conditions. The objective of case studies can be categorised into intrinsic and instrumental (Stake 1995). The intrinsic case study refers to situations where the researcher is interested in the case itself and not the general problem across multiple cases. Alternatively, the instrumental case study type is chosen in situations where the aim is to investigate the general problem by understanding its context and effects. Within these types of case studies, the selection includes a single case, multiple cases having the same context, or different individual cases (Creswell & Poth 2018).

This research uses an instrumental case study design using two different and contrasting cases. According to Yin (2017), the selection of multiple cases adopts the replication logic, which is different from the sampling logic used in surveys for generalisation. Replication is either literal for predicting the same results or theoretical for predicting contrasting results (Yin 2017). Multiple cases having the same context require more resources to conduct several studies and analyse the data generated. As in any research approach, there are advantages and disadvantages. While multiple cases can provide robust findings, much more in-depth insights and findings can be provided from a single study (Bryman 2016; Travers 2001). Yin (2017) argues that a small number of cases can meet the higher research validity requirements because of the deep investigation of the context. Therefore, the case study approach enables deep exploration of the data and findings to provide new understandings and insights, which matches the constructivism and interpretivism paradigms and qualitative approach adopted in this research.

Despite the wide use of case study across various research disciplines, it has been criticised for the lack of generalisation of the finding and its reliability and validity (Flyvbjerg 2006). To address these criticisms, Yin (2017) developed a logical framework for conducting case study including four tests: construct validity, internal validity, external validity and reliability. Construct validity refers to the degree of accuracy of operational measures to capture the studied phenomenon. Yin (2017) advocates using multiple sources of evidence, establishing a chain of evidence and reviewing informants. The strength of the case study approach relies on using different methods of data collection to understand a phenomenon. As such, this research uses multiple sources of data, including short surveys, observations, interviews and archival documents, as detailed in the following sections. Internal validity ensures that the research inquiry was carried out using credible methods. This test deals with the methods of data analysis including the use of pattern matching, logic models, explanation building and addressing rival explanations. External validity refers to the generalisation of the research findings. This problem is addressed in the research design by choosing between the literal replication for predicting the same results or theoretical for predicting contrasting results. Lastly, the reliability test refers to the dependability and consistency in the process of data collection. Yin (2017, p. 116) advocates the use of a case study protocol database to organise and document the data collection methods.

To avoid misinterpreting the findings and to refrain from subjective judgments, case study research requires the researcher to collect data using various sources of evidence and to verify the findings using triangulation of methods (Yin 2017). Data triangulation is defined as a protocol for ensuring accuracy and providing an alternative explanation by converging the multiple sources of evidence to study the same situation rather than analysing each data source separately (Bryman 2016; Patton 2002; Stake 1995; Yin 2017). The concept of data triangulation addresses potential construct validity problems (Yin 2017). The use of triangulation through multiple methods of data collection in this study is best described by Merriam (1995, p. 54): "if the researcher hears about the phenomenon in interviews, sees it taking place in observations, and reads about it in pertinent documents, he or she can be confident that the reality of the situation, as perceived by those in it, is being conveyed as truthfully as possible".

Before explaining the case studies used in this research and the data types in the following section, the pilot study and data collection challenges are discussed first as they guided the selection of cases.

5.2.2 Lessons learnt from the pilot study

A pilot study was conducted before the data collection phase to get a better understanding of the nature of the detailed design meetings in complex construction projects. The pilot study aimed to get feedback on the proposed collaboration framework of the CPDD model from consultants in the construction industry to adjust the research design if necessary. This step involved interviewing three senior consultants who had from 15 to 25 years of experience in the construction industry: a structural engineer working in a Tier 1 contractor organisation, a BIM manager working in a Tier 2 contractor organisation, and a senior architect in one of the leading architecture organisations in Sydney.

The pilot study helped to refine the research design based on these participants who gave an overview of their collaboration experience. For instance, one interviewee suggested that the success of the interactive process depends on participants who possess a collaborative personality and proactive attitude. Another interviewee was more concerned about maximising client value in terms of design quality, especially after using modern technological tools such as BIM that promote collaboration between project parties. A different comment was made in the process of decision making in the absence of a contractual setting that advocates collective decisions such as alliance contracts (Davis & Love 2011). One interviewee explained that in traditional procurement approaches, collaboration between participants helps to produce a better quality of decision rather than achieving consensus between participants involved in the meeting. Lastly, the interviewees shared the same view about complex projects being hard to compare because they differ even if they have the same contractual setting.

Based on these insights, the research design took into consideration the duration of data collection needed to capture participants' interactions in collaborative sessions and the nature of the construction project to be studied. Construction projects are divided into a number of major trade packages including foundations, structure, mechanical, electrical and plumbing, interior fit-out and landscaping. Some of these packages represent proportionally high cost parts of a building such as the structure, services and curtain walls (Forsythe 2018). As such, any of these key packages would be suitable for this research because project participants are expected to benefit from improved collaboration. The pilot study showed that there is a need to define the research scope in a practical way to meet the research time limitations.

5.2.3 Data collection challenges

The major challenge in selecting case studies is the ability to gain access to design meetings and approvals for data collection to take place. Construction projects are difficult to access due to the confidential discussions that occur, especially in detailed design meetings, to adjust the scope of work and its associated cost. The design documentation submitted for tendering is conceptual and is not detailed enough to be priced. Some design items in the detailed design phase go through a series of evaluations and repricing of components. The cost information discussed in such meetings is considered very confidential, and participants prefer not to share it outside the project boundary. This confidentiality was the reason for several unsuccessful attempts by the researcher to gain access to suitable projects even though confidentiality provisions were dealt with extensively as part of the research ethics approval process.

Furthermore, approvals were needed from different organisations involved in design meetings, such as the client, designers, contractor and subcontractors, which was very hard to achieve. Thus, there was a need to find a project manager interested in the research who was prepared to help get approvals from the supply chain members to take part in the empirical stage of this research.

5.3 Case study project

Two case projects that were part of the same overarching project were used to investigate the research questions. The selection criteria were that each case should (i) have a sufficient number of stakeholders representing perspectives such as the client, architect, design consultant, main contractor and subcontractor, and (ii) represent a different degree of design complexity to reflect the contrasting design environments. The overarching case project selected was a $230 million educational building of 32,400 square metres in Sydney. The client, as an organisation in the educational field, secured the researcher's access to this project and facilitated the process of getting other parties' approvals.

The proposed case study educational building has 17 floors with two underground levels, a five-storey podium and a 10-storey tower. Two façade packages of the building were the basis for the empirical research: a standard façade design and a bespoke façade design. The first case study (case study A) within the overarching project was a standard façade that included a closed cavity façade system that the designers and nominated subcontractor have used before in previous projects. The second case study (case study B) in the same overarching project had a bespoke façade type, which included several design challenges that the subcontractor needed to resolve when designing the supporting structural system.

The standard façade type represented a less complex set of design challenges than the bespoke façade, thus providing two contrasting settings in which to explore collaboration. These work packages were treated separately in terms of subcontractors' procurement and budget. These features enabled the research design to adopt the theoretical replication in the longitudinal study to capture the collaborative process throughout the detailed design phase. The differences between the two façade systems enriched the observation data because it allowed the researcher to observe and capture different types of interactions between participants. Figure 5-1 below illustrates the overarching shell project and the two case studies.

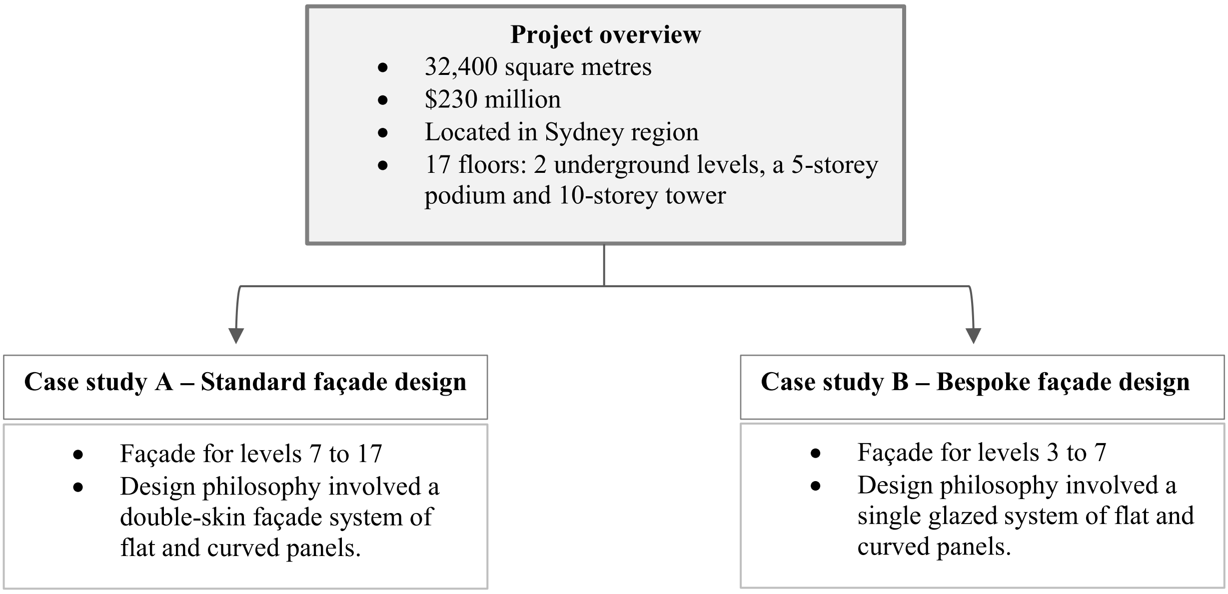

Figure 5-1 Representation of the overarching project and two case studies

5.3.1 Contractual relationships in the façade project team

The client procured this project as a managing contractor with a cost-plus contract. Based on this delivery method, the main contractor was responsible for managing the façade detailed design phase to ensure that the client's objectives were met in terms of achieving the design intent and managing the financial aspects of this façade package. Other separate contracts existed between the façade project team members. The client had a direct consultancy agreement with the architectural firm. This agreement included a set of standardised provisions commonly used by the client, where a reference was made to attendance and participation in design meetings and workshops. A similar consultancy contract existed between the client and the façade engineering organisation. As such, the façade engineer needed to liaise with the main contractor and subcontractor on the compliance of all façade testing requirements. The main contractor had a separate design, construct and maintenance (DC&M) contract with each of the façade subcontractors. The client's delivery manager expressed to the researcher his satisfaction with this contract type as it creates a sense of ownership because the subcontractors would be responsible for the façade maintenance after project completion. Of note, the client used a collaboration provision in all the contracts that stated that organisations' representatives should be involved regularly in the design meetings and collaborate in developing the design. The client asked the main contractor to add the same collaboration provision in the contract with their subcontractors. This procurement setting was suitable to study collaboration because it provides the platform for integrating design and construction knowledge and processes (Section 2.2.3).

The project complexity also matched the selection criteria in terms of the diversity of stakeholders involved and the suitability of the trade packages that provide two different design environments. Figure 5-2 below illustrates the contractual relationships between the façade project team members for the two case studies.

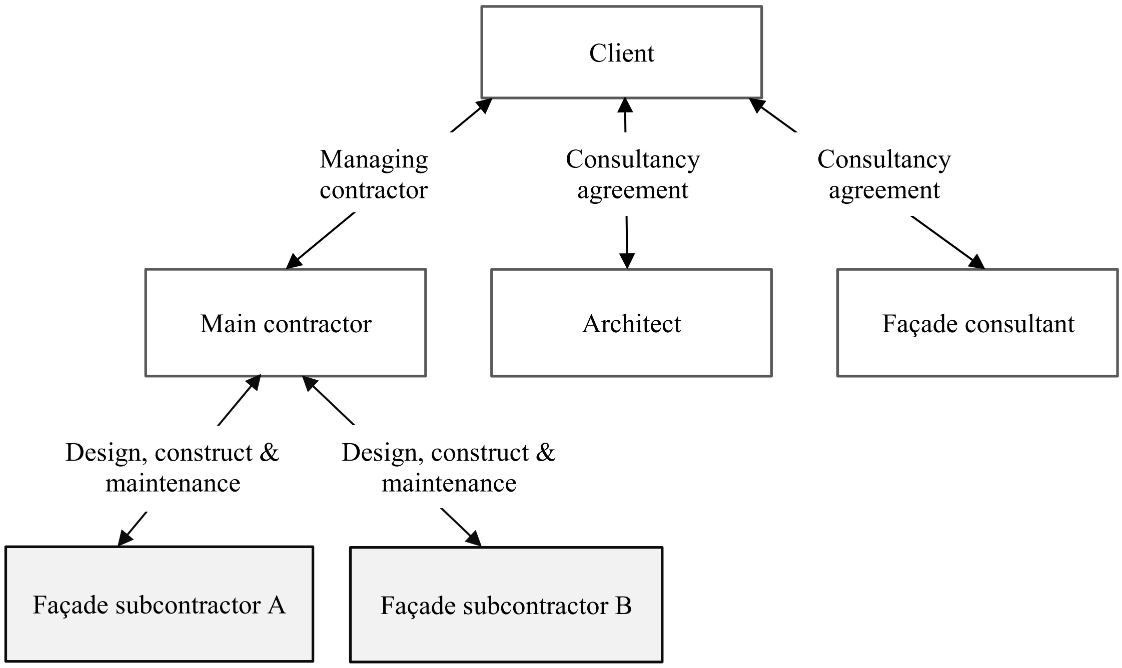

Figure 5-2 Façade project team contractual relationships

5.4 A holistic system for capturing collaboration

The longitudinal method was underpinned by data collection at detailed design meetings over the course of a year. To answer the first research question, the data collection included non-participant observations, a simple rating tool to collect participants' views about their collaboration experience after each meeting, short interviews and examining minutes of meetings. These multiple methods were needed to measure a perception-based phenomenon such as collaboration because it involves people working together. Therefore, people's views on whether they collaborate, or not, were highly important. To answer the second research question, the data collection included an extended version of the interviews to get deeper insights about the management aspect of collaboration from participants' perspectives.

The first qualitative data collection method involved non-participant observation in the design meetings. Observing participants' interaction from inception to completion on a continuous time scale enables the researcher to capture the complete profile of team interactions (Buvik & Rolfsen 2015). The method used here involved observing participants' interactions in the weekly design meetings, which aimed to emulate this approach. The second data collection method involved participants' perception and understanding of the collaboration context. In this method a concurrent nested design approach was used to collect the data (Creswell & Plano Clark 2011). This approach was useful when different forms or levels of information are needed and cannot be obtained by a single method. This is different from the sequential approach, where each method is conducted and analysed separately (Bryman 2016). The concurrency in data collection matched the research needs to capture collaboration in its normal setting, and also to capture participants' perception repeatedly after each meeting throughout the detailed design phase, which was the second data collection method.

The third data collection method was designed to study participants' interpretations of their collaborative experience. This was achieved by conducting qualitative interviews to encourage participants to explain the reasons behind their ratings. The fourth data collection method gathered minutes of meetings to verify the data collected from the observations. Figure 5-3 below illustrates the data collection process.

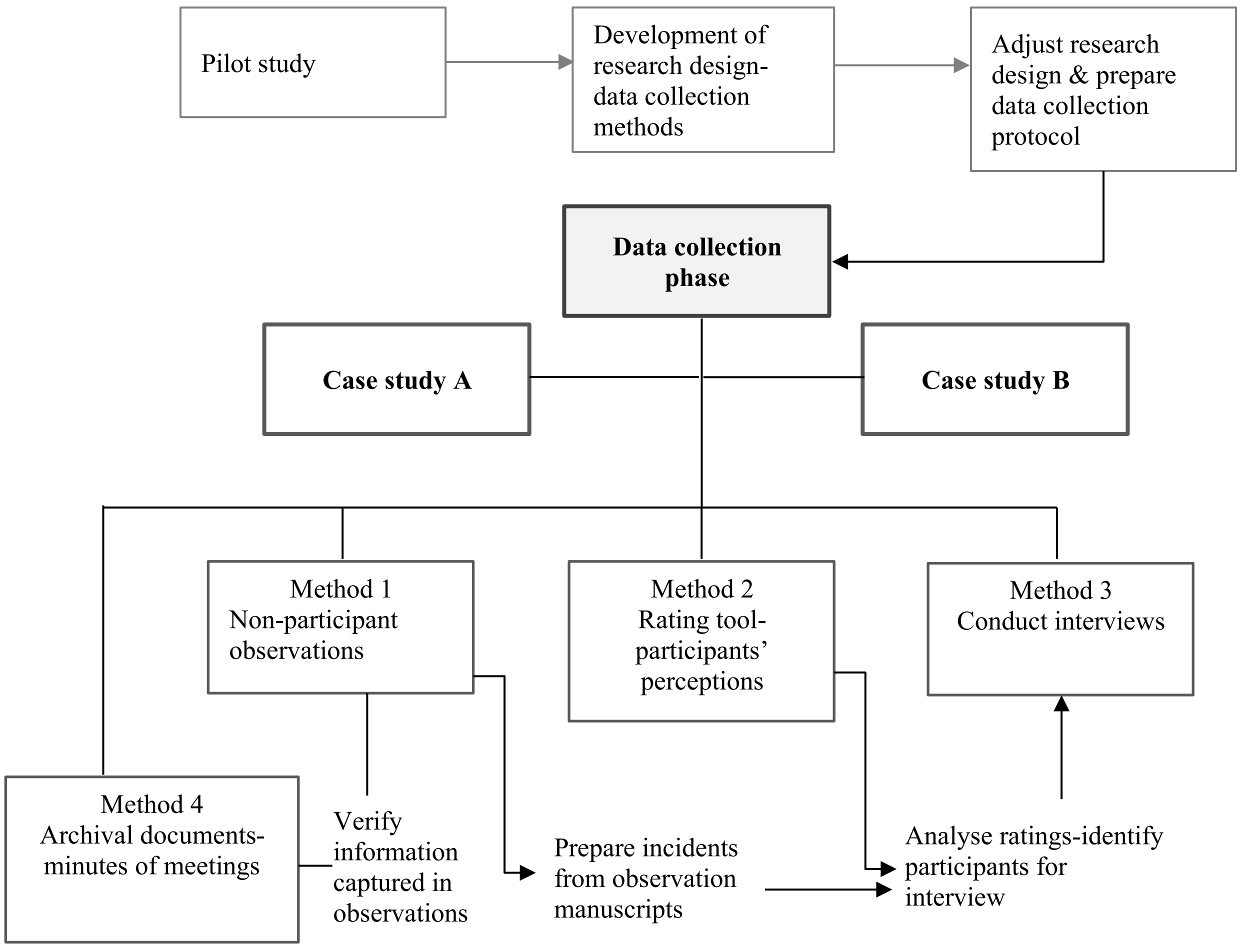

Figure 5-3 Data collection methods and process

As noted in Figure 5-3, there are different types of data collection involving participants and documents. Method 1 included non-participant observations conducted in weekly meetings. This type of data captured the interactions that took place between all participants who were involved in the meetings. Each organisation had a number of participants representing it, where one leading participant was assigned as the point of contact for this project. These participants are referred to as key participants in this research. There were other participants from each organisation involved in the meetings depending on the type of design, construction or management problem under investigation. For instance, there were six participants representing the main contractor, including the project engineer, contract manager, delivery manager, design manager, construction manager and site superintendent. The project engineer as the key participant (point of contact) was present in all meetings, the construction manager attended most of the meetings and the delivery manager attended the meetings where time and cost concerns were raised. The design manager was present in some meetings to coordinate design information between trade packages. The site superintendent was present in a number of meetings that included façade alignment adjustments because of the implications for the structural trade package. Method 2 (collecting collaboration ratings) and method 3 (interviews) of the data collection involved key participants only.

Table 5-1 below presents all participants involved in the data collection for method 1 in both case studies. The participants highlighted in bold font and shaded were the key participants involved in the rating of collaboration and the interviews as part of method 2 and method 3. This is followed by a detailed discussion of these data collection methods.

Table 5-1 Participants involved in the detailed design meetings

Organisation	Participant's role	Participant's code (and label used in observations and interview findings)
Client	**Delivery manager**	**L1**
	Planning manager	L2
	Design manager	L3
	Architectural academic	L4
	Program delivery manager	L5
	Senior project manager	L6
Main contractor	**Project engineer**	**C1**
	Contract manager	C2
	Delivery manager	C3
	Design manager	C4
	Construction manager	C5
	Site superintendent	C6
Architectural organisation	Design director	R0
	Principal architect	R1
	Senior architect	**R2**
	Associate principal façade engineer	R3
	Architect	R4
Façade consultant	**Façade engineer**	**F1**
Subcontractor case study A	Project manager	T1
	Senior project manager	**T2**
	Design manager	T3
	Project design manager	T4
	Quantity surveyor	T5
	Draftsperson	T6
	Façade engineer	T7
Subcontractor case study B	Design manager	P1
	Façade engineer	P2
	Project manager	**P3**
	Structural engineer 1	P4
	Structural engineer 2	P5
Shading system case study B	Design manager	M1

5.4.1 Capturing the collaboration context – observations

A major part of the method was non-participant observations in the detailed design meetings over the course of a year. Observation is a means to describe a phenomenon to see what is happening, especially when there is little known about it. It is a common technique for data collection in social research that focuses on the actions and interactions of people in their natural settings (Spradley 2016). This method is consistent with constructivism inquiry in qualitative studies. Observations allow the researcher to compare things to understand why and how they differ. They provide an insightful comparison between what people say they do and what they actually do (Brewer 2000). Thus, observation is important to distinguish this gap between the actions and testimony of participants about their collaboration experience.

An observer is an overlooker who does not take part in the setting being studied, and the role is either covert or overt (Patton 2002). The overt observer matches the nature of this research. Being an overt observer is unavoidable because the detailed design meetings took place weekly in the office of one of the organisations in a closed meeting room. Thus, the researcher role needs to be known to all participants to gain regular access to these meetings. However, the researcher needs to be passive throughout the discussions and not be involved in any form to ensure that the meeting's flow is not interrupted (Taylor, Bogdan & DeVault 2015). One of the weaknesses of the observation method is reflexivity, in which participants' behaviour might be influenced because they are being observed (Yin 2017). The length of the data collection for a whole year minimised this negative effect as participants eventually became used to being observed and considered the researcher as one of the client's team taking notes for administrative purposes.

To further guard against the problem of distraction, other techniques were adopted in this data collection method to make the observations as unobtrusive as possible including sitting at the end of the table, not between participants, and moving back a little to avoid being in participants' line of sight (Seaman 1999). In addition, the researcher always arrived at the meetings early by a few minutes to avoid walking into the room during discussions. Being present early helped in recording participants' presence as they arrived and being prepared to take field notes as soon as the discussion started.

Two distinct approaches guide the type of data collected during observations: structured and unstructured. The structured method assumes that there are predefined operational quantifiable dimensions about the phenomenon such as behavioural actions in terms of presence or absence, frequency or intensity in the form of checklists or schedules (Mack 2005). Unstructured observational data is used where little is known about the phenomenon. The researcher in this type of study knows little about the phenomenon under investigation. As such, unstructured observation follows an inductive naturalistic approach in being flexible in collecting data (Turnock & Gibson 2001). This flexibility does not mean that the data is collected in an unsystematic fashion as was mistakenly considered about unstructured data (Mulhall 2003). The difference between structured and unstructured data relies on the researcher's mindset before entering the field. In unstructured data, researchers do not have a set of predetermined concepts about what they are about to observe, but rather some initial ideas that could help capture the phenomenon. Some benefits can be achieved by triangulation between these two opposing approaches of data collection, such as using a structured coding system to analyse less structured data (Silverman 2006), which was adopted in this study by using Bales' (1950) IPA method to code the observation data.

Audiotaping these meetings was not possible since agreement would be difficult to obtain from each participant, and to ensure the agreement would remain during the course of a full year. Given that an average of four participants represented each organisation in the detailed design meetings, it is unlikely that all of these participants would be comfortable with their conversations being audiotaped. Therefore, a shorthand method was adopted to capture the interactive process in situ guided by the IPA (Bales 1950) protocol (Figure 4-2). The shorthand method is a substitutable approach in field note-taking to capture what is happening quickly by using abbreviations and acronyms such as keywords (Mulhall 2003). The shorthand method is helpful to overcome the problems that researchers usually experience because they are trying to record observed acts at the same time as paying attention to what is occurring in the discussions (Huxham & Vangen 2003). These field notes were then expanded into sentences that can be read and understood by others, and for the analysis process (Spradley 2016). Another critical point is that field notes need to capture participants' actions in the design meetings as they occurred chronologically. This step was essential for the analysis process.

Field notes can include information about space description, actors, activity, objects used and time (Spradley 2016). Therefore, the base information collected included meeting location, participants, start time and finish time. To facilitate note taking, participants were given codes, including a letter and number to differentiate between organisations involved in the meetings (Table 5-1). Organisations were assigned letters such as C, R, L, F, P and T, then a number was assigned to each participant, for example, L1, L2, C2, C3, R1, R2. The shorthand method included assigning keywords to record the IPA (Bales 1950) task-related actions such as asking for information, giving information, explaining design and construction issues, asking for clarifications, opinions and suggestions, and proposing solutions. Other keywords summarised the topic that participants were discussing, for instance, modelling, installation, fabrication, maintenance, testing and submission. Field notes also included recording the duration of each design item discussed as participants moved from one agenda item to the next, and the information format used such as 2D technical drawings or 3D models. In the process of note taking, the focus is on the participant who is talking and to whom, for instance, C1–T2 records that C1 was interacting with T2. To capture the IPA (Bales 1950) social reaction categories, agreements and disagreements were recorded with symbols used for jokes, and face expressions to show satisfaction, dissatisfaction and frustration.

5.4.2 Capturing participants' perception – rating of collaboration

A perception measure is a method of evaluating past performance that can be conducted at any point in the project (Beatham et al. 2004). However, for this research, this was a challenging task because it required participants' involvement each week. Participants were busy professionals with very full, daily schedules and so were not inclined to wait to rate the meeting before leaving. Therefore, a simple question was needed to encourage participants to take an active part in the research rather than just being observed. Given the long duration of the data collection phase, a simple rating tool was designed to capture participants' perception that included a short and easy question to answer to encourage participants to answer it regularly.

The key participant from each organisation was the only one involved in these aspects of the research, including answering the perception question every week and participating in interviews. All the organisations preferred this approach because these leading key participants were assigned as their point of contact for the research projects – case studies A and B. Following key participants' agreement to contribute to the rating process, an email was sent explaining the research aim and data collection methods and clarifying that the question would be sent after each meeting, and a short interview would be conducted afterwards for extreme ratings (very low or very high). The email also included information to assure participants the research methodology was ethically approved by the UTS human research ethics committee (UTS HREC Reference Number 2014000586), and all data would be treated with a high level of confidentiality. The Ethics approval information is provided in Appendix I.

These key participants were asked to rate their collaboration experience after each meeting using a Likert (1932) scale level of quality of 1–9, where 1 is very poor, 5 is neutral, and 9 is excellent. The closed categorical request was chosen because it uses a set of defined measures for responses such as an ordinal scale that enables quick input from key participants, which can be easily compared for analysis (Saris & Gallhofer 2014). The perception question was emailed to each key participant because email is simple to answer and does not require logging into survey websites. Participants can access their emails from mobile devices, iPads and computers. The weekly emails were sent to key participants shortly after the meetings to make sure participants rated their collaboration in the same week. The survey question is shown below.

Can you please rate your collaboration experience in [insert trade package name] meeting [insert date] using the scale 1–9 (where 1=very poor, 5=neutral, 9=excellent).

5.4.3 Capturing participants' views on their collaborative experience – interviews

Interviews were used to understand the reasons behind participants' extreme ratings. Participants who gave extreme rates such as very low (1–3) or very high (7–9) were selected for interviewing because these ratings represented higher and lower levels of satisfaction with collaboration. The interviews included two types: a short and an extended version. The short interview version included one open-ended question that asked for the reasons behind their extreme ratings of collaboration and were conducted at several points in the project. The extended interviews were conducted at the end of the design intent principles (DIP) and shop drawing documents (SHD) phases with each key participant.

Both the short and extended interviews were conducted using a standard procedure recommended by (Patton 2002) to facilitate interviewing different participants in a more systematic way. This means determining the exact wording and question order in advance and asking all questions in the same sequence. The interview guide is provided in Appendix I. Before starting the interviews, participants were assured that their names would not be revealed in the data analysis process and the outcome of this research.

The short interviews included an open-ended question asking participants to explain the reasons for giving extreme ratings to explore the different views about collaboration. This type of question is not a leading question because it does not limit answers to a specific topic. It allows participants to elaborate more on their subjective experience in a particular session (Seidman 2013). Given the diversity of participants involved in these meetings, the open-ended question approach provided several interpretations of collaboration, which enhanced the analytical processes. The average duration of the short interviews was 15 minutes. The aim was to make these interviews as short as possible to motivate participants to accept being interviewed more than once during the detailed design phase. The observations, rating tool and the short interviews aimed to answer the first research question.

The extended version of interviews was used to explore participants' reflection about their collaboration and how it was managed to address the second research question. Semi-structured interviews were chosen to gather rich information and insights and to develop a deep understanding of the collaboration processes. These interviews were carried out face-to-face with each of the key participants at the end of the design intent phase (DIP) and at the end of the shop drawing phase (SHD). They targeted participants' inner thoughts, beliefs and knowledge about their collaborative experiences. Questions were categorised according to the four phases of the CPDD model. As such, a mixture of question types was used, including open-ended and semi-structured questions. The extended interview guide is provided in Appendix 1.

The first question was an open-ended one followed by probing questions because they direct participants' focus to a particular area (Saunders, Lewis & Thornhill 2019). The probe questions were aimed at gathering insights into phases 1 and 2 (problem setting and direction setting) by gathering participants' experiences in design discussions, challenges and satisfaction with the feedback they received regarding their technical concerns. Participants were also asked to reflect on the positive and negative outcomes of the concluded design phase and improvements they would like to see in this project or to apply in future construction projects. These questions aimed to address phases 3 and 4 of the CPDD model (objective and subjective outcomes). The questions were designed to extend participants' reflections on their collaborative experience beyond subjective opinion about another participant's negative attitude in the meeting that might have influenced their collaboration rating.

5.4.4 Examining archival project documents

The case study approach encourages the use of project documents as other data collection methods (Yin 2017, p. 103). In this study, minutes of meetings were collected progressively during the design development phase. Access to minutes of meetings was given by the client. These documents recorded design options, decisions needed and program status. The research design used these documents to verify the information captured during the meetings. The aim was to seek verification with the previously discussed data collection – especially the observations as they were captured by the researcher. For instance, minutes of meetings included design status such as waiting for information, progressing with evaluating design options, design changed, and deliverables status. Additionally, the client allowed the researcher to access the façade architectural drawings as another form of project documentation. These drawings were helpful in understanding the different types of façade sections and their complexity to be able to follow the design discussions during the weekly meetings.

5.4.5 Dataset

Because of the weekly meetings and the long duration of the detailed design phase, a large amount of data was generated especially for the observations. The observation manuscripts covered 21 meetings (40,180 words) for the closed cavity façade case study A and 18 meetings (56,670 words) for the bespoke façade design case study B. The design complexity of the second case study required longer meeting durations for discussing tasks in terms of design intent and parameters.

The data collected from the second data collection method of participants' rating of their collaboration perception included 100 ratings collected for case study A and 115 ratings from case study B. The variation in number of ratings was due to the change in meeting timings. After progressing in the shop drawing documentation phase, case study A meetings changed to fortnightly to give the subcontractor enough time to finish detailing the design. Also, the architects needed that gap to review the high number of shop drawings. The design discussions in case study B took longer to approve the design intent principles, thus the meetings were running weekly to finalise the design decisions in the shop drawing phase.

The key participants were the ones who rated the weekly meetings and were interviewed based on their rating. As such, the third data collection method provided 17 interviews conducted for each case study. The fourth data type was the minutes of the meetings, representing the archival documents for the case studies. The minutes of each meeting for the closed cavity façade design in case study A ranged from 4 to 6 pages, while the minutes for the weekly bespoke design meetings in case study B ranged from 6 to 13 pages because of the several design decisions that needed to be solved to progress according to the project schedule.

5.5 Data analysis methods

The analysis involved transforming the data collected into explanations that interpreted participants' views and insights. The data collected allowed for triangulating the findings in this research from the observations, participants' ratings, interviews and documentary information. In light of this, it is important to determine the unit of analysis for the research, which is the detailed design meetings of the chosen trade packages. Focusing on observing and studying interaction patterns among group members provided a better understanding of the interactive processes (Luft 1984). The dynamic setting in detailed design meetings is different from other forms of collaboration that examine communication patterns through emails and virtual collaboration sessions via video cameras. The focus of this research is on the participants' collaborative interactions to develop the façade design documents. The façade teams included participants representing several organisations such as the client, architect, façade consultant, main contractor and subcontractors. The case study building had two separate façade types, which provided a degree of replication and the fact that these packages occurred on the same project helped control what would otherwise be intervening variables if using separate projects. Examples of these confounding variables include contract type, managing responsibilities, type of technology used in communication and design software, location and building type. This contrasting approach allows data analysis to focus on the collaborative processes that occur between participants during design discussions.

5.5.1 Observation protocol to analyse collaborative actions

The observation data in method 1 represented a large portion of the data corpus. To address the first research question, there was a need to identify a method for condensing the data in a systematic way to perform the analysis. As noted earlier in Chapter 4 and shown in the CPDD model in Figure 4-5, this research adopted Bales' (1950) IPA method of studying small group interactions to code the observation data. This method is well-established and was tested in different profiling groups including professionals, married couples, children and postgraduate research students (Bales 1950, 1970). The IPA method was found suitable for coding and analysing the observation data because it provides a detailed protocol including 12 mutually exclusive categories and a complete operational definition for each category to inform users of this method. The clear differentiation between task-based and social reactions and the classification of task types make this method easy to implement and it has been replicated in several studies (Gorse & Emmitt 2003). Design meetings are also known to be conducted in a structured and formal manner that follows the meeting's agenda, which documents actions and decisions needed to meet the design deliverables timeframe (Gorse & Emmitt 2007). In design meetings, participants are aware that they will collectively try to find solutions to develop the design, which will be seen in their discussions and how they tackled design constraints to reach an acceptable solution.

Although the IPA (Bales 1950) is a well-established and widely used method for coding and analysing interactions among small groups, there were some limitations highlighted in literature. The defined 12 mutual categories preclude multiple interpretations of the same interaction such as studies concerned with leadership styles (Gouran 1970). Another criticism of Bales' (1950) IPA method comes from those who advocate quantitative analysis methods due to its limitation in studying the relationships between the interaction categories and being limited to labelling the interaction type without referring to the nature of the problem (Field 1964). The research design considered these limitations by relying on multiple methods of data collection (Figure 5-3) to understand and study collaboration among participants involved in the detailed design meetings and modifying the IPA method to capture other common interaction in construction project as explained in the section below.

5.5.2 Modification and implementation of the IPA method in design meetings

A pilot study was conducted to test the implementation of the IPA method in coding interactions before using the method in the observation of the detailed design phase. The client allowed the researcher to attend ten tender meetings, which helped in testing the field note taking method and coding the data. The early access in these meetings allowed the researcher to understand the project context and stakeholders involved in the façade trade package. At the tender phase, the subcontractors had not yet been assigned, and the design documents were continually updated to the level that allowed the main contractor to get estimated prices from a list of subcontractors. Observing the tender phase meetings enabled the researcher to test the suitability of the IPA method as an analytical approach in real design meetings to fulfil the training part that is recommended before the actual data collection (Bales 1950, 1970).

The tender meetings included design discussions to clarify the design intent and cost information on the estimated prices based on market information. Thus, capturing task-related categories was tested in addition to some social reactions that occurred because of conflicting views around cost. Categories related to acquiring information and some of the other coordination actions related to asking for and giving information fitted the description of categories 6 and 7. However, some coordination actions were different from simple information inquiries; these involved actions such as asking for confirming dimensions and giving commitment to recheck design tasks because of cost constraints. These confirming actions are considered a step higher than categories 6 and 7 in participants' interactions as they provide a level of commitment. Therefore, the researcher decided to add two categories labelled as 'gives confirmation' and 'asks for confirmation' to the original IPA protocol to tailor the method for the construction environment. These two extra categories capture participants' interactions in coordinating technical constraints to meet the design deliverables timeframe.

The concept of confirmation is explored elsewhere in construction projects to address planning problems associated with the high degree of uncertainty by managing construction projects as a network of interrelated commitments (Ballard 2002).

Adding categories about commitment in the IPA method was implemented in a study of communication among construction site groups during the planning process (Ghosh 2012). Table 5-2 below shows the modification of the IPA method with the new categories added, and new numbering developed. The new categories of ‘gives confirmation’ (the new number 6) and ‘asks for confirmation’ (the new number 9) tailored the category definitions to match the design development meetings for this study. This coding protocol guided the research in analysing participants’ interactions during the observations for the entire detailed design phase.

Table 5-2: IPA (Bales 1950) categories for coding observation data modified for construction environment

Category ID	Category Description	Category type
1	Shows Solidarity – praises others' work, reinforces (rewards) good work, contribution, greets others in a friendly way, uses positive social gestures	Social-Emotional Area Positive Reactions-Behaviours showing satisfaction, positive relationships
2	Shows Tension Release – jokes, laughs, shows satisfaction signs, relieves or attempts to reduce tension	
3	Agrees – shows passive acceptance, complies, approval of proposed solution, view or opinion	
4	Gives Suggestion – provides a solution, suggestion, direction, resolution attempts, implies autonomy for others, attempts to give direction	Task-based Area: Attempted Answers Acts of developing understanding, information, coordination
5	Gives Opinion – provides a detailed explanation, reasoning, insights, evaluation, view, exploring, analysis	
6	Gives Confirmation – confirms information needed to proceed, shows obligation, commitments to perform a task	
7	Gives Information – gives orientation, reports information, facts, repeats, updates, brings relevant information into the discussion	
8	Asks for Information – asks for orientation, information, facts, repeats, updates, asks for relevant information to understand the topic	Task-based Area: Questions Acts of seeking information, commitments, analysis, solution
9	Asks for Confirmation – asks to confirm information needed to proceed, asks for obligation, commitment to perform a task	
10	Asks for Opinion – asks for more explanation, reasoning, insights, evaluation, view, exploration, analysis	
11	Asks for Suggestion – asks for a solution, suggestion, direction, resolution of how to solve a task	
12	Disagrees – shows disagreement with what another participant said, passive rejection, disapproval of proposed solution or task, view or opinion	Social-Emotional Area Negative Reactions Behaviours showing dissatisfaction, rejection of solutions, being difficult
13	Shows Tension – shows concerns, dissatisfaction signs, frustration, signs of tension	
14	Shows Antagonism – acts used to deflate others' status, undermining others' work, defends or asserts self, blocking conversation	

5.5.3 Coding the observation transcripts

The IPA coding process relies on understanding the meaning of the words said in the meetings to be able to allocate each sentence to the correct interaction category (Bales 1950). Understanding the language used in the design meetings, such as the design and construction terms, facilitated the coding process in differentiating between task categories. For instance, acts such as asking for a missing dimension are different from acts asking when the revised design is going to be submitted. The first act is coded as category 8 'asks for information' while the second act is coded as category 9 'asks for confirmation'.

Boyatzis (1998, p. 63) differentiated between the unit of analysis and unit of coding, where the latter is "the segment of data that can be assessed in a meaningful way regarding the phenomenon". Coding manuscripts generated from observation data followed (Bales 1950, p. 37) method of coding the smallest sentence or a statement in which the unit to be coded is a single act defined as "the smallest discriminable segment of verbal or nonverbal behaviour". Every part of a complex sentence must be coded separately. For example, if one participant was explaining a design issue, extra care is needed in coding the statement because it could include several categories. Coding such a complex statement could include any sequence of task categories such as 'gives opinion', 'gives information' or 'gives solution'. It worth noting that the disagreements (category 12) can play an important role in participants' discussions and therefore may not always be classified as negative communication behaviour (Senge 2006). However, they were classified as negative reactions in this study - phase 3 of the CPPD model (Figure 4-5) to document whether participants managed to reach an agreement or not, which aligns with the objective outcomes of the collaboration (Gray 1989).

To manage the quantity of observation narratives, the coding process was conducted using NVivo. It is well-known software used in coding direct segments of data into codes (known as nodes in NVivo) that can be retrieved faster for further analysis. The following extract from meeting 8 of case study B illustrates the coding process of the interactive collaboration categories in Table 5-2. Category numbers are displayed after each sentence or unit in parentheses. Numbers at the beginning of each line represent participant codes for who is talking and to whom. Participants in the extract below were discussing one of the complex façade types.

[C1– P4]: will you give an update on this (pointing at a 2D drawing) (8)
[P4–All]: explains top and bottom details (using own 2D drawings) (5)
[C1–F1]: I looked at your comments this morning (7)
[F1] face expression shows that he is unhappy with the way his comments were treated (13). He displayed five 2D drawings A4 size on the table in front of him (7)
[F1–P4]: (pointing on his drawings) I need material confirmation here (9), design confirmation here (9)
[R3] is watching closely as he is sitting opposite [F1] and nodded showing agreement with what [F1] said (3)
[P4–F1]: comments on glass thickness selected (7)
[F1–P4]: I do not think Rs will agree on this (12). There is inconsistency in your documents in this detail here (7), what is the fixing, where is your engineering drawings? (10)
[P4–F1]: these will be done in the shop drawings phase (7)
[F–-P4]: I need confirmation on glass (9), you need to tell us, you are heading in the right direction (13), and I know it is too much to ask now (2)
[C4–F1]: I do not want to cross you (2), what you say is valid, but it is not part of the DIP process (12)
[R3–C4 and P4]: I agree (3) with [F1], joints and transoms are fundamental to the DIP (6): I am not attacking you (2)

5.5.4 Analysing observation data

In the theoretical replication approach of case studies, the analysis should balance the cross-case and individual case findings as separate and unique to identify similarities and differences that arise among the cases. In the context of this research, this presented a challenge due to the size of the data collected to cover the whole duration of the detailed design phase. The implementation of the IPA method helped in examining the observation data using a more manageable form for analysis. Before starting the analysis process, meeting manuscripts were prepared by organising data into segments under each design item. The output of the coding process was entered into a computer-based Excel spreadsheet for statistical analysis. The first step of the analysis is useful in providing standard descriptive statistical information to identify the frequency of interactions and ratios between categories (Gorse & Emmitt 2007). Then aggregate results of all meetings were calculated and presented graphically to provide a single profile for each case study.

The second step in analysing observation data involved identifying the sequential interactions to provide a more comprehensive understanding of the emerging collaboration patterns to address the first research question. Bakeman and Gottman (1997, p. 41) defined the sequential interactions as “segmenting the stream of talk into successive units of thoughts to provide a continuous record of how different kinds of thought units were sequenced in the conversation”. This technique analyses a set of data that coded uninterrupted sequences of action or behaviour. Therefore, the initial coding outcome of each meeting was arranged into sequential interactions representing two consecutive collaborative interactions taking into consideration the separation in discussions after each design task. Participants usually stopped for a few seconds after discussing a design task to record actions needed or to prepare drawings needed for the following design task discussion. This separation of data into segments was needed for the accuracy of coding sequence interactions. For example, a discussion of task 1 that ended with ‘gives confirmation’ that the design will be investigated further and submitted before the following meeting is not followed by an act such as ‘asks for information’, which is typically used at the beginning of discussing task 2 to update participants on design status. Thus, these two categories were not considered as one sequential interaction, but two separate interactions linked to the categories that were preceding and following them.

To examine patterns of interactions that aligned with positive or negative outcomes of collaboration, descriptive statistics were used to calculate the probabilities of the sequential interactions. This method involves organising the identified sequential interactions in a matrix (14 by 14) to examine the transitional probabilities between the 14 interaction categories. This approach is known as “the conditional probability that describes the lag or displacement in time between two sequential interactions with respect to other categories” (Bakeman & Gottman 1997, pp. 95, 103-6). This technique helped researchers to study the bidirectional effects in relationships, for example, educational psychologists studied children’s aggressive behaviour in schools by examining how they move from take, hit, cry and give (Sackett 1979). Although the calculation of the transition matrices is based on Markov models, the sequential probabilities are a way for describing and summarising the data with no underlying mathematical assumptions (Bakeman & Gottman 1997). Calculating the transitional probability of a category following or lagging another category provided a better representation of the data because it is informative to know, for example, that 25% of category 7 (‘gives information’) were followed by category 5 (‘gives opinion’).

5.5.5 Analysing collaboration perceptions

Participants' perceptions in method 2 were measured using the rating scale tool designed to capture ratings after each meeting. The use of the fixed response question is useful in simplifying the data analysis as answers can be easily compared (Patton 2002). The ratings were analysed following a systematic approach using quantitative statistical results to direct the next step in the data collection, which was selecting participants for conducting interviews based on extreme rates. In an ideal situation, participants should have similar perspectives about how they collaborated. In other cases, their ratings might not be aligned, which triggers an investigation into the reasons and barriers that prevented them from collaborating effectively.

The ratings were analysed further to investigate the emerging trends, including high, consistent and low rating patterns. These results also helped link the interview findings to specific meetings that caused participants to be either satisfied or dissatisfied with the collaborative process. For instance, if a participant rated a meeting a 7 or higher out of 9, the participant is expected to be able to connect this satisfaction to the interactions (processes or social reactions) during that particular meeting. The connections between the ratings on the satisfaction with collaboration and the interactions during the meeting were explored further in the extended version of the interviews.

5.5.6 Analysing interview data

Analysis of the findings from method 3 interviews involved coding and analysing qualitative data. Qualitative data analysis involves transforming the collected data into an explanation and understanding of the phenomenon being investigated, and interpretation of people’s views and actions. It requires exploring the meaningful content of the qualitative data, organising the data, coding and searching for patterns in the data (Creswell & Poth 2018). The analysis processes aim to identify themes in the data to provide clear, readable and insightful report (Patton 2002).

Coding is the fundamental step in most forms of qualitative data analysis. Coding data is a method of condensing qualitative data that allows a better retrieval of relevant material by close reading through the data to assign a descriptive label to pieces of data, thus becoming more familiar with the data corpus (Miles, Huberman & Saldana 2014). Initial coding breaks down qualitative data into discrete parts to closely examine and compare these parts by being open to all possible theoretical directions (Corbin & Strauss 2014). This step is critical as it allows the researcher to move beyond the tangible data collected to explain and interpret their meaning (Saldaña 2015). The coding process can be applied to different data types, such as interviews, documents and other qualitative data types to explain participants’ views, attitude and mood, and the activities they were involved in (Saldaña 2015; Silverman 2006).

In this research, codes were used to identify participants’ views, values and beliefs regarding their collaboration experience. The coding process also helped identify the various perceptions regarding the technical concerns and how participants evaluate the processes and outcomes of their collaboration. As in all qualitative analysis, the codes were generated from the initial CPDD model, research questions and aim. The interview data was coded with particular attention to the diversity in participants’ disciplines and roles, such as management, design and construction. Coding helped in understanding the multiple constructions of collaboration to develop a holistic understanding of the phenomenon.

This research adopted the Saldaña (2015) coding process that involves first and second cycle coding. As the name suggests, the first coding cycle is the initial step in organising the data. There are a number of methods that can be applied in this coding phase, which allow coding the same data using different coding methods, such as attributes codes, descriptive codes, process codes and emotions codes. Participants are expected to bring differences in views, objectives, methods of dealing with constraints, and working practices. As the purpose of this research is to study interdisciplinary collaboration, the first coding cycle included two rounds as shown in Table 5-3 below. This was followed by the second coding cycle, which involves focused coding to categorise data into themes and subthemes for pattern matching (Miles, Huberman & Saldana 2014).

Table 5-3 Types of coding used in each coding cycle (Saldaña 2015)

Coding order	Types of coding	Description
Pre-coding	Themes and subthemes	Initial step guided by research questions
First coding cycle (round 1)	Attribute coding	Include basic information about the data, e.g., case study information and participants details
	Descriptive coding	Labelling the data by topics, e.g., meeting number, façade type
First coding cycle (round 2)	Process coding	Labelling actions, e.g., designing, constructing, installing, working practice
	Dramaturgical coding	Labelling 1) objectives and motives, 2) conflicts and constraints, 3) tactics and methods to deal with the constraints, 4) attitudes towards the problems and setting, 5) emotions, the way they feel, and 5) subtexts of un-spoken thoughts or impressions e.g., personal opinion about another participant
Second coding cycle	Pattern coding	Classifying and assigning meaning to categorised data

To conduct the above coding cycles, the process involved four stages: pre-coding preparation, first coding cycle rounds 1 and 2, second coding cycle involving synthesising and developing themes to illustrate the phenomenon. Each stage is discussed below.

a) Pre-coding stage

The coding framework was developed to organise the data for both case studies and to give the basic structure for the coding process. This framework guided the process of developing nodes and cases in NVivo. The development of nodes was guided by the research questions and themes identified initially in the CPDD model. As such, the coding framework outlines the initial key themes and subthemes needed to understand how participants evaluate their collaboration. In this research, the coding framework consisted of five categories where one is the general category and the other four are the key topic area categories, as listed below:

- collaboration perceptions: to understand interviewees' evaluation of their actions and interactions with others
- process of collaboration: understanding the process, their involvement in the ongoing interaction
- challenges: management and technical problems
- constraints: factors that hinder their actions
- consequences: the outcomes of their actions and results of their behaviour.

b) First coding cycle (round 1)

The first round involved close reading of all interview transcripts to become familiar with participants' views and gain a sense of the whole dataset (Miles, Huberman & Saldana 2014). This coding stage began with the attribute codes and descriptive codes. The attribute codes included interviewees' background details such as job title, firm, role and responsibilities. The descriptive coding involved highlighting sections of the data related to each façade type. The primary codes developed in this stage using

NVivo included 6 cases for participants, 23 subcases for case study A, and 13 subcases for case study B. The subcases refer to the façade design tasks. The nodes included descriptive codes to identify problems such as management (cost of façade components, design deliverables timeframe, interdependence of design disciplines), design integrity, construction process, functionality, and facility management.

c) **First coding cycle (round 2)**

This stage of coding began with assigning labels to sections of data using the coding types shown in Table 5-2. This involved using process coding to capture participants' interpretation of the actual working processes and dramaturgical coding to explore participants' experience and actions. The process coding is useful in capturing human actions and activities in response to a problem, situation, or reaching a goal (Saldaña 2015). The dramaturgical coding approach focuses on studying how people interact in face-to-face contact, which is known as the interaction order (Goffman 1983). It is useful in analysing actions and participants' explanation of their action (Travers 2001). The dramaturgical coding approach records conflict (CON), objective (OB), attitude (ATT), emotion (EMO), tactics (TAC) and subtexts (SUB) recording unspoken thought or expressions (Miles, Huberman & Saldana 2014; Saldaña 2015). As such, this round of coding involved extracting and listing all the words and phrases of participants that relate to both process and dramaturgical codes. In addition to allocating codes to a portion of transcribed data, the researcher's analysis, ideas, impressions and emerging thoughts and concepts for categories were also recorded using the memo writing feature in NVivo. Similarly, any links between codes and the literature, or links across data, were also noted in the analytical memos.

d) Second coding cycle

This stage involved advancing in the analysis process by linking codes from the first coding cycle to the CPDD model based on the theoretical understanding of collaboration phases. The aim was to reorganise and condense the first coding cycle into categories. Themes that emerged from the first coding cycle are classified into positive and negative practices based on participants' ratings of the corresponding meetings. The high ratings (7–9) represent the positive practices and the low ratings (1–3) indicate the negative practices. The themes are then classified under the four phases of the CPDD model. Table 5-4 shows the outcome of these classifications.

Table 5-4 Second coding cycle categories and subcategories

Categories	Subcategories	Link to perceptions of collaboration	Collaboration phases
Process coding	offering detailed feedback/offering alternative solutions/being receptive to other's concerns/use of design sketches/raising awareness of the design problem/being informed when evaluating design options	Positive practices	Problem setting
	delaying response/late design refinements and changes/revisiting confirmed design decisions/submitting un-coordinated design solutions/changing design in tender documents/hedging risks/submitting design solutions that do not match design intent	Negative practices	
	aligning working procedures/flag out urgent information/adopting practical design solution	Positive practices	Direction setting
	excessive coordination actions/communication across team boundaries	Negative practices	
Tactics coding	forming focused design meetings/temporarily changing roles/change language used to understand technical implications	Positive practices	Problem setting
Conflict coding	differences in perception of risk/value engineering/design solution practicality/cost evaluation/timeframe anticipation/level of details of design solution	Negative practices	
Objectives codes	achieve value for money/achieve design integrity/smooth working process	Positive practices	Objective outcomes
	need closure decision/ineffective management/delays in design development	Negative practices	
Attitude codes	appreciate others' contribution in discussions/satisfaction/dissatisfaction/trust in expertise and capabilities	Positive practices	Subjective outcomes
	conservative answers to design inquiries	Negative practices	
Subtexts	thoughts and expressions about another participant and organisation	Negative practices	Subjective outcomes

The second coding cycle followed the Miles et al. (2014) method of pattern matching, where the codes are categorised and grouped according to themes or conceptual similarities. It involves viewing a theme as a common thread that runs through the data to capture the research issues under investigation. This step relied on the analytical memos that documented the ideas and discussions about the links between themes and links to theory as well as to interpret the findings by reflecting on the participants' data from the first cycle codes. Illustrations were developed to demonstrate participants' interpretations of collaboration and highlight the key findings from the data, which is discussed next.

e) Qualitative modelling – Event network diagrams

This stage of the qualitative analysis involves developing event network diagrams to interpret the data and present a holistic view of the complex process of collaboration identified by the interdisciplinary team interviewed. Event networks are qualitative diagrams used to conceptualise complex phenomenon or relationships into a simple and clear communicative picture. According to Miles (2014), there are four interrelated summaries, such as themes or categories, causes or explanations, relationship among people, and theoretical construct. The analysis process followed the causes and explanations approach to interpret participants' views on their collaborative experience. In this step the similarities and differences between participants' interpretations were identified by linking themes and then integrating the findings (Miles, Huberman & Saldana 2014). For example, as illustrated in Figure 5-4 below, giving detailed feedback when discussing technical constraints makes participants more informed while evaluating proposed design solutions, which helps them choose practical design solutions without compromising the design integrity.

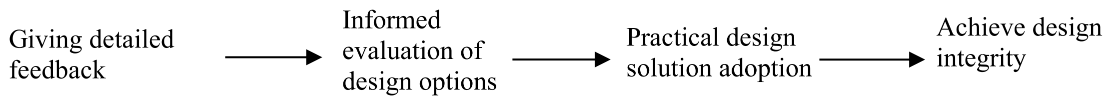

Figure 5-4 An example of an event network diagram

The above illustration reflects the view of one of the participants about the process and outcome of collaboration process, however other participants might have a different interpretation. As such, the event networks were developed to collectively capture participants' mental models. These models describe their perceptions, opinions and insights into collaboration and connect them to visually represent their different views of the problem holistically (Silverman 2006). This shared representation of their actions and views helped in understanding the process of collaboration in the detailed design phase from different perspectives, providing new insights and explanations about this complex phenomenon.

5.5.7 Cross-case analysis

Cross-case analysis is an essential component of this research because of the theoretical replication in the two case studies. The first case study was expected to be less challenging in terms of design complexity than the second one. The first case study was the closed cavity façade, which was regarded as a standard façade system. The façade in the second case study needed a bespoke design approach because of the length of curved glass panels and their supporting structure system. The objective of the cross-case analysis is to look beyond initial impressions and findings between these two cases (Miles, Huberman & Saldana 2014). Cross-case analysis in a case study approach is coupled with comparing patterns (Yin 2017). Eisenhardt (1989) identified three strategies for cross-case analysis to avoid premature conclusions. The first strategy focuses on selecting a dimension to study the similarities within cases and check for differences between cases. The second strategy looks at similarities and differences in pairs of cases in the form of comparisons to help the researcher to develop more understanding of the emerging dimensions and study their context from a broader perspective. However, one of the main concerns in performing these comparisons is the large number of cases needed for cross-case tabulation (Yin 1981).

The third strategy takes a different approach by focusing on types of data rather than cases. This analysis approach deals with data types separately where patterns emerging from analysing observation data in all cases are combined. Similarly, the analysis outcomes of the interviews are combined. The same step is done with any other type of data, such as surveys and questionnaires. This analysis strategy gives more in-depth insights into a pattern emerging from different data types, or if a pattern was explained more in another data type (Eisenhardt 1989). This approach is useful in studies that use qualitative and quantitative data because it explores the outcomes of each data type. This cross-case analysis approach was deemed appropriate because collaboration needed to be studied using multiple data types. To study the emerging patterns rigorously, the cross-case analysis should cover all data, significant findings and rival interpretations (Yin 2017), which aligns with the third strategy that investigates all data types. This strategy helped in comparing interaction patterns and participants’ ratings to get useful insights into design meetings using an integrative view. Most importantly, the method of comparing data types helped triangulate findings across both cases to study what derived a smooth collaboration path and a disruptive collaboration path.

5.6 Conclusion

This chapter discussed the chosen research theoretical paradigms that informed the methodological framework. It also discussed the relevance of the case study approach for the research and presented the data collection methods, as provided in Figure 5-3. The multiple methods of data collection developed to observe collaboration in its natural setting and to capture the multiple views of participants involved in the design meetings have been explained, followed by the data analysis methods. The results of the analysis are presented as descriptive narrations of the findings, in figures and tables, and as event network diagrams in the following Chapters 6, 7 and 8.

Chapter 6 Case study A – Standard Façade Design

The chapter reports on the analysis and discussion of the first research question in the context of case study A that represents the standard design environment. The chapter provides an overview of the design package followed by a description of participants involved in the detailed design phase to explain the context of this façade trade package. The analysis presents the general description of the observational data as a foundation of subsequent analysis of the emerged collaboration patterns. The analysis then examines participants' ratings and views about their collaboration, which are illustrated graphically using event network diagrams.

6.1 Overview of the standard façade design

This case study reports on the tower façade, which is one of two separate façade work packages of the building envelope system. This package involved the high technology state-of-the-art glass façade system applied to the tower building shape. It incorporated a high technology closed cavity façade (CCF) that is used widely in Europe and has been introduced recently in Australia in two other projects that were completed in Sydney. The design approach of the ten-level tower involved a twisting and rotating building with a change in its orientation as it reached high levels. The stepping back of each level as the building increases in height forms the incremental and rotational shape of the tower. The closed cavity façade type (CCF) forms the external curtain wall system of the tower. The CCF is a double-glazed cavity with motorised blinds that adjust automatically with the changing angle of the sun's rays providing solar and glare protection. The closed cavity unit includes four elements: a single outer glass; a sealed closed cavity ventilated by low volumes of dry air to prevent condensation and dust infiltration; movable blinds; and an inner doubleglazing unit (DGU) of high-performance insulating glass that prevents heat from entering the building. The combination of this façade type and the geometric shape of the building created a total of 13 design items which were discussed in the weekly meetings (Appendix II). Figure 6-1 below illustrates the building design in four photos. The first photo was taken from the architectural design drawings (with access given to the researcher by the client) showing four elevation views of the tower. The three other photos were taken by the researcher during the construction phase and after completion.

Figure 6-1 Case study A – Photos of the CCF façade at different construction stages

The façade project team is described below to show the organisation structure and familiarity with the CCF system.

- The client had an experienced management team that practised the client's representative role in managing the delivery of new buildings on campus and renovating old ones. However, the team did not have previous experience with the CCF system.
- The main contractor was a leading Tier 2 contractor in Australia specialised in the design and construction of a range of complex project types, including residential, commercial, community, education, health and industrial. However, they were not involved in any of the previous projects that used the CCF system.
- The subcontractor was a leading international contractor in engineering, project management, manufacturing and installation of architectural envelopes and interiors systems. They developed the CCF type and introduced it into the international construction market in 2008 (National Institute of Building Science 2021) then released it in several projects in Europe. The subcontractor's experience in the CCF system is a distinctive feature of this case study because they standardised the CCF façade system and had a solid understanding of the design and construction of each component and connection of the façade system.
- The architectural design organisation was a leading architectural design organisation in Australia, specialised in architectural, interior, landscaping, urban and community projects. The architects had previous experience with the CCF type as they were involved in designing one of the recently built projects that used this façade system.

- The façade consultant organisation was specialised in providing sustainable façade structural and mechanical engineering solutions. The organisation had previous experience in the CCF system as they were engaged as consultants in the two Australian projects that had used this façade type.

6.1.1 Detailed design phase timeline

In total, data gathering covered a period of 27 weeks of the detailed design phase which began after engaging the subcontractor. The average duration of each meeting was 90 minutes. The detailed design involved two stages: design intent principles (DIP) and shop drawing phase (SDP). The DIP phase was planned to last four weeks but ultimately lasted nine weeks because the façade team needed more time to finalise discussions around design principles and issue DIP drawings for final sign off by all parties. The shop drawing phase involved 18 weeks in total. This long duration was needed to cope with the high volume of shop drawings that needed to be produced. In total, the detailed design phase included 21 meetings. Figure 6-2 shows the meeting timeline for the detailed design phase, the focus of this research.

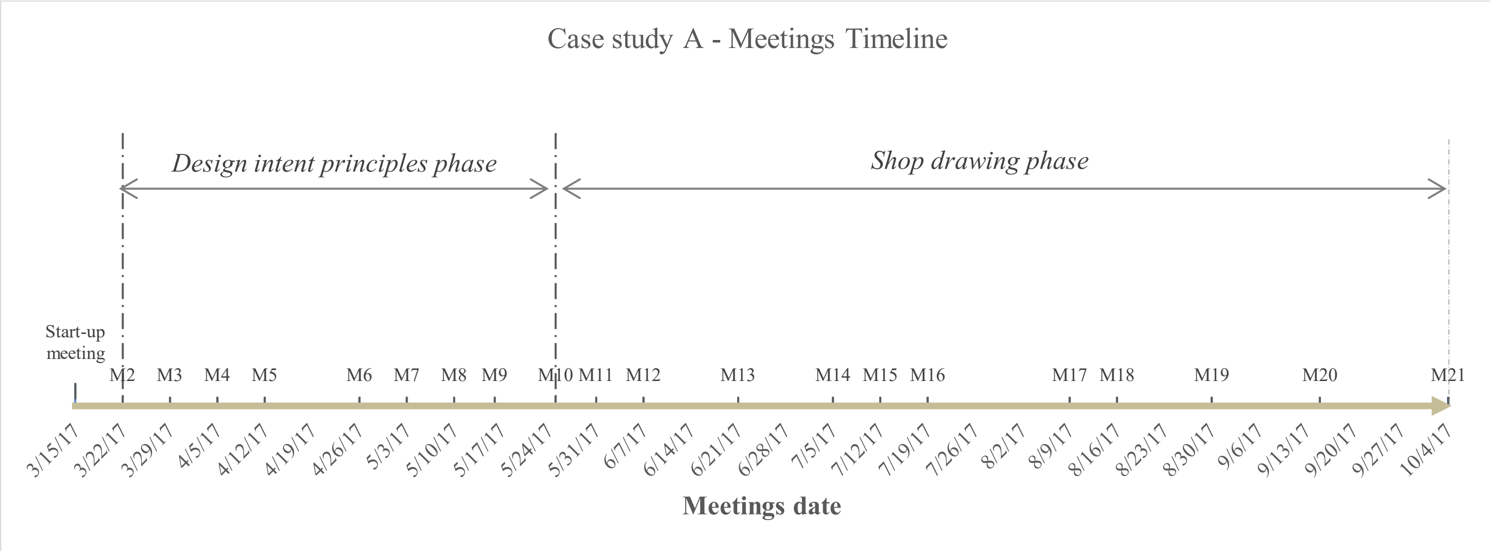

Figure 6-2 Case study A – Timeline for meetings

6.1.2 Preparatory phase of collaboration

This phase sets up the working environment for participants before the actual discussions in design meetings start. The collaboration enablers that were identified earlier (Figure 4-1) are examined in this case study. The interdisciplinary team included five firms: the client, architects, consultant, main contractor and subcontractor. An average of 10 participants representing these firms attended the weekly meetings, including key participants and other interim participants who attended the meetings when needed. Key participants were involved regularly in all design meetings as their firms assigned them as the point of contact for the façade trade package (Table 5-1). These key participants included the delivery manager (client L1), project engineer (main contractor C1), senior project manager (subcontractor T2), senior architect (architectural firm R2) and façade engineer (façade consultant firm F1). For instance, the subcontractor team included the design manager in meetings related to panel modelling concerns, drafting technicians for documenting, and the façade engineer for operating and maintenance concerns. The main contractor team included other participants who were present in several meetings, such as the construction manager and delivery manager. Two representatives from the architectural firm, other than the key senior architect, were present in the majority of meetings: the associate project architect and the associate principal façade engineer. The associate project architect was present to ensure that the design intent was understood, and the associate principal façade engineer was deeply involved in design discussions of façade connections.

Participants were co-located in one common place. The main contractor was given a temporary office in one of the buildings on campus to be located near the construction site. The weekly meetings were held in this office in a meeting room big enough to accommodate 20 people. The room had a digital screen to display technical drawings and 3D models, and other project documents such as the scope registrar and program charts. It was noted that participants adopted a specific seating arrangement in the meetings, with participants from each organisation preferring to sit next to each other. This arrangement was convenient in design discussions, especially for the architect and subcontractor teams because more than one participant from each organisation was involved in the design process. This seating arrangement was practical because participants spent a few minutes after each design discussion to confirm decisions, information or submissions needed.

All participants had access to shared construction management software Aconex that had all the project information, including the design drawings, specification, 3D models, minutes of meetings and project schedule. This was observed in the start-up meeting when the main contractor needed confirmation that the subcontractor had access to the latest design documentation uploaded on the software. The process of introducing roles and responsibility took place in the start-up meeting as participants introduced themselves because it was the first time of meeting the subcontractor team. In the start-up meeting, the main contractor displayed on the digital screen the project deliverables and scope of subcontractor work and all participants expressed their commitment to develop the design within the timeframe displayed demonstrating the common goal theme.

The section below reports the data analysis and discussion related to the first part of the first research question in the context of the standard design environment, stated as:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.1: Are there different patterns of group interactions in different design environments?

6.2 Analysis of participants' discussions in the detailed design phase

The four phases of the CPDD model are problem setting, direction setting, objective outcomes and subjective outcomes. This section reports findings of participants' interactions in a number of analysis steps. The first step calculated the percentage of single interactions in each meeting. The next step organised these interactions into four groups: task-based questions and attempted answers categories, and positive social and negative social reactions. These four phases are then examined qualitatively to demonstrate participants' discussions by extracting incidents from the observational data. The third step organised the single interactions into sequential interactions. A sequential interaction is two consecutive single interactions. The step is needed to calculate the transitional probabilities of these sequential interactions to identify the most common collaboration patterns.

6.2.1 Single interactions analysis

As discussed in Chapter 5, Table 5-2 outlines the categories for coding the collaboration interactive process and outcomes that were used for coding participants' interactions in each of the 21 meetings. To determine the frequency of each single interaction category and the aggregate sum, the percentage of interactions coded in each meeting was calculated using matrix coding in NVivo. A total of 4462 interactions were observed in the 21 meetings of the detailed design phase. The single interactions were grouped into four groups: questions and attempted answers (representing the interactive process), and the positive reactions and negative reactions (representing the outcomes) of the CPDD model. The first group represents the task-based questions categories, which are 'asks for information' (category 8), 'asks for confirmation' (category 9), 'asks for opinion' (category 10) and 'asks for suggestion' (category 11). The second group represents the task-based attempted answers categories, which are 'gives suggestion' (category 4), 'gives opinion' (category 5), 'gives confirmation' (category 6) and 'gives information' (category 7). The third group represents positive social reactions, which are 'shows solidarity' (category 1), 'shows tension release' (category 2) and 'agrees' (category 3). The last group is the negative social reactions represented in 'disagrees' (category 12), 'shows tension' (category 13) and 'shows antagonism' (category 14). Figure 6-3 presents the percentage of coded interaction categories in the four groups (y axis) for all meetings (x axis).

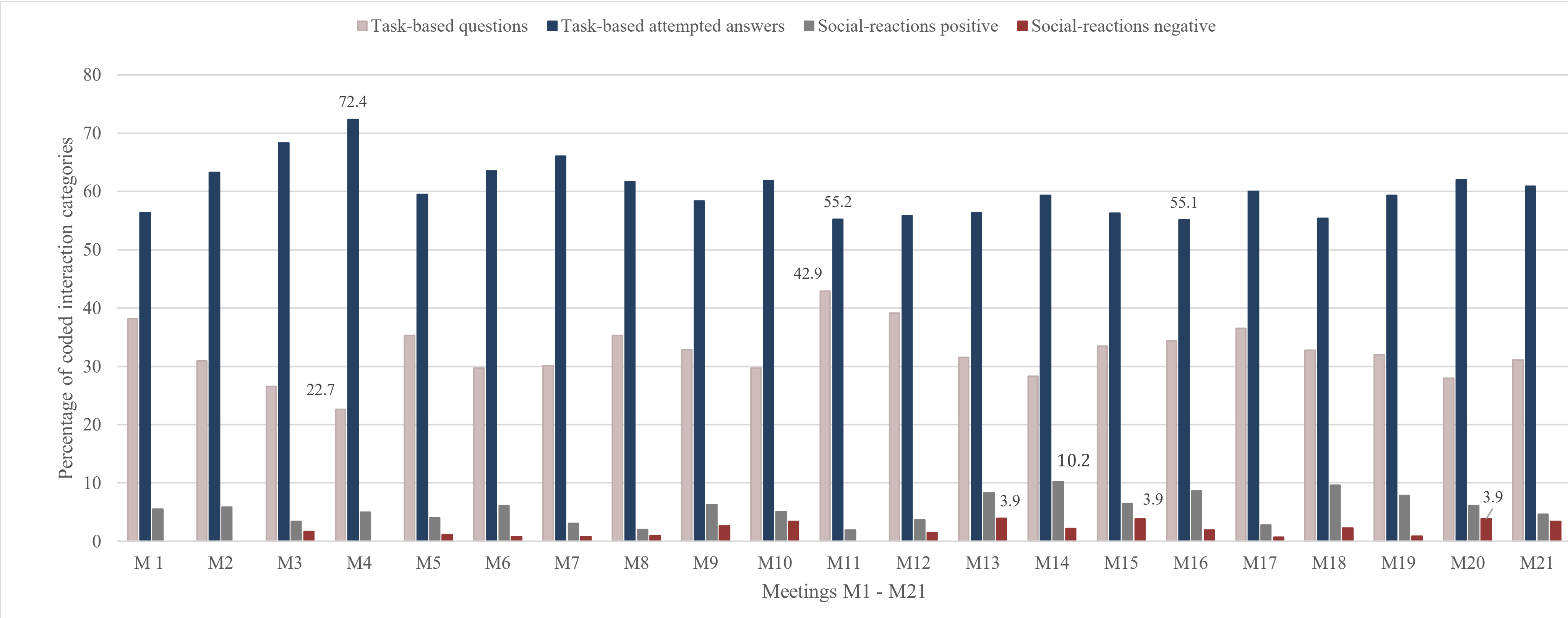

Figure 6-3 Case study A – Percentage of coded interaction categories in the four group

As illustrated in Figure 6-3, the task-based attempted answers (categories 4–7) were the most frequent in all meetings followed by the task-based questions (categories 8–11). These two groups were the most frequently occurring interaction categories compared to both the positive and negative social reactions categories. The highest percentage of attempted answers was seen in meeting 4 (72.4%) and the lowest was in meeting 16 (51.1%). The highest percentage of task-based questions was seen in meeting 11 (42.9%) and the lowest was in meeting 4 (22.7%). These figures indicate that in meeting 4, the attempted answers were three times more frequent than the questions categories. The smallest difference in percentages between attempted answers and questions was recorded in meeting 11 where the percentage of the attempted answers (55.2%) was very close to the question categories (42.9%). Figure 6-3 also showed that the social reactions were very infrequent compared to the task-based interaction categories. The highest percentage of positive social reactions (categories 1–3) was 10.2% in meeting 14. The negative reactions (categories 12–14) were most frequent (3.9%) in meetings 13, 15 and 20.

These numbers indicate that the majority of participants' interactions were task-based categories, which represent the problem setting and direction setting phases in the CPDD model. Participants focused more on providing detailed explanations to investigate technical concerns related to the proposed solutions, offering solutions and suggestions, and confirming and providing information. This indicates that participants managed to make use of their face-to-face interactions to get instant answers to inquiries related to design problems. Similarly, the positive social reactions exceeded the negative ones, which suggests that participants managed to finalise design decisions in the majority of the tasks being discussed. The negative social reactions existed in some difficult discussions because participants were under stress to finalise design discussions within the design deliverables timeframe. However, the positive social reactions indicate that despite the tension that occurred, participants managed to get the discussions back on track by showing appreciation of each other's contribution in the ongoing discussions. A breakdown of participants' interactions in all design meetings illustrating these interaction categories and their aggregate sums for this case study is provided in Appendix II. Below is the detailed discussion of the four groups of interactions illustrating phases of collaboration.

a) Task-based questions (categories 8–11)

The task-based questions (categories 8–11) of 'asks for information' (category 8), 'asks for confirmation' (category 9), 'asks for opinion' (category 10) and 'asks for suggestion' (category 11) are demonstrated in the example 1 below. Participants involved in the discussion below are the main contractor's project engineer (C1), the subcontractor's senior project manager (T2), the architectural firm's senior architect (R2) and associate principal façade engineer (R3) and the client's delivery manager (L1). Of note, in all the examples below, category numbers are displayed after each sentence or unit in parentheses as in Table 5-2. Numbers at the beginning of each line represent participant codes for who is talking and to whom as in Table 5-1.

Example 1: Doors discussion (meeting 20)

[T2–R3&C1]: explains having sub sill down/structural frame (5), the only problem is exposure to weather (6)
[T2–R3]: I think whether you go sliding or go swing; still the problem is with water getting in (4)
[R3–T2]: does an operable opening door give a better sealing from sides? (9) Height pressure, would you do that?(8)
[T2–C1]: yes (6), what size?(8)

[R3–L1]: if we are talking about operability, what do you think? (10)
[L1–R3]: I don't know,(7) is it a weather issue, or is there no difference (9), is sliding a better solution?(10)
[C1–L1]: I think you have one on the face looking at the green area opposite to the building (7)
[R2–L1]: yes (6), and one on the other side (7)
[C1–L1]: the thing here is the weather (7)
[T2–All]: for me, it was a pair of swing doors or sliding/swing is better because it is sealed off, but still get the possibility of water getting in (6)
[L1–T2]: look we put swing doors in some of our buildings, but if it is an entry condition like level 4, we got slider doors (7) It's fine if they are undercover but if not, we are exposed to the weather (6)
[R3–L1]: the question is that structure here (pointing on 2D drawings) (6), so I don't see why we cannot have it (10)
[L1–R3&T2]: Thank you (2), I think we still need a solution here (11)
[C1–T2]: using 2D drawings, I guess you need set-out here (7)
[T2–R2]: pointing at 2D drawings, yes as long as we get that dimension (6)
[R2–T2]: this is 1500 mm (7)
[C1–R2 &T2]: 1500, so if you have 2 of 1500, then it is 3 m wide (6)
[T2–C1]: explains dimensions (5)
[L1–All]: we should have the sliding and put some sort of awning over it (4), is that appropriate? (9)
[T2–All]: well, that will take away your weather concerns out of the way (6), but it is possible that wind and rain will come in (7)
[R3–T2]: yes, wind should be considered also (6)

The above example showed that participants were keen to ask for more explanation and information to clearly understand design and functionality constraints. They needed to discuss the impact of wind pressure and protection against weather conditions to be more informed when selecting the door type. The process of investigating different types of doors took into consideration the functionality aspects, which was one of the client's primary concerns to ensure the safety of building users. These interactions demonstrate the *interactive coordination* theme in the literature that is concerned with the contribution of designers and contractors in the discussion to provide design and constructability inputs to raise the awareness of technical constraints (Luth 2011).

b) Task-based attempted answers (categories 4–7)

The attempted answers (categories 4–7) are 'gives suggestion' (category 4), 'gives opinion' (category 5), 'gives confirmation' (category 6) and 'gives information' (category 7). The example 2 below was extracted from meeting 4 about the façade components of the roof panels and example 3 is about the helix stairs design discussion in meeting 18. Participants involved in the first example discussion were the subcontractor's senior project manager (T2) and draftsperson (T5), the architectural firm's associate project architect (R1) and the client's design manager (L3). Of note, in all the examples below, the numbers in the parentheses after each sentence represent the interaction categories as in Table 5-2.

Example 2: Roof facade panel discussion (meeting 4)

[R1–T5]: what about the cost of connections of curved panels corners and roof? (8)
[T5–R1]: we would provide this information soon (6)
[T2–R1]: explains…the majority of the money is in curving of corners coming to the winter gardens (5)
[R1–T2]: using 2D drawing where is the cost he was talking about, which location? (8)
[T5–R1]: can you clarify further your concerns? (10)
[R1–T5]: using 2D drawing...explaining concerns panels curvature, design of connection and visual impact when looking at the building (5)

[L3–R1]: CCF is cheaper if it is single panel than the option that T2 is offering (4)
[R1–L3]: explaining…if they use the same section as the one on the lower level, which is CCF and extended to roof it would be cheaper (4)
[T2–R1]: annotating 2D drawing…explaining how they looked at the connection from inside because of all the waterproofing components coming from lower levels are straight and not curved (5)
[R1–T2]: can you explain further? (10)
[T2–R1]: clarifying the configuration of components in curved and straight areas (5)
[R1–T2]: our aim is all panels look the same (6), so why not use CCF from lower level to continue to roof (10), and then there would be no need for a junction (4)
[T2–R1]: we need to check this option because CCF has black connection from inside unless the view from inside matches the design intent (7) because it would look different near the mother of pearl colour (6)
[T2–R1]: explaining transom location and connections (5) we need to look at it again (6)
[R1–T2]: explaining the design intent to clarify the visual impact (5)
[T2–R1]: explaining the look of the transom from inside (5)
[T2–R1]: I think we can hide the black connections of CCF by adding a panel (4)
[R1–T2]: ok (3),we will look at this solution and investigate it (6), this is why we needed to know your feedback (7)
[R1–All]: There is an opportunity here (2)

The presence of attempted answers categories (4–7) continues in all meetings, especially in complex design tasks such as the helix stairs design illustrated in example 3 below extracted from meeting 18. Participants involved in the discussion were the main contractor's project engineer (C1), the subcontractor's senior project manager (T2) and draftsperson (T5) and the architectural firm's associate principal façade engineer (R3).

Example 3: Helix stairs discussion (meeting 18)

[C1–T2]: what is the depth here (pointing at 2D drawing)? (8) Is it 1.75? (9) Can you explain it? (10)

[R3–T2]: can you please explain because this is a major deflection for us? (10)

[T2–R3&C1]: explains design using 2D drawing loads coming from the upper level, dimensions, gap and tolerance (5)

[R3–T2]: pointing at 2D drawing, how do you connect this?(8)

[T2–R3]: it is already prefabricated (7)

[R3–T2]: pointing at 2D drawing, is there any reason why you don't want to use these points?(10)

[T2–R3]: explains steel tolerance (annotating 2D drawings) we need to allow 6 mm/joint 10-12 mm (5)

[R3–T2]: what bothers me is these bolts [points at 2D drawing], cannot weld that?(11) Glass will not fit (6), so we need some tolerance in both directions, you cannot fit glass in both directions, you will lose this area (pointing at 2D drawings) (5)

[T2–R3]: if we lose this, there will be 10 mm left (7)

[R3–T2]: I will draw my point [draws a sketch to show these two bolts fit](7)

[T2–R3]: explains the installation process of this detail (5)

[R3–T2]: my concern is that this connection was never made correctly (6)

[T2–R3]: explains further installation process (5)

[R3–T2]: this is my real concern, please rethink (11), you cannot get this vertical and horizontal connection correct, you have three panels coming in here (5), can you think post fixing (4)

[T5–T2]: clarifies connection detail using 2D drawings (5)

[T2–T5]: I understand what R3 mean (6) we might change this (4)

[R3–T2]: thank you for listening as usual (1)

[T2–R3]: you are always welcome...laughs and jokes between T2 and R3(2)

The above two discussions are consistent with the literature as they demonstrate the merging of design and construction knowledge to develop a common understanding of technical concerns (Denerolle 2013). Achieving this level of understanding enabled participants to work closely to refine solutions, which illustrates the collaboration theme of *collective decision making* process that is supposed to exist in the direction setting phase. In this phase, participants evaluate potential solutions before agreeing on a specific design approach based on their skills and knowledge (Arroyo, Tommelein & Ballard 2012) . This finding is important as it confirms the attempted answers categories as the most common in all meetings suggesting that participants managed to move forward into the direction setting phase (phase 2 in the CPDD model).

c) Positive social reactions (categories 1–3)

Positive social reactions of 'shows solidarity' (category 1), 'shows tension release' (category 2) and 'agrees' (category 3) were less frequent than the task-based interactions. Participants were concerned with discussing the technical concerns, including scope of work and cost information. However, there were distinct incidents present in the discussions showing that participants were keen to express their satisfaction when the design intent was understood. The example 4 below demonstrates these positive social reactions using an extract from the façade panel modulation discussion in meeting 6. Participants involved in the discussion were the main contractor's site superintendent (C6), the subcontractor's senior project manager (T2) and design manager (T4) and the architectural firm's associate project architect (R1).

Example 4: Panel modulation discussions (meeting 6)

[R1–T2]: can you work the other way around by looking at the middle panels because they are similar, and you can work your way out for the ones that have different dimensions?(10)
[T2–R1]: I know what you mean (6), but we need to find a way to model them because it affects the manufacturing of panels, glass, blinds and others (5)
[C6–T2]: what is the tolerance between mullions?(8)
[T4–R1&C6]: the problem is that we need a typical panel size for manufacturing (7), can I use this type? [pointing on the 2D drawings] (9)
[R1–T2&T4]: we tried not to emphasise junctions if you say we have 15 panels …explaining the design intent. There should be a formula somehow to solve this (5)
[C6–R1]: the problem is during construction if they found this gap between panels, they will stuff it up (7)
[T2–C6]: no need because of the way these panels are constructed; they need to meet the tangent points at both ends (6)
[R1–T2]: exactly (3), that is right! [face expression showing great satisfaction and relief that the design intent is understood] (2)
[R1–T2]: we are happy to sit with you if it helps to think together how you are going to manage this (4)
[T2–R1] explaining how to figure out the fixed panels and mix and match the other ones along the floors up (5)
[R1–T2]: you need to see full line of soffit with fascia (7)
[T2–R1]: explaining glass sizes and consistency of panels for configuration (5)
[R1–T2]: ok we need to look at a single panel (6)
[T2–R1]: we will work out one panel and send it to you (6)
[R1–T2]: yes (3), that's good! (2)

The above example of positive social reactions is consistent with the literature as it demonstrates the theme of achieving design integrity shown in phase 3 of the CPDD model. The above discussion was in meeting 6, one of the earlier meetings, showing that the architect was relieved because the design intent was understood, and it would not be comprised later due to construction constraints. This objective outcome also helped in ensuring that the design will progress in the right direction as the subcontractor showed a good understanding of the geometric aspect of the façade curvature.

d) Negative social reactions (categories 12–14)

The negative social reactions (categories 12–14) of ‘disagrees’ (category 12), ‘shows tension’ (category 13) and ‘shows antagonism’ (category 14) were the least frequent group compared to positive reactions, attempted answers and questions categories. However, there were a few incidents where participants expressed their dissatisfaction with design changes and repetitive inquiries because of the associated coordination efforts. The example 5 shown below demonstrates the escalation of disagreement about the performance testing of the façade panels and how it triggered other coordination inquiries in the discussion that increased the tension between participants. Participants involved in the discussions below are the main contractor’s project engineer (C1) and construction manager (C5), the subcontractor’s senior project manager (T2), the architectural firm’s associate principal façade engineer (R3) and the façade consultant (F1).

Example 5: Performance testing discussion (meeting 15)

[T2–F1]: explains waterproofing/connections details/gusset fixing (5)
[F1–T2]: but I still cannot rationalise that (12), I appreciate your proposal (2), but the curved parts need to be tested (6)
[T2–F1]: explains segmented panels location (5)

[F1–T2]: having curves here, I cannot rationalise, so I cannot explain to L1 (12), I really cannot see why not testing it (13)
[C1–T2]: what is the implication on cost? And program? (8)
[T2–C1]: test due in January next year (7)
[T2–F1]: I was trying to push sill testing earlier (4)
[F1–T2]: I see but cannot rationalise it (12)
[T2–C1]: then it is all about a difference in opinion between F1 and me (13)
[R3–T2]: does it affect your program? (8)
[T2–All]: explains program implications (5)
[R3–T2]: and if doing it your way? (8)
[T2–R3]: I can start earlier (6)
[C5–T2]: does it affect your start date?(9)
[T2–C5]: yes (6)
[C5–T2]: but still the same delivery date? (9)
[T2–C5]: I know we are pushing, but it affects us (6)
[C5–T2]: how long this has been around?(8)
[T2–C5]: 3 months from April (7)
[C5–T2]: and still you are saying it will affect program!! (13)
T2 is quiet, and all were quiet for 2 seconds (signs of dissatisfaction) (13)
[R3–C1]: keep going to the other item (4).

Although the occurrence of negative social reactions is less frequent in the above example, it did change the mood of the discussion and shift participants' focus. To bring participants back into the discussion, one of the participants (R3) had to step in to ease the tension by ending the discussion about the performance testing as no agreement was reached. It worth noting that participant (R3) was active in most of the discussions in providing thorough explanations related to design problems and suggesting practical solutions that helped the team to progress with the design development.

6.2.2 Sequential interactions analysis

While the above section shows the prominent presence of task-based interactions, the four phases of collaboration can only be compared by calculating the percentage of all coded interaction categories. To identify collaboration patterns in phases 1 and 2 that are associated with good and poor collaboration in phases 3 and 4 in the CPDD model, the single interactions were further categorised into sequential interactions. Organising the categories into sequential order generated 154 mutually exclusive sequential interactions that occurred in the 21 meetings. The sequential interactions in each meeting are provided in Appendix II.

The identified sequential interactions provided the base for computing the transitional probabilities using the method discussed in Section 5.5.4. The transitional probability investigates the one-step transition from one state to another and is presented in a matrix form (Kemeny & Snell 1976). The identified sequential interactions were arranged into a matrix where categories listed in the left columns are the state 0 (occurred first) and categories listed in the rows are the state 1 (occurred second). This step used the pivot tables function in Excel. The next step calculates the transitional probability for each entity by dividing each number by the total of its row as shown in Table 6-1 below. The table satisfies the three conditions of transition matrices that record the move from one state to another being in a square matrix, each number is equal to or greater than zero, and the sum of each row is equal to 1 (Kemeny & Snell 1976). The numbers in Table 6-1 are highlighted by using the heat chart formatting option in Excel. The colour scale used shows three frequency levels starting with the darker colours for high, lighter for moderate and white for less frequent values. This colour formatting approach is useful in visualising higher and lower numbers so the common patterns of sequential interactions can be easily detected. Of note, 'shows antagonism' (category 14) is excluded because it had an inflated level of probability reported (1%) due to the presence of only one incident, which would have influenced the range of high and low values. The sequential categories are read from the left side of the matrix. For example, it is easier to visualise that 39% of 'asks for information' (category 8) as state 0 was followed by 'gives information' (category 7) as state 1 in Table 6-1 below.

Table 6-1 Case study A – Transitional probabilities for two-event sequences

State 1

State 0

Interaction categories	**AI**	**AC**	**AO**	**AS**	**GI**	**GC**	**GO**	**GS**	**AE**	**DE**	**TR**	**SS**	**ST**	**SA**
AI	0.08	0.03	0.03	0.00	0.39	0.21	0.20	0.04	0.00	0.00	0.01	0.00	0.0	0.00
AC	0.05	0.04	0.03	0.01	0.11	0.53	0.13	0.07	0.01	0.00	0.00	0.00	0.0	0.00
AO	0.05	0.03	0.05	0.01	0.12	0.15	0.54	0.04	0.00	0.00	0.01	0.00	0.0	0.00
AS	0.07	0.02	0.07	0.09	0.10	0.15	0.32	0.14	0.00	0.02	0.02	0.02	0.0	0.00
GI	0.18	0.07	0.10	0.03	0.14	0.15	0.19	0.08	0.01	0.01	0.03	0.00	0.0	0.00
GC	0.17	0.10	0.10	0.03	0.14	0.14	0.18	0.09	0.03	0.00	0.02	0.00	0.0	0.00
GO	0.11	0.08	0.14	0.04	0.07	0.14	0.25	0.08	0.04	0.02	0.01	0.00	0.0	0.00
GS	0.13	0.07	0.08	0.03	0.11	0.25	0.14	0.06	0.09	0.01	0.02	0.00	0.0	0.00
AE	0.11	0.11	0.09	0.03	0.13	0.05	0.24	0.06	0.07	0.01	0.02	0.05	0.0	0.00
DE	0.05	0.00	0.03	0.05	0.32	0.05	0.22	0.16	0.00	0.03	0.03	0.00	0.1	0.00
TR	0.20	0.09	0.11	0.04	0.20	0.02	0.16	0.09	0.04	0.00	0.04	0.02	0.0	0.00
SS	0.00	0.00	0.09	0.09	0.00	0.09	0.27	0.18	0.00	0.09	0.18	0.00	0.0	0.00
ST	0.06	0.12	0.09	0.06	0.09	0.12	0.09	0.15	0.06	0.06	0.03	0.03	0.0	0.00
SA	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00

Key: AI = asks for information (8), AC = asks for confirmation (9), AO = asks for analysis (10), AS = asks for suggestions (11), GI = gives information (7), GC = gives confirmation (6), GO = gives analysis (5), GS = gives suggestion (4), AE = agrees (3), DE = disagrees (12), TR = shows tension release (2), SS = shows solidarity (1), ST = shows tension (13) and SA = shows antagonism (14).

Note: The darker colours for high frequent values, lighter for moderate and white for less frequent values.

The data in Table 6-1 suggests that the attempted answers categories were more frequent in all the sequential interactions than the questions categories. The column of 'gives opinion' (category 5) referred to in the table as GO has the most number of high and moderate sequential interactions. This suggests that the process of analysing technical problems was a prominent component in the discussions showing that participants created an environment that encourages expressing views and opinions to explore different aspects of the problem. The data also shows the importance of exchanging information and confirmation to coordinate design tasks needed for developing the conceptual design into a set of shop drawings ready for construction as the second and third most frequent sequential interactions. The social reactions were less frequent when compared to the task-based categories.

The sequential interactions in Table 6-1 were examined in four parts based on their frequency levels: task-based followed by task-based categories, task-based categories followed by social reactions, social reactions followed by task-based categories, and social reactions followed by social reactions. The sequential interactions are illustrated below in descending order.

Task-based followed by task-based categories:

Highly frequent interactions:

- *'asks for opinion' → 'gives opinion' (54%)*
- *'asks for confirmation' → 'gives confirmation' (53%)*
- *'asks for information' → 'gives information' (39%)*

Moderately frequent interactions:

- *'asks for suggestions' → 'gives opinion' (32%)*
- *'gives opinion' → 'gives opinion' (25%)*

- *‘gives suggestion’ → ‘gives confirmation’ (25%)*
- *‘asks for information’ → ‘gives confirmation’ (21%)*
- *‘asks for information’ → ‘gives opinion’ (20%)*

The above patterns show that the three mutual interactions of exchanging opinion, confirmation and information were the most common ones as seen in the highly frequent set of interactions. The second set of moderately frequent interactions are important in showing the presence of attempted answers categories of opinion and confirmation as the common practice. For instance, requesting suggestions was followed by giving opinion to raise awareness of the technical constraints before offering a solution. Also, these patterns showed that proposed design solutions were followed by confirming information needed to proceed with developing the design task. The presence of giving opinion after giving information in coordination tasks shows that participants preferred to elaborate on explaining technical views in their discussions. This set of sequential interactions demonstrated participants’ discussions in the problem setting (phase 1) and direction setting (phase 2) in the CPDD model.

Social reactions followed by task-based categories:

Other sets of interactions that are moderately frequent in Table 6-1 are interesting patterns of social categories (1–3 and 12–14) which existed as state 0 (occurred first) and followed by task-based categories (4–11) as state 1 (occurred second), which are presented below in descending order.

- *‘disagrees’ → ‘gives information’ (32%)*
- *‘shows solidarity’ → ‘gives opinion’ (27%)*
- *‘tension release’ → ‘gives opinion’ (27%)*
- *‘agrees’ → ‘gives opinion’ (24%)*

- *'disagrees' → 'gives opinion' (22%)*
- *'tension release' → 'gives information' (20%)*

Social reactions followed by social reactions interactions

- *'shows solidarity' → 'tension release' (18%)*

Task-based categories followed by social reactions

- *'gives suggestion' → 'agrees' (9%)*
- *'gives information' → 'tension release' (3%)*
- *'gives confirmation' → 'agrees' (3%)*

The first group of patterns is interesting in showing the association between social reaction with attempted answers of giving opinion and information. These sequential interactions suggest that participants were focused on the problem and direction setting phases 1 and 2 of the CPDD model in the majority of their discussions. The first pattern shows that disagreements were followed by giving information, which suggests that participants preferred to align views rather than escalating the conflict by providing orientation, facts, repeats and updates. The second and third patterns suggest that showing appreciation and signs of tension release encouraged participants to elaborate in their explanations and opinions. The fourth and fifth patterns show that both agreements and disagreements were followed by giving explanations. These sequential interactions suggest that participants preferred the practice of giving explanations even when they did not reach an agreement rather than expressing negative social reactions. The sixth pattern shows that tension release was followed by giving information. This set of interactions suggests that participants were practical in their discussions and managed their conflicting views in a positive manner, which is also demonstrated by the association between social reactions in the second group. Despite the low frequency of the sequential interactions in the third group, they still show the positive environment of participants' discussion.

6.2.3 Summary of interactions findings

The analysis of single interactions and sequential interactions across the 21 meetings showed that questions (8–11) and attempted answers (4–7) categories represent the majority of participants' interactions, suggesting that participants were focused on task-based interactions. Although the IPA (Bales 1950) method considers all four stages of interactions as equally important in profiling a group's interactions, this finding does not suggest that the focus on social reactions was a primary concern in design discussions, but rather a means of expressing satisfaction to sustain collaborative efforts, or dissatisfaction with their collaboration experience. However, using the IPA method as the theoretical framework in coding and analysing observation data provided new insights into profiling face-to-face interactions between participants involved in the detailed design phase. Five key findings emerged from the data analysis of the standard design environment discussions:

- In detailed design meetings, interdisciplinary participants' discussions mainly included task-based questions and attempted answers.
- The task-based questions were highly frequently followed by attempted answers to deal with technical constraints.
- The positive collaboration pattern included a highly frequent presence of task-based interactions (questions and attempted answers) followed by less frequent agreement and expressing signs of satisfaction and gratitude.

- The ‘gives opinion’ (category 5) was the most frequent task-based interaction followed by other task-based categories and social reactions.
- The negative collaboration pattern was less frequent. However, when disagreements occurred, they were followed by task-based attempted answers of giving information and explanations to clarify technical problems rather than escalating problems.

The rest of the chapter reports the data analysis and discussion related to the second part of the first research question in the context of the standard design environment, stated as:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?

6.3 Analysis of the standard design collaboration perceptions

The purpose of this section is to present the results of investigating collaboration processes and outcomes from participants’ perspectives. The research methodology enabled the quick capture of perceptions about collaboration from the key participants representing the organisations involved in the project (section 5.4.2). The key participants involved in this phase of data collection (ratings and interviews) were the client’s delivery manager (L1), the main contractor’s project engineer (C1), the architectural firm’s senior architect (R2), the façade consultant (F1) and the subcontractor’s senior project manager (T2). A total of 100 ratings were collected starting from meeting 2 to the end of the detailed design phase (meeting 21). A matrix displaying all participants ratings is provided in Appendix II. The start-up meeting

(meeting 1) was excluded because it was a preparatory meeting where the subcontractor team members were introduced to the client, architects and façade consultant. The start-up meeting was needed to confirm the subcontractor scope of work, design deliverables, submission of glass samples and list of façade performance tests. The design discussions started at meeting 2, thus rating collaboration was useful. The diversity in participants' views was reflected in their ratings (to a maximum of 9) as shown in Figure 6-4 below.

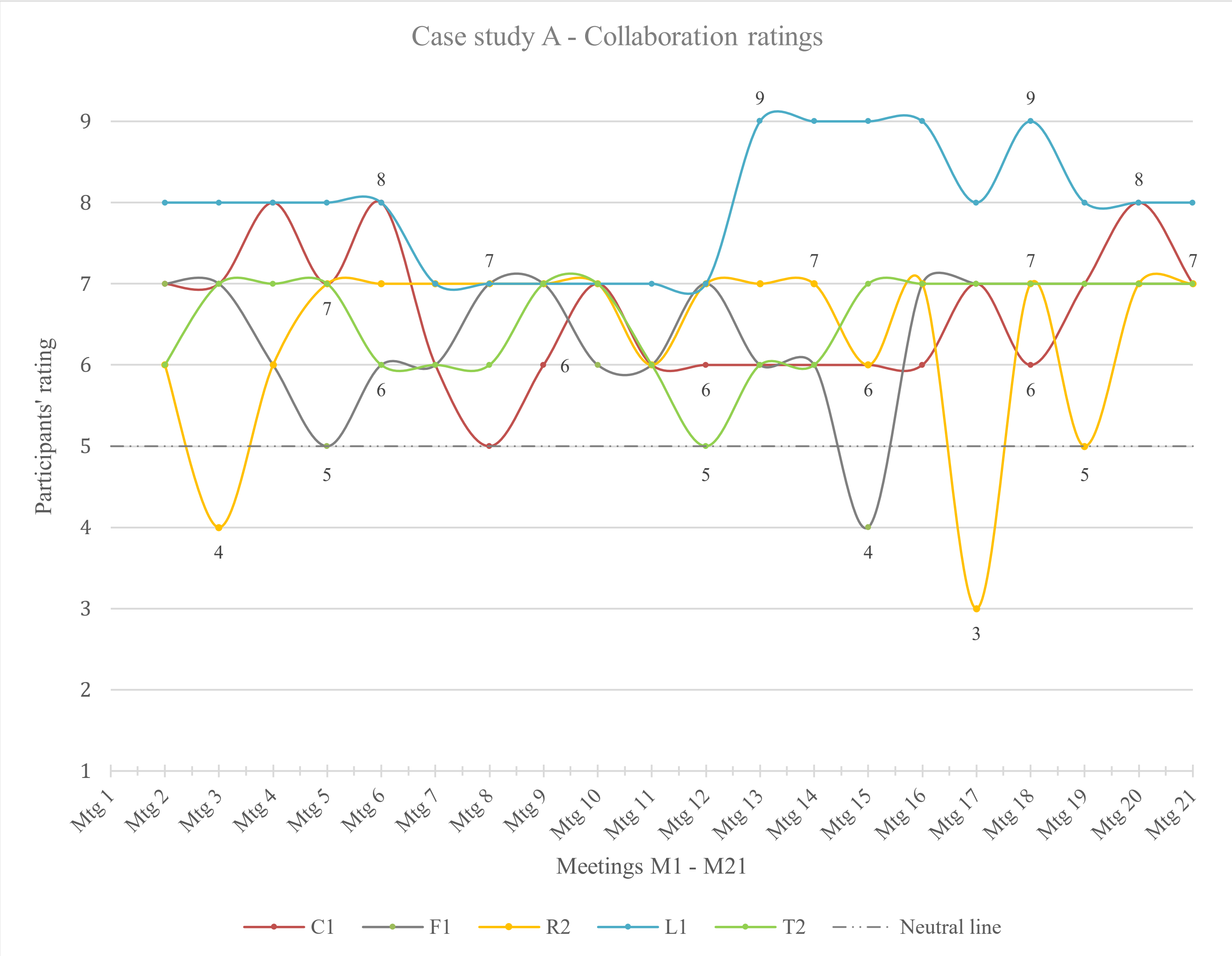

Figure 6-4 Case study A – Collaboration ratings by meeting

The first observation from Figure 6-4 is there was no consensus among participants about their collaborative experiences as the ratings did not align in any meeting. However, the majority of the ratings were in the positive part of the graph above the neutral line (rating of 5). Only three ratings out of the collected 100 were below the neutral line. The most common ratings were 7 (50%) and 6 (26%). The second observation is the constant high ratings suggesting ongoing satisfaction with the collaboration, such as the client (L1) who believed that collaboration was excellent (rating 9) in meetings 13, 14, 15, 16 and 18. As noted earlier, the subcontractor was one of the leading international contractors who developed the CCF façade system. This assured the client (L1) that the subcontractor was aware of every façade component in terms of design, manufacturing and installation on site and was capable of adapting the façade system to match the architectural design criteria. The client (L1) was confident that the ongoing collaboration process would lead to the desired outcome, which was reflected in the high rating of collaboration as seen in the quote below extracted from the interviews:

The process is positive because they know their system; they are looking at winter gardens, glass curves, and everything. The meetings are positive in general. [L1, rating of 8 for meeting 6]

Similarly, the subcontractor (T2) ratings did not change much as the majority were 6 or 7 showing constant satisfaction with the collaborative experience. The subcontractor's ratings were affected by team formation, which is one of the collaboration enablers dealing with clustering designers and contractors for major trade packages in the form of an interdisciplinary team. The subcontractor was satisfied with the presence of the architects as part of the team to get instant feedback on the proposed design solutions, as quoted below:

Because in the meetings mainly to do with façade. So, it wasn't just a normal meeting that has everybody else on the project in the meeting, but for the façade to have an understanding of the design. [T2, rating of 6 for meeting 8 and 7 for meeting 9]

On the other hand, the ratings of the main contractor (C1), architect (R2) and façade consultant (F1) fluctuated between a high of 8 and a low of 3, creating gaps between participants' ratings as they rated the same meeting differently. Three significant gaps between the highest and lowest ratings for a meeting were identified: a gap of four rating points in meeting 3, a second gap of five points in meeting 15 and a third gap of five points in meeting 17. The interactions that took place in these meetings are presented in Table 6-2 below for further investigation. The numbers in brackets are the percentages.

Table 6-2 Case study A – Coded interaction categories for meetings with high gaps in rating of collaboration

Interaction categories	**Meeting 3 N (%)**	**Meeting 15 N (%)**	**Meeting 17 N (%)**
Shows solidarity (1)	2 (0.8)	1 (0.3)	0 (0)
Shows tension release (2)	0 (0)	7 (2.3)	0 (0)
Agrees (3)	6 (2.5)	12 (3.9)	4 (2.8)
Gives suggestion (4)	12 (5.1)	21 (6.8)	10 (6.9)
Gives opinion (5)	68 (28.7)	41 (13.2)	37 (25.5)
Gives confirmation (6)	54 (22.8)	41 (13.2)	13 (9.0)
Gives information (7)	28 (11.8)	72 (23.2)	27 (18.6)
Asks for information (8)	15 (6.3)	53 (17.0)	26 (17.9)
Asks for confirmation (9)	12 (5.1)	26 (8.4)	7 (4.8)
Asks for opinion (10)	28 (11.8)	17 (5.5)	16 (11)
Asks for suggestion (11)	8 (3.4)	8 (2.6)	4 (2.8)
Disagrees (12)	0 (0)	7 (2.3)	0 (0)
Shows tension (13)	4 (1.7)	5 (1.6)	1 (0.7)
Shows antagonism (14)	0 (0)	0 (0)	0 (0)
Total	237 (100)	311 (100)	145 (100)

As shown in Table 6-2, there were four incidents of ‘shows tension’ in meeting 3 due to the confusion about design intent and the mismatch between design drawings and design sketches. These concerns were discussed in the context of the scope register of the winter gardens external façade. The architects were trying to understand the difference between the design intent in the tender documents and the design solutions offered by the subcontractor. This exercise was needed to explore the cost of each design solution to adjust the scope register at an early stage of the detailed design phase. In doing so, participants provided information about façade components and their costs, and explanations about the façade system and how it works, which was received by acceptance and satisfaction reflecting the high rating given in this meeting. However, in the same discussion, the architects were concerned about the scope register because they needed to be sure that the subcontractor understood the design intent before agreeing on the scope. This was seen in the 'shows tension' (category 13) interactions that occurred because of the need to understand the façade system and its installation requirements as quoted below:

I guess it is a complex façade stepping in stepping out, twisting... it is a closed cavity façade system and there is a lot of sort of services and extra constraints along with that façade type because you know there is an air supply and ...it is just more complex than a traditional façade type. [R2, rating of 4 for meeting 3]

The second gap of five points occurred in meeting 15. In this meeting, there were several negative social reactions recorded as seven incidents of 'disagrees' (category 12) and five incidents of 'shows tension' (category 13). The tension between participants increased because of the conflicting views about the performance testing requirements of the façade (part of this discussion is illustrated in example 5 in Section 6.2.1), which was reflected in the façade consultant's (F1) low rating of 5 points. Participants were negotiating testing methods and their timeframe, including warranty problems of the inner glass of the closed cavity façade system because it did not meet the client's guidelines. As a result, additional tests were requested to cover material, performance and change in material colour. These requests caused dissatisfaction because of the associated cost of the tests exceeded what was allocated in the tender documents. At the same time, the high rating of 9 points given by the client (L1) reflected the interest in the outcome rather than the process because the focus was on making sure the performance tests met the guidelines.

The gap of five points occurred in meeting 17 because of the low rating of 3 points given by the architect (R2) compared to the client's (L1) high rating of 8 points. This meeting specifically focused on understating the operation and maintenance of the operable blinds of the CCF panels, which called for new participants to be involved in this meeting only. The subcontractor team included their speciality designers to explain the blind automated system in detail. The client's team included the facility and maintenance managers. The role of the architects was to answer inquiries related to the functionality of internal space and layout design. The main contractor's representatives were focused on the manual and warranty requirements. In this meeting, a high number of inquiries occurred to understand the operation system of the blinds and implications on the internal space's usage in terms of glare on computer screens and amount of sunlight permitted. The one negative social incident 'shows tension' (category 13) that occurred was related to expressing stress because of the complexity of operating an automated blind system after building occupation. However, the architect's (R2) low rating of 3 points was related to the excessive inquiries because they should have been addressed in a separate meeting focusing on mechanical aspects of the blinds operation system as quoted below:

With regards to the blinds meeting, I felt they [referring to the client team] weren't prepared with their requirements or an understanding of the blind system, which made the meeting invalid. [R2, rating of 3 for meeting 15]

To sum up the first section, the above findings showed that participants regularly had differing views of the collaboration when they evaluated the same event as their ratings did not align once in the 21 meetings. The analysis of participants' ratings revealed an interesting insight. While all participants were asked the same question, the ones that reported higher levels of satisfaction were focused on the outcomes and antecedents of collaboration. In contrast, participants who were less satisfied with their collaboration and showed variation in their ratings were focused on the process of collaboration. These findings support the strong subjectivity aspect of collaboration because it involves people who have different views, attitudes and backgrounds that shape their working practices (Gray 1989; Gray & Purdy 2018). The variation in rating the collaboration process also demonstrates that collaboration is not a constant process as it fluctuated between easier and more difficult discussions (Gray 1989; Thomson & Perry 2006).

Next, participants' views about collaboration in the four phases are interpreted using event network diagrams.

6.4 Analysis of the standard design collaboration phases

This section further investigates the first research question (1.2) by analysing participants' interpretations of collaboration in the problem setting and direction setting phases 1 and 2 and their associations with positive and negative outcomes in phases 3 and 4 in the CPDD model. This was done using open-ended question in the short interviews and review of minutes of meetings to validate the findings. The data gathered was coded by using NVivo software followed by manually coding the interpretations derived from the analytical memos that were compiled throughout the coding process using the method explained in Section 5.5.6. The coded data was interpreted using event network diagrams to visualise the development of collaboration efforts through the four phases. Figure 6-5 below presents the results by demonstrating participants' practices in the four phases followed by a breakdown of the event diagram into simpler event diagrams to explain the emerged themes of collaboration processes and outcomes.

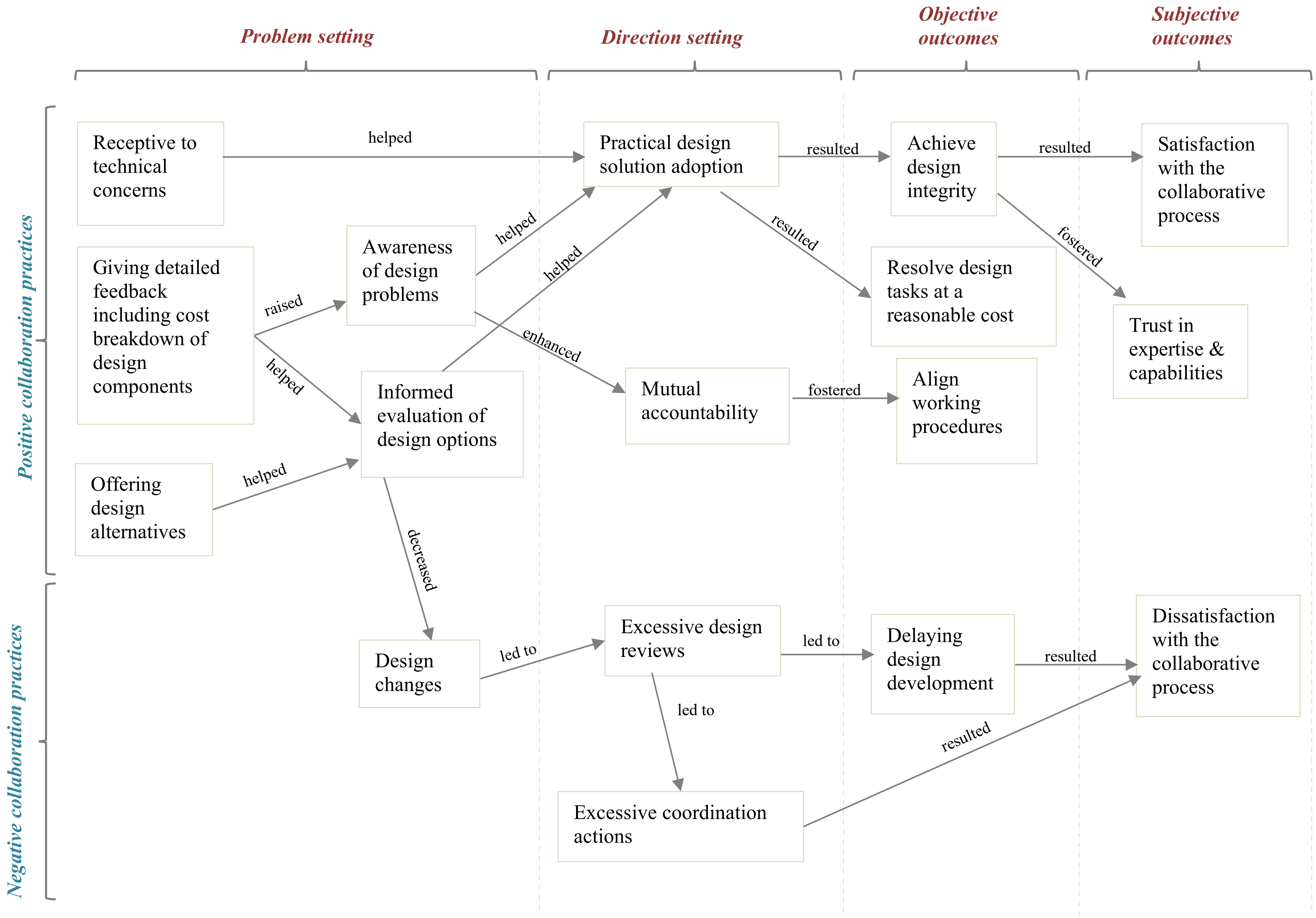

Figure 6-5 Case study A – Collaboration events network diagram

6.4.1 Phases 1 and 2 associated with positive collaboration outcomes in phases 3 and 4

As shown earlier in Figure 6-3 and Section 6.2 the attempted answers (categories 4–7) were prominent in all meetings, especially ‘gives opinion’ category 5. The repetitive process of providing explanations triggered the discussion between design partners (architects and subcontractors) to explore and refine the proposed design solutions, which were received by appreciation as shown in the subsections below.

a) Adopting practical design solution due to detailed feedback

According to Figure 6-6 below, the process of giving detailed explanations of technical tasks including cost breakdown of design components and offering alternative design solutions enabled participants to be more informed about their design decisions and aware of the associated problems. They were thus able to work out practical design solutions within the allowable cost and technical constraints.

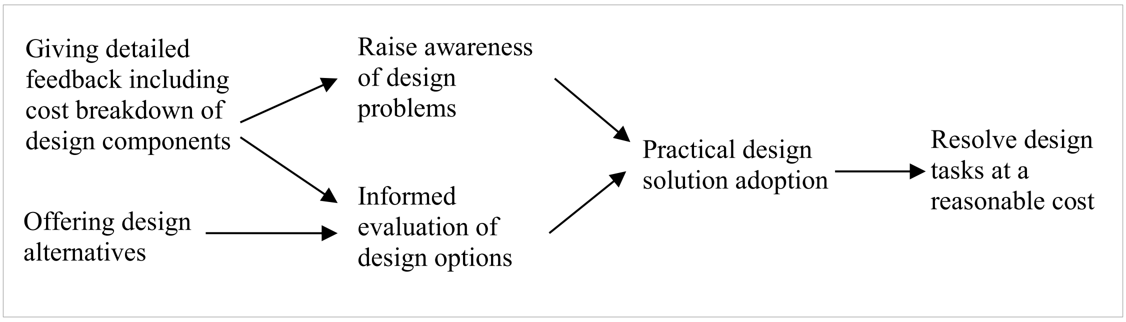

Figure 6-6 Case study A – Adopting practical design solution due to detailed feedback

The thorough explanations including the cost associated with each design component informed the designers about which part of the design was expensive. This information was helpful when designers were asked to refine the design intent while staying within the allowed budget. Some design tasks were not fully developed when the tender documents were submitted to the subcontractor to price them. As a result, some of the design options offered in their discussions exceeded the allocated budget. Participants needed to work closely to choose the best design solution that satisfied both practicality and cost.

The best example illustrating phases 1 and 2 and their positive collaboration outcomes in phases 3 and 4 of the CPDD model is the detailed investigation of design solutions seen in the helix stairs design discussions. This design task included the façade surrounding a double helix stair that spanned three floor levels. The helix stairs were an added component to the original design intent, thus participants had to discuss the scope register to include the extra curved glass in initial meetings. The façade components needed to be quantified to check the feasibility of this scope addition. In meeting 9, the subcontractor (T2) proposed two options: the first one was a frameless system based on the original architectural drawings that would cost $311,000 and the second one was a nil cost D&C solution of a framed system using 1500 mm wide glass panels. Participants discussed the second option thoroughly to understand the impact on the surrounding structural elements. The architects (R1 and R2) explained that the cost-neutral solution would involve moving the stairs and consequently re-documenting all their structural set-out drawings. Meanwhile, the main contractor (C1) clarified that the approved construction documents for the stairs were due in three weeks to avoid potential delays in the project program. Thus, participants had to work out a practical design solution within these cost and time constraints.

The architects needed to understand the components of the framed system because it would affect the existing columns connecting all floors. The discussion included explaining dimensions, manufacturing, installation processes and tolerance needed for the construction crew to be able to secure connections. The explanation of these construction limitations made the architects willing to consider the proposed design option again to try and work out a practical solution. In meeting 10, the architect (R1) proposed a third design option using steel wind beam and mullions with 3100 mm wide and 1600 mm high glass fixed to the mullions with patch fittings. The client (L1) needed to understand the implications of using this design option in terms of cost and functionality of the area leading to the stairs. The subcontractor (T2) provided a cost estimate for option 3 (at one-third of the cost of option 1) because there was still some cost associated with installing the wind beam on site in terms of extra equipment and labour because it would not be prefabricated. The team then discussed in this meeting the feasibility of choosing option 3 and explored further ways to improve it. The architect (R1) proposed reducing the length of the stairs to reduce cost. Based on this design approach, the subcontractor (T2) managed to get the cost down by a further 20%. Consequently, the client (L1) gave a direction to proceed with option 3. The satisfaction with the ongoing discussions is quoted below:

They gave us how much it costs; they break it up for us, it is easy to see if we make this decision it will cost this much money. [R2, rating of 7 for meeting 8]

Later in meeting 16, the subcontractors developed the design documents to the extent that made the architects think of another way to reduce cost without changing the design intent. The architects' approach included removing part of the balustrade surrounding the stairs because they were located close to the façade, but they needed to close the gap between the stairs and façade resulting from this design change. The design documents showed that the façade connection in this area was very crowded. Thus, a series of interactions took place to understand gap size, installation and airflow concerns. Participants used 2D drawings and sketches to clarify their design views. The subcontractor was receptive to these design refining inquiries and agreed to look at the feasibility of implementing them.

Two meetings later, at meeting 18, the architect (R3) had another design concern about the connections' installation on site. Part of this discussion is provided in Section 6.2.1 Example 3. Based on previous experience, connecting both horizontal and vertical elements in one joint was never done correctly, and it was requested that the subcontractor (T2) consider prefabricating this connection. The subcontractor agreed to refine the design of this connection. It is worth noting that several positive social reactions (see Figure 6-3) occurred in this discussion despite the process of refining design occurring at a later stage of the detailed design phase. This showed that participants managed to create a positive collaborative environment that allowed them to collectively develop the best design solution that met the program timeframe and budget limits. This was articulated in the quote below.

They are really receptive towards our idea; they do not just say no and don't back it up with any sort of information… they seem to take on board what we want… giving us a choice, information. [R2, rating of 7 for meeting 18]

b) Aligning working procedures due to awareness of design problems

The second set of events in phases 1 and 2 (the problem setting and direction setting phases in CPDD model) leading to positive collaboration in phase 3 (objective outcome) is illustrated in Figure 6-7 below. Practices of giving detailed feedback helped in raising awareness of the design problem, which in turn facilitated the process of working out practical design solutions and elevated mutual accountability among participants and consequently helped in aligning their working procedures to meet the due dates for submitting design documentation.

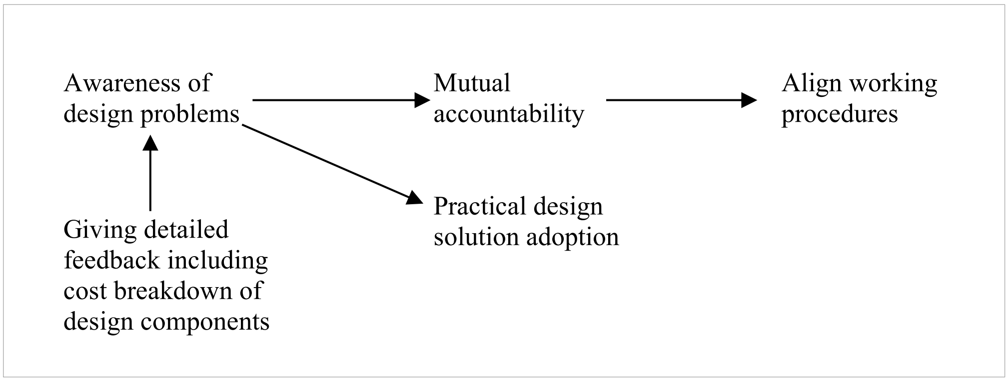

Figure 6-7 Case study A – Aligning working procedures due to awareness of design problems

The above set of events is better represented by complicated design tasks because discussions could take longer than expected and might cause delays. One of these tasks is the slab edge design configuration. The design scope of the slab edge included four connection types related to the building shape: stepping in straight panels, stepping in curved panels, stepping out straight panels and stepping out curved panels. There were a number of subtasks related to these connections such as the slab edge configuration, cladding zone, set-down size, falls and duct skirting. Of these subtasks, the duct skirting size was critical because it was associated with technical and functionality concerns.

The architect (R1) was concerned about the consistency in slabs and duct sizes across floor levels. The main contractor (C1) was concerned about the impact of changing the cladding zone on the concrete profile because the construction of the main structural system had already started on site. Other construction concerns were related to the formwork because of space limitation in the curved areas of the slabs. In meeting 5, participants discussed the implication of increasing the duct size from 75 mm to 150 mm based on the client's (L1) request. This increase in size led to several implications such as changes in the front detail of the slab, limited access for post-construction maintenance, and duct position near an existing beam. Participants explored several solutions by articulating their views using sketches of the proposed solutions, including using a flat duct, pushing down the concrete level and using a rectangular section duct 75 x 150 mm. These solutions were discussed under a tight timeframe as the main contractor (C1) mentioned that this task was on the critical path because of its implication for the concrete profile.

Participants collectively discussed limiting the design options by exploring the feasibility of using a smaller duct size. In this meeting, participants covered all technical concerns related to the new duct size such as the internal space usage to locate wiring for power and internet, consistency in the skirting dimension across the whole floor and tolerance for formwork. Participants proposed to the client (L1) a 100 mm duct size as the best option because 150 mm would go above the glass line and would have a visual impact on the aesthetic features of the façade.

Upon receiving the client's (L1) approval, both the subcontractor (T2) and architects (R1 and R2) organised the design submission and reviewing process to cope with the time constraints imposed by the main contractor (C1). To do so, the architects changed their working procedures by submitting their design drawings in an order that matched the subcontractor's necessity for information to proceed with the design development. This sequence of submissions started with the elevations for set-out dimensions, then plans for showing locations, followed by sections for detailing connections. The architects typically would update the 3D models, including all sections and drawings and then disseminate them. Thus, the alignment of working procedures meant that they changed their procedures. This change was acceptable after the excessive practices of giving detailed feedback and explanation because participants were aware of each other's technical concerns. This approach of organising submissions occurred in other design tasks that had a limited timeframe or were delayed due to conducting several design iterations to reach a practical solution. Participants' views about the working procedures include:

The process is more organised definitely; I'm actually finished going through the fascia drawings and there are always a few things that need to change but generally the thing is there, it is done and it's almost ready to go. [R2, rating of 7 points for meeting 7]

If we have something which is urgent, we need obviously to bring that on in the meeting so they can respond within a certain timeframe so we can have it. [T2, rating of 7 points for meeting 9]

c) Achieving design integrity due to receptiveness

Participants managed to work out practical design solutions by being receptive to each other's technical concerns, which enabled them to meet the design criteria and consequently improved the working process and fostered trust between them as illustrated below in Figure 6-8.

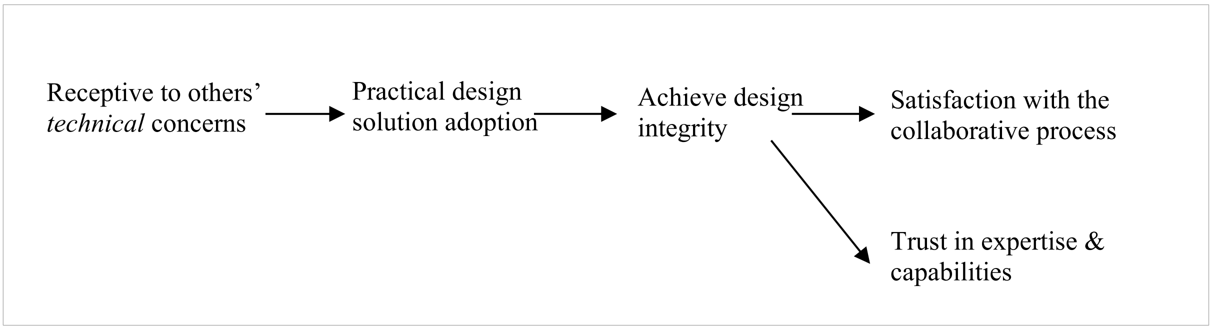

Figure 6-8 Case study A – Achieving design integrity due to receptiveness

The geometric shape of the building as explained earlier in Section 6.1 created design concerns for participants who were interested in achieving the design intent. These design concerns are common in projects where the proposed design has special aesthetic features that could easily be affected if the contractors did not fully understand the design intent. The architect (R1) needed to be assured that the design philosophy would not be lost for constructability reasons. The client (L1) also needed to feel confident that the design intent would not be comprised because of the procurement method used. For these reasons, participants conducted a rigorous analysis of the design tasks related to the external features of the building. A good example of such tasks is the panel modulation of the CCF façade design because of the variations in the building curvature.

The panel modulation design task was first brought up in meeting 3 and lasted for 11 meetings. Initially, the subcontractor (T2) did not realise the variations in the curves' length until they started to model the façade panels. In meeting 3, the subcontractor's representatives at this meeting (T2 and T3) were concerned because they found that the panels' size and length were different in each floor corner and for each floor level. This variation would affect their manufacturing and installation process on site as the panels had to be arranged in the correct order for installation. The architects (R1 and R2) were keen to know that the subcontractors understood the curves' design. In doing so, the architect (R1) explained the geometry behind the curves, which was using the same radius and changing the curve length and orientation of each panel to achieve the twisting shape of the building. The architects thought that this design approach was better from the manufacturing point of view.

The modelling progressed further in meeting 6, which triggered discussions about construction concerns. The subcontractor (T2) needed a typical façade panel for manufacturing because the high number of panel variations would also affect the blinds and glass sizes. The architect (R1) explained the design intent to clarify possible ways of modelling these panels such as starting from the middle where the typical panels were located and working out the variation as moving towards the curved edges. The main contractor's site superintendent (C6) mentioned a common practice on site would be filling any gap if found between the façade panels. The subcontractor (T2) replied instantly that this would not happen because façade panels were meant to meet at tangent points in the curved area, so there is no place for gaps. The architect (R1) praised the subcontractor and showed great relief and satisfaction that the geometric aspect of the design intent was clearly understood. A portion of this discussion is provided in Section 6.2.1 Example 4.

In meeting 7, the subcontractors (T2 and T3) had a clearer image of the panels' variation because they looked at each floor separately to recalculate the number of panels. The subcontractors found that some connections were very crowded in terms of detailing, which would affect manufacturing and installation on site. The architects (R1 and R3) asked them to submit their proposed design solutions, and they would be mindful when reviewing and commenting back, especially in the curved area. Later in meeting 10, the panels' modulation progressed further, and participants were able to explore ways of refining the design. The architects (R1 and R2) asked for more elevation sections to be submitted because they were thinking of moving the irregular panels to curved edges. The client (L1) liked this idea because it would be useful to place the offices near the curved area for better visualisation. Thus, it would be practical to keep the consistency in panel sizes centred and move irregular panels to the building edges. The two quotes provided below illustrate satisfaction with achieving the design intent, and trust in expertise and capabilities.

They are very helpful, and they explain the details and procedures good. I actually think we will get the job we want and I'm quite comfortable with that. [R2, rating of 7 points for meeting 10]

Subcontractors are actually working really closely to get the outcome. In fact, in many ways where the architects have put up a criterion; the subcontractor has actually worked really hard and even offered other suggestions as a way of getting there. [L1, rating of 8 points for meeting 12]

The panels' modulation was an example of a non-cost related design task that showed positive discussions where participants managed to find ways of improving the proposed solution and being mindful about constructability concerns.

d) Discussion of results for phases 1 and 2 leading to positive outcomes in phases 3 and 4

The findings in this section demonstrate several practices implemented in the problem setting phase to get a better understanding of the complexity of problems, sharing cost information freely, and willingness to examine design alternatives. According to the

CPDD model, phase 1 represents the definition and analysis of design problems through the interactive coordination and practices of aligning incentives interest. The findings provided more insights in the interactive coordination theme by demonstrating practices of being receptive to others' concerns during the process of analysing design problems, elaborating in providing feedback, and proposing other alternatives. These practices were seen in the subcontractor approach in explaining design problems by using sketches and annotating 2D drawings, which raised the architects' awareness of the implications of their design decisions when choosing between proposed solutions. The façade engineer and main contractor were attracted to listen to these explanations to understand how the CCF components work to evaluate the proposed design options. Also, on several occasions, the client would move closer to get a better view of these sketches and follow the discussions. Given that the CCF is a new façade type that was not commonly used in Australia, participants were interested to learn about the design and functionality aspects of its components.

These practices led to raising awareness of technical constraints and informing participants about the consequences of their decisions. This finding substantiates Luth's (2011) view that involving contractors in design discussions allows designers to make better decisions when evaluating proposed solutions. In addition, the practices of giving detailed feedback provide useful insights in the aligning incentives interests theme. The detailed feedback given in the discussions included the cost breakdown of every design component. Thus, participants would know which part of the design was expensive and organise their thoughts accordingly, which demonstrates how participants managed to align their interests in cost-related discussions. This practice aligns with Denerolle's (2013) approach of fostering face-to-face collaboration through weekly meetings to help designers and contractors develop a common understanding of each other's technical concerns in a traditional procurement setting.

The direction setting – phase 2 – in the CPDD model is the stage where participants refine design solutions and collectively decide on the best option. The findings in this section provided further insights into this phase such as practices of adopting practical design solutions and developing mutual accountability. Participants' practices in analysing design problems raised their awareness of the design problems, which allowed them to collectively agree on the best design option within the allowable cost constraints. Consequently, these practices elevated the sense of mutual accountability where all participants shared the responsibility of meeting the design deliverables timeframe.

The objective outcomes – phase 3 – outcome in the CPDD model were identified from the literature as achieve value for money, achieve design integrity and manage to stay within budget and time limits. Findings that emerged from this section aligned with these themes by demonstrating practices in phases 1 and 2 that led to adopting practical design solutions and achieving these desired outcomes in phase 3. The analysis added a theme in the objective outcomes, which is aligning working procedures. This practice demonstrated how participants were willing to change their common working procedures to match each other's needs. This finding provided useful insights into addressing the differences in working practices between designers and contractors by providing the themes that allowed them to align their views. As Eynon (2013) argued, the working practices of the designers are highly iterative and in a continuous change to refine the design, which differs from the contractors' focus on reducing uncertainty because of schedule deadlines. Lastly, findings in the section aligned closely with the trust in expertise and capabilities theme in phase 4 of the

CPDD model. Participants expressed in the interviews a high level of trust in the subcontractor expertise and capabilities and consequently satisfaction with their working processes.

6.4.2 Phases 1 and 2 associated with negative collaboration outcomes in phases 3 and 4

While participants managed to proceed in the design development, some negative practices occurred as in any construction project such as design changes, and excessive design reviews and coordination actions. This in turn caused a delay in development of one of the façade types and dissatisfaction with the working processes as shown in the subsections below.

a) Design changes causing dissatisfaction with working process

According to Figure 6-9 below, when participants were not well informed in the process of evaluating the proposed solutions, design changes occurred that needed several reviews to be conducted by the architects to approve design solutions. As a result, the main contractor needed to perform additional coordination tasks to disseminate information and get approvals from the client causing delays and dissatisfaction with the working processes. This sequence of events demonstrates how design changes in the problem setting phase affect participants' working procedures in the direction setting phase and consequently have a negative impact on the outcomes.

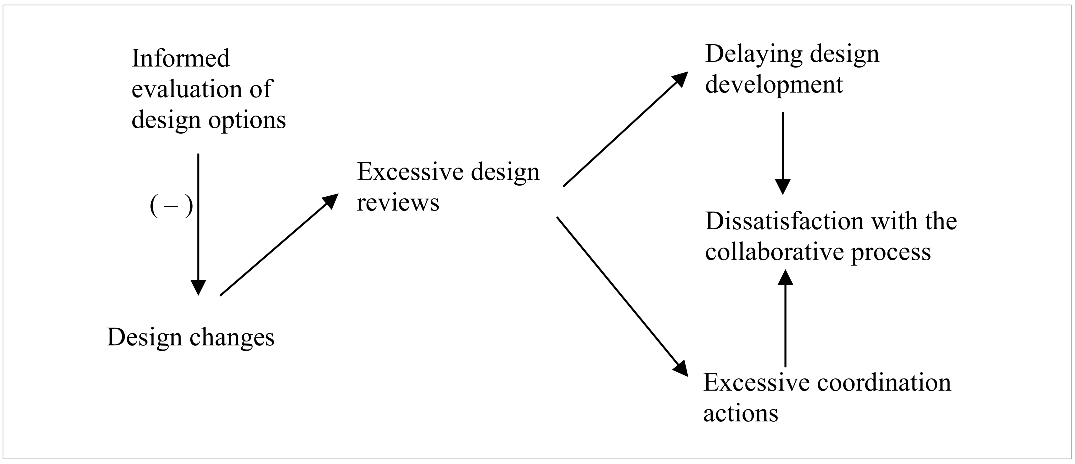

Figure 6-9 Case study A – Delays and dissatisfaction due to design changes

The selection of ledge and soffit cladding material was one of the design tasks that illustrated the above sequence of events. This design task involved a decision on materials, designing a junction detail between the curved façade and ledge cladding taking into account the consistency in colours, performance testing, and ensuring weatherproofing requirements are met. This design task lasted for the whole detailed design phase because there was a high degree of uncertainty around these technical issues. The design discussion started in meeting 4 by investigating technical concerns of the cladding material because it would have an impact on the aesthetic feature of the façade. The architects (R1 and R3) were concerned about the outside look of these connections. The subcontractor (T2) explained the connections in case aluminium composite panels were used. The main contractor (C1) was interested to know the difference between the aluminium composite panels and solid aluminium. The subcontractor (T2) mentioned that it should be the same connection and the only difference is that solid aluminium sheets are more compressed than aluminium composite panels. The main contractors (C1 and C5) needed confirmation on material selection because of its implications on fire testing.

In meeting 7, the subcontractors proceeded with submitting connection details based on aluminium composite panels and confirmed that the cladding colour matched the blinds. The discussion followed the positive collaboration pattern of providing a detailed explanation and responding to concerns and inquiries about the implications of this proposed design solution. The architects approved this design solution from the aesthetics perspective. In meeting 11, the subcontractor (T2) proposed using an alternative type of aluminium composite panels they had previously used in other projects in Europe. The main contractor (C5) required fire engineering approval for this new product. Participants in meeting 13 agreed to consider the alternative material for cladding. The client (L1) was also concerned about its performance in Sydney's extreme weather conditions. In meeting 18, the subcontractor (T2) provided a cladding sample, and the architects (R2 and R3) were impressed with the quality of the sample and the cleanness of the curvature cut.

The fire rating testing became an extreme concern to the client (L1) because of the Grenfell Tower cladding fire tragedy that occurred on 14 June 2017 in West London. As such, the suppliers' credibility and their testing procedures were questioned because they needed to match the Australian standards. The subcontractor (T2) highlighted that the contract was signed in March 2017 before the Grenfell cladding fire accident as an indication of dissatisfaction with these concerns. In meetings 20 and 21, the ledge and soffit cladding design discussion took another collaboration path because of this unforeseen incident. The façade consultant (F1) rejected the fire engineering tests submitted by the subcontractors because they were outsourced and requested the same test be conducted by the subcontractor. The client (L1) made it clear that the tests had to comply with the Australian standards regardless of any previous experience of using the alternative composite material. As a result, the subcontractor (T2) was unhappy with this late change from what was initially approved and felt that their integrity as an organisation was questioned. To ease this tension, the architects (R2 and R3) suggested using another version of the solid aluminium sheet that had been used before in Sydney and complies with the Australian standards.

This discussion did not follow the same collaborative pattern as the previous meetings despite the efforts of the client (L1) to show appreciation of the subcontractor's (T2) work and clarify that it is an executive decision made by the project control group. The subcontractor (T2) was dissatisfied with the outcome of this discussion because of the tough negotiation about the performance test requirements. However, this dissatisfaction did not affect the collaboration ratings. As discussed earlier in Section 6.3, the client (L1) and subcontractor's (T2) ratings of collaboration were high through the detailed design meetings as they preferred to link the high ratings to the objective outcomes and enablers of collaboration. The quotes below are interesting in demonstrating how these participants reflect on their dissatisfaction with the processes of collaboration, while giving their experience a high rating.

What was used on the Grenfell tower was not even fire rated, so it is almost criminal negligence, but we will not place anyone in that position, so this is the position we are taking now. [L1, rating of 8 for meeting 20]

For the ledge and soffit cladding, in reality I could have just said no, the job has been issued and then all of a sudden because of what happened in Grenfell tragedy. It means that I need to go and change the alternative material which is still not good enough from a fire rating point of view for people, but now I have to use solid aluminium sheet which is quite expensive, and it will be a variation. [T2, rating of 6 for meeting 20]

b) Excessive reviews and coordination actions causing dissatisfaction with working process

As depicted in Figure 6-9, a sequence of events emerged from the design changes leading to excessive design reviews and coordination efforts to get a fixed decision to proceed with the design development, which caused dissatisfaction with the working process. An example illustrating this problem was seen in the design discussions of the drip edge of the CCF panels. This design task came up in discussions in meeting 8 and lasted until meeting 12. The design intent documented by the architects showed a drip edge installed at the top and bottom of the façade panels. The rationale for using this approach was to keep the façade clean as these drip edges would distribute the dirt evenly across the façade. The façade consultant (F1) also supported this design approach. The subcontractor (T2) had a different view that they would not make much of a difference to the façade appearance because it should be cleaned twice per year for warranty issues. As such, the main contractor (C1) needed to do a cost analysis to calculate the cost for one extra clean per year if no drip edge was fitted. The client (L3) clarified that if adding a second drip edge involved extra cost, they needed firm advice that it would lead to a cleaner building and fewer maintenance requirements to justify this additional cost.

The subcontractors were asked to provide cost advice based on the most simplified D&C solution. The client (L1) requested a cost-neutral solution, but the subcontractor (T2) mentioned that this was hard to achieve and offered three design solutions. The first solution was based on what the architects documented, the second was the D&C solution of installing a more simplified drip edge at the top and bottom of the panels, which was priced as $70,000 less than option 1, and a third option of installing the drip edge at the top of the panels only that would cost half of option 2.

Participants were engaged in a constructive discussion to tackle several aspects of the drip edge, such as welding sill details, extrusions dimensions, connection type and its impact on curves and drainage capacity. The subcontractor (T2) responded to these concerns by explaining their methods of manufacturing and installing these connections, including using laser cutting and weld joints and using silicone seal to prevent air leakage. The architects (R2 and R3) required further explanation about using a closed box versus a flat plate (option 1 vs. option 2) in these connections to enable them to test the visual impact and functionality of these solutions. This request caused several coordination tasks that were regarded as excessive design reviews by the main contractor (C1).

In the following meeting, the main contractor (C1) provided the cost of cleaning the façade twice per year. Thus, participants needed a clear direction to proceed with the design documentation. However, they still discussed option 3 to understand which components cost more than the others to be able to choose between options 2 and 3. The process of preparing and investigating these design options included several repricing cycles that caused some degree of frustration among the contractors. This dissatisfaction with the working process translated into some of the low ratings for meeting 8.

The client (L1) gave a direction in meeting 12, which was rejecting one of the main components of the proposed solution because of cost overrun. This decision put the whole discussion of the drip edge task on hold until further notice causing further dissatisfaction among participants, especially the main contractor (C1), because of the excessive coordination actions to gather information and disseminate it as seen in the quotes below.

The drip edge, I'm sick of it, that's why I gave a low rate… how many times I've been through that, so we priced it and that they [designers] don't like that, and we price something else and they don't like that as well. [C1, rating of 5 for meeting 8]

I sent many correspondences between meetings outlining everything fully, it takes me a lot of time to outline the history, the marked-up drawings, and this is option A and this option B, but no response. [C1, rating of 6 for meeting 12]

c) Discussion of results for phases 1 and 2 leading to negative outcomes in phases 3 and 4

The above section demonstrates practices in phases 1 and 2 causing negative outcomes in phases 3 and 4. The presence of design changes is common in construction projects because of the highly iterative nature of the design process to seek improvements (Eynon 2013; Kalsaas, Rullestad & Thorud 2020). Given the diversity of participants involved in the detailed design meetings, different interpretations or ways to frame the problem existed in their discussions. While the contractors considered the design changes as excessive reviews and coordination efforts, the architects and façade consultant regarded them as a common practice in the design phase. The findings provide further insights into the excessive design reviews and coordination task by demonstrating occasions where participants had different risk perceptions and approaches in framing the same design problem. Incidents involving risk discussion in design meetings are different from the fundamental risk management exercise that main stakeholders do at the initial stages of any construction project (Winch 2009). While participants understood the consequences of the unforeseen risk that emerged halfway through the detailed design phase, they had conflicting opinions about the performance tests causing negative outcomes. The subcontractor treated it as a variation because of the rework needed to document the new cladding material and the cost associated with testing its performance.

6.5 Conclusion

This chapter presented results relating to research question 1 for case study A, which demonstrated collaboration practices in a standard design environment. The results indicated that the task-based interactions are more evident in design discussions than social reactions. The key findings related to research question 1 are:

- The positive collaboration pattern included a highly frequent presence of task-based interactions (questions and attempted answers) followed by less frequent agreement and expressing signs of satisfaction and gratitude.
- The negative collaboration patterns were less frequent. The task-based interactions (questions and attempted answers) were followed by disagreements or negative social reactions. However, disagreements, when they occurred, triggered attempted answers of giving information and explanations to clarify technical problems.

Participants' perceptions of collaboration did not align in the 21 meetings. Further investigation through the interviews provided new insights explaining the process and outcomes of collaboration. Participants regularly had differing views of the collaboration when they evaluated the same event. The key findings from analysing participants' interpretations of their collaboration experience are summarised below.

Positive collaboration patterns

- The interactive coordination in the problem setting phase (phase 1) includes practices of being receptive to others' concerns, elaborating in providing feedback with cost breakdown, and proposing design alternatives. These practices raised awareness of technical constraints and informed participants about the consequences of their decisions before proceeding to refine the chosen design solution.
- Interpreting participants' experiences highlights the significant role of detailed feedback in aligning their interests and further emphasises the need for including the cost breakdown of design components to show which part of the design was expensive to organise design thoughts accordingly.
- The impact of practices in analysing design problems (phase 1) is recognised in direction setting (phase 2) in adopting practical design solutions and developing mutual accountability where all participants shared the responsibility of meeting the design deliverables timeframe. These practices are supported by phases 3 and 4 of the initial CPDD model, which demonstrates the achievement of design integrity at a reasonable cost, alignment of working procedures as participants matched their working processes and satisfaction with the process of collaboration.

Negative collaboration patterns

- The impact design changes on the excessive design reviews and coordination task highlight the need to consider the differences in participants' perceptions of risks and their different approaches in framing the same design problem to sustain collaboration efforts.

The next chapter presents the results related to case study B, the bespoke façade design that was analysed to investigate collaboration in a different design context.

Chapter 7 Case study B – Bespoke Façade Design

The chapter reports on the analysis and discussion of the first research question in the context of the second case study representing the bespoke design environment. The chapter provides an overview of the design package and then follows the same steps in the previous chapter by presenting the general description of the observational data and then discussing the emerged collaboration patterns. The analysis then examines participants' ratings and views about their collaboration and presents the results graphically using event network diagrams.

7.1 Overview of the bespoke façade design

The second case study represents the façade component of levels 3–7 of the same building used in case study A. The design philosophy involves a highly transparent glazed façade on the north and south facing sides, and curved panels extending around the corners of the building. The design intent included a triple-height atrium that had large skylights with an uninterrupted glass façade to create a light-filled space for studying and working. The design also included a shaded system to control the solar penetration through the transparent glass and regulate the light and internal temperature because one of the façade types faces north and thus would be exposed to high temperature in summer.

This case study is another trade package of the shell project described in detail in Chapter 5 (Section 5.3). Therefore, the same organisations were involved in the detailed design phase, including representatives of the client, the main contractor, the architect and the façade consultant. The subcontractor organisation was different. For this case study, a different subcontractor was appointed to design and construct the bespoke façade. The subcontractor was one of the leading façade companies operating nationwide in Australia. They were specialised in glass and aluminium manufacturing, fabrication and installation. They had an in-house engineering department for designing and documenting façade components.

The façade scope included approximately 1100 panels made from 40 different glass types. The largest glass panel measured 6 m by 2.3 m and weighed around 700 kg. The subcontractor had to design the structural system to support such large panels with minimal visual interruption to achieve the seamless glass appearance proposed in the design intent. These design criteria created structural design challenges that were discussed throughout the detailed design phase. A total of 11 design items were discussed in the weekly meetings (Appendix III).

Figure 7-1 below illustrates the design complexity of the building in four photos. The first photo was taken from the architectural design drawings (with access given to the researcher by the client) showing the design intent. The other three photos were taken by the researcher during the construction phase and after completion.

Figure 7-1 Case study B – Photos of the bespoke façade at different construction stages

7.1.1 The detailed design phase timeline

Data gathering covered a period of 36 weeks of the detailed design phase which began after engaging the subcontractor. The average duration of each meeting was 4 hours. The detailed design involved two stages: design intent principles (DIP) and shop drawing phase (SDP). Problems in adjusting the façade scope package caused some interruption at the DIP stage of the detailed design phase. After the first two meetings, the weekly meetings stopped for two weeks to finalise the subcontractor's contract. Two meetings later, another stop of two weeks occurred to adjust the scope of work.

The meetings resumed afterwards but the DIP phase lasted longer than planned due to the design complexity. There was no definite date marking the end of the design intent principles meetings. Some design tasks were approved before the others and proceeded to the shop drawing phase, while other tasks were still under further investigation. In meeting 12, four design tasks were ready for the shop drawing phase and the others followed progressively. Figure 7-2 below shows the timeline of the meetings for the detailed design phase with meeting 12 marked as the start of the shop drawing phase.

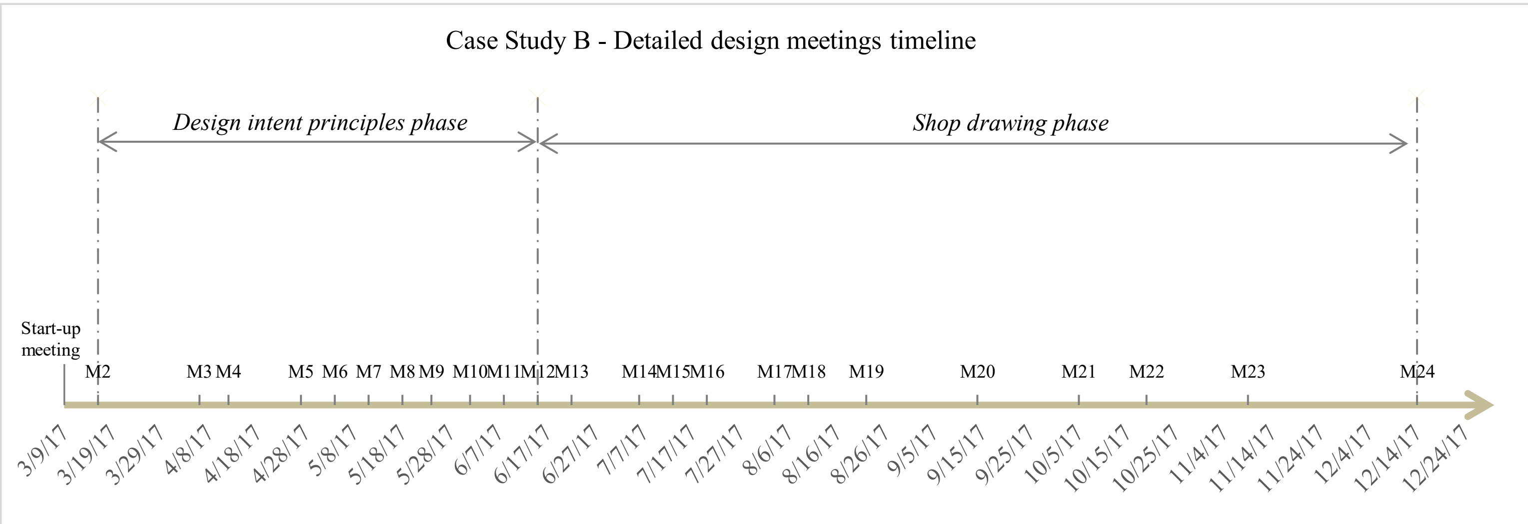

Figure 7-2 Case study B – Timeline for meetings

7.1.2 Preparatory phase of collaboration

The collaboration enablers were present in this case study as seen in forming the interdisciplinary team. An average of 12 participants attended the weekly meetings representing the firms involved in the detailed design meetings including the client, the architects, the façade consultant, the main contractor and the subcontractor forming the cross-functional team. Three participants represented the subcontractor in the weekly meetings including the design manager, senior structural engineer and project manager. The project manager was nominated as the point of contact for this project and therefore was the key participant involved in the data collection for this study. The subcontractor team included other interim members such as structural engineers and drafting technicians. These participants were involved in discrete meetings depending on the design progress as each one was responsible for design documentation of one of the major façade types. Co-locating the team in one common place was implemented as the weekly meetings were held in the main contractor's temporary office on campus near the construction site. Of note, the subcontractor team was based in Brisbane and had to fly to Sydney weekly to attend the meetings.

The shared construction management software Aconex was also used in this trade package. Participants had access to the project information, including the design drawings, specification, 3D models, minutes of meetings and project schedule. However, the main contractor asserted that this façade package would be treated separately in terms of budget and detailed design meetings. In the start-up meeting, participants introduced themselves to the subcontractor team. In this case study the subcontractor team members mentioned their roles because it was necessary to know who was responsible for the structural design because of its importance in the design discussions. The main contractor displayed the project deliverables and scope of subcontractor work on the digital screen because of the changes made in reducing some façade scope of work to make sure that all participants were updated. The subcontractor team expressed their commitment to develop the design within the timeframe displayed demonstrating the common goal theme.

The section below reports the data analysis and discussion related to the first part of the research question in the context of the bespoke design case study demonstrating the complex design environment, stated as:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.1: Are there different patterns of group interactions in different design environments?

7.2 Analysis of participants' discussions in the detailed design phase

This section of the analysis focuses on the linear development of the four phases of the CPDD model: problem setting, direction setting, objective outcomes and subjective outcomes. It reports findings of the single interactions and sequential interactions analysis following the same analysis steps provided in the previous chapter. The first step calculated the percentage of single interactions in each meeting. The next step organised these interactions into four groups: task-based questions and attempted answers categories, and positive social and negative social reactions. These four phases are then examined qualitatively to demonstrate participants' discussions by extracting incidents from the observational data. The third step organised the single interactions into sequential interactions. The step is needed to calculate the transitional probabilities of these sequential interactions to identify the most common collaboration patterns.

7.2.1 Single interactions analysis

Analysing the single interactions was guided by Table 5-2 which outlines the categories for coding the collaboration interactive process and outcomes used for coding participants' interactions in each meeting. To determine the frequency of each single interaction category and the aggregate sum, the percentage of interactions coded in each meeting was calculated using matrix coding in NVivo. A total of 6251 interaction categories were observed in the detailed design phase. The single interactions were grouped into four groups: questions and attempted answers (representing the interactive process), and the positive reactions and negative reactions (representing the outcomes) of the CPDD model. Figure 7-3 below presents the percentage of coded interaction categories of these four groups (y axis) for all meetings (x axis). As illustrated below, the task-based attempted answers categories were the most frequent in all meetings followed by the task-based questions. These two groups were the most frequent interaction categories compared to both the positive and negative social reactions categories.

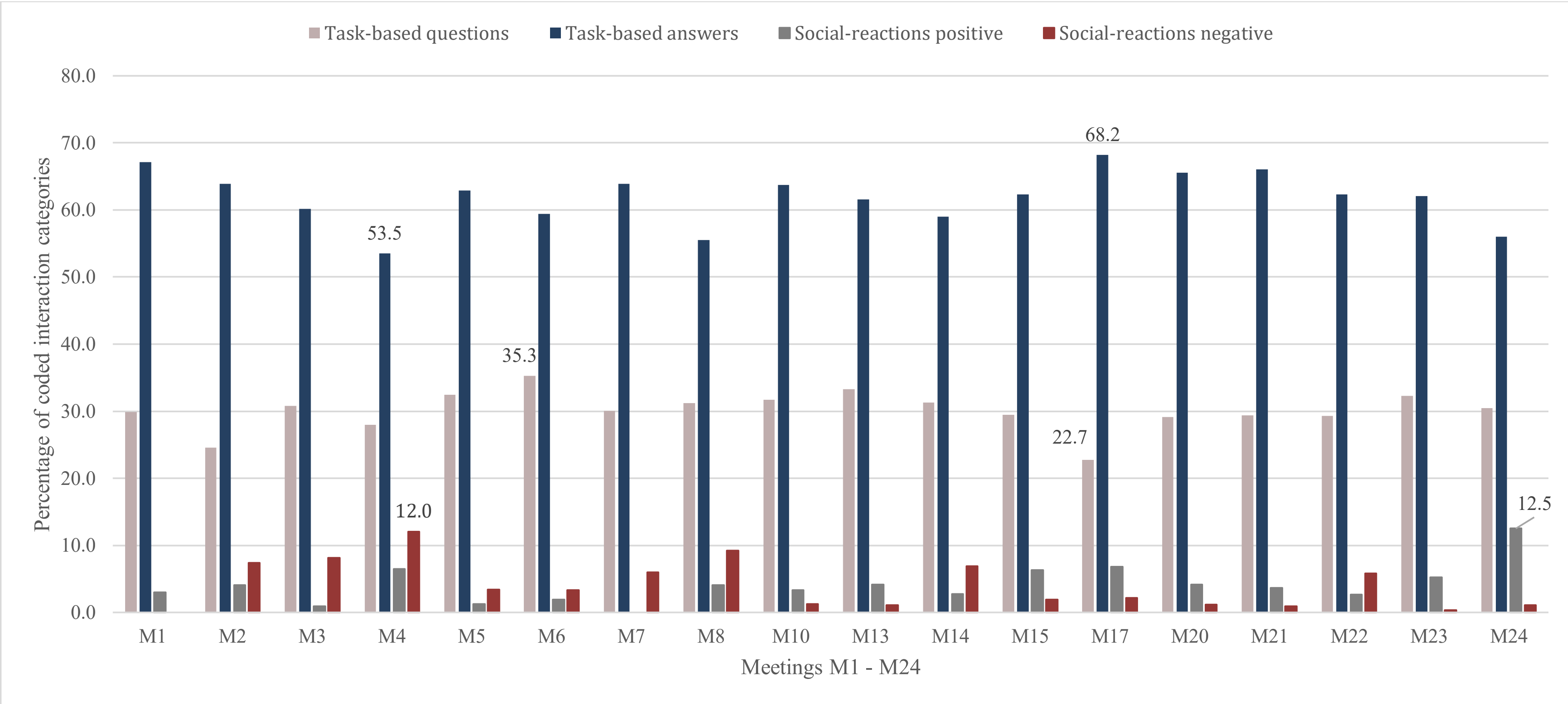

Figure 7-3 Case study B – Percentage of coded interaction categories in the four groups

The task-based attempted answers (categories 4–7) were the most frequent in all meetings followed by the task-based questions (categories 8–11). These two groups were the most occurring interaction categories compared to both the positive and negative social reactions categories. The above figure also shows that the attempted answer categories were twice as common as the question categories in the majority of the meetings. The highest occurrence of attempted answers was in meeting 17 (68.2%) and the lowest was in meeting 4 (53.5%). The highest occurrence of task-based questions was in meeting 6 (35.3%) and the lowest was in meeting 17 (22.7%). These figures indicate that in meeting 17, the attempted answers categories were three times more frequent than questions categories showing a high number of technical discussions occurred in this meeting to clarify several design tasks and understand the design complexity.

Another interesting observation is the comparison between the social reactions. As shown in Figure 7-3, the negative social reactions (categories 12–14) were more frequent than the positive social reactions (categories 1–3) in meetings 1 to 8, 14 and 22. For instance, in meeting 3, the percentage of negative social reactions was 7.1% compared to 0.9% for positive social reactions. This result indicates that, despite the presence of positive task-based interactions, several proposed design solutions were rejected with negative social reactions. A breakdown of participants' interactions in all design meetings illustrating these interaction categories and their aggregate sums for this case study is provided in Appendix III. Below is the detailed discussion of the four groups of interactions illustrating phases of collaboration.

a) Task-based questions (categories 8–11)

The task-based questions (categories 8–11) are 'asks for information' (category 8), 'asks for confirmation' (category 9), 'asks for opinion' (category 10) and 'asks for suggestion' (category 11). There were a number of incidents illustrating these categories especially in early meetings because negotiations were still underway to understand the updated scope of work. Example 1 below demonstrates these interactions by providing a sample of participants' discussion in the performance testing requirements. Participants involved in the discussion below are the main contractor's project engineer (C1) and construction manager (C5), the case B subcontractor's project manager (P3), the architectural firm's associate principal façade engineer (R3), the façade consultant (F1) and the client's senior project manager (L6). In all the examples below, category numbers are displayed after each sentence or unit in parentheses as in Table 5-2. Numbers at the beginning of each line represent participant codes for who is talking and to whom as in Table 5-1.

Example 1: External façade reading room (meeting 6)

[P3-F1]: voids behind this will increase (pointing at 2D drawing), no space to install steel for 2 floors high (7), I understand FT09 (façade type) is there (6), can work something out (6)

[F1-P3]: does that change (pointing at 2D drawing)? (9)

[P3-F1]: what is that?(8) We need elevation drawing to tell us (8)

[C1-P3]: is there a slab here (pointing at 2D drawing? (8)

[P3-C1]: don't know but trying to figure out the structure (7)

[F1-P3]: there is steel rod going around (7), is this answer your question? (9)

[R3-P3]: explains the rod location (using 2D drawing) (5)

[P3-R3]: pointing at 2D drawing, what are these items in winter gardens, what is above and what is under? (8)

[R3-C1]: we need to hear from structural engineer (8)

[P3-R3]: they are doing this part but won't do that (referring to the façade) (6)

[L6-C5]: what is he doing? explain more (10)

[C5-L6]: it is a building issue (7)

[R3-C5]: how is that?(10)

[C5-R3]: column needs time to be developed (7)

The above example shows a situation where participants needed more information and clarification to help understand the design and scope of work. There were several inquiries and scarce information given in the discussion. These interactions suggest deficient or missing information for making decisions, which is one of the common problems in the design phase (Dossick et al. 2013; El.Reifi, Emmitt & Ruikar 2013; Emmitt, Sander & Christoffersen 2004; Love et al. 2018). It also highlights the need for better coordination between disciplines because of the interdependent nature of design tasks (Pryke & Smyth 2012) as participants needed information and explanations from the structural consultant.

b) Task-based attempted answers (categories 4–7)

The attempted answers (categories 4–7) are ‘gives suggestion’ (category 4), ‘gives opinion’ (category 5), ‘gives confirmation’ (category 6) and ‘gives information’ (category 7). Example 2 provided below was extracted from meeting 23 about the shading system. Participants involved in this discussion included the main contractor’s project engineer (C1), the subcontractor’s project manager (P3), the architectural firm’s façade engineer (R3), the client’s delivery manager (L1) and design manager (L3) and the shading system design manager (M1).

Example 2: shading system discussion (meeting 23)

[L1-M1]: can you fix that on hinge? (9)
[M1-L1&R3]: yes, we can do that (6). It is an elegant solution/min surface area (3)
[R3-M1]: explain/square set/rigid plate/more towards the circular hollow section/explains loads/wind/man walking on it for maintenance (5)
[R3-M1&P3]: explains further loads imposed on the structure (5)
[P3-R3]: here is the loads plan that P5 did earlier (7)

[R3-P3]: it is fine because I did the beam 1.5 (6) and here it is 1 so close (7)
[P3-R3]: this has no façade load or wing load just maintenance loads (6)
[R3-P3&M1]: proposed box section/it could be T section (4)
[M1-R3]: comments on span dimension (7)
[R3-P3&M]: explains another section max steel/box vary but max is 150/another one near the circular hollow section varies (5)
[P1-R3]: inquires that back box is running straight? (9)
[R3-P1]: yes (6)
[R3-R3&M1]: explains design proposal on plan view/connections/transfer loads/floppy plate useful in connection (5)
[P1-R3]: inquire about corner connection? (10)
[R3-P3&M1]: explains no more transfer of loads to the shading system/explains using own sketch (5)
[L1-R3]: inquires will curve part hit the outrigger? (9)
[R3-L1]: explains box section (5)
[C1-L1]: explains box section isn't fixed to outrigger (5)
[R1-L1]: I understand what L1 means; it is an exposed connection (6)
[R3-All]: explains plate connection, fixation, loads (5)
[L1-R3]: so, plate is curved that's ok (9)
[R3-L1]: yes (6)
[R3-All]: explains design proposal/how to deal with wind (5)
[P1-R3]: box trimmed at diagonal? (9)
[R3-P1]: explains connection.. no problem to go till meet diagonal (5)

The above discussion was the first item on the meeting agenda as M1 attended only the shading system discussion. Before that meeting, participants had seen a visual mock-up of the shading system and prepared a design proposal that would solve their concerns regarding the visual aspect of the connections. This explains the repetitive use of category 5 'gives opinion', which recorded detailed feedback and thorough explanations. During these explanations, participants needed to confirm loads, capacity, dimensions, orientation and locations. It was also noticed that 'gives suggestion' (4) was recorded only once indicating that not many design solutions were offered in interactive discussion but rather prepared separately and brought to discussions for feedback.

c) Positive social reactions (categories 1–3)

The positive social reactions (categories 1–3) 'shows solidarity' (category 1), 'shows tension release' (category 2) and 'agrees' (category 3) were the least occurring group compared with the task-based interactions and negative social reactions, which showed participants were concerned with discussing the technical concerns. Example 3 provided below was extracted from a discussion about the inner north facing façade. Participants involved in these examples were the main contractor's project engineer (C1), the subcontractor's draftsperson (P4), the architectural firm's senior architect (R2) and the client's delivery manager (L1).

Example 3: Inner north facing façade (meeting 16)

[P1-All]: we need to talk about inner façade of the north façade (7)
[P4-L1]: gets 2D drawings near L1, I need to discuss two issues here (7)
[L1-P4]: what is the difference here? Pointing at the 2D drawings (6)
[P4-L1&R2]: explains using 2D drawings difference in radius of curved glass (5), can we use both 150?(9)
[R2-L1]: explains the radius differences (5)
[R2 & L1-P4]: yes, we agree if both are 150 (3)
[P4-C1]: explains the design proposal using 2D drawings (5)
[L1-P4]: I assume the cost increase is minimal?(9)
[P4-L1]: yes, just labour is required (6)
[C1-P4]: so, we can proceed with these changes (9)
[L1-C1]: yes proceed (3)
[R2-P4&C1]: yes, we are fine with that (3)

The above example of positive social reactions is consistent with the literature as it demonstrates the theme of achieving design integrity shown earlier in the CPDD model. The above discussion was in meeting 16 after the complex design problems had been solved. As such, participants started to feel that the design was progressing in the right direction and the architect was assured the design intent was understood.

d) Negative social reactions (categories 12–14)

Negative reactions categories including 'disagrees'(category 12), 'shows tension' (category 13) and 'shows antagonism'(category 14) exceeded the positive social reactions in meetings 2–5, 7, 8, 14 and 22. In example 4 below, this extract was chosen to illustrate a whole discussion where the negative reactions were coded extensively. Participants involved in this discussion included the main contractor's project engineer (C1), design manager (C4) and construction manager (C5), the subcontractor's design manager (P1), the architectural firm's façade engineer (R3) and the façade consultant (F1).

Example 4: Frameless shop front façade system (meeting 7)

[F1-P1]: (using 2D drawings) I need material confirmation here (9), design confirmation here (9), confirmation that you are using Australian steel here (9) and their specifications (9), confirmation on whether you are going to use plates here (9), confirmation on glass because there is a discrepancy in glass thickness in the drawings you submitted (9), actual design here (9) and product finishes (9)
[R3]: is watching closely as he is sitting opposite F1 and agrees with F1 by nodding
[P1-F1]: comments on glass thickness selected (7)
[F1-P1]: I don't think R3 will agree on this (6)
[F1-P1]: there is inconsistency in your documents in this detail here (12), what is the fixing (8), where is your engineering drawings (8)?

[P1-F1]: these will be done in the shop drawings phase (7)

[F1-P1]: I need confirmation on glass (9), you need to tell us, you are heading in the right direction (13), and I know it is too much to ask now (2)

[C4-F1]: I don't want to cross you (2), what you say is valid (2), but it is not part of the DIP process (12)

[R3-C4&P1]: I agree with F1 (12), joints and transoms are fundamental to the DIP (13), I'm not attacking you (2)

[F1-P1]: expansion joints, not sure what are you going to do (9), if it is inside a box (8), don't have any engineering details to tell me so I have to figure it out?! (13)

[R3-P1]: if there was narrative here it would help to understand your design; we can't approve this (4)

[P1-F1]: if it is approved, we will fill in these details (6)

[F1-P1]: I'm not sure about this detail here, how are the connections (10)?

[P1-F1]: it is joints not 100 m steel (7)

[F1-P1]: 10 m in length is high (9)?

[P1-F1]: what was important for us is the height and width here (8)

[F1-P1]: I guess we moved away from this stage (indicating that this was agreed upon previously and no progress since that) (12)

[R3-C1]: if we look at individual rod connections, what is inside (10)? This is going ahead, no progress from last week (14)

[P1-R3 &F1]: it will be done in shop drawings (12)

[R3-P1]: we are going until the DIP get approved (12)

[P1-R3]: but sizes did not change (7)

[R3-P1]: yes, we agreed on that (6)

[F1-P1]: steel here (10)?

[R3-F1&P1]: again, this can be narrative (4)

[P1-R3]: that's fine at level of details (6), we can submit as long as sizes are not changed (6)

[R3-P1]: just it is just supplementary details (2)

[C5-P1]: but this shows that there is a still lot of details and work to be done (13)

[P1-C5]: I know (7)

[P1-F1]: so, are you going to send us these valuable questions to address? (8) (13)

[F1-P1]: I already wrote that and sent it to C1 [unsatisfied face expression] (6) (13)

The above example from meeting 7 detailed the escalation resulting from delaying design progress. The designers (architects and façade consultant) were dissatisfied because they had not yet received any feedback or detailed engineering calculations. The main contractor was more concerned about the slow progress in general. While designers requested detailed engineering information, they received limited answers which did not help in addressing their concerns nor did it give an indication about how the design was progressing. As a result, tension and frustration between participants existed because of the short answers that were given. However, a couple of participants suggested a solution to ease this tension by submitting a narrative explaining the proposed design solutions until the engineering calculations could be developed further.

In summary, the questions and attempted answers groups represent the majority of participants' interactions reflecting that they were focused on task-based interactions. However, disagreements and tension were evident in some of the meetings, which are investigated further in the subsequent sections of sequential interactions.

7.2.2 Sequential interactions analysis

Table 7-1 provides the descriptive statistics for all meetings to examine collaboration patterns in this case study by following the same analysis steps as in the previous chapter. Organising the categories into a sequential order generated 165 categories of mutually exclusive two sequential interactions forming a total of 6063 sequential interactions in the detailed design phase. The frequently occurring sequential categories in each meeting and the identified sequential interactions matrix are provided in Appendix III. Table 7-1 below presents the transitional probabilities of the sequential interactions. The sequential interactions are highlighted using the colour scale to demonstrate the difference between the frequency levels: high, moderate and less frequent. Of note, 'shows antagonism' (category 14) is excluded because it had an inflated level of probability reported (1%) due to the presence of only one incident, which would have influenced the range of high and low values. Categories listed in the left column are the state 0 (occurred first), and categories listed in the rows are the state 1 (occurred second) and the sequential categories are read from the left side of the matrix. For example, 42% of 'asks for information' (category 8) were followed by 'gives information' (category 7).

Table 7-1 Case study B – Transitional probabilities for two-event sequences

State 1

State 0 – Interaction categories	AI	GI	AC	GC	AO	GO	AS	GS	AE	DE	TR	SS	ST	SA
AI	0.10	0.42	0.04	0.17	0.04	0.18	0.00	0.03	0.00	0.01	0.01	0.00	0.01	0.00
GI	0.16	0.23	0.08	0.11	0.09	0.19	0.02	0.04	0.02	0.03	0.02	0.00	0.02	0.00
AC	0.07	0.14	0.08	0.53	0.02	0.09	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00
GC	0.19	0.19	0.07	0.13	0.08	0.18	0.02	0.06	0.02	0.01	0.03	0.00	0.01	0.00
AO	0.07	0.18	0.03	0.06	0.06	0.52	0.01	0.03	0.01	0.02	0.00	0.00	0.00	0.00
GO	0.16	0.21	0.08	0.10	0.13	0.18	0.03	0.04	0.02	0.02	0.01	0.00	0.01	0.00
AS	0.07	0.20	0.04	0.07	0.07	0.17	0.04	0.22	0.03	0.03	0.02	0.00	0.05	0.00
GS	0.10	0.16	0.09	0.13	0.10	0.10	0.02	0.07	0.12	0.05	0.02	0.00	0.03	0.00
AE	0.07	0.22	0.07	0.06	0.10	0.24	0.03	0.06	0.06	0.01	0.06	0.00	0.01	0.00
DE	0.10	0.22	0.05	0.08	0.04	0.17	0.03	0.07	0.00	0.12	0.03	0.00	0.07	0.00
TR	0.13	0.20	0.03	0.11	0.13	0.15	0.01	0.03	0.03	0.05	0.15	0.00	0.00	0.00
SS	0.08	0.00	0.08	0.08	0.08	0.42	0.00	0.00	0.00	0.00	0.17	0.08	0.00	0.00
ST	0.19	0.22	0.04	0.11	0.06	0.13	0.02	0.07	0.01	0.06	0.01	0.00	0.05	0.01
SA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

Key: GO = gives analysis, AO = asks for analysis, GI = gives information, AI = asks for information, GC = gives confirmation, AC = asks for confirmation, GS = gives suggestion, AS = asks for suggestions, AE = agrees, DE = disagrees, TR = shows tension release, ST = shows tension, SS = shows solidarity, and SA = shows antagonism.

Note: The darker colours for high frequent values, lighter for moderate and white for less frequent values.

The table suggests that questions and attempted answers categories were both among the highly frequent sequential interactions. The confirmation interaction was a key component in participants' discussions suggesting that there was a lot of uncertainty about the design. The figures also show the importance of exchanging explanations and information to coordinate design tasks needed to understand the design intent. It was also noted that some social reaction interactions were important because they highlight the association with the task-based ones.

Table 7-1 also shows that most of the high values are located in the task-based columns, especially in the questions and attempted answers categories. The sequential interactions were examined in four parts: task-based categories followed by task-based categories, task-based categories followed by social reactions, social reactions followed by task-based categories, and social reactions followed by social reactions. The sequential interactions are illustrated below in descending order.

Task-based followed by task-based categories:

Highly frequent interactions:

- *'asks for confirmation' → 'gives confirmation' 53%)*
- *'asks for opinion' → 'gives opinion' (52%)*
- *'asks for information' → 'gives information' (42%)*

Moderately frequent interactions:

- *'gives information' → 'gives information' (23%)*
- *'asks for suggestion' → 'gives suggestions' (22%)*
- *'gives opinion' → 'gives information' (21%)*
- *'asks for suggestion' → 'gives information' (20%)*

The above interactions demonstrate the interactive processes of collaboration in the problem and direction setting phases 1 and 2 of the CPDD model. The need for confirmation illustrates the high degree of uncertainty about the design that was present in the majority of participants' discussions. The designers needed to be sure that the design intent was fully understood because of the change in the tender documents that occurred prior to engaging the subcontractor. At the same time, the subcontractor did not provide enough information about the majority of the complex façade types. As a result, participants needed to get confirmation on several design issues including the engineering calculations. The second most frequent sequential interaction showed that participants focused on providing explanations to help clarify the design intent and giving feedback on the submitted solutions. It was also noted that 'gives information' was the common response in the majority of the task-based interactions, which can be interpreted in two different ways. First, it can indicate that information was a key issue in participants' discussions to clarify the design because of its complexity. Second, it shows a conservative attitude when asked for suggestions and solutions as seen in the above figures.

Social reactions followed by task-based categories:

Another set of interactions that are moderately frequent in Table 7-1 demonstrated phases 3 and 4 (outcomes) followed by task-based interactions in phases 1 and 2 (problem and direction setting phases) of the CPDD model. These interesting patterns of social categories (1–3 and 12–14) existed as state 0 (occurred first) followed by task-based categories (4–11) as state 1 (occurred second). These are presented below in descending order.

- *'shows solidarity' → 'gives opinion' (42%)*
- *'agrees' → 'gives opinion' (24%)*
- *'agrees' → 'gives information' (22%)*
- *'disagrees' → 'gives information' (22%)*

- *‘shows tension’ → ‘gives information’ (22%)*
- *‘tension release’ → ‘gives information’ (20%)*

As seen above, when appreciation incidents occur, they encourage participants to elaborate in their explanations. Similarly, agreements triggered explanations. The rest of the patterns show that giving information was the common response to both positive and negative objective and subjective outcomes, which indicate that it was not a straightforward process. It is also noted that the percentage of disagreements falls in the same range as frequently moderate interactions. These figures suggest that participants experienced problems followed by information in their discussions. The last example in Section 7.2.1 illustrates some of the problems associated with information.

Social reactions followed by social reactions interactions

- *‘shows solidarity’ → ‘tension release’ (17%)*
- *‘tension release’ → ‘tension release’ (15%)*
- *‘disagrees’ → ‘disagrees’ (12%)*

The association between the social reactions suggests a mixed mode in participants’ discussions. On some occasions, participants appreciated and praised each other’s work, which eased the tension in their discussions. On other occasions, they escalated the problems by repetitive disagreements showing that they were not willing to make compromises.

Task-based categories followed by social reactions

- *‘gives suggestion’ → ‘agrees’ (12%)*
- *‘gives suggestion’ → ‘disagrees’ (5%)*

- *'asks for suggestion'* → *'shows tension' (5%)*
- *'gives suggestion'* → *'shows tension' (3%)*
- *'gives information'* → *'disagrees' (3%)*
- *'gives confirmation'* → *'tension release' (3%)*

The above patterns illustrate another form of mixed mode as seen in the attempted answers that were followed by positive and negative outcomes. The first three patterns showed that not all of the suggested solutions were accepted indicating that there was a degree of disparity between participants' views that caused disagreements and tension. The fourth pattern is important as it illustrated the closed cycle of rejecting information offered in some participants' discussion. This cycle was noted from the previous group of interactions (social reactions followed by task-based categories) that disagreements were followed by giving information (0.22%). Then, in the above interactions, giving information was followed by further disagreements (0.03%). The last pattern indicated that giving confirmation was helpful in releasing the tension between participants in a very few incidents.

7.2.3 Summary of interactions findings

The analysis showed that questions (8–11) and attempted answers (4–7) categories represent the majority of participants' interactions, which consolidate previous findings that participants' discussions were more focused on task-based interactions. The social reactions were less frequent when compared to the task-based interactions. However, when examined within the outcome phases (3 and 4) of the CPDD model, the negative social reactions exceeded the positive ones. The Interaction Process Analysis (IPA) (Bales 1950) was helpful in detecting task-based interactions that were followed by negative social reactions. Thus, using the IPA method as the theoretical framework in coding and analysing observation provides further insights into participants' interactions. Four key findings emerged from the data analysis:

- In detailed design discussions, interdisciplinary participants' discussions included task-based questions and attempted answers.
- Confirmation is much needed to move forward with the design development in bespoke design tasks.
- The positive collaboration pattern included a highly frequent presence of task-based interactions (questions and attempted answers) of exchanging confirmation, opinion and suggestions followed by agreement and expressing signs of satisfaction.
- Examining the task-based and social reaction sequential interactions, a mixed mode of attempted answers followed by positive and negative outcomes emerged from the analysis. The exchange of suggestions was followed by both positive and negative social reactions. The sequential interactions also showed that negative collaboration outcomes in the form of disagreements caused tension between participants that was rectified by giving more information. As such, a closed cycle of giving information and disagreement was formed.

The following section of the chapter reports the data analysis and discussion related to the second part of the first research question in the context of the bespoke design case study demonstrating a complex design environment, stated as:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?

7.3 Analysis of the bespoke design collaboration perceptions

This section presents the results of investigating collaboration processes and outcomes from participants' perspectives. The research methodology enabled the quick capture of perceptions about collaboration from the key participants representing the organisations involved in the project (section 5.4.2). To recall, the key participants involved in this phase of data collection (ratings and interviews) were the client's delivery manager (L1), the main contractor's project engineer (C1), the architectural firm's senior architect (R2) and façade consultant (F1), and the subcontractor's project manager (P3) as noted earlier in Table 5-1.

Participants' perceptions of collaboration were collected after each meeting. A total of 115 ratings were collected starting from meeting 2 to the end of the detailed design phase (meeting 24). A matrix displaying all participants ratings is provided in Appendix III. The start-up meeting was important to confirm the subcontractor scope of work, especially after the changes that were made in the tender documents because of budget constraints. Collecting participants' ratings of their collaboration experience started in meeting 2 when the design discussions began. The diversity in participants' views was reflected in their ratings (ratings range from 1 -9) as shown below in Figure 7-4.

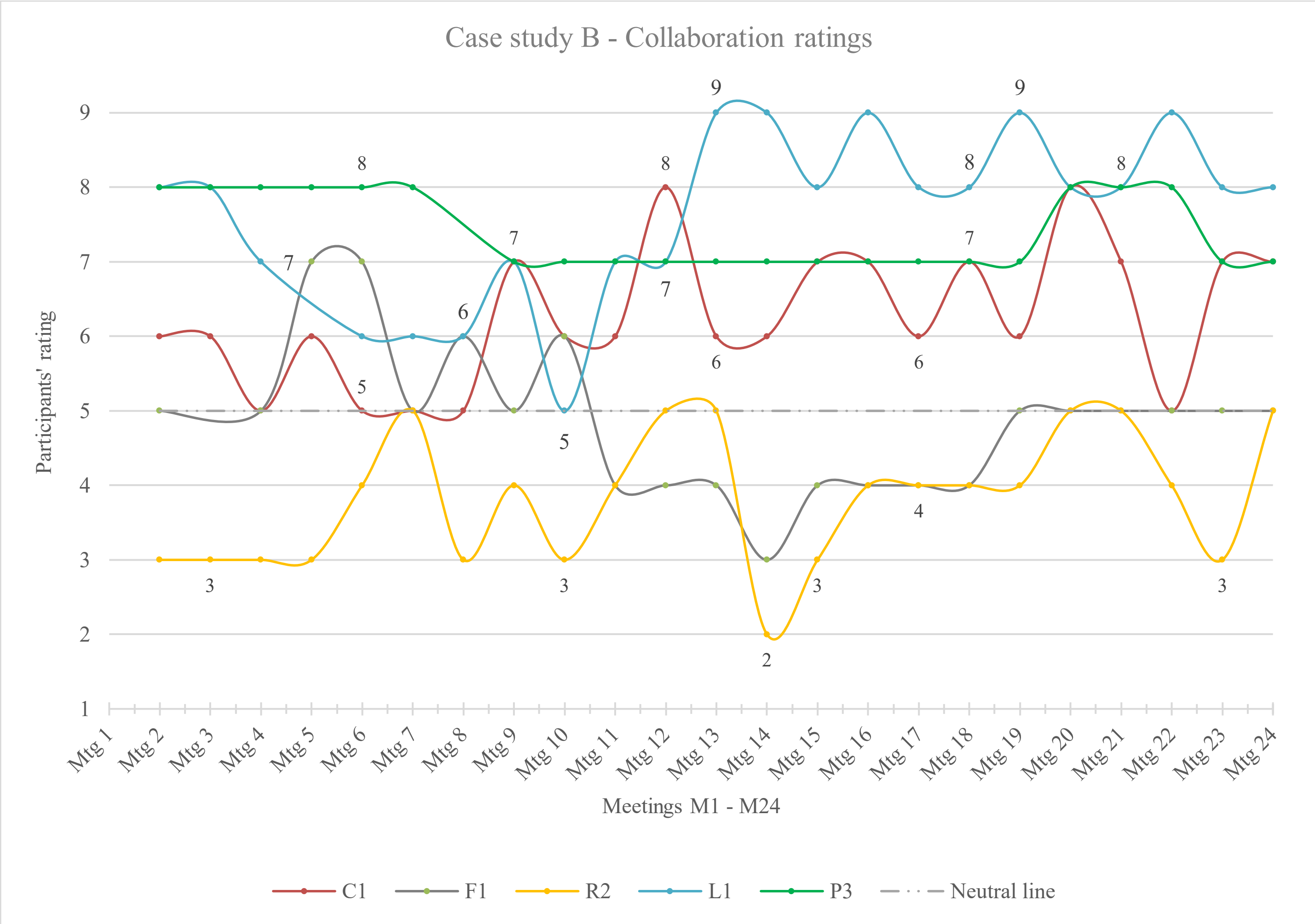

Figure 7-4 Case study B – Collaboration ratings by meeting

The first observation in the figure is there was no consensus among participants about their collaborative experiences. Second, there was no alignment between individuals' ratings due to the significant divergence between their ratings. Third, participants' ratings were widely scattered across the neutral line (rating of 5 points), with the most frequent ratings being 7 (22%), 8 (19%) and 5 (17%). For instance, all of the architect's (R2) ratings were below the neutral line (rating of 5 points) indicating a continuous dissatisfaction with the collaboration process as shown in the quote below.

They don't seem to be listening to our views, like how many times we explained our view on the lower connection of reading rooms, we removed the louvres and its structure, but they keep asking or acting as if it is still there, it's frustrating. [R2, rating of 3 for meeting 5]

A slightly different rating pattern is seen in the ratings of the façade consultant's (F1) who focused on the process as well. The ratings were above the neutral line at initial meetings and then were continuously below or at the neutral line (rating of 5 points) indicating dissatisfaction with the process in the majority of the meetings. One of the reasons for this dissatisfaction was related to the long time spent answering inquiries and explaining the design intent; however, there was not much known about the design solutions as noted earlier in example 4 (Section 7.2.1). As such, the façade consultant and architects were not sure that the design integrity would be achieved.

Another rating pattern was seen in the main contractor's (C1) ratings that were positive but fluctuated between a maximum of 8 and a minimum of 5. The main contractor focused on the process of collaboration, but ratings varied due to the disagreement incidents that were prominent in the initial meetings as quoted below.

I suppose collaboration changes you agree on a few of things and disagree on others, try to put a circle around this, it is that experience. [C1, rating of 5 for meeting 5]

On the other hand, the client's (L1) ratings were positive in general with all ratings above the neutral line showing an overall satisfaction with the collaborative experience. The client (L1) mainly focused on the outcome of collaboration rather than the process. For example, in meeting 4, there were tough design discussions and a high number of incidents were coded as disagreements among participants as seen earlier in Figure 7-3. In this meeting, the client (L1) had a different opinion about collaboration than the designers as quoted below.

I gave a rate of 7 because at the end they [referring to the subcontractor] agreed to look at the design again and that is what matters to me. [L1, rating of 7 for meeting 4]

Similarly, the subcontractor's (P3) ratings were positive throughout the meetings at either 7 or 8 indicating continuous satisfaction with the collaboration experience in all meetings. For example, in one of the earlier meetings that included tough design discussions, the subcontractor viewed the collaboration process as positive because of the concept of the early involvement in the design decisions and being part of the team, which is related to the antecedent of collaboration (Section 4.1.1) as seen in the quote below.

Yea, my ratings were a lot higher because we had a lot of coordination on something like this, where in previous projects a lot of decisions were already been made before we get involved so we also don't get a say in deciding how the project goes ahead. [P3, rating of 8 for meeting 5]

The dispersion in participants' ratings created gaps in all meetings. The largest gap recorded was seven points in meeting 14 because L1 gave this meeting a rating of 9 points while R2 found the collaboration was very low and rated it only 2 points. In addition to this meeting, other meetings had slightly smaller gaps but were important to study because of their timing. These meetings were at the initial stage (meetings 3, 4 and 7). The identified meetings with significant gaps are analysed further by extracting their single interactions from the tables provided in Appendix III. Table 7-2 below shows the interaction categories that occurred in these meetings. The numbers in brackets are the percentages.

Table 7-2 Case study B – Negative social reactions meetings

Interaction categories	Meeting 3	Meeting 4	Meeting 7	Meeting 14
Shows solidarity (1)	0 (0)	1 (0.5)	0 (0)	0 (0)
Shows tension release (2)	1 (0.5)	12 (6)	0 (0)	12 (2.2)
Agrees, understands (3)	1 (0.5)	0 (0)	0 (0)	3 (0.5)
Gives suggestion (4)	11 (5)	10 (5)	4 (1.1)	16 (2.9)
Gives opinion (5)	55 (24.9)	29 (14.5)	66 (18.9)	90 (16.4)
Gives confirmation (6)	19 (8.6)	24 (12)	40 (11.5)	89 (16.2)
Gives information (7)	48 (21.7)	44 (22)	113 (32.4)	129 (23.5)
Ask for information (8)	31 (14)	27 (13.5)	68 (19.5)	85 (15.5)
Asks for confirmation (9)	7 (3.2)	4 (2)	14 (4)	33 (6)
Asks for opinion (10)	25 (11.3)	22 (11)	20 (5.7)	42 (7.7)
Asks for suggestion (11)	5 (2.3)	3 (1.5)	3 (0.9)	12 (2.2)
Disagrees (12)	13 (5.9)	16 (8)	14 (4)	10 (1.8)
Shows tension (13)	5 (2.3)	8 (4)	7 (2)	27 (4.9)
Shows antagonism (14)	0 (0)	0 (0)	0 (0)	1 (0.2)
Total	221 (100)	200 (100)	349 (100)	549 (100)

The initial meetings included tough discussions because of the uncertainty about the scope of the subcontractor work causing confusion among participants. These meetings had a high number of negative social reactions recorded such as 'disagrees' and 'shows tension'. For example, in meeting 3, the designers wanted to make sure that the design intent would not be compromised because of cost issues. As mentioned in Section 7.1.1, the meetings stopped for two weeks before resuming again in meeting 3. The subcontractor needed to readjust the scope of work because of budget limits and came back with some design solutions to simplify the supporting structural system that were rejected by the architects because they did not align with the design intent. The discussions in this meeting included several task-based interactions to explain the design intent and clarify the overarching design philosophy. However, the idea of simplifying the structural system did not get approved and caused tension between the architects, subcontractor and main contractor. This disagreement between participants, especially the design partners, had a negative impact on the design progress. To mitigate this, the following meeting included senior people to contain the problem at such an early stage of the design development. The design director and the client's director attended meeting 4 for the first half an hour to help get the design discussions back on track.

The involvement of these seniors in meeting 4 caused a high number of disagreement interactions to occur, but there were also a high number of 'tension release' interactions recorded because they expressed their appreciation of the work and effort so far in the project several times. At the same time, they asserted that the design intent should not be changed or simplified and asked participants to try harder to reach a middle ground. This was articulated in the high number of disagreements recorded in this meeting showing the rejection of any design solutions that would affect the design philosophy. This incident also explained the reasons for the low rating of 3 points given by R2 in meeting 4 as shown in Figure 7-4.

A high number of disagreements occurred again in meeting 7 because of the inadequacy of engineering calculations. The architects and façade consultant required detailed design solutions. In this discussion, participants were arguing that the available design information was not enough to progress with the engineering solutions. The main contractor (C1) regarded this request as hindering subcontractor progress because these design details could be provided later in the shop drawings. An extract of this discussion is provided in example 4 in Section 7.2.1 illustrating the negative social reactions.

In meeting 14, the number of negative social reactions increased again as seen in 'shows tension' (n=27) and 'disagrees' (n=10) due to a late design change proposed by the architects despite it having been approved by the client. While this design change was supposed to solve one of the complex design connections located at the intersection between the curved façade and straight ones, the subcontractor (P3) expressed dissatisfaction because of the associated rework. Similarly, the main contractor (C1) was unhappy with the repetitive design reviews and gave a rating of 5 points in this meeting. A more detailed discussion about this late change is provided in the subsequent sections.

To conclude this section, Figure 7-4 depicted the different views about collaboration that were clear in this case study. The rating patterns demonstrated the strong subjective aspect of collaboration due to the presence of different objectives (Gray 1989; Gray & Purdy 2018). This was seen in the client's (L1) focus on the outcome and subcontractor's concern about the opportunity to be engaged in the design discussions, which is one of the antecedents of collaboration. The main contractor's focus on the process demonstrated practices of being cost and schedule centric in the detailed design phase (Forbes & Ahmed 2011). The architect and façade consultant ratings also focused on the process demonstrating dissatisfaction with the design discussions. The tough design discussions at initial meetings and low ratings demonstrated their interest in achieving the design integrity and protecting it from being compromised because of cost saving (Winch 2009).

Next, participants' views of their collaboration in the four phases are interpreted using event network diagrams.

7.4 Analysis of the bespoke design collaboration phases

The second section presents the analysis of participants' interpretations and views about the collaboration process and achieved outcomes. Descriptive narrations and supporting quotes are used to represent participants' views. Interpretations of the findings are presented by event network diagrams to visualise collaboration phases. These findings emerged from analysing the open-ended short interviews and review of minutes of meetings to validate the findings. The coded data was interpreted using event network diagrams to visualise the development of collaboration efforts through the four phases of collaboration in the CPDD model. Figure 7-5 below presents the results by demonstrating participants' practices followed by a breakdown of the diagram into simpler event diagrams to explain the emerged themes of collaboration processes and outcomes.

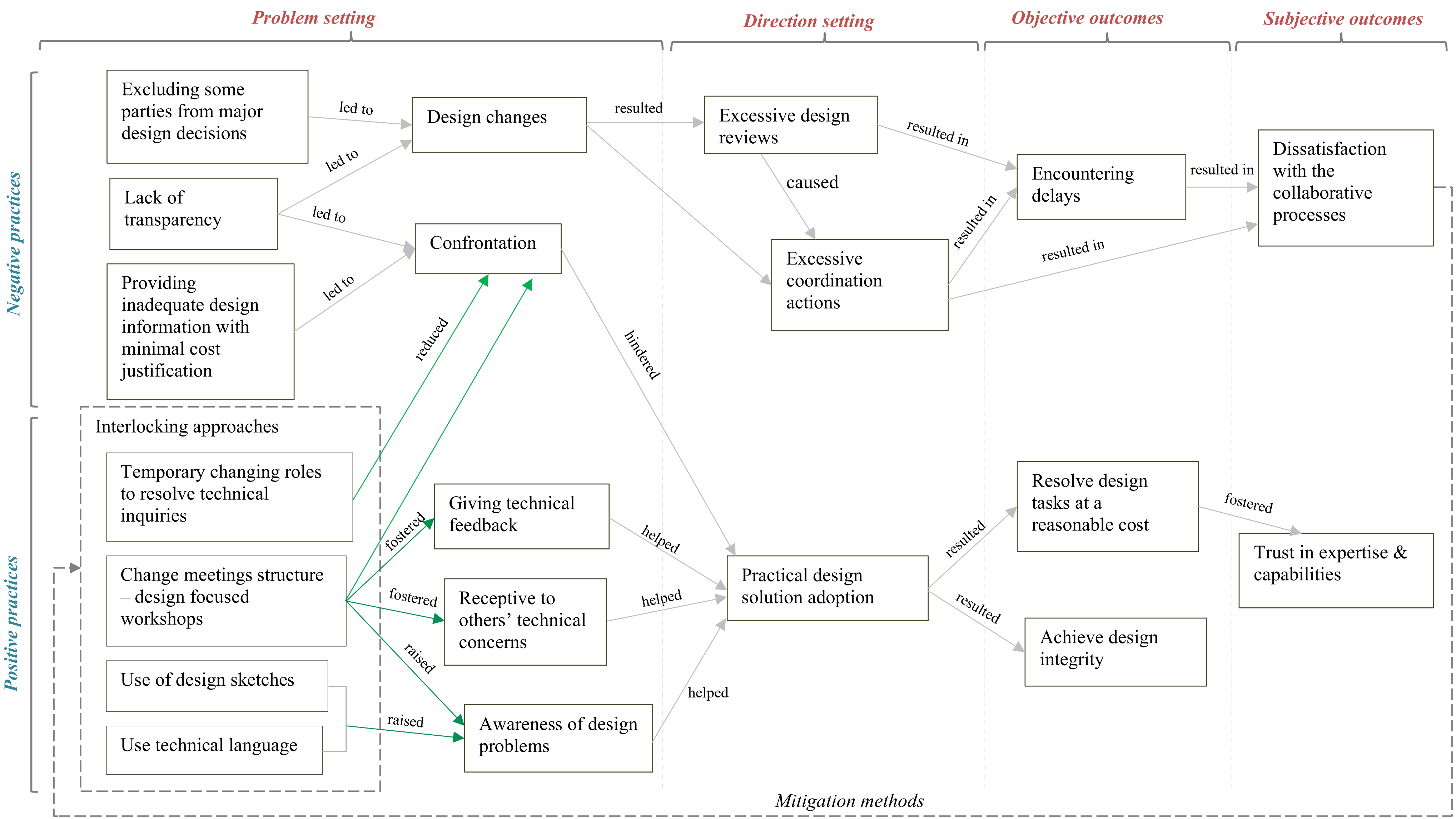

Figure 7-5 Case study B – Collaboration events network diagram

7.4.1 Phases 1 and 2 associated with negative collaboration outcomes in phases 3 and 4

As shown earlier in Figure 7-3 and in Section 7.2, despite the questions and attempted answers categories being prominent in all meetings, the number of negative social reactions exceeded positive ones in the first eight meetings and also later in meetings 14 and 22. These results suggest that there were tough design discussions in the problem and setting phases where participants did not reach an agreement as explained in the sections below.

a) Delays in the design development

As shown in Figure 7-6 below, excluding some parties from the major design decisions and lack of transparency about the new design scope caused design changes due to the discrepancy in the design documentation as participants had different versions of the tender documents. As such the proposed solutions did not match the design intent, thus design changes occurred to bring the design as close as possible to the conceptual design causing excessive reviews and coordination tasks to get approvals. Consequently, delays in design development were encountered because of the design complexity, which caused dissatisfaction with the collaborative processes. The figure also shows the lack of transparency about the new design scope caused confrontation, which hindered the participants in finding practical design solutions.

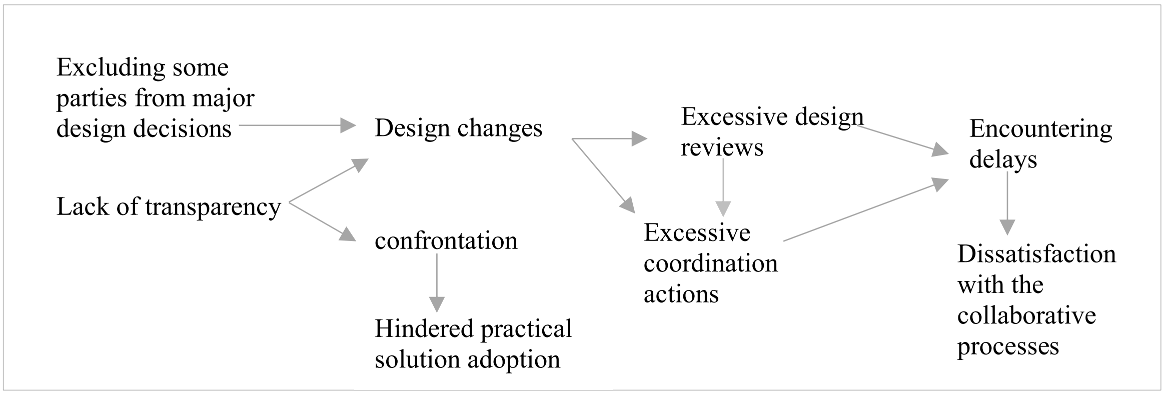

Figure 7-6 Case study B – Delays in the design development

The process of preparing the tender documents had several iterations because the initial cost estimates were higher than the budget allowed for this façade package. The main contractor proposed some design changes to reduce the scope by removing some of the inner façade panels and reducing the size of outer façade panels. The client approved these design changes as it was the only way to move forward with tendering this façade package. These design changes were introduced to the rest of the façade team (architects and façade consultant) after the subcontractor was awarded the contract. At initial meetings, the new design scope was unclear to the architects and façade consultant due to the discrepancy between the set of design documentation submitted for tendering and the design documents signed off after the tender. The architects mentioned that the design was incomplete for this façade package and they were still working on it before the detailed design phase began. Some conceptual design decisions were still not finalised with the client's executive representatives. At the same time, the main contractor team had to search for a solution to finalise the tender phase because of constraints related to both project schedule and budget. Therefore, they introduced the solution of reducing the design scope to reduce the cost of this façade package as the cost of the documented conceptual design was much higher than the budget allowed for the façade package. Thus, there was a new set of design documentation issued by the main contractor for tendering. The decision on changing the design is seen in the quote below.

It is not as per their [referring to the architects] drawings, but we had to let it be based on something because if otherwise we would be behind, and we wouldn't have a building … if we build as per their drawings it would have been another $5 million, it is already too expensive. [C1, rating of 5 for meeting 4]

As mentioned above, the change in design scope was introduced to the architects and façade consultant after the subcontractor was awarded the contract. This caused some confusion at initial meetings due to the discrepancy in design documentation, and the architects and façade consultant were not involved in the process of reducing the design scope, but they were asked to comment on the subcontractor's design approach. As a result, there were several inquiries in initial meetings about what was allowed for in the subcontractor's scope of work. This is explained in the quote below.

The scope, yea, if everyone was clear on that it would be much simpler; we will know who is doing what… but that's taken us since April basically till now to understand that because no one declared it openly… I keep asking questions and every time I ask a question; I find something new. [F1, rating of 5 for meeting 7]

The impact of reducing the design scope is best illustrated in one of the complex façade tasks, such as the north facing outer façade design task. This façade design task included a number of subtasks, including adjustment of scope of work and investigating engineering solutions for the floor-to-floor glass height, glass panel width, structural system supporting glass panels (pinned vs. cantilever struts), uplifting resistant calculations, and suitable orientation of patch fittings to reduce cantilever length. In addition, a feasibility study on glass size for straight and curved panels, fabrication, shipping, glass weight, installation and required equipment, lead times, and installation duration was required to finalise the technical decisions.

The discussions for this façade type started in meeting 2 and lasted till meeting 22. The design intent presented to the client comprised free-standing highly transparent large glass panels. However, the scope adjustments made by the main contractor team included changes in this façade type because such a large glass system was very expensive and had major constructability issues. Consequently, the subcontractor (P2) changed the cantilever system to a pinned system at both ends of the panels, which was rejected by the architects (R1 and R2) because this solution did not match the design intent. Several constraints were mentioned in meetings 3 and 4, such as pricing façade items, transferring these large glass panels onto site and site access restrictions. These discussions caused the high number of disagreements that were recorded in these meetings (see Table 7-2). The importance of the design and the challenges were articulated below.

This type of facade is really important to the client's executives and how much time we've spent on it and if we conform to what they are trying to put on us, it will be like completely redesign everything we've spent months and months sort of getting here, and there are so many decisions behind everything to do with that façade. [R2, rating of 3 for meeting 4]

The above extract showed that major changes in the design were not feasible and participants had to work out a solution that could match the new scope. In doing so, the architect (R1) proposed some design changes to bring the design back as close as possible to the initial design intent. In the following meeting, the architects (R1 and R3) proposed reducing the panel height and using patch fittings to reduce the cantilever length. The subcontractor (P2 and P3) provided the panels' size limitations and the architect (R1) agreed to reduce the height further and use the maximum width allowed. This proposed solution was investigated further in the subsequent meetings to understand its implications, which caused excessive design reviews to confirm dimensions and locations. These excessive reviews created dissatisfaction and frustration for the main contractor (C1) because of the repetitive need for decisions from the client (L1) and architects to approve the proposed solution.

Later at meeting 6, the pricing of the proposed design solution was submitted, including glass thickness, glass awning and associated patch fittings, adding a new glass balustrade, and removing some items such as louvres and their steel support. The outcome of this cost adjustment was still expensive (over $1 million) and was rejected by the client (L1). Participants had to investigate other ways to reduce the cost, which required further design changes and consequently more reviews. The main contractor (C1) was dissatisfied with these excessive reviews because of the potential delays in the DIP process because the design was not progressing as scheduled. Participants were still investigating and refining design solutions, which was not considered a positive outcome as quoted below.

We just got 12 very different façade types that have constantly changed… timing, we should be sticking to the design not just keep changing and changing… we don't know where the beam is and still changing, today the wind beam is changed again! [C1, rating of 5 for meeting 8]

The delay was inevitable because of the implications of the design changes. Notes of delay were recorded in the minutes of meetings so participants would be aware of the time limitations of the detailed design phase. However, the repetitive process of refining the north facing façade design delayed its development till meeting 16 where the design intent principles were signed off and shop drawing started.

b) Coordination actions causing dissatisfaction

The direction setting phase 2 of the CPDD model was affected by the problems encountered in discussing design problems, which caused a high number of negative social reactions as shown earlier in Figure 7-3. In a further example, participants experienced some coordination problems in discussing the shop front façade facing the south side. The main contractors (C1, C4 and C5) were confused about the concrete outline and RLs (reduced level) because they received an update about the RL from the architecture organisation in the design consultancy meeting (another type of meeting managed by the main contractor). The architect (R2) who is responsible for the façade was unaware of this update and therefore could not comment on the proposed design solution in the meeting. The subcontractors (P1, P2 and P3) needed these comments to proceed with the engineering calculations. Discussing the RLs increased the tension between participants because the main contractor needed a confirmed design decision to proceed with coordinating the concrete outline with other trade packages that were directly impacted by this change in RLs. The architect (R2) articulated dissatisfaction with the way the information was managed in this quote.

They [referring to the main contractor] talked to the guys from our office who are doing the structure. There was another meeting on Tuesday, and they bring up façade issues… and I go to a façade meeting and they bring up structural issues… I said no this is what I've been told… they can't really bring up façade issues while we aren't there who actually know everything that has been going on and dealing with the subcontractors. [R2, rating of 2 for meeting 14]

In another example related to the previous section about delaying the design, the rejection of the cantilever structural system was justified by the high cost of large glass panels and their future replacement. Several inquiries about breaking up the cost of façade items and installation were made. The architects and façade consultant could not rationalise the high cost associated with the installation process and consequently were not willing to accept the reason for rejecting the large size glass panels. The subcontractors (P1and P2) provided minimal information regarding the feasibility of installing large panels because the aim was to simplify the design of the supporting structural system. This view created disagreement among participants because the design intent proposed a complex curved façade.

The approach of requesting a cost breakdown was repeated in other design tasks to understand the new scope of work after reducing the design. For instance, in the first seven meetings, the architects and client requested a clear schedule of façade types and the cost of their components, such as the cost of removing façade from internal areas, reduction of skylight numbers, frit panel options and cost associated with installing cantilever glass panels. The discussions around the scope register and updating cost information continued until meeting 12, which was regarded as an unnecessary repetition of inquiries around cost by the main contractor (C1) because it could be interpreted as mistrust by the subcontractor's firm. The dissatisfaction with the repetitive cost inquiries is articulated in the extract below.

The subcontractors need to make money to stay in. As soon as they don't they think they are not making money, the collaboration disappears very quickly… that's fair enough, no one is in business to spend this time and money and not make profit… So, if they say to us this is the way they priced that, then we have to accept it. We have a relationship to maintain with them and that is based somewhat on trust. [C1, rating of 5 for meeting 9]

c) **Holding back information and confrontation and practices**

As shown in Figure 7-7 below, practices of holding back design information and providing minimal cost information led to confrontational discussions, which hindered the process of adopting practical solutions.

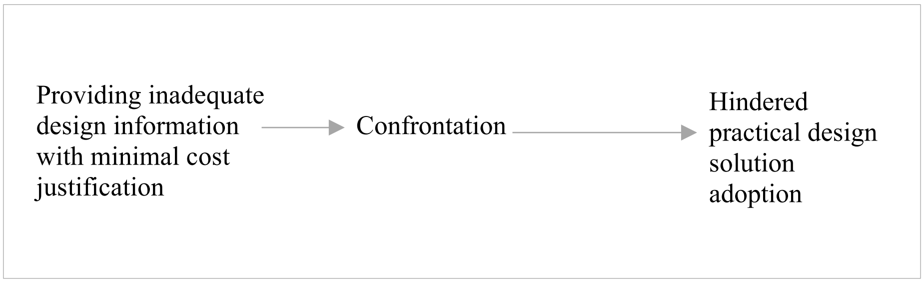

Figure 7-7 Case study B – Confrontation and holding back information practices

At initial meetings, the design was still under investigation and minimum information was given about the proposed design solutions, which limited the architects' ability to comment on these solutions. However, this practice of providing limited information was ongoing. From the architects' perspective, there was no actual outcome in the meetings, but several inquiries related to simple information such as dimensions, orientation and locations that could have been sent by email or RFIs. The architects and façade consultant were expecting to discuss the engineering details of the structural system and connections. Therefore, they did not give final approval of the design principles because of the risk associated with signing off these incomplete drawings. They interpreted the approach of giving scarce information as non-awareness of design problems because of the insufficient explanations given about the proposed design solutions.

An example illustrating this practice was seen in meeting 7 in discussing one of the complex façades, the frameless shop front façade. This design task included studying the feasibility of using a wind beam, its dimensions, and loads on the façade. Some of the context of this discussion was provided earlier in the Example 4 in Section 7.2.1. The architects and façade consultant were concerned about the insufficient fundamental information about the structural system. However, from the subcontractor's perspective there was no need to go into detailed engineering calculations before agreeing on the design principles. Similarly, the main contractors (C1, C4 and C5) agreed that these engineering details could be submitted later in the shop drawings. While the architect (R2 and R3) and façade consultant (F1) were trying to work out a practical design solution with the subcontractor in the meetings, delaying the engineering calculations was not helping in progressing with the design. The difference in these views is illustrated in the extracts below.

They don't want to say too much because the more you say the more you get feedback on… once they engaged the steel contractor, they will progress their shop drawings, which means that the steel guy would start his shop drawings and will have a note on his drawing that says need to confirm connection if they didn't tell us what that is beforehand. [F1, rating of 3 for meeting 14]

The drawings weren't detailed enough, yea ok, probably they are right….it's people hedging their risk really so they just wanted an agreement in principle on the system where designers probably saying yea but if we signed that off and then there are bits of things we are unsure about then you guys can come to us and say well we've signed off the drawings so they are just defending and that's ok. [C1, rating of 6 for meeting 14]

Another form of confrontational discussion between some participants was seen in the instant rejection of design solutions. The low ratings for collaboration given by the architect (R2) triggered further investigation through the interviews to understand the reasons. The analysis revealed that confrontation was caused by previous unsatisfactory experience with other participants. Complex construction projects commonly include senior professionals who have been working in this industry for a long time. Thus, they had a consolidated idea that this sort of confrontational behaviour was expected. The impact of confrontational practices was seen in the process of negotiating the proposed design solutions in initial meetings. After a number of unsuccessful attempts to reach a middle ground, the discussions drifted towards confrontation rather than aligning views. This was also noted in the high negative social reactions, which exceeded the positive ones in the first eight meetings (Figure 7-3).

For instance, confrontation and instant rejection of proposed design solutions was seen in the discussions of the structure system of the façade for the north east side balconies. The design task for this façade type included agreeing on ceiling and transom heights, concrete profile and set out dimensions, waterproofing detail at the top of the panel, door height, and investigating using perforated sheet rather than louvres at spandrel. The architects felt that the design moved away from the design intent because the subcontractors suggested a reduction in the dimensions of the façade panels. The architects articulated this as departing from the overarching design and they had to defend their design as per the conceptual design presented to the client's project control group. The subcontractors (P1, P2 and P3) were still insisting that the installation of large glass panels was very challenging and expensive. Therefore, they rejected the architects' approach in the design intent documents and proposed a different approach that splits the panels using a horizontal beam, which was rejected by the architects. Similarly, in meeting 4, participants were still negotiating the maximum glass panel size because the subcontractor (P2) proposed a width of 3.4 m, which was acceptable, but a height of 5 m was rejected by the architect (R1) because of visual and aesthetics reasons. Instead the architect (R1) suggested increasing the panel's height to 5.2 m or 5.3 m as this was the minimum dimensions that they could accept.

In meeting 8, the negotiation continued and disagreements between participants persisted. These negative social interactions were related to lacking engineering calculations and discussing the north east balconies' design as the architects and façade consultant were trying to refine the proposed design solution. Notes of potential delays were already documented in the minutes of meetings and participants were working under pressure to get the design principles approved. Participants expressed signs of dissatisfaction in the meeting as they were repeatedly reminded about the delays. After this meeting an organisational decision involving the client and main contractor was taken, which was a change in the meeting structure as a mitigation plan for the encountered delays and the consistent disagreement between participants.

This approach was one of several 'interlocking' approaches that worked together to mitigate problems in the collaboration. These approaches are referred to as interlocking approaches in this thesis to highlight the way that the approaches complemented and built on each other to reach the desired outcomes.

d) Discussion of results for phases 1 and 2 leading to negative outcomes in phases 3 and 4

The above section demonstrates several practices in phases 1 and 2 causing negative outcomes in phases 3 and 4 of the CPDD model that are largely characterised by lack of transparency, differing frames of design problems and unwillingness to examine design alternatives. The conflicts that arose in this case study centred around framing the problem and risk perceptions. The conflicting views about the suitable design solutions for the structural system could be interpreted as an adversarial approach by the subcontractor to reduce the cost associated with the complex structural system and large glass panels. This is because, as in any D&C contracting agreement, the bidding process is based on minimal design data and quality and the design might be compromised because of cost saving (Forbes & Ahmed 2011). However, the interviews revealed that participants framed the problem differently, which impacted their actions and discussions.

The subcontractor's designers focused on the complexity of the cantilever system in terms of deflection, weight of large glass panels and transporting and installing them on site. The architects did not consider these constraints as valid because similar structural system and large panels were done in another project in Sydney and overseas. The client's delivery manager thought about the cost of replacing these large panels in the future. The main contractor's project engineer focused on the budget because of the high cost of large glass panels, which was not helpful in adjusting the scope of the subcontractor's work. These different frames in addressing the same problem did not revolve around the feasibility of the design. Instead participants' thoughts were distracted by other factors. While the factors of cost, constructability and facility management are legitimate and essential in making a decision, there was no method or approach proposed to organise participants' thoughts. As such, there were several unsuccessful attempts to reach an agreement on a design approach that lasted till meeting 8. When participants failed to align their views, they reached a frame break stage (Goffman 1974), where the problems at the micro level were amplified at the macro level (cross-organisational level) (Gray & Purdy 2018). This led to seeking mitigation actions to ease the tension between participants and reduce confrontation and avoid further problems associated with variations or claims for delay (Walker & Hampson 2003).

Risks related to the structural system design and sizes of façade panels were central in participants' views and discussions. The differences in risk perceptions substantiate Gray's (2018) view that it is one of the reasons for conflict and dissatisfaction among interdisciplinary teams. Participants' trials of hedging risk associated with the design and providing design drawings with missing engineering details provide useful insights into project level practices related to procurement methods. The data analysis showed that participants did not achieve a positive outcome till meeting 8, which affected the program in terms of the encountered delays. As such, there were some solutions implemented to minimise the impact of these delays and help participants reach a middle ground, which are discussed next.

7.4.2 Phases 1 and 2 associated with positive collaboration outcomes in phases 3 and 4

To mitigate the negative outcomes and encountered delays, a number of interlocking approaches were adopted to improve participants' collaboration. The interlocking approaches included a change in meeting structure and other individual attempts to avoid confrontation that negatively impacted the design progress. According to Figure

7-5 and as simplified in Figure 7-8 below, the change in meeting structure fostered positive practices of elaborating on explanations of technical concerns, being receptive to others' concerns and increased awareness of design problems. Practices of confrontation that hindered the process of adopting practical design solutions were mitigated by individuals' approaches. The architect (R3) temporarily changed role with the façade consultant (F1) in directing design engineering inquiries to the subcontractor (P2) to avoid confrontation. Another mitigation approach was adopted because the architects had an impression that the subcontractors did not fully recognise the design complexity. These approaches included the use of design sketches to better articulate their ideas and the use of appropriate technical language when explaining the design refinements to the subcontractor team.

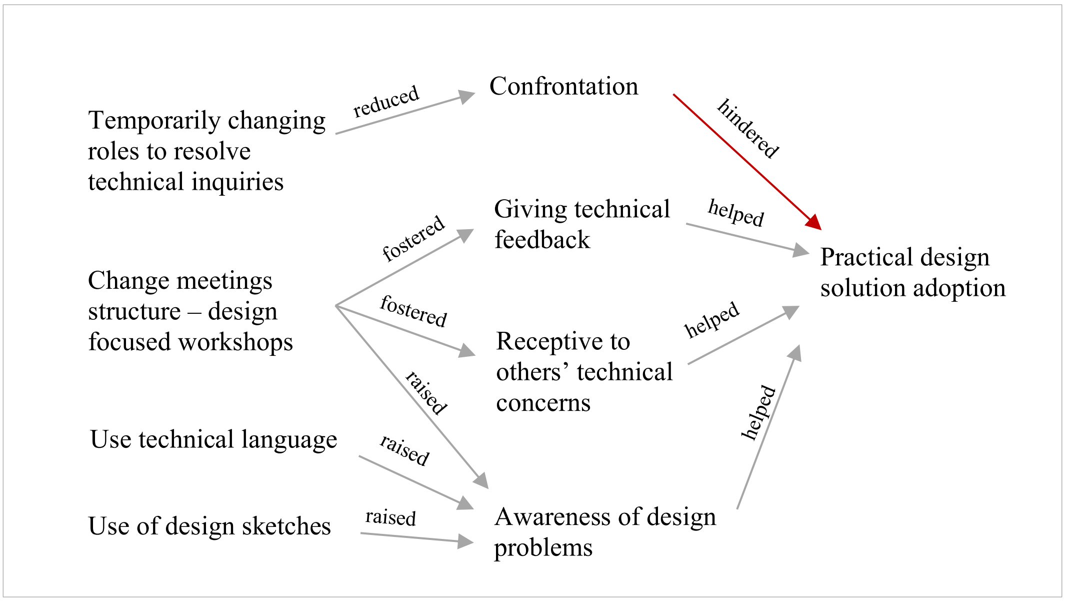

Figure 7-8 Case study B – Interlocking approaches

a) Focused design workshops

At the inter-organisational level, a management decision was made after meeting 8 to help accelerate the design progress and minimise the disagreements that persisted in participants' discussions. A design-focused workshop at the subcontractor's office in Brisbane was proposed by the main contractor and the client. The aim was to allow the architects to have direct interaction with the subcontractor's draftsmen who were responsible for documenting the major façade design items. A total of six workshops took place to substitute for the weekly meetings 9, 11, 12, 16, 18 and 19. The number of negative social interactions changed after the workshops, marked W1 to W6 on Figure 7-9. For instance, the number of 'disagrees' and 'show tension' reactions decreased after the first workshop and positive reactions increased as shown in Figure 7-9 below, illustrating the change in negative and positive social reactions after the workshops.

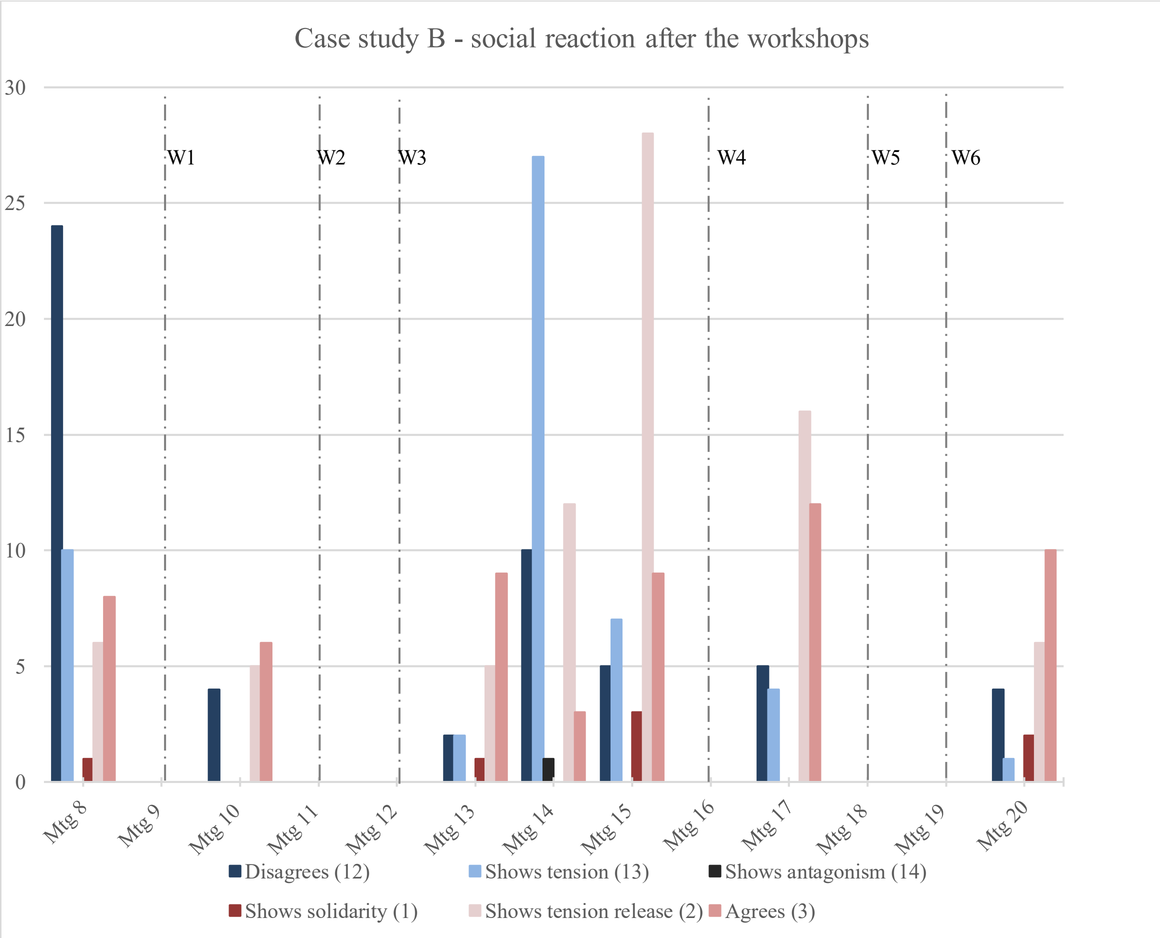

Figure 7-9 Case study B – Percentage of coded social reactions after the workshops

The architects used these workshops to better understand the technical concerns directly from the people who were documenting the design drawings and therefore they were more receptive to their concerns. These workshops allowed participants to discuss proposed solutions and to be more informed about the impact of their design decisions. Referring again to the outer north facing façade design, designers rejected the proposed pinned system and were questioning the feasibility of using a cantilever system as documented in the design intent. The design status of the proposed pinned versus cantilever system in the minutes of meetings was unchanged until meeting 8.

The reasons for rejecting the cantilever system were related to the engineering calculations and constructability reasons. For instance, in meeting 6, the architects and façade consultant requested a cost breakdown for the cantilever system because the client (L1) asked for a cost-neutral solution as there were some credits gained from deleting the louvres and their steel support system. In meeting 8, the subcontractors still preferred the pinned system solution because of constraints related to the uplifting force. The architects insisted on viewing the engineering details to evaluate the pinned system, which meant that they were not going to approve the submitted design solution because of the minimal justification that was provided. At this point the client's delivery manager suggested the workshop approach to solve these issues due to the time limitation.

The discussions between participants changed after the workshops as they included detailed information regarding the uplift force, which made the architects more informed about these constraints. The subcontractor (P4) mentioned that uplift force was a concern in only a few locations where the struts were inclined by 12–20 degrees from the vertical support and proposed using a 165 circular hollow section that was documented so the architects could investigate the implications of this solution. In the following meeting, participants discussed the impact of this solution on the cladding and agreed that connections needed to be in line with the struts and as small as possible to minimise visual impact on the cladding. Another positive outcome was seen in the subcontractor's (P4) approach to further reduce the circular hollow section size to 114, which helped in minimising the cost of this design solution, and participants were able to collectively conduct several design investigations such as the lateral stability of the system and fixation with the awning system.

In meeting 10, participants' overall interactions improved as records showed in Figure 7-9 that the positive reactions were higher than the negatives ones for the first time since the meetings started. Participants articulated their satisfaction with these workshops in the following extracts:

Brisbane meetings [workshops] are more collaborative … generally I would say that Brisbane has been better than Sydney because the group is not as big… plus the actual draftsmen that work and try and get this resolved sort of coming with real problems and architects a bit more receptive to going 'oh ok it doesn't work' and get it to work. [C1, rating of 8 for meeting 12]

On the advantages of having the meetings [workshops] in Brisbane, they can get the engineers that are working on each individual section to come in and discuss the issues. Rather than bringing 10 people down to Sydney, it is better for us to take 3 people to Brisbane. So that has been a great advantage, actually going to their office and dealing with that. [L1, rating of 9 for meeting 13]

The workshops in Brisbane definitely are more constructive because it is a workshop rather than one person going through minutes sort of point by point. It is much easier to get things done and decisions made and to work through details rather than having more of a formal meeting atmosphere and going through a heap of stuff that isn't always super critical to what we are doing at the moment. [R2, rating of 5 for meeting 13]

b) Temporarily changing roles

This interlocking approach was an individual trial aimed at reducing the spontaneous rejection that was occurring when a design solution was introduced. To avoid such confrontation, the architect (R3) delegated all structural design inquiries to the façade consultant (F1). This approach was adopted in meeting 13 where several inquiries were discussed thoroughly and the façade consultant (F1) was able to get the required responses from the subcontractor (P2). The following extract shows the architect's objective in this interlocking approach.

No, they don't give reasons… It's actually interesting watching F1 [façade consultant] and participant P2 [subcontractor's structural engineer] working together… it is a much easier relationship and so F1 and I talk a lot about how he is going to make sure P2 does the things we actually need, so I stopped talking to P2 because it is too much confrontation between us. So, F1 has to ask the questions that I would normally ask just so P2 does not respond to it negatively. [R2, rating of 5 for meeting 13]

c) The use of appropriate technical language

As mentioned earlier, the architects did not have enough time to finish the design before the tender phase. Consequently, a lot of design refinements were conducted during the meetings, which caused frustration among other participants, especially the main contractors (C1 and C5). The architects (R1and R3) came up with a design solution for the shop front façade at the building entrance on the north side that should be easier to construct. The shop front façade was located at either side of the building entrance and was originally designed to be curved seamless glass. There were several design complications associated with using curved glass at this connection, such as the structural supporting system and weatherproofing issues because of wind and rain hitting the façade at the building entrance. The architects proposed replacing the curved glass at these corners with a masonry wall. After discussing it with the client (L1) in a separate meeting, they put it out for discussion with the main contractor team. This was a separate meeting that took place a day before meeting 12 and included all participants of the façade team excluding the subcontractor team. The aim was to explain the benefits of this design refinement and get the main contractor's feedback in terms of feasibility, and program and cost implications before introducing it to the subcontractors.

In meeting 12, the design solution was explained to the subcontractor's team purely from the structural design perspective. The architects prepared a 3D model showing the wall rendering and 2D drawings showing a conceptual design of all connections and interface with the adjacent glass façade. Participants' interactions in this meeting recorded a high number of explanations and exchanging information interactions to clarify the design aspect of the masonry wall and its benefits in improving constructability. There were also social reactions recorded because the architects were trying to introduce the design change in a friendly way to avoid spontaneous rejection because of its timing. After long discussions in this meeting, the subcontractors agreed to adopt this design option and were convinced of its benefits. However, the main contractor (C3) counted it as a design change and asked the architects to submit a design change order, thus it was treated as a variation. This explains the low rating given by the architect in meeting 14 despite the acceptance of the proposed design solution. The architect's approach of using technical language in this example is shown in the following extract:

This change should facilitate subcontractor work. The decision was architecture driven first because we think it will look better and the client likes it. We spent two weeks studying this change and I know it is a minor change to their work [referring to the subcontractor] to the best. They needed someone who speaks their language to explain this change for them which I did. They were very close to saying yes, we agreed but C3 [main contractor' delivery manager] said to P [subcontractor team] *submit your program change!! I told them submit your shop drawing because I know it is a minor change. [R2, rating of 2 for meeting 14]*

d) The use of design sketches

The several design explanations that occurred throughout the meetings made the architects search for a way to articulate the design concepts faster. This approach was using design sketches in some meetings to explain comments on the submitted design solutions and send them to the subcontractor to work on the engineering calculations faster. This approach was adopted because of the limited timeframe due to the encountered delays. The minutes of meetings data provided better insights about documenting the use of design sketches rather than the observation data because the observation data recorded participants' use of different type of sketches to explain design views such as annotating 2D drawings, or drawing sketches on paper or a white board. The use of design sketches as submissions was documented in 13 meetings making a total of 42 times where design sketches were used with different façade types. For instance, some design documents were received as sketch packs and participants used them as a reference in their discussions and in coordinating actions needed to proceed, such as reviewing and updating drawings. The approach of using design sketches is illustrated in the quote below.

Didn't have enough time to finish the drawings before tender and we were told not to submit any drawings after that. That is why we give them [subcontractor] sketches to help them, and we will continue helping them to understand the design… we are offering some stuff all the time and always drawing sketches and sending them. [R2, rating of 4 for meeting 17]

However, the main contractor (C1) felt the use of design sketches was not an ideal approach as it slowed down the progress because the subcontractor team would still come the following week asking for further clarification. The design sketches approach was considered inefficient because the sketches were missing key information to link the façade connection to the main structural elements to help the subcontractor in shop drawings. However, it was observed in one of the meetings that the architect (R3) mentioned that he added a reference point in the sketches for the subcontractor to work out the other dimensions. The main contractor's conflicting view is shown below.

If you give them [the subcontractor] a set of drawings and it is coordinated they would draw it like this, quick smart, it is not their interest to drag this process out. So that is where time is lost because we were not even drawing on proper drawings or CAD, it is bits of paper that are shuffled across the table. The problem of bits of papers is that they are not coordinated with all of the other bits of design… the ideas are pretty good, but again we deal with sketch packs. [C1, rating of 6 for meeting 17]

e) **Discussion of results for phases 1 and 2 leading to positive outcomes in phases 3 and 4**

The main objective of these interlocking approaches was to help participants focus on adopting practical design solutions. Participants' social reactions were positively impacted after adopting the workshops as there was a significant increase in their occurrence as shown in Figure 7-9. This increase was considered a major outcome given that these weekly meetings were four hours long. To clarify this further, the total number of task-based interactions before starting the workshops (meetings 1–8) was compared to the rest of the meetings 10–24. The highest increase calculated was in 'gives confirmation' (category 6) interactions (185%) as the total number of interactions before workshops was 224 and after was 638. The second highest was seen in ‘gives suggestions’ (category 4), where the total increased 110% from 91 to 191, followed by ‘gives analysis’ (category 5) which increased 100% from 409 to 820 and ‘gives information’ (category 6) which increased by 80% from 537 to 967. These numbers showed that participants’ collaboration improved by adopting the design focused workshops as more confirmation, solutions and explanations were provided in discussions.

Participants’ ratings showed a little change after adopting the workshop approach when compared to the interactions’ findings. This is shown in Figure 7-4 where participants did not show a major change in rating patterns. The majority of participants who gave positive ratings (above the neutral line of 5 points) kept the same rating pattern after meeting 8. The ratings pattern of R2 and F1 did not change after the workshops as they were at or below the neutral line of 5 points. This is because these participants on several occasions referred to the collaborative process as being difficult as shown in the quotes below.

I’m not worried about the outcome, but it is the pathway to get that outcome. [F1, rating of 5 for meeting 21]

I’m not happy with the processes in general; they [referring to the subcontractors] have been a bit difficult for various reasons. [R2, rating of 3 for meeting 23]

The interlocking approaches demonstrate the collaboration feature that revolves around ownership of decisions on how to reach an agreement without external interventions such as mediation or litigation actions (Gray 1989) (Section 1.5). While the first and major approach proposed was an inter-organisational one, it encouraged other participants to be proactive and seek ways to overcome the negative practices that were hindering their progress. This finding is also important as it provides further insights into the subjectivity aspect of collaboration in construction projects. Given the long duration of the detailed design phase over 36 weeks, the motivation of participants is important to encourage them to maintain their collaboration efforts (Gray 1989; Mattessich & Monsey 1992).

The confrontation practices that were caused by unsatisfactory experiences of working on previous projects do not fully align with Dainty's (2007) argument that there is a low chance that the same participants will work together again even if their organisations are involved in future projects. The finding in this case study shows that there are some exceptions, especially in complex construction projects because there is a chance that senior professionals know each other. For instance, the architect (R3) had had a difficult experience with subcontractor P2 but a very successful experience with subcontractor P5. Similarly, the façade consultant (F1) had previous experience working with the subcontractor team in other projects as quoted below.

This is basically how the industry works and I guess because I see it every day so I can measure things against how other projects work and other contractors and what not. It is a quite common saying around the industry about this subcontractor are really easy at the start and at the end but in the middle, they are really difficult, and I think it is true. [F1, rating of 3 for meeting 14]

7.5 Conclusion

This chapter presented results relating to the first research question for case study B, which demonstrated collaboration in a complex design environment. The analysis indicated that task-based interactions are more evident in design discussions than social reactions, which consolidates the earlier findings in the previous chapter. The analysis presented in this chapter showed that the IPA (Bales 1950) method was useful in detecting the high frequency of negative social reactions in initial meetings and their association with task-based interactions. These findings informed the second method of data collection especially in the prominent presence of low ratings of collaboration. There are four key findings:

- Despite the presence of highly frequent task-based interactions (questions and attempted answers), the negative collaboration outcomes were detected by comparing the social reactions.
- The negative collaboration patterns that were prominent in initial meetings and represented by task-based interactions (questions and attempted answers) were followed by disagreement and expressing signs of dissatisfaction and tension.
- Participants experienced problems with lack of information in design discussions illustrated by the closed cycle of giving information followed by disagreement.
- The positive collaboration pattern, when it occurred after the mitigation approaches, included a highly frequent presence of task-based interactions (questions and attempted answers) of exchanging confirmation, opinion and suggestions associated with agreements and expressing signs of satisfaction.

Participants' perceptions of collaboration did not align once in all the meetings as they were widely scattered across the neutral line rating of 5 points out of a maximum of 9. Further investigation through the interviews provided new insights explaining the process and outcomes of collaboration. The key findings from analysing participants' interpretations of their collaboration experience are summarised.

Negative collaboration patterns

- Excluding some parties from major design decisions, lack of transparency and providing inadequate design information with minimal cost information led to design changes and confrontation practices between participants in the problem setting (phase 1 of the CPDD model). Consequently, excessive design reviews and coordination actions were common practices in the direction setting (phase 2) to get approvals and consequently delayed the progress and caused dissatisfaction with the collaborative processes (phases 3 and 4).

Interlocking approaches leading to positive collaboration patterns

- The inter-organisational mitigation plan of design-focused workshops fostered collaboration by elevating practices of providing feedback, being receptive to others' concerns and raising awareness of design problems, which in turn helped in the process of adopting practical design solutions.
- At the individual level, problems of holding back information and practices of confrontation were mitigated by delegating structural inquiries to another participant to avoid spontaneously rejecting requests to investigate design, which proved to be effective in clarifying complex design inquiries and improving the flow of discussions.
- At the individual level, the architects used technical language that focused on engineering terms to articulate the design and design sketches to communicate the proposed design. This approach raised the awareness of the design problems but added some pressure on the main contractor because the sketches were not clearly coordinated with the main structural elements.

The next chapter compares findings of the two case studies on the first research question and discusses the second research questions.

Chapter 8 Discussion of Results

This chapter discusses the results from the cross-case analysis of the data presented in Chapters 6 and 7 in relation to the research questions. First, findings are presented that address the first research question about the patterns of interactions that occur in detailed design meetings, and the differences between standard and bespoke design environments. The discussion incorporates relevant literature to provide an integrated understanding of the interdisciplinary collaboration in detailed design meetings. A revised CPDD model of collaboration phases is presented that incorporates the findings of the study. The revised CPDD model contributes to the design and construction management literature, and provides a framework for evaluating the development of collaboration through the four phases. Findings related to the second research question about the approaches used to manage and improve collaboration are then presented, concluding with findings on the process and social reactions factors of collaboration.

8.1 Discussion of the first research question

This section reports the findings of the cross-case analysis of the data presented in Chapters 6 and 7 on the first research question:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.1: Are there different patterns of group interactions in different design environments?

RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?

The first step in addressing the first research question involved analysing the data on interactions observed and recorded using the IPA method during the detailed design phase meetings. The analysis involved three main steps: (1) investigating patterns of interactions that were observed during the four phases of the CPDD model, (2) analysing the data on participants' ratings on their perceptions about the collaboration experience along with data from a short version of the interviews that allowed in-depth understanding of collaboration processes, and (3) developing an integrative model of collaboration in the detailed design phase.

8.1.1 Patterns of interactions between participants in detailed design meetings

The first step examined participants' interaction using the modified IPA (Bales 1950) method and identified patterns of interactions that describe the difference between collaboration in the standard design environment and the bespoke design environment. Interactions were analysed first as single interactions and then as pairs of sequential interactions.

a) Single interactions

Task-based interactions (questions and attempted answers) were more frequent than social reactions in both case studies despite the difference in design complexity levels. Although there were similarities between both façades, they were different in terms of the level of design complexity. The façade design in case study B was more complex than in case study A, and the construction methods were not as standardised. Due to the complexity, the weekly design meetings for case study B (bespoke design) required 4 hours to investigate the design thoroughly while case study A (standard design) only took 1.5 hours. Despite the difference in meeting duration and degree of design complexity, the patterns of interactions in both cases were dominated by exchanging information, confirmation, opinion and suggestions as shown in Figure 8-1 below. This figure follows the traditional method of displaying the IPA aggregate data in a line graph (Bales 1950).

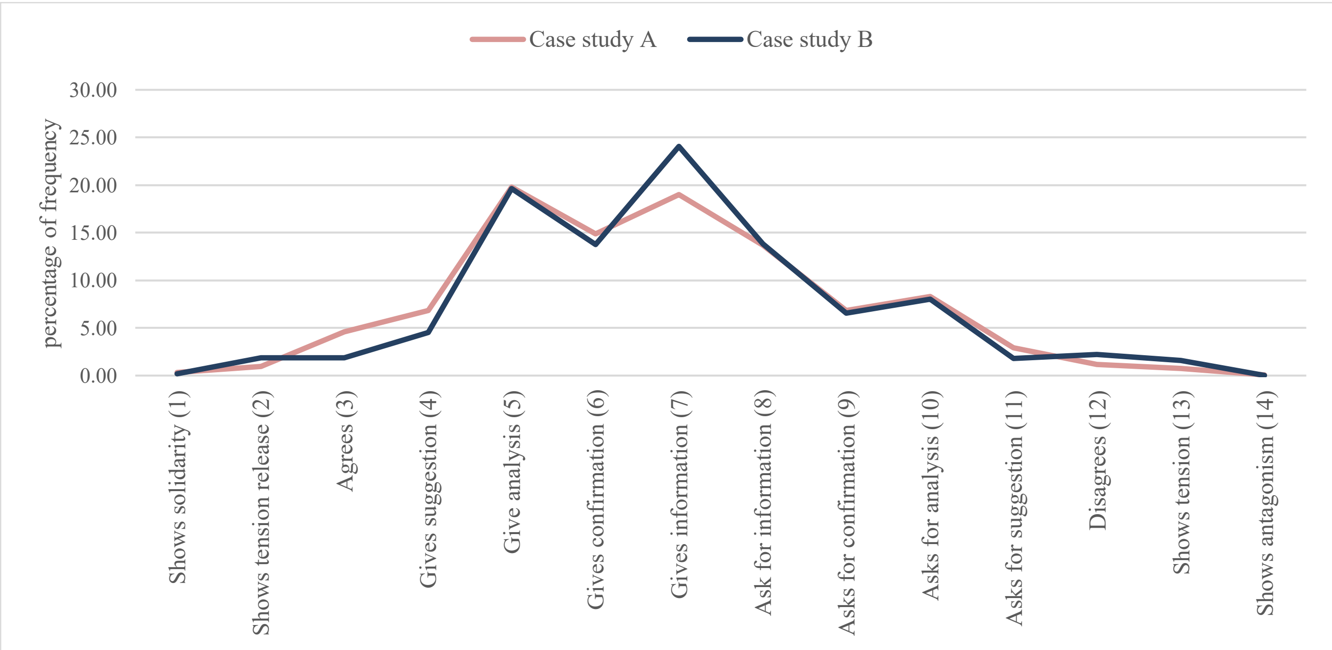

Figure 8-1 Aggregate collaboration profiles for case studies A and B

Note: interaction categories are classified as:1-3: Positive social reactions, 4-7: Task-based attempted answers, 8-11:Task-based question, and 12-14: Negative social reactions.

The prominent presence of task-based interaction in participants' discussions compared to the social reactions (as shown above) aligns with findings from other studies on the management and design meetings of construction projects. The findings of the task-based attempted answers being more frequent than the task-based question categories align with Gorse and Emmitt's (2007) and Ghosh's (2012) analysis of site-based planning and design meetings. One of the benefits of displaying the aggregate interactions as seen in Figure 8-1 is that multiple profiles can be displayed for comparison. As such, to validate the use of IPA to code observations for this research, the aggregate single interactions for case studies A and B were compared with two other research studies conducted on construction projects using the IPA (Bales 1950) method.

The first research study used for comparison, referred to as research study 1 (RS1), used a modified version of the IPA method by adding two interactions related to commitment (Ghosh 2012). This approach is similar to the thesis study in recognising the importance of commitment and confirmation among participants in the construction industry and modifying the IPA method accordingly, although the added categories do not align directly. The second research study used for comparison, referred to as research study 2 (RS2), used the original 12 categories of the IPA method to measure communication patterns in site-based management and design meetings (Gorse & Emmitt 2003). A comparison of the context of meetings where the data collection of the IPA method took place is provided below in Table 8-1.

Table 8-1 Comparison of meeting features between case studies A and B, and reference data

Meeting features	**Case study A**	**Case study B**	**Reference data 1 (RS1) (Ghosh 2012)**	**Reference data 2 (RS2) (Gorse & Emmitt 2003)**
Number of single interaction categories	14	14	14	12
Meeting type	Detailed design meetings	Detailed design meetings	Site-based planning meetings	Site-based management and design meetings
Number of meetings observed and coded	21	18	6	36
Participants involved	client, architect, consultant, main contractor and subcontractor (25 participants, average of 10 participants per meeting)	client, architect, consultant, main contractor and subcontractor (24 participants, average of 12 participants per meeting)	project manager, superintendent, subcontractors	client, architect, consultant and contractor (96 different professionals)

The comparison between the interaction profiles is presented in Figure 8-2 below. Of note, for consistency in comparison, only the 12 original types of IPA interactions are included, however the numbering is aligned with the findings from this study (Table 5-2).

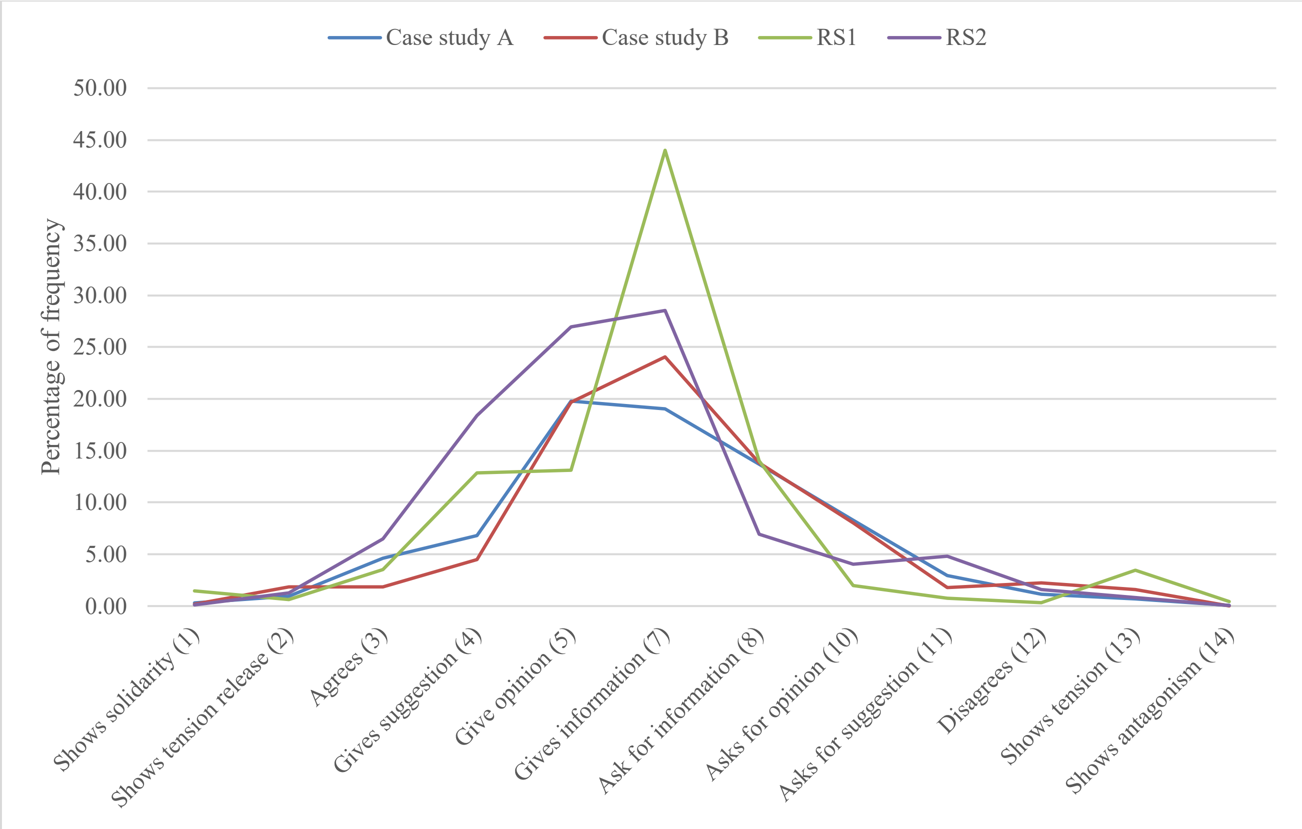

Figure 8-2 Comparison of profiles of case studies A and B and site-based planning RS1 and management and design RS2 meetings

Although the data used for comparing interactions' profiles was captured in different situations, the analysis across these studies substantiates that task-based interactions are more common in design and construction discussions than social reactions. As shown in Figure 8-2, the four profiles are similar with the task-based interactions being more common than the social reactions. Also, within the task-based interactions the attempted answers categories are more frequent than the question categories. Another common pattern is seen in the 'shows antagonism' category as the least common of all categories. Although the construction industry is known as a contentious environment (Eynon 2013; Gorse & Emmitt 2007), this was not evident in the data collected in both case studies for this research. This finding also aligns with the Gorse and Emmitt (2003) and Ghosh (2012) studies based on the data in Figure 8-2. As such, the degree of similarity in IPA patterns between the cases in this study and the other studies from construction provides support for the accuracy of the methodology used in this research study to code and analyse the single interactions.

One of the clear findings of the analysis of single interactions is the high focus on task-based interactions in participants' discussions.

b) Sequential interactions

Building on the findings on single interactions, the similarity between both case studies was seen in the predominance of sequential interactions involving categories of asking and giving opinion, confirmation and information. This finding suggests that participants' discussions in the detailed design meetings focused on analysing technical problems and exchanging information and confirmation to explore different aspects of the problem. The similarities and differences between the sequential interactions in both case studies (see Tables 6-1 and 7-1) are summarised below in Table 8-2. Bold text is used to highlight areas of strongest differences between patterns in case studies A and B.

Table 8-2 Summary of sequential interactions in both case studies

Type of Sequential Interactions	**Case A (Standard Design)**	**Case B (Bespoke Design)**
Task-based followed by task-based	Highly frequent exchange of opinion, confirmation and information. Common attempted answers were **opinion and confirmation**	Highly frequent exchange of confirmation, opinion and information. Common attempted answers were **information and suggestion**
Social reactions followed by task-based categories	Showing solidarity and tension release were followed by giving opinions Tension release was followed by giving opinion and **information** Agreements were followed by giving opinion Disagreements were followed by giving information and opinion	Showing solidarity and agreements were followed by giving opinions Agreements and tension release were followed by giving opinion Disagreements and showing tension were followed by giving information
Social reactions followed by social reactions	Showing solidarity was followed by tension release	Showing solidarity and tension release were followed by tension release Disagreements were followed by disagreements
Task-based categories followed by social reactions	Giving suggestions and confirmation were followed by **agreements** Giving information was followed by **releasing tension**	Giving suggestions were followed by **agreements more than disagreements** Both asking and giving suggestions were followed by showing tension Giving confirmation was followed by tension release Giving information was followed by **disagreements**

Key:
Question categories: asks for information, confirmation, opinion and suggestions.
Attempted answers categories: gives information, confirmation, opinion and suggestions.
Positive social reactions: agrees, shows tension release and shows solidarity.
Negative social reactions: disagrees, shows tension and shows antagonism.

As shown in Table 8-2, participants' discussions in case study A – standard design – were largely characterised by giving explanations about technical issues and confirming design information to facilitate their working procedures. The high presence of these interactions showed that participants developed a good understanding of the design problem, which allowed them to proceed to the direction setting (phase 2 of the CPDD model). In occasions of disagreements, participants responded by providing information and explanations. This approach of responding to the negative social reactions by attempted answers categories showed that participants preferred to align views rather than escalating the conflict. This was also seen in the sequential interactions of social reactions categories where showing solidarity was followed by tension release, which reflects the positive working environment that participants developed in their discussions. These practices agree with Suprapto et al.'s (2015) finding that relational attitudes representing the soft and people aspects had a positive effect on team performance because these aspects supported participants as they spent a considerable amount of time and energy in solving problems that emerged from their interdependent tasks.

The sequential interactions in case study B – bespoke design – were characterised by a high presence of questions and attempted answers task-based categories, especially the highly frequent exchange of confirmation. This finding shows that confirmation interactions were a key component in participants' discussions reflecting the high degree of uncertainty that was present in the bespoke design discussions. The social reaction that followed these confirmation interactions was tension release indicating that it was an important factor in reducing the stress in discussions. These findings support much of the work of Kalsaas et al. (2020) on improving the detailed design phase by recognising the high degree of complexity and uncertainty in the design, and the need for an alternative management approach instead of linear planning methods. The disparity between the two cases was demonstrated in the association between task-based categories and social reactions. In the bespoke design (case study B), the sequential interaction analysis suggested that participants experienced problems with exchanging information because such exchanges were often followed by disagreements and tension in the discussions. This finding explains the findings from the single interactions that showed more negative social reactions in case study B than positive ones. Problems related to lack of information were suggested by patterns where the subcontractor gave a short answer rather than providing explanations or long answers when asked to explain the design approach and to offer an alternative solution. These short answers were not sufficient for the architects and façade consultant as they expected to get a detailed explanation of the design and engineering calculations when they were trying to understand the proposed solutions. These practices suggested that there was a closed cycle of giving information followed by disagreement. Participants kept getting short answers to their design inquiries, leading to circular and extended discussions attempting to understand the problem (phase 1 of the CPDD model). As such, it is suggested that the progress to the direction setting (phase 2) might have been slowed down as participants were unable to proceed in evaluating design solutions and deciding on a direction to follow. Taken together, these findings support Dietrich et al.'s (2010) argument that detailed feedback is an important aspect for knowledge creation in dynamic interactions at the project level.

These findings provide new insights into participants' working practice in the detailed design phase by illustrating the movement between collaboration phases and reflection on the objective and subjective outcomes (phases 3 and 4 of the CPDD model). More specifically, these findings give an indication of how the collaborative process unfolds by identifying two different patterns: a smooth collaborative path of elaborating on explanations, demonstrated more in case study A; and a more disruptive collaborative path that slows down participants' progress by limiting the information given in their discussions, demonstrated more in case study B. These findings can help design managers and project coordinators recognise and monitor the collaborative process, foresee the impacts on the outcomes and potentially take actions to mitigate effects.

8.1.2 Similarities and disparity in participants' views

This section continues the discussion of the first research question by investigating participants' interpretations of their collaboration and comparing the differences in their perceptions of the subjective aspects of collaboration in an interdisciplinary team. The research method designed for this study included a quick capture of perceptions through a one-question survey asking participants to rate their collaboration experience for each meeting, followed by in-depth interviews of targeted participants for deeper explorations of their views. This analysis provided an in-depth look at collaboration perceptions that reflected the realities constructed by the participants involved in the design meetings. The analysis of participants' ratings reveals differences in the ways that people from different organisations viewed the collaboration. The short interviews exploring the reasons for the extreme ratings revealed that different participants focused on different phases of the CPDD model when explaining how they rated the collaboration.

For each case, five key participants, each representing one of the main collaborating organisations, provided ratings after each meeting. These ratings varied among participants for each meeting in both case studies, demonstrating that participants tend to perceive the same event differently. Further investigation into the reasons for the extreme ratings (very low or very high) through the short interviews revealed an interesting insight: while all participants were asked to rate the collaboration experience using the same question, the interviews exposed the differences between the reasons behind extreme ratings.

The participants’ patterns of rating collaboration in the meetings, and the reasons for the rating, fall into two groups as summarised in Table 8-3 below. In short, the participants in the first group that reported higher levels of satisfaction were focused on the objective outcomes (phase 3 of the CPDD model) and antecedents of collaboration (preparatory stage, preceding phase of the CPDD model). In contrast, participants in the second group who were less satisfied with their collaboration and showed high volatility and variation in their ratings were focused on the processes of collaboration (phases 1 and 2 of the CPDD model). These patterns and the existence of the two groups were observed in both cases. These findings reinforce the findings by Kalsaas et al. (2020) that revealed the differences in the opinions of stakeholders involved in the detailed design phase in evaluating design decisions, late changes and design iterations. These differences provide new insight into face-to-face interactions that might be useful in studying the cohesion of project teams. This finding also raises some interesting questions about how the process and outcomes of collaboration are viewed by participants with different roles in the collaboration setting, and whether the perceptions are related to their industry types or roles.

Table 8-3 Summary of collaboration ratings

	Firms and Key Participants	Rating on Collaboration	Main Basis for the Ratings
Group 1	Client: delivery manager (L1)	Relatively high and consistent ratings (7, 8 and 9 points)	Outcomes based perceptions: satisfaction associated with the subcontractors' efforts to achieve the required outcome; the design criteria set up by the architects within the cost and schedule limits (case studies A and B)
	Subcontractor A: senior project manager (T2)		Antecedent based perceptions: satisfaction with cross-functional team concerning the availability of participants who can give real-time feedback and decisions on proposed design solutions
	Subcontractor B: project manager (P3)		Antecedent based perceptions: satisfaction with cross-functional team concerning the early involvement of subcontractors in the design phase
Group 2	Architectural firm: senior architect (R2)	Volatile and inconsistent ratings (fluctuating between a high of 8 and a low of 2)	Process based perceptions: high ratings associated with giving detailed feedback including cost breakdown of design components, being receptive to technical constraints and offering alternative design solutions (case study A) Process based perceptions: low ratings associated with lack of transparency, excluding some parties from major design decisions, providing inadequate design information combined with minimal cost justification and confrontation (case study B)
	Façade consultant: façade engineer (F1)		Process based perceptions: high ratings associated with giving detailed feedback and offering alternative solutions (case study A) Process based perceptions: low ratings associated with lack of transparency, excluding some parties from major design decisions, providing inadequate design information combined with minimal cost justification (case study B)
	Main contractor: project engineer (C1)		Process based perceptions: high ratings associated with adopting practical design solutions (case studies A and B) Process based perceptions: low ratings associated with questioning proposed cost calculations, design changes, excessive design reviews and excessive coordination actions (case studies A and B)

a) Group 1 – High and consistent ratings

The interviews conducted to explore the variance in participants' views showed that the client's delivery manager (L1) was interested in the outcomes rather than the processes and rated the collaboration highly in both case studies. This high level of satisfaction was associated with the subcontractors' ability to achieve the specific outcomes such as design criteria set up by the architects within the allowable budget. The client's satisfaction with the outcomes was seen in several occasions in case study A (standard design), such as in refining the façade connections for better visualisation, providing glass and blinds samples that match the colours chosen by the architects, and providing visual mock-ups to test the façade before the manufacturing process. While case study B had a very complex design, and participants were struggling in initial meetings to agree on design principles, the client (L1) was still satisfied with the subcontractor's willingness to reconsider their design approach. This finding suggests that the client was more concerned about the objective outcomes (phase 3 of the CPDD model) and less worried about the processes or ways for reaching these outcomes. In doing so, the client's delivery manager showed interest in the subcontractor's abilities in dealing with the design challenges to make sure value was not lost in this change over phase of design responsibilities.

The subcontractors also rated their collaboration experience highly in both case studies. Interviews revealed that this high level of satisfaction was mainly associated with the opportunity to be engaged early in the design discussions to provide their input before the design was fully developed, and with the team diversity, which represent antecedents of collaboration (preparatory stage, preceding phase of the CPDD model). The aligns with the design and construction literature that emphasises the early involvement of subcontractors in the design phase to provide timely feedback about constructability issues so the designers can be more informed about the limitations of the proposed solutions (Ballard & Pennanen 2013; Denerolle 2013; Erik Eriksson 2010). Although the subcontractors demonstrated these practices of providing constructability feedback, both of them rated the collaboration experience highly and linked the high ratings to the existence of antecedents, rather than the processes of collaboration. It could be that the processes of collaboration are relevant to the subcontractors' views, but that they are not in the habit of expressing their views about the actual working practices. It is possible that the low emphasis on the processes is related to the lack of attention from managers to improving work processes and encouraging team effectiveness and a fair working environment where participants are assured that they have equal opportunities to voice their opinions in collaborative practices (Patel, Pettitt & Wilson 2012).

b) Group 2 – Fluctuating ratings

The participants in the second group, who were less satisfied with their collaboration and showed high volatility in their ratings were the senior architect (R2), façade consultant (f1) and main contractor's project engineer (C1). In-depth interviews revealed that their ratings were more focused on the processes of collaboration rather than the outcomes when providing ratings of their collaboration experiences.

Practices associated with their higher ratings from this group revolved around collaboration processes for reaching a common understanding of the technical problems, including elaborating on providing feedback backed up with cost breakdown of design components, being receptive to others' concerns during the process of analysing design problem, and proposing other alternatives. These practices helped in adopting practical design solution, aligning working procedures and elevating the sense of mutual accountability where all participants shared the responsibility of meeting the design deliverables timeframe. The senior architect (R2) and façade consultant (F1) in case study A referred to the subcontractor's (T2) approach in explaining design problems in detail by using sketches and annotating 2D drawings as the main reason for their high ratings and satisfaction with the collaboration processes. Aligned with Dietrich et al. (2010), these findings together provide insights into the knowledge creation process (interaction activities of feedback, brainstorming, and innovation) that are specific to the design discussions.

A large range of ratings in the same meetings demonstrated variance in participants' views of the same collaboration event. This was seen in meetings where the main contractor's project engineer (C1) gave a low rating while the architect (R2) and facade consultant (F1) gave a high rating. The interpretations of participants' views revealed that they judged design refinements differently. One of the main differences was related to the excessive design reviews. While it is common in construction projects that design refinements exist due to the highly iterative nature of the design process to seek improvements (Eynon 2013), the main contractor (C1) regarded these as excessive design reviews causing unnecessary coordination tasks to get approvals from the client. The architects (R2) and façade consultant (F1) regarded the design reviews as a fundamental part of developing the design. The designers' view is substantiated by Kalsaas et al.'s (2020) argument that design changes are normal in the detailed design phase and there is a need for a planning management approach that is capable of handling change. On the other hand, the main contractor's view that there are an excessive number of design changes, and that they are largely unnecessary, aligns with the well-established lean concept of process waste in the design phase in the form of non-value adding tasks that need to be minimised (Ballard et al. 2001; Koskela & Howell 2001).

Practices associated with low ratings emerged in case study B (bespoke design) because of the dissatisfaction of the architects (R2) and façade consultant (F1) with the practices of lack of transparency, excluding some parties from major design decisions, and providing inadequate design information combined with minimal cost justification. Communication difficulties and differences in views led to repeated confrontation between participants as the architects (R2) and façade consultant (F1) adopted a policy of protecting the design from being compromised due to cost and constructability reasons, and resulted in a call for mitigation actions to ease the tension between participants and reduce confrontation. These sequences demonstrate how goal misalignment at initial meetings led to unhealthy communication behaviours and poor decision quality, which was also observed by Manata et al. (2020) and Suprapto et al. (2015). Interestingly, the mitigation actions taken in case study B, particularly the workshops, were aligned with Manata et al.'s (2020) recent findings that recommended a similar workshop approach for team building to mitigate problems by realigning goals and facilitating an open information environment.

Although Suprapto et al. (2015) point to the lack of willingness of senior management to be involved in improving team building and interpersonal relationships between participants at a project level, the findings of this study do not support that view. Instead the findings from case study B tend to reveal interventions led by senior management, which aligned with the findings from Manata et al. (2020) that outline possible approaches taken by project delivery managers to increase group cohesion. A series of mitigation actions were taken in case study B at both the inter-organisational level and the individual level to improve the collaboration. These mitigation actions offered interlocking approaches that worked on different levels and complemented each other to address and resolve collaboration issues in case study B. At the inter-organisational level, the client and main contractor imposed some changes in the structure of the meetings by proposing design-focused workshops in the subcontractor's office to replace some of the weekly meetings. This approach helped in developing a common understanding of technical concerns as the architects were able to discuss the design problems with the draftsmen who were responsible for documenting the major façade types. Additionally, these workshops were design-focused meaning that coordination inquiries were removed from the meeting agenda so participants could focus only on discussing technical concerns related to the design and constructability. The rest of the interlocking approaches were performed at the individual level, such as temporarily changing roles to avoid confrontation, using technical construction language during design explanations, and using design sketches to clarify the proposed design solution (Section 7.4.2). The low collaboration ratings in case study B reflected differences in perspectives, tensions and communication problems that were largely resolved through these interlocking mitigation actions.

8.1.3 Integrative model of collaboration phases in the detailed design phase

Findings of case studies A and B enabled a refinement of the CPDD model derived from the literature which was originally proposed in Section 4.3 and Figure 4-5. The purpose of the CPDD model was to facilitate understanding interdisciplinary collaboration in detailed design meetings and to guide the methodology to study such collaboration as described in Chapter 5. Figure 8-3 shows the integrated collaboration model of interdisciplinary teams in the detailed design phase of construction projects, incorporating findings from this research. The integrated CPDD model is an important contribution from this study. It enhances the understanding and supports research by providing a holistic view of collaborative practices in the detailed design environment.

Note: The added themes representing findings of this research in each of the four phases are highlighted in italics font in Figure 8-3.

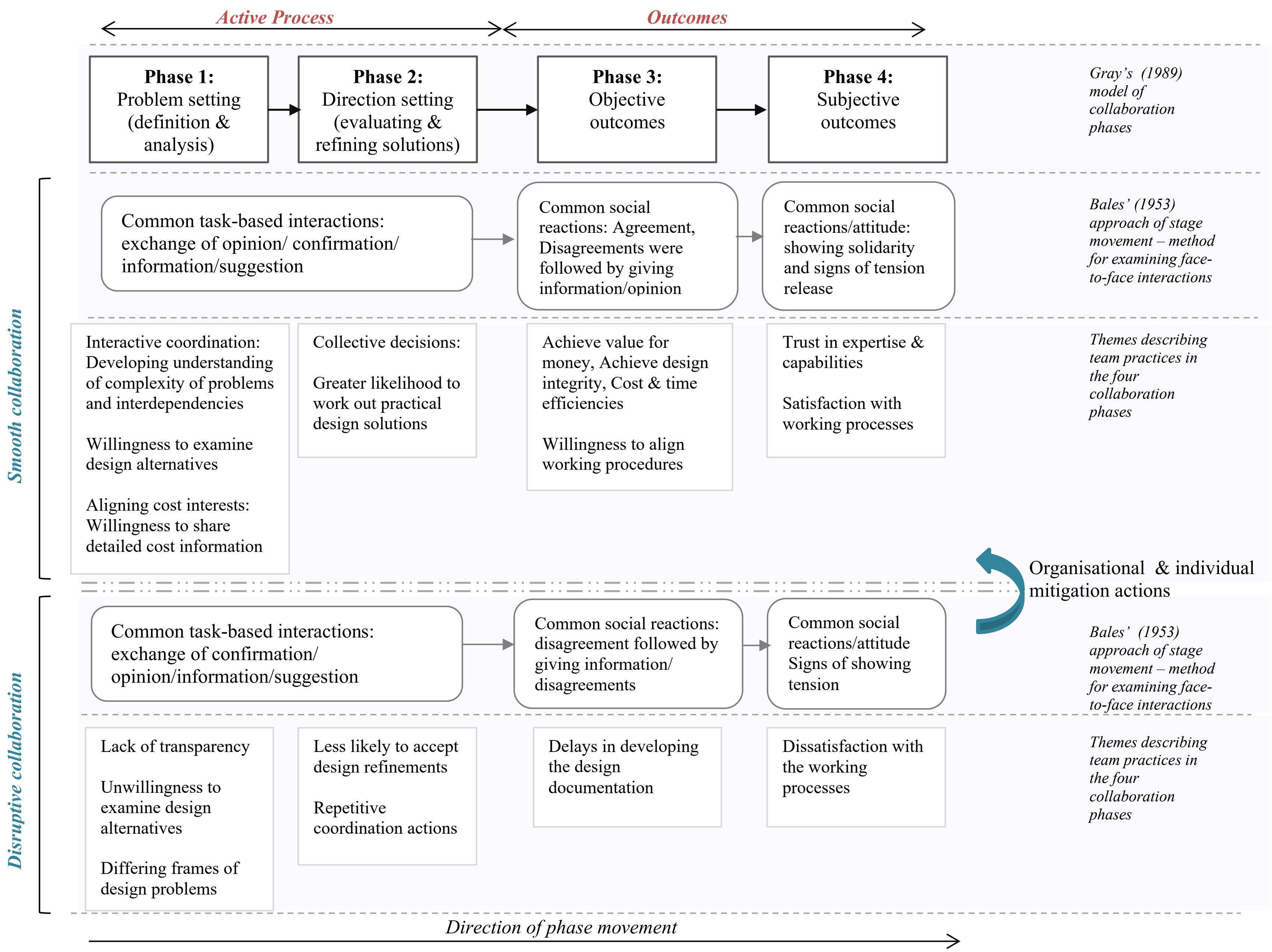

Figure 8-3 Integrated collaboration model of interdisciplinary teams in the detailed design phase of construction projects

In Figure 8-3, the horizontal axis displays the development of the collaboration process and outcomes through four phases: problem setting (phase 1), direction setting (phase 2), objective (phase 3) and subjective (phase 4) outcomes. In addition, the vertical axis positions themes that outline collaboration paths, with the smooth collaboration path towards the top, and those that overview the disruptive collaboration path towards the bottom. An explanation of these relationships is as follows.

Smooth collaboration path (top part of the model)

- The positive collaboration patterns in problem and direction setting phases 1 and 2 showed a smooth path demonstrated by seamless interactions suggesting that participants managed to work through conflicts and were keen to show their satisfaction with the working processes (objective and subjective outcomes phases 3 and 4).
- Findings expanded on the interactive coordination theme by practices showing that participants managed their interdependencies and developed a great level of understanding of complexity of design and constructability problems through examining design alternatives and being transparent in cost-related information.
- Findings expanded the collective decision theme by practices showing willingness to work out practical design solutions and being accountable by facilitating each other’s working procedures to meet the design deliverables timeframe.

Disruptive collaboration path (bottom part of the model)

- The disruptive collaboration patterns in problem and direction setting phases 1 and 2 illustrated a more difficult path where reaching agreement was unlikely despite the time spent in explaining the design complexity.
- Findings showed that participants could not manage the difference in their views and only received limited feedback. As such, their collaboration was disrupted causing delays in documenting the design and dissatisfaction with the working processes.

The arrow labelled 'organisational and individual mitigation actions' in the model in Figure 8-3 refers to the purposeful actions that enabled collaboration to move from the disruptive path into a more smooth one for successful outcomes.

In explaining the relationships above, this model represents the dynamics of participants' interactions shaping their collaboration practices in the detailed design phase of construction projects by adopting the inter-organisational theoretical perspective (Gray 1989) and small group interactions theory (Bales 1950). Through this study, the model has demonstrated its usefulness as an explanatory model in mapping the development of interdisciplinary collaboration efforts through the four phases, including the identification of a smooth collaboration path and a disruptive one. These paths can help scholars and practitioners predict the specific conditions under which project teams are likely to perform effectively in the detailed design phase (Kalsaas, Rullestad & Thorud 2020). In addition, the model enabled mitigation actions to be observed, and these actions may be useful for organisations seeking to address collaboration problems.

8.2 Discussion of the second research question

This section presents the findings related to the second research question:

RQ 2: How do organisations manage interdisciplinary collaboration in detailed *design meetings of construction projects?*

> *RQ 2.1: What factors are relevant to the success of interdisciplinary collaboration in detailed design meetings?*
>
> *RQ 2.1: What approaches do organisations use to address problems in interdisciplinary collaboration in detailed design meetings?*

This question was investigated through analysis of data from the extended version of the interviews on participants' views and insights about collaboration processes and outcomes. This step involved analysing the practices of the smooth and disruptive collaboration paths discussed in Sections 6.4 and 7.4 using the coding methods of analysing the interviews outlined in Section 5.5.6. The analysis identified a range of factors including process and social-reaction factors for managing interdisciplinary collaboration. These findings are important as they provide new insight into face-to-face collaboration that help in differentiating between a smooth process that leads to a collaborative advantage and a disruptive one in which participants feel strained and collaborative inertia occurs. As highlighted in the above section, the variance in participants' collaboration rating was reflected in their different interpretations of the processes and outcomes of collaboration. Hence, to determine the level of focus on processes and outcomes, the extended interviews were further categorised and coded on the four phases of collaboration in the CPDD model together with the antecedents that the subcontractors referred to when discussing reasons for their ratings. Accordingly, the percentage of coded sections for the phases (problem and direction settings) and outcomes phases (objective and subjective outcomes) are presented in Tables 8-4 and 8-5 below.

Table 8-4 Case study A – Percentages of coded sections for process and outcome phases

Participants	*Antecedents*	*Problem setting*	*Direction setting*	*Total: Process*	*Objective outcomes*	*Subjective outcomes*	*Total: Outcomes*
Client (L1)	-	22%	11%	33%	67%	-	67%
Architect (R2)	-	50%	31%	81%	6%	13%	19%
Façade consultant (F1)	-	45%	27%	72%	9%	18%	27%
Main contractor (C1)	-	55%	27%	82%	9%	9%	18%
Subcontractor A (T2)	7%	40%	53%	93%	-	-	-

Table 8-5 Case study B – Percentages of coded sections for process and outcome phases

Participants	*Antecedents*	*Problem setting*	*Direction setting*	*Total: Process*	*Objective outcomes*	*Subjective outcomes*	*Total: Outcomes*
Client (L1)	-	7%	26%	33%	48%	19%	67%
Architect (R2)	-	55%	25%	80%	3%	18%	21%
Façade consultant (F1)	-	58%	12%	70%	10%	20%	30%
Main contractor (C1)	-	37%	39%	76%	7%	17%	24%
Subcontractor B (P3)	12%	58%	12%	71%	12%	6%	18%

Note: (-) sign indicates that no comments were coded for that category

The percentages in Tables 8-4 and 8-5 show that the interviews were dominated by discussion about the process phases (problem and direction setting) for all participants except the client (L1) who did not put as much emphasis on these phases. As noted in the previous section, the client was primarily concerned with the objective outcomes. The interviews also showed the variety of views related to the subjectivity aspect of collaboration, especially for participants who focused on the processes in their ratings, the architect (R2), façade consultant (F1) and main contractor (C1) in both cases. These participants were keen to reflect on their satisfaction or dissatisfaction with the process and the way it was managed as seen in both cases. Tables 8-4 and 8-5 also show that the client (L1) expressed some opinions in case study B (bespoke design) as reflected in the subjective outcomes, while keeping his comments in case study A on the objective outcomes only. These findings raised the need to explore both process and social reaction factors. These factors are important in illustrating how the interactive process and outcomes of collaboration are viewed by firms in different collaboration environments, which are explored in the following subheadings.

8.2.1 Process factors

The analysis of participants' interviews identified several themes related to processes of collaboration that may be relevant to the success of the collaboration. These themes are: dyadic relationships as a catalyst, centralised control of information flow, bias in judgements on design status, practices that do not align with contract obligations, and unclear assignment of cost responsibilities

a) Dyadic relationships as a catalyst

The study reinforces findings in the literature that a dyadic relationship can be an important stage in developing a broader collaboration that includes all participants (Bedwell et al. 2012; Goffman 1974; Gray & Purdy 2018). This was practically evident in case study A (standard design) as a mutual understanding between the architect team and the subcontractor's senior project manager (T2) developed in early meetings. From the very beginning of the design discussions, the principal architect

(R1) was confident that the geometric shape of the façade panels was understood, as discussed in Section 6.4 achieving design integrity. Thus, a pattern of exchanging explanations, opinions and suggestions emerged between them that led to developing a common understanding of each other's technical constraints. Such practices would have been helpful in case study B (bespoke design), however successful dyadic relationships did not develop despite the architects and subcontractors being design partners. The architects developed the conceptual design, and the subcontractor completed the design documentation. In separate occasions in case study B, the architect's façade engineer (R3) had successful collaboration interactions with the subcontractor's engineer (P5) because they had known each other for a very long time. However, this relationship was limited to a particular task and their successful dyadic relationship did not affect wider collaboration. This relationship was interesting as the same architect's façade engineer (R3) had a very confrontational relationship with the structural engineer (P2), who was one of the main members of the subcontractor's team. When they should have been working together because of the interdependency of the structural system design task, their discussions were confrontational causing collaboration inertia. This problem was resolved later by one of the individual interlocking approaches, the intervention of temporarily changing roles (Section 7.4).

The observation of dyadic relationships that were based on the interdependence of design tasks represents an interesting finding because it suggests that collaboration in construction projects starts by having the knowledge to build a shared understanding of the issue under investigation, even if all participants were not included initially. Some participants have the ability to attract others to adopt their frame, and thus it spread across the entire team. For example, in case study A, the subcontractor's senior project manager (T2) elaborated in his explanations of the façade design, components, manufacturing and installation on site, which matched the architects' interest in achieving the design integrity forming a dyadic relationship. The extensive explanations of the subcontractor's senior project manager (T2) attracted other participants listening to these discussions, such as the client's delivery manager (L1), façade consultant (F1) and main contractor (C1), to adopt T2's frame of viewing the design problems and methods of solving them. Thus, his frame diffused across the façade team and became the norm method for exploring solutions at a cross-organisational level. These practices of frame alignment highlight the potential value of inter-organisational theory (Gray 2003; Gray & Purdy 2018) as a novel approach to study collaboration processes at a project level in future research in construction management. Further, this process factor illustrates the collaborative practices that can exist in a traditional procurement setting such as the one studied in this research (Section 5.3.1) and supported by findings from a recent study (Koolwijk et al. 2018).

b) Centralised control of information flow

Centralised control of information flow was found to be a negative factor in achieving smooth collaboration. Sharing information freely among participants is one of the fundamental antecedents of collaboration. Multiple research studies suggest benefits when participants in a collaboration setting are allowed to communicate project information among the team without restrictions (Aghania, Ramzani & Raju 2019; Baiden, Price & Dainty 2006; Rantsatsi, Musonda & Agumba 2020). Participants in this study felt that managing information flow centrally was a tactic to control their working procedures that affected collaboration negatively. For example, in both case studies, the main contractor's project engineer (C1) repetitively directed the architects and façade consultant to send him their inquiries, comments on the proposed design solutions and design suggestions and he would disseminate them to the subcontractors. In other words, he did not encourage direct communication between the architects and façade consultant and the subcontractors despite the fact they were involved in face-to-face weekly meetings. This practice could be regarded as a suitable planning management approach to control the project program, however it slowed down the design progress because of the waiting time associated with processing these inquiries. In many cases, the architects and façade consultant did not receive the subcontractor's responses early enough to prepare their comments before the next meeting. As the architect mentioned, this was an "*impediment to progress because they [main contractor] don't issue information to the subcontractor quickly enough and they don't submit stuff to us*".

A clear example was seen in case study B. The façade consultant (F1) raised issues of the lack of engineering information provided by the subcontractor team to the main contractor's project engineer. After a long confrontational discussion between the façade consultant (F1) and the subcontractor's design manager (P1) regarding the missing engineering details, the main contractor' project engineer (C1) just asked the façade consultant to send him these inquiries. It is interesting that the façade consultant (F1) sent these inquiries earlier but they were not passed on to the subcontractor team as the subcontractor's design manager (P1) was unaware of them causing delays as quoted by the façade consultant: "*the problem is that they [referring to the subcontractors] haven't completed their engineering to a level where they know if it is or isn't a problem and we've been chasing that for a long time now"*. As such, due to the attempt to control information centrally, the main contractor's project engineer (C1) was not fully engaged in this discussion to protect the subcontractor team from being blamed for delaying the design developing, demonstrating practices highlighted in the literature as the highly transactional relationship between the main contractor and subcontractor (Deep, Gajendran & Jefferies 2020).

Another form of centralised control of information flow was seen in the communication about the design scope that occurred at the very start of the detailed design phase. In case study B (bespoke design), the architects and façade consultant were newly informed of changing the design scope and were given limited information about it. Managing such major design change was not successful from the perspective of the architects and façade consultant because the new scope of the subcontractor's work was not shared with them. This practice made them think that the main contractor team played the architects' role and redesigned parts of the façade as quoted by the architect "*they [referring to the main contractor] took it upon themselves to play architects and to accept things that were not on our documents and we have to live with those, well some of them we managed to change and get back*". This misunderstanding caused a very intensive period of collaboration with several disagreements and tension between participants, especially in the first eight meetings.

Lastly, another form of centralised control of information flow was seen in the main contractor's construction manager's (C5) practices of using it as a means of exerting more control over participants' working procedures. For example, in both case studies, he would repetitively ask the architects and façade consultant about a specific date for submitting their design drawings indicating that they were slowing down the design development. The architects and façade consultant ignored these inquiries because they were dissatisfied with the way the information flow was managed.

These practices together reflect the recognised and yet unresolved challenges of managing information flow in a way that can handle design changes while coping with the interdependence between firms involved in the detailed design phase (Kalsaas, Rullestad & Thorud 2020). As Suprapto et al. (2015) noted, the quality of communication between team members is reflected in the openness, structure and timeliness of the exchange of information. As shown in the findings of this study, centralised control of information flow reduced the openness and timeliness of information exchange and reduced the quality of communication and collaboration.

c) Bias in judgements on design status

Perceptions of bias in judgements on the design status was another process element related to negative views of collaboration. The design progress needed to be fairly evaluated to manage the deliverables timeframe and interdependence of design tasks. This involved impartial judgements about the level of details in submitted design solutions, the centre of the ongoing discussions. For example, in several occasions in case study B (bespoke design), the main contractor's team was not impartial in the way they judged the level of details in the subcontractor's design solutions, which created tension between participants as articulated by the façade consultant: "*what I really don't like is when people like the subcontractors get asked that same question about the design submissions and they don't do what they are supposed to do by that date so the subcontractors haven't issued anything on time so far*". The architects and façade consultant complained that they spent the whole meeting answering inquiries about dimensions rather than discussing the feasibility of the proposed structural system and façade connections due to the lack of information given by the subcontractors. On the other hand, the subcontractor's design manager (P1) and structural engineer (P2) avoided discussing engineering details because they wanted to simplify the design due to the cost and risk associated with selecting the cantilever system as per the architects' drawings and this approach was accepted by the main contractor team due to the complexity of the façade (discussed in Section 7.4 holding back information). As such, the design development was delayed by eight weeks as the design intent principles were not approved as scheduled.

In a further example, in case study A (standard design), the façade consultant (F1) submitted a report to the main contractor detailing the required performance tests for the glass panels and cladding materials that matched the client's guidelines. The subcontractor's senior project manager (T2) thought that his performance tests satisfied these requirements and proposed conducting the tests earlier than the scheduled date to help save time. The façade consultant (F1) raised his concerns about the missing tests and accordingly rejected some of the subcontractor's glass samples. Later, the main contractor's project engineer (C1) and construction manager (C5) argued that these requirements were not clearly articulated in the report, and the façade consultant was unhelpful in this performance testing task. This triggered tension in the meetings as the main contractor team was trying to use the opportunity to reduce the timeframe of performance tests proposed by the subcontractor but had to accept the additional tests to fulfil the client's requirements as articulated by the main contractor's project engineer (C1): "*I mean the aesthetics drive this project beyond its means; aesthetics comprise cost and comprising time and also performance*". Thus, the main contractor team blamed the façade consultant for delaying the process, and again the façade consultant ignored these claims because of his dissatisfaction with the impartial judgements about the level of details in submitted design solutions.

These practices present examples of goal misalignment in ongoing collaboration processes and its impact on communication behaviours. These findings support arguments by Manata et al. (2020) and Suprapto et al. (2015) that there is a need for continuous monitoring of actual processes of collaboration at the project level to elevate team building and interpersonal relationships.

d) Practices that do not align with contract obligations

Practices that do not align with contract obligations are associated with negative collaboration experiences. The contract type formed obligations on firms involved in the project that need to be followed as part of the agreement. At the individual level, these obligations shape participants' practices and responsibilities that might not be their preferred way of working practices, causing discomfort and conflicts. For example, the main contractor organisation had a managing contractor agreement with the client, meaning that they need to ensure that the design integrity is achieved, and the project is completed within the cost and time limitations. At an individual level, participants might have a different preference than their organisational goals because it involved changing their common working practices. The main contractor's project engineer (C1) preferred the design and construct (D&C) contract environment because it limits the number of design refinements, thus as the design progressed he became frustrated with the architects changing their mind about some design tasks regardless of whether these changes would benefit the client or improve constructability on site as quoted: "*if this was a D&C contract, we would be making the decisions and we would no longer be talking about these issues, they would be gone*". These practices add further insights into the work done by Bresnen and Marshall (2000b, 2002) on understanding the implementation of contract obligations at a project level and how the preferred working practices of some participants can impact their intention to collaborate effectively.

e) Unclear assignment of cost responsibilities

The unclear assignment of cost responsibilities is associated with negative perceptions of collaboration. The responsibility of managing cost was not clearly assigned, and therefore was all participants' responsibility. This process factor was evident in case study B (bespoke design) as the cost information was not adequately discussed in the meetings. The subcontractor team prolonged proposing a clear design approach of the main structural system and major façade types because of the associated risk related to the size of façade panels. After a number of meetings, the architect team started to complain about the missing design information and were not given clear answers but had long discussions about design complexity with no clear direction. The subcontractor adopted this policy of restating the design complexity and providing minimal cost information to hedge their risk. The main contractor's project engineer (C1) could not push them to develop the design because it might be outside their scope of work, thus it would cause cost overruns. The result was long design discussions with minimal cost information and uncertainty about cost responsibilities.

The architects and façade consultant felt that the scope reductions and the cost implications were everyone's problem while they were not involved or informed about this decision. For instance, the façade consultant (F1) was confused about the scope as quoted: "*it wasn't in their scope, I don't know who made that decision; I wasn't a part of that discussion and the architects issued a document to the main contractor a month before they went out to tender and they actually said these are all the facade types performance needed to be included in the tender*". The architects shared the same concerns because they were worried about the design integrity in the initial meetings as quoted: "*Number one the way in which the scope was managed through the tender process meaning that every time the tender was sent back out again, every time adjusted the opportunities not to provide what was required multiply and they don't just go up incrementally they double and they quadruple*". These ongoing problems of cost adjustments made the principal architect (R1) decide not to attend the meetings and he left the senior architect (R2) and façade engineer (R3) to handle the subcontractor's inquiries about the design information as no major design decisions had been made in the first eleven meetings.

On the other hand, case study A (standard design) demonstrated a clear flow of cost information between participants because the subcontractor's senior project manager (T2) was clear about the cost information. The approach was to send the proposed design solutions and the cost of façade components to the main contractor team to disseminate it so the team could discuss the proposed design solutions openly in the following meeting. Participants were then clear about the cost responsibilities, which facilitated the process of deciding on the best design option as explained in Section 6.4 on adopting practical design solutions due to detailed feedback.

The above practices represent two contrasting approaches of open cost-related information environments despite both cases having the same contractual setting. This finding suggests that the working structure set up by the subcontractor in case study A was the driver of good collaboration reinforced by the positive process factor of *dyadic relationships as a catalyst* explained earlier. The main finding is collaboration can exist in traditional procurement methods. This is an important finding because collaboration has been dominated in the construction industry as a result of using formal multi-party agreement (Bresnen & Marshall 2002; Eriksson & Westerberg 2011; Meng 2013). This finding is also supported by Koolwijk et al. (2018) who found similarities between the traditional and integrated project delivery methods in fostering successful collaboration given the long-term relationships between main contractors and clients, or main contractors and subcontractors. On the other hand, the implications of the lack of transparency about cost information together with the design complexity that was seen in case study B (bespoke design) represent some of the challenges in managing the design because of its interdependence and iterative nature in the detailed design phase (Kalsaas, Rullestad & Thorud 2020).

In summary, while the dyadic relationships were seen as a positive factor, collaboration was found to be negatively affected by centralised control of information flow, bias in judgements on design status, working practices that did not align with contractual procurement obligations, and unclear assignment of cost responsibilities. However, these process factors were not reviewed or addressed by managers. The management interlocking approach was implemented only after recognising the implications of social reactions on participants' progress in the detailed design phase. Social reactions tend to lag the process factors – reflecting outcomes from the process. The social reaction factors are discussed next.

8.2.2 Social-reaction factors

In addition to the above process factors, a number of other themes related to social reactions affected the collaboration. The social-reaction factors demonstrate differing personalities and attitudes and tend to reflect the outcomes from process factors. The following sections explain the social-reaction factors of 'differing frames' and 'signs of impending tension'.

a) Differing frames of design problems

Social reactions related to differing frames underpinned negative perceptions of collaboration. Participants' interviews revealed that they drew on different frames and risk perceptions when they evaluate the same problem. For example, in case study A (standard design), participants interpreted the design changes associated with the proposed cladding material and the risks involved differently. As discussed in Section 6.4 in case study A, the frames included concerns about standards and methods for testing fire safety, the impact of changes, and the influence on reputation if a cladding product was to be rejected. These different frames resulted in serving the client a variation because the decision of changing the cladding material occurred in meeting 17 after the design documents were almost finished and thus it would delay the subcontractor work.

A further example was seen in case study B (bespoke design) in the difference of risk perceptions when participants evaluated the design of the structural system and had different ways of framing the same design problem. As discussed in Section 7.4, participants' frames included concerns about being unable to achieve the design integrity, the risk involved with designing large glass panels, and cost overruns. Thus, the discussions of the main structural system lasted for several meetings with no clear direction as all the proposed design solutions were rejected by the architects causing eight weeks of delays in approving the design intent principles.

The concerns expressed about the number of design reviews were another area where different frames existed in both cases and were demonstrated in the design and construction literature. The main contractor's project engineer (C1) considered the design refinements as excessive reviews that increased the workload required to coordinate information needed for approving the design solutions (Smith 2010). Meanwhile, the architects and façade consultant considered the design refinements as fundamental as they are common practices that add value to the client (Kalsaas, Rullestad & Thorud 2020). As the meetings progressed, the main contractor team could not tolerate the design refinements and adopted a policy of rushing the design discussions between architects, the façade consultant and subcontractors. As such, these participants felt interrupted and uncomfortable when incidents of stopping their design discussion occurred. The disparity in views about these design reviews and refinements caused dissatisfaction for both sides, which was seen in their collaboration rating patterns.

Theoretically, this study provides a novel approach using inter-organisational theory (Goffman 1974; Gray & Purdy 2018) to explain different views of collaboration in interdisciplinary teams in construction projects. The disparity in framing problems highlights that people from different organisations viewed their collaboration differently and tended to perceive the same event differently. When two participants have similar frames and manage to influence others to adopt their frame, the frame diffuses and will spread across the team and organisations (Gray & Purdy 2018). An example of these joined frames is explained in the positive process factor *dyadic relationships as a catalyst.* On the other hand, participants might not be able to persuade others to join their frame, especially in settings where conflicting frames are more likely to occur because of different backgrounds or disciplines. The existence of conflicting frames aligns with the fragmented nature of construction projects that are commonly known to involve participants from different firms and with diverse backgrounds, skills and expertise (Dainty, Moore & Murray 2007; Emmitt 2010). Conflicting frames result in what is known as a frame break (Goffman 1974). The implication of differing frames occurring at a micro level is that problems stretch in time and amplify in scope at a macro level (cross-organisational level) (Gray & Purdy 2018).

By examining the problem of differing frames in case study A (standard design) about the cladding material, the client's delivery manager (L1) and façade consultant (F1) managed to attract the architects to join their frame, but failed to persuade the subcontractor and main contractor teams. As such, a frame break (Goffman 1974) occurred and the problem amplified in scope at a cross-organisational level (Gray & Purdy 2018) in the form of a variation that increased cost of the project. Similarly in case study B, the architects and façade consultant frames aligned, however they could not persuade the subcontractor and main contractor teams to join their frame. Consequently, these differing frames were not helpful in convincing the client's delivery manager (L1) to join either of these two frames. The resulting frame break (Goffman 1974) caused the problem to stretch in time and to be amplified in scope at the cross-organisational level (Gray & Purdy 2018). This was seen in the prolonged process of agreeing on the design principles in case study B causing delays in progressing in the design intent principle stage as most of the major façade types were not resolved, which needed a mitigation plan.

Mitigating collaboration problems: An inter-organisational interlocking approach

The frame breaks threatened to cause ongoing collaboration problems that would continue to negatively affect the progress of the project. This was particularly problematic in case study B (bespoke design), and triggered a response in the form of an inter-organisational mitigation action. In order to ease the tension between participants, action was taken to change the structure of some of the meetings so that they became design-focused workshops for the complex façade types instead of the usual weekly design meetings where participants had to go through all design tasks on the meeting agenda (Section 7.4.2). A total of six design-focused workshops were conducted with the subcontractor's extended team to enable the architects to interact directly with the people who were documenting the design. As noted in Figure 7-9, the number of interactions that signalled agreement started to exceed the number representing disagreement after the design-focused workshops replacing the usual meetings were implemented. This shift suggests that the inter-organisational mitigation action of changing the structure of the meetings was successful in improving the collaboration. However, the mitigation action did not work independently – it worked with other 'interlocking' mitigation actions at the individual level as explained below in the mitigating collaboration problems: interlocking approaches at the individual level.

b) Signs of impending tension

The other type of social reaction that promoted mitigation actions involved signs of impending tension. The collaboration was perceived more negatively when there was a history of confrontation from past experience. Such experiences of confrontation from working in other projects have the potential to create tension in discussions, especially in situations where participants negotiate major design tasks and their proposed solutions such as in case study B. For example, the architect's façade engineer (R3) as a senior consultant in the industry and the façade consultant (F1) as a specialist in façade engineering had previously worked on multiple projects that included the same contractors and involved confrontation. The architect's façade engineer (R3) had a history of confrontation with subcontractor's B senior structural engineer (P2) that manifested in the current project, and instant rejection of design solutions proposed by the architectural firm. The façade consultant (F1) had learned about subcontractor B's approaches in negotiating the design through experiences in other projects. Thus, he helped the architect's façade engineer (R3) find a way to mitigate these negative practices. The mitigation approaches developed to address these issues were initiated by individuals – the architect's façade engineer and façade consultant. The mitigation actions involved temporarily changing roles to avoid confrontation and using design sketches and appropriate technical language when proposing design solutions to avoid instant rejection, as explained in Section 7.4.2.

In another example, tensions quickly developed between the architect's façade engineer (R3) and the main contractor's delivery manager (C3) due to their history of confrontation. The early tensions involved different opinions about the subcontractors' scope of work, and later tensions developed when the main contractor's delivery manager (C3) opposed a late change proposed by the architects, as discussed in the *centralised control of information flow*. These tensions affected the ongoing collaboration and was acknowledged by the main contractor' project engineer (C1), but at the end this conflict was put into perspective with C1 saying: "*as much as we fought and argued with R3 [architect's façade engineer], we actually like him, he is smart, he knows what he is talking about, we don't always agree but we do get design solutions*".

The confrontation practices resulting from previous experience point to the possibility that some participants will meet again in future projects. Dainty (2007) and Suprapto et al. (2015) argued that relationships between participants in construction are temporary because they are limited to the project timeframe, however the findings of this study challenged that view. This study showed that, although the relationships during a particular construction project were temporary, key participants are likely to have met in other projects and developed long-term professional relationships that could affect collaboration.

Mitigating collaboration problems: Interlocking approaches at the individual level

The history of confrontation between some participants created tensions and conflict that threatened the success of the project in case study B. Mitigation actions were taken at the individual level to manage collaboration. The three interlocking approaches adopted by individuals were temporarily changing roles to avoid confrontation, adopting appropriate technical language to avoid instant rejection of proposed design solutions, and using design sketches to clarify the design intent. These mitigation plans were initiated by the architects' façade engineer (R3) and the façade consultant (F1) who took part in the first interlocking approach. The first two approaches were conducted in case study B due to the complexity of the bespoke design. The third approach was implemented in both case studies because it was useful in articulating the design intent and participants used it in explaining how the proposed solutions would serve the design intent. In the absence of management attention to the conflict between participants and lack of methods to realign their goals, participants initiated individual approaches to help them move forward with the design. This finding highlights the problems that are encountered at the project level and supports Manata et al.'s (2020) argument that goal misalignment could eventually lead to unhealthy communication behaviours in the project team and impact the quality of their decisions, and needs attention from managers. However, the findings show how, in the absence of attention from managers, individuals can develop approaches at the individual level to address communication problems.

In summary, the analysis of the in-depth interviews provided deeper insights into the factors that affected the collaboration between participants in the detailed design meetings. These process and social-reaction factors and the management approaches are summarised below in Table 8-6.

Table 8-6 Process and social-reaction factors and management approaches

Elements	Observed in case A (standard design)	Observed in case B (bespoke design)	Process or social reaction factor	Impact: satisfaction /dissatisfaction/ delays/conflict	Approach in place to manage it (y/n)	Type of management approach: inter-organisational/ individual
Dyadic relationships as a catalyst	X		Process	Satisfaction	Not needed	
Centralised control of information flow	X	X	Process	Dissatisfaction	None	
Bias in judgements on design status	X	X	Process	Dissatisfaction/ conflicting opinions	None	
Practices that do not align with contract obligations	X	X	Process	Dissatisfaction	None	
Unclear assignment of cost responsibilities		X	Process	Dissatisfaction/ delays	None	
Differing frames	X	X	Social-reaction	Conflict/delays	Yes	Inter-organisational (design-focused workshops implemented in case B only, not needed in case A)
Signs of impending tension	X	X	Social-reaction	Conflict/ dissatisfaction/delays	Yes	Individual (temporarily changing roles, adopting appropriate technical language implemented in case B, using design sketches implemented in both cases)

The process and social-reaction factors summarised in Table 8-6 highlight different types of collaboration problems and identify some approaches implemented to manage and mitigate collaboration problems, and were only implemented after social-reaction factors started to impact the project progress. For example, the inter-organisational approach of changing the structure of some meetings was only adopted after the problem stretched in time, and was revealed through the social-reaction factor '*differing fames of design problems*'. In other situations, where collaboration between participants was negatively affected by the other social-reaction factor '*signs of impending tension'*, it was left to individuals to figure out ways of aligning their views and working procedures. The process factors caused dissatisfaction, especially for participants who focused on the processes in their ratings, and were not reviewed or addressed by managers.

These findings show that the inter-organisational theoretical lens (Gray 1989; Gray & Purdy 2018; Huxham 1996; Huxham & Vangen 2013) was helpful in providing valuable insights as they propose process and social-reaction factors that can be used in conjunction with the refined CPDD model (Figure 8-3) to help manage interdisciplinary collaboration in the detailed design meetings. These findings emphasise the need to recognise both the process and behavioural aspects of participants' working practices.

8.3 Conclusion

The chapter discussed the cross-case analysis and presented findings related to the second research question. The purpose of the cross-case analysis was to demonstrate a detailed account of collaboration practices in two different settings of a standard design environment and a bespoke design environment. In doing so, the first research question was revisited to investigate the similarities and contrasts between the cases in each data collection method. The second research question investigated how organisations manage interdisciplinary collaboration in detailed design meetings of construction projects. There are seven key findings.

- Detailed observation and analysis revealed differing patterns of interaction between the two case studies.
- Collaboration in case study B was more disrupted than in case study A, probably due to the increased complexity of the façade design and differing views in discussing design problems that lengthened the design approvals process.
- The patterns for smooth collaboration were characterised by a common understanding of the complexity of design and construction, and willingness to examine design alternatives, align working procedures and work out practical design solutions that generally ended in agreement among participants.
- The patterns for disrupted collaboration were characterised by lack of transparency, differing frames of design problems, being less likely to accept design refinements, and confrontation discussions that largely ended in disagreement among participants.
- Process and social-reaction factors that affect collaboration were observed across both cases.
- Process factors did not seem to prompt mitigation actions, as social-reaction factors often lagged process factors (representing outcomes from process factors) and were the impetus for mitigation.
- Mitigation actions at inter-organisational and individual levels were taken to improve collaboration, often prompted by social-reaction factors.

These findings represent the basis for future research and refinement of current understanding of interdisciplinary collaboration processes in detailed design meetings, which are presented in the conclusions of this research in the following chapter.

Chapter 9 Conclusion

The aim of this research is to understand interdisciplinary collaboration in the detailed design meetings of construction projects. A novel longitudinal methodology was developed to allow investigating the research questions into how interdisciplinary collaboration occurs and how it is managed. The method explored detailed design meetings over the course of a year, including non-participant observations, short surveys, interviews and project documents, to support an in-depth study of collaboration. Two different design environments are represented by the two case studies included in the research. Case study A involved a fairly standard design environment, while case study B was a more complex environment involving a bespoke design. This chapter summarises the key findings of this study and their contributions to knowledge, followed by a discussion of the practical implications of the study, research limitations and areas of future research.

9.1 Research question 1

The first research question stated:

RQ 1: How does interdisciplinary collaboration occur in detailed design meetings?

RQ 1.1: Are there different patterns of group interactions in different design environments?

RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?

The first section answers the research question How does interdisciplinary collaboration occur in detailed design meetings?

The literature suggests that there is a growing need to improve interdisciplinary collaboration in construction projects and highlights the challenges in bringing disparate groups together to work closely. The findings from the first research question support these literature themes, and provide new insights that suggest managers need to take an integrative approach when managing interdisciplinary collaboration. A primary contribution of this study is the development of a new collaboration model, called Collaboration Phases in Detailed Design (CPDD), tailored for collaboration in the detailed design phase of construction projects.

Collaboration in construction projects is challenging due to the involvement of multiple organisations and skilled professionals such as the client, architects, design consultants and contractors (Winch 2009). Past research has focused on examining success factors of collaboration in multi-party projects that improve the client–contractor relationship by aligning their views and interests (Meng 2013; Suprapto, Bakker & Mooi 2015). Some of the benefits from multi-party agreements are also achievable in traditional project delivery methods where they foster collaboration by integrating design and delivery processes knowledge such as in the design and construct (D&C) and construction management (CM) contracting settings (Koolwijk et al. 2018; Walker & Lloyd-Walker 2015).

The design and construction literature has identified collaboration themes that focus on collaboration enablers and outcomes leaving the interactive process the least understood and needing a systematic approach to examine it at a project level (Boton & Forgues 2017). Collaboration varies throughout the whole design phase because of the change in interests between the designers and contractors (Forbes & Ahmed 2011). As such, the detailed design phase is critical as it represents the change point between the design and construction phases. Participants' discussions in the detailed design phase include exploring and refining design solutions, explaining and reflecting on each other's ideas and concerns, and negotiating design and cost decisions. Due to the confidential nature of discussions in the detailed design phase, it is difficult for researchers to gain access. Studies have been limited to projects facilitated by university research centres and by being a researcher involved in the construction project (Nguyen, Lostuvali & Tommelein 2009; Parrish et al. 2008; Staub-French & Khanzode 2007).

A primary contribution of this research is the development and refinement of a four-phase collaboration model, the collaboration phases in detailed design (CPDD). The CPDD model incorporates and expands on themes from the literature that were limited in describing the interactive processes of collaboration (phases 1 and 2 of the CPDD model), and findings from the research reflect the nature of the interactions in the detailed design phase. A unique aspect of the CPDD model is the way it brings together two theoretical perspectives of an inter-organisational theoretical lens (Gray 1989) combined with methods for analysing group interactions (Bales 1950). Inter-organisational theory recognises the complex nature of interdisciplinary collaboration and differentiates between antecedents, process and outcomes. The CPDD model draws on Gray's (1989) four phases and pairs this with theories on group interactions (Bales 1950) to represent and investigate interdisciplinary collaboration in the detailed design phase.

The use of Bales (1950) protocol for coding participants' interactions supported the ability to capture the interactions in this research through observations and coding. This is an important aspect of the CPDD model and the associated novel research methodology of using a structured approach of coding observation data compensated for the inability to record the meetings in such a sensitive environment. In addition, the original Interaction Process Analysis (IPA) (Bales 1950) categories were modified by adding two categories labelled as ‘gives confirmation’ and ‘asks for confirmation’ to capture participants’ interactions in coordinating technical constraints to meet the design deliverables timeframe that exists in the construction environment.

The CPDD model incorporates the themes related to the interactive process and outcomes dimensions and aligns them with the relevant phase of Gray’s (1989) model of collaboration process. The first phase of the CPDD model is the problem setting where participants define the problem by conducting a rigorous analysis to develop a common understanding of each other’s concerns regarding the design task they are investigating in terms of design, cost and program constraint. Two interactive process themes are represented in this phase: the *interactive coordination* and *aligning incentives interests*. The second phase in the CPDD model is the direction setting phase where participants work towards refining design solutions and collectively reaching an agreement on the best solution, which is represented by the *collective decision making* theme. Participants’ interactions in these two process phases are combined with task-based questions and attempted answers categories (Bales 1950) to capture participants’ interactive discussions.

Lastly, the outcomes themes were split into objective ones measuring what participants achieved, such as *value for money, design integrity and manage to stay within budget and time limits* and subjective themes measuring satisfaction with the collaboration processes. The third phase in the CPDD model, the objective outcome phase, is combined with the social reactions that recorded agreement and disagreements between participants (Bales 1950). The subjective measure represented by the developed *trust in expertise and capabilities* is combined with the IPA (Bales 1950) social emotional reactions that capture signs of satisfaction and tension. As such, the initial CPDD model guided this research to study collaboration as a phenomenon that is socially constructed by the participants through a longitudinal investigation involving observations, capturing perceptions and in-depth exploration of their interpretations of collaboration. Therefore, the initial CPDD (Figure 4-5) model brings the inter-organisational theory (Gray 1989) and group interaction (Bales 1950) concepts together and incorporates the design and construction themes into the four phases of collaboration in design meetings, highlighting the differences in interactions between the processes and outcomes.

RQ 1.1: Are there different patterns of group interactions in different design environments?

The findings suggest that there are different patterns of group communication in different design environments, and provide detailed insights into the nature of these patterns and some possible explanations. The research investigated this question by providing detailed findings on the nature of collaboration in detailed design meetings and on the differences between a standard design (case study A) and a bespoke design (case study B). As expected, the complex case encountered more problems with the collaborative process than the standard case. The difference between participants' discussions in the two cases was primarily reflected in the social reactions, especially disagreements, which were much more common in the complex, bespoke design (case study B), and in different patterns of interactions.

The interaction patterns were further investigated by using (Bakeman & Gottman 1997) method of transitional probabilities to examine the sequential interactions to detect the movement between phases in the CPDD model. In the standard design (case study A), collaboration advantage was detectable and emerged from patterns of giving explanations that were followed by positive social reactions such as expressing gratitude demonstrating mutual understanding of technical problems and tolerance in their discussions. These findings demonstrate the process of knowledge creation and integration proposed by Dietrich et al. (2010) at a project level and how activities of feedback lead to collaboration advantage. These task-based interactions were followed by social reactions in the form of signs of appreciation and gratitude, which substantiate the findings of Suprapto et al. (2015) related to the impact of positive social reaction on team performance. This level of mutual understanding was much needed in the bespoke design (case study B) due to the additional design challenges, however the quality of information given in the meetings was inadequate, which resulted in collaboration inertia. This static status was detectable by patterns of giving information followed by disagreements and signs of dissatisfaction suggesting that participants were less willing to make compromises in negotiating design decisions and reflecting low levels of commitment that affect the quality of decisions and consequently the team performance (Manata et al. 2020).

These findings can help managers monitor participants' interactions and encourage feedback and brainstorming to facilitate agreement on proposed solutions. The findings also suggest that failing to consider the disagreements and signs of tension between participants might lead to bad consequences on team performance in the form of goal misalignment that hinder decision making.

RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?

The findings suggest that participants had different views of their collaboration and focused on different phases of the CPDD model when explaining how they rated the collaboration. The in-depth interviews incorporated in the research methodology enabled further investigation of participants' views, which revealed that the client was concerned with the outcomes rather than the processes of collaboration, and the subcontractors were interested in the antecedents of collaboration. On the other hand, the main contractor, architects and façade consultant shared the same view of focusing on the processes of collaboration. The variance between participants' rating of collaboration was much higher in the bespoke design (case study B), especially due to the lower ratings from these participants who focused on the processes of collaboration showing a great deal of dissatisfaction with managing their working procedures.

Participants in case study A managed to develop a good understanding of complexities of technical problems, which made them willing to examine design alternatives and share cost-related information freely among them. Consequently, practices of aligning working procedures emerged and participants were able to collectively agree on the best design option. These practices were essential elements to the collaboration advantage in the standard design (case study A). On the other hand, in the bespoke design (case study B), practices of lacking transparency and different ways of framing problems made participants unwilling to examine design alternatives and unlikely to accept design refinements due to the excessive design changes causing collaboration inertia. Taken together, these working practices illustrate two collaboration paths: a smooth path in case study A and a disruptive one in case study B. The smooth collaboration path suggests practices that bridge the opposing traits between designers' and contractors' working practices at the project level (Emmitt 2010; Eynon 2013; Winch 2009). The disruptive collaboration path represents the differing frames of addressing technical problems that interdisciplinary teams might experience and demonstrated the need for interventions to improve collaboration performance (Gray & Purdy 2018).

However, further plausible explanation is offered to understand the lack of consensus between participants' ratings of collaboration in both case studies (Figures 6-4 and 7-4). It could be that participants had different levels of expectations of their working processes that were not declared or discussed in the start-up meeting. Such discussions would be beneficial, as an interdisciplinary team needs to agree on acceptable methods that govern their working procedures, which would be helpful to align their views on problems as they emerge in the discussions (Huxham & Vangen 2013; Thomson & Perry 2006). Another explanation could be related to the goal misalignment that can occur at any point during the detailed design phase and the lack of attention from the management level to address team building activities to improve team performance (Bresnen & Marshall 2002; Suprapto, Bakker & Mooi 2015).

9.2 Research question 2

The second research question stated:

RQ 2: How do organisations manage interdisciplinary collaboration in detailed *design meetings of construction projects?*

> *RQ 2.1: What factors are relevant to the success of interdisciplinary collaboration in detailed design meetings?*
>
> *RQ 2.2: What approaches do organisations use to address problems in interdisciplinary collaboration in detailed design meetings?*

Overall, the findings suggest a lack of attention from management to the ongoing working processes of collaboration during the detailed design meetings. Rather than focusing on the processes, management sought to improve collaboration through mitigation action when social reactions became negative and delays or other problems emerged. The research identified of a range of collaboration process and social-reaction factors that are thought to be relevant to managing collaboration in the detailed design phase. Both process and social-reaction factors were related to collaboration problems, however management did not seem to measure or address collaboration process problems. Instead, the management approaches were only implemented to help participants restore their collaborative efforts once social-reaction factors were observed.

A positive influence on collaboration was observed from a process factor where a dyadic relationship resulted in a broader collaboration that included all participants, such as the one that started between the architect and subcontractor in the standard design (case study A). While these practices would have been helpful in the bespoke design (case study B), constructive dyadic relationships did not develop as participants in initial meetings had conflicting views that were reflected in their confrontational discussions. Interestingly, collaboration between participants was negatively affected in case study B, but it was not addressed from the management perspective. Instead of reviewing participants' practices, management approaches were implemented after recognising the implications of confrontational discussions on the development of the design documentation.

The first sub question investigated was *What factors are relevant to the success of interdisciplinary collaboration in detailed design meetings?*

Another contribution of this research is the identification of a range of process and social-reaction factors that influence the collaboration and reflect participants' working practices, attitudes and behaviours in the detailed design meetings. The research identified one process factor that was related to the success of collaboration, which is the establishment of dyadic relationships as a catalyst for broader collaboration that occurred in case study A. This relationship was established between the architect's representatives and the subcontractor's senior project manager as they managed to develop a good understanding of the technical problems. From the inter-organisational theoretical perspective, the way these practices attracted other participants who joined discussions, extended their knowledge and consequently changed their views represents the concept of frame diffusion at the organisational level (Gray & Purdy 2018). These practices also demonstrate that collaboration can exist in traditional procurement settings and have some similarities with integrated teams in multi-party procurement approaches (Koolwijk et al. 2018).

The other process factors observed in this study affected collaboration negatively. First, centrality in managing information flow that was practised as a managing approach for project control caused dissatisfaction among participants, especially the architects and façade consultant, as it restrained their communication with the subcontractors. Second, practices of partial judgements on design status caused dissatisfaction among some participants because the level of detail in the submitted design solutions was not fairly evaluated in managing the design deliverables timeframe. Third, the unclear assignment of cost responsibilities was one of the main drivers of the disruptive collaboration path in case study B because of the lack of transparency about the scope of the subcontractor's work coupled with limited cost information provided in the meetings. These practices caused delays in approving the design principles and dissatisfaction with managing the working processes. Finally, working practices that did not consider procurement obligations, such as the difference between construction management (CM) and design and construct (D&C) environments affected collaboration negatively. A design and construct (D&C) approach was the main contractor's representatives preferred working environment because it tends to limit the excessive design refinements. However, the construction management (CM) approach was the contracting setting for the cases studied. The main contractor's working practices reflected preferences that were not aligned with the current contract, resulting in dissatisfaction with design refinements despite the benefits in the construction phase.

Taken together, these process factors add specific insights to the design and construction literature by identifying barriers to collaboration advantage among interdisciplinary teams in detailed design meetings. However, they were not addressed by management approaches in the two cases. These findings draw attention to the importance of open communication channels within project team to minimise practices of centrality in managing information flow (Baiden, Price & Dainty 2006). The findings also reveal how lack of attention to goal misalignment can have a social impact on participants' working procedures (Manata et al. 2020; Suprapto, Bakker & Mooi 2015) and they might feel that they were not fairly treated when documenting the design solutions. These process factors substantiate Kalsaas et al.'s (2020) argument that there is a lack of attention to the importance of planning the design deliverables in a way that it copes with the interdependent nature of the design tasks in the detailed design phase. Further, the process factors provide in-depth insight into participants' practices at the project level that is reflected in their preference of working environment, which is different from the agreement obligations at the organisation level (Bresnen & Marshall 2000b, 2002).

The social-reaction factors observed in this study included different ways of framing the problem and reactions that gave signs of impending tension. This research examined the differing frames in the detailed design phase from the inter-organisational theoretical perspective. Findings identified situations where a frame break (Goffman 1974) occurred between participants and caused delays in developing the design documents. The impact of these differing frames was realised at the organisational level because the problem stretched in time (Gray & Purdy 2018). Social reactions that reveal signs of impending tension were related to the history of confrontation from the previous experience of some participants who had worked together in previous projects. This social-reaction factor reflected the potential to create tension in discussions, especially in situations where participants negotiate major design solutions such as in case study B leading to disagreements. This social-reaction factor affirms that relationships in projects may not be as temporary as suggested in the literature (Dainty, Moore & Murray 2007; Emmitt 2010; Suprapto, Bakker & Mooi 2015), and adds a different view by highlighting the possibility that participants will meet in future projects and that managing their interactions could prevent confrontation discussions.

The observation of these process and social-reaction factors contributes valuable examples from practice to help advance inter-organisational theory (Gray 1989; Gray & Purdy 2018) in understanding and managing the interaction between interdisciplinary teams at a project level in construction projects.

The second sub question investigated *What approaches do organisations use to address problems in interdisciplinary collaboration in detailed design meetings?*

Approaches designed to mitigate collaboration problems were observed at both inter-organisational and individual levels in case study B (bespoke design). These interlocking mitigating approaches complement each other, working together to improve collaboration and overcome delays.

The structure of meetings was adjusted (to a design workshop format) through an inter-organisational mitigation approach which was implemented after meeting 8 to ease the social reactions that were due to escalating tension between participants. Clear benefits of these workshops were aligning participants' views and maintaining relationships (Jefferies, Brewer & Gajendran 2014; Manata et al. 2020) as the number of disagreements between participants decreased in the meetings following the workshops (Figure 7-9). Interestingly, although process factors indicated the potential for such collaboration problems, it was not until the social reactions appeared that the mitigation actions were implemented.

Another set of mitigation approaches was initiated by individuals, such as temporarily changing roles to avoid confrontation in discussing engineering details and instant rejection of proposed design solutions, the use of appropriate technical language when explaining the proposed design solution, and using design sketches to clarify the design intent and proposed solutions. These mitigation actions, initiated at the individual level, were prompted by social reactions that caused delays, highlighting how participants' practices in the ongoing design discussions had disrupted their collaboration but were not addressed by management approaches and were left for them to resolve.

The identification of these mitigations actions is an important finding, in particular the role of social reactions during interdisciplinary collaboration in prompting the mitigation actions.

Table 9-1 below summarises the key findings with regard to the research questions.

Table 9-1 Summary of the research key findings

Research questions	Key findings
RQ1: How does interdisciplinary collaboration occur in detailed design meetings?	Improved understanding of interdisciplinary collaboration in the detailed design phase meetings through the development of a four-phase model (CPDD) that incorporates and expands on themes from the literature– Sections 4.3 and 8.1.3
RQ 1.1: Are there different patterns of group interactions in different design environments?	Different patterns of group interactions were observed between the standard design environment and the more complex bespoke design environment. Although some aspects of the group interactions were consistent between these two environments, differing patterns of providing information and explanations led to increased levels of dissatisfaction and a more disruptive pattern of collaboration in the bespoke design environment (Sections 6.2, 7.2 and 8.1.1).
RQ 1.2: Are there patterns of group interactions aligned with positive or negative outcomes of collaboration?	Smooth patterns of group interactions characterised by transparency and provision of clear and detailed information were more common in the standard design environment and associated with positive outcomes (Sections 6.3 and 6.4). Negative outcomes were associated with the more disruptive collaboration paths observed in the bespoke design environment (Sections 7.3 and 7.4).
RQ2: How do organisations manage interdisciplinary collaboration in detailed design meetings of construction projects?	Findings suggest a lack of early attention from management on the ongoing working processes of collaboration during the detailed design meetings. The management approaches were only implemented later, when social reactions became negative and caused delays (Section 8.2).
RQ 2.1: What factors are relevant to the success of interdisciplinary collaboration in detailed design meetings?	One positive process factor was identified, which is the dyadic relationship. The other four process factors affected collaboration negatively included centralised control of information flow, bias judgements on design status, practices that do not align with contract obligations, and unclear assignment of cost responsibilities (Section 8.2.1). The two social-reaction factors identified were differing frames and signs of impending tension (Section 8.2.2).
RQ 2.2: What approaches do organisations use to address problems in interdisciplinary collaboration in detailed design meetings?	Approaches designed to mitigate collaboration problems were observed at both inter-organisational and individual levels in case B (bespoke design). The inter-organisational approach involved changing the structure of some of the meetings to design-focused workshops (Section 7.4). Three individuals interlocking approaches were identified, including temporarily changing roles, adopting appropriate technical language, and using design sketches (Sections 7.4 and 8.2.2). The inter-organisational and individual mitigating approaches complemented each other to improve collaboration and overcome delays encountered in Case B.

9.3 Contributions and implications

The significance of this research lies in its contributions to theory and knowledge, in the practical implications in the form of recommendations to managers and practitioners, and in research methodology.

9.3.1 Theoretical contribution

This study makes a theoretical contribution by combining two theoretical perspectives in a novel way to offer a new model, the Collaboration Phases in Detailed Design (CPDD) model (Figure 8-3) tailored for collaboration in the detailed design phase of construction projects. This model is informed by combining the inter-organisational theoretical lens with methods for analysing group interactions (Bales 1950; Gray 1989). Although the inter-organisational theory is useful for understanding phases of collaboration, it is limited in measuring participants' interactions in ongoing design meetings. This has been addressed in this research by combining the inter-organisational perspective with theories on group interactions (Bales 1950) in the CPDD model. Applying Gray's (1989) model of collaboration phases in the construction context is a novel aspect of this research because the inter-organisational theoretical perspective has not been previously discussed or evaluated in design management studies. The theoretical contribution is extended through the application of the model to structure and analyse this research, including demonstrating the use of the modified IPA coding scheme, tailored for the construction environment. The combination of two theoretical perspectives in the CPDD model assisted researching and revealing patterns of interactions between interdisciplinary teams to identify the interactions that indicate a smooth collaboration path and those that signal disruptive collaboration in detailed design meetings. The inter-organisational perspective (Gray

1989; Gray & Purdy 2018) also provided a lens and a structure to analyse the in-depth interviews and reveal the process and social-reaction factors that influence collaboration.

9.3.2 Practical implications

The research offers a number of contributions through the practical implications arising from the findings. The findings reinforce and extend other studies in the design and construction industry where interdisciplinary collaboration is essential to improve performance in the design phase. Professionals in the construction industry can benefit from the findings of this study in several aspects. The integrated CPDD model can be used for detailed explanation or evaluation of participants' practices in the four phases of collaboration. It can be used by design and construction firms to evaluate and predict team performance or to modify their current practices to improve the process of managing interdisciplinary collaboration in design meetings. The integrated CPDD model can also be used for training purposes in graduate programs in engineering and construction firms to explain the working process in design meetings by portraying the collaborative phases.

Findings from this research suggest that collaboration needs a more tailored management approach based on the understanding of its four phases and regular monitoring of the process and behavioural actions. Managers could encourage communicating information freely between parties in a transparent environment, setting aside personal preference of working practices and adhering to the contract obligations, maintaining impartial evaluation of design details, clear assignment of tasks and monitoring differing frames when a problem occurs. Managers could remind participants that different interpretations of a problem do not mean by definition that they are opposing views and their underlying concerns are initially intertwined and need their interdependence. These different frames of the same problem can enhance creativity and innovation if well managed. Furthermore, if managers turn their attention to participants' attitude and signs of impending tension because of history, then they would be able to minimise confrontation and disagreements. More importantly, if participants started to lose their momentum, interventions designed to address the reasons for collaboration inertia can be implemented to help them restore their efforts. This research provided examples of interlocking approaches that were used to mitigate collaboration problems that could inspire organisations to try similar approaches.

9.3.3 Contribution to research methodology

The research has developed and applied a longitudinal methodology to measure and assess collaboration in two different design environments. The methodology used in this study contrasts with the positivist approaches often used. For example, recent studies focused on multi-party projects and adopted a positivist approach to examine the similarities between collaboration attributes in integrated project delivery approaches and traditional project delivery methods (Koolwijk et al. 2018), to test the role of teamworking as a mediator of collaboration (Suprapto, Bakker & Mooi 2015) and to examine the effects of communication behaviour, goal alignment and decision quality on team dynamics in integrated project delivery projects (Manata et al. 2020).

The methodology designed for this research enabled capturing collaboration interactions and participants' perceptions that allowed the investigation of a range of contextual and complex views through a series of meetings over the duration of a full year. The methodology provided the levels of depth and details needed to explore collaboration in context and capture participants' insights through a case study framework that was adopted, which enabled following the theoretical replication logic for predicting contrasting results and investigating the similarities and differences between two cases with different levels of design complexity and challenge (Yin 2017). Two projects involving different types of façade packages for the same educational building project were the basis for the research: a standard façade design (case study A) and a bespoke façade design (case study B). The standard façade type represented a less complex set of design challenges than the bespoke façade, thus providing two contrasting settings in which collaboration was explored.

A primary contribution from the methodology is extending the observations method incorporated and extended Bales' (1950) Interaction Process Analysis (IPA) coding framework to capture participants' interactions while observing meetings, and later to analyse collaboration patterns in the four phases of the CPDD model. The research modified the original IPA method after testing the application of this method in the pilot study that was conducted in ten meetings in the tender phase of the chosen project. The modification included adding two task-based categories to the existing 12 categories to differentiate between incidents of confirming actions and incidents of exchanging information and coordination actions. The new task-based categories are 'asks for confirmation' and 'gives confirmation'. These additional categories helped in coding unique situations in the detailed design phase where a participant confirmed design information needed to proceed, and showed obligation and commitment to perform a design task. Thus, the developed coding framework included two new task-based interactions categories tailored for the specific environment of detailed design meetings, and enabled investigation of participants' interactions by following a systematic method of coding each incident in participants' discussions.

Further, the research method designed for this study enabled the quick capture of perceptions about collaboration from key participants representing the organisations involved in the project through a short survey, along with deeper explorations of their views and insights into the processes and outcomes through in-depth interviews. This led to a further contribution: an in-depth look at collaboration perceptions that reflected the realities constructed by the participants involved in the design meetings. The analysis of participants' ratings reveals differences in the ways that people from different organisations in construction viewed the collaboration. Thus, the research methodology provided a holistic means of evaluating collaboration practices among interdisciplinary project teams that was tailored to meet the challenges associated with detailed design meetings.

The novel methodology designed for and applied in this study contributes to the methodological options available to researchers facing similar challenges. Through a mix of multiple methods, informed by and tailored to the detailed design meeting environment, the research methodology provided a practical and holistic means of evaluating interdisciplinary collaboration practices in the detailed design meetings. The findings from the use of the novel methodology for the study demonstrate its utility in identifying patterns of interactions and themes relevant to management in such meetings. Other researchers may draw on or further adapt this methodology in future studies.

9.4 Research limitations and recommendations for future research

The findings must be considered taking into account the limitations of the study, which are outlined in this section. Future research can address limitations as well as other future ideas suggested by this research.

First, the two case studies were limited to vertical construction (including client, architects, consultant, main contractor and subcontractors) in a construction project in Sydney, Australia. Restricting the study to two cases enabled gathering the data for the whole duration of the detailed design phase, but the cases may not be representative of other cases in Australia or cases in other countries or other situations. Future research is needed to explore other environments, and to test the application of the CPDD model and the methodology. Future studies could aim to investigate other projects, perhaps in other locations or with larger teams, in similarly complex construction projects in order to increase understanding and provide indications of the confidence in the findings presented in this study.

Second, the confidentiality of the information exchanged in the detailed design phase affected the method of recording participants' interactions in the design meetings. Although Bales' (1950) IPA method was instrumental in supporting this study, further detail and understanding could be obtained if future researchers are able to gain access to audio or video recordings that would provide rich data. However, in situations where the recording of meetings is not possible and direct observations are undertaken, future research could replicate the multiple types of data collection methods used in this research. Such future research would provide further evidence of the utility of coding data using Bales' (1950) IPA method, and look for ways to further tailor the categories for detailed design environments, or apply this type of approach to new environments and tailor accordingly.

Third, the thesis built on the collaboration themes extracted from the design and construction literature and examined the inter-organisational domain to develop a theoretical understanding of collaboration phases in construction projects. Further replication efforts will increase the credibility of the CPDD model presented here, especially if they are conducted at the detailed design phase to help generalise the results. Future research can focus on validating the developed CPDD model by gathering feedback about collaboration processes from professionals in different types of projects to specify additional practices at the project level that lead to smooth or disruptive collaboration paths. Such practices will contribute to the development of the application of the existing inter-organisational theoretical collaboration model (Gray 1989) in construction projects, which would address concerns relating to generalisation of findings. The study also highlighted other inter-organisational frameworks that can be used in future research to study the administrative aspect of collaboration in construction projects.

Fourth, it is important to highlight the limitation of the methodology used to investigate collaboration patterns, in particular that such a methodology cannot be used to determine statistical or causal relationships between any interactions. The method is suitable to identify patterns and suggest possible associations within task-based interactions and social reactions resulting from the sequential analysis. Future research might investigate whether the patterns observed in this study exist in different procurement settings to develop consolidated information about face-to-face interactions in design discussions. Future research could also explore team dynamics by using the modified IPA coding scheme (Table 5-2) to compare the number of interactions of each participant to profile collaboration patterns for people from different organisations and measure the degree of their involvement in ongoing discussions and whether they differ in other procurement settings. Such replications would provide more insights into the collaboration process, improve the generalisation of findings, and further test the methods and model developed for this study.

Finally, the research design developed a simple survey tool to collect participant ratings after each meeting, asking them to rate their collaboration experience. The simplicity of the survey question was designed to maintain a high level of response by making it very quick and easy for participants to reply to the rating emails weekly for a whole year. However, findings showed that the participants focused on different aspects of the collaboration when rating. Future research could split this survey question into two parts: one part asking participants to rate the process, and the second part to rate the outcome. This modification would help direct participants' focus on phases of collaboration, and may affect whether and how participants' ratings align.

9.5 Concluding Comment

Through a novel methodology, this research explored collaboration during the detailed design phase of construction projects and contributes to the growing literature on the need for better interdisciplinary collaboration in the construction industry to improve performance. The detailed design phase is critical for managing the change point between the design and construction phases. This research developed a four-phase collaboration model, the CPDD model, that reflects the nature of the interactions in the detailed design meetings and presents a new approach to monitor and evaluate participants' practices. A key emphasis of this model is to differentiate between the interactive processes and outcome phases of collaboration.

A combination of the inter-organisational theoretical lens and group interaction analysis theories provided a holistic approach to research collaboration and its management. The results demonstrate the use of a tailored approach to provide understanding of the four phases of collaboration, revealing patterns of both smooth and disruptive collaboration, themes related to process and social reactions that may affect the success of the collaboration, and actions that were used to mitigate collaboration problems.

In summary, this study contributes to research methodology through a novel longitudinal data collection and analysis approach tailored to the detailed design method and contributes to knowledge and theory through incorporating inter-organisational and group interaction theories to present and refine the CPDD model and to derive findings on patterns of interactions. The findings have multiple implications for practice including offering a model and methods that organisations can use to analyse and review collaboration, and providing examples of approaches to mitigate collaboration problems that may inspire organisations to apply similar approaches.

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Appendices

Appendix I – Interview Questions And Ethics Approval

Documents needed before conducting the interviews:

- Participant's ratings to remind them
- Prepare critical incidents (positive and negative) occurred in the meeting that might have influenced participant's rating.

Appendix I – Interview questions short version

Name:

Date:

Case study name:

I recorded from the survey question that you rated your collaboration experience (*insert rate)* in the (*insert trade name*) meeting on (*insert meeting date*) for the given scale of 1 to 9 where 1=very poor, 5=neutral, 9=excellent.

1. What has been influencing your thoughts when you evaluated collaboration?

    a. If required: Can you please elaborate more on incidents that influenced your rating?

2. Has anything else influenced your opinion on collaboration that we have not discussed?

Appendix I – Interview questions long version

Name:

Date:

Case study name:

I recorded from the survey question that you rated your collaboration experience (*insert rate)* in the (*insert trade name*) meeting on (*insert meeting date*) for the given scale of 1 to 9 where 1=very poor, 5=neutral, 9=excellent.

1. What has been influencing your thoughts when you evaluated collaboration?

If required

a. Can you please elaborate more on incidents that influenced your thoughts?
b. Are there any other factors that affected collaboration (positively or negatively) from your opinion?

(Process question)

2. From your perspective, what are the most challenging parts of the design?
3. Were you able to discuss these concerns/views in the meetings?
4. How far are you satisfied with the feedback you get regarding your concerns/views in discussions?

(Outcomes question)

5. In your opinion, what are the positive outcomes of your collaboration with designers/contractors in facade meetings so far?
6. Have there been any other things that affected your collaboration negatively?

7. If you look back at the detailed design phase, what would you like to improve in this process for future projects?
8. Has anything else influenced your opinion on collaboration that we have not discussed?

Appendix I – Ethics Approval

UTS HREC Approval - 2014000586

Research.Ethics@uts.edu.au <Research.Ethics@uts.edu.au>
Wed 07/09/2016 15:36
To: Mona Abd Al-Salam <Mona.AbdAl-Salam@student.uts.edu.au>; Perry Forsythe <Perry.Forsythe@uts.edu.au>; Research Ethics <research.ethics@uts.edu.au>

Dear Applicant

The UTS Human Research Ethics Committee reviewed your application titled, "The Impact Of Using Lean Construction, BIM & Integrated Project Delivery On Design Management

The updated title is:
Collaboration in detailed design phase of construction projects - A micro level study", and agreed that the application meets the requirements of the NHMRC National Statement on Ethical Conduct in Human Research (2007). I am pleased to inform you that ethics approval is now granted.

Your approval number is UTS HREC REF NO. 2014000586
Approval will be for a period of five (5) years from the date of this correspondence subject to the provision of annual reports.

Your approval number must be included in all participant material and advertisements. Any advertisements on the UTS Staff Connect without an approval number will be removed.

Please note that the ethical conduct of research is an on-going process. The National Statement on Ethical Conduct in Research Involving Humans requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually from the date of approval, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

You should consider this your official letter of approval. If you require a hardcopy please contact Research.Ethics@uts.edu.au.

To access this application, please follow the URLs below:
* if accessing within the UTS network: https://rm.uts.edu.au
* if accessing outside of UTS network: https://remote.uts.edu.au , and click on "RM6 - ResearchMaster Enterprise" after logging in.

We value your feedback on the online ethics process. If you would like to provide feedback please go to: http://surveys.uts.edu.au/surveys/onlineethics/index.cfm

If you have any queries about your ethics approval, or require any amendments to your research in the future, please do not hesitate to contact Research.Ethics@uts.edu.au.

Yours sincerely,

Professor Marion Haas
Chairperson
UTS Human Research Ethics Committee
C/- Research & Innovation Office
University of Technology, Sydney
E: Research.Ethics@uts.edu.au

APPENDIX II – CASE STUDY A

Appendix II- Case study A – Description of the Design Tasks

Task No.	Task name	Description	Started in meeting...	Ended in meeting…
Task 1	Slab edge design	Slab edge design task is directly related to the design intent because facade panels are stepping in and out along the floors to form the twisting shape of the building. As a result, the slab edge design task is dealing with 4 typical connection types; stepping in straight panel, stepping in curved panel, stepping out straight panel, and stepping out curved panels. As a result, a number of sub tasks emerged such as the slab edge configuration, cladding zone, set down sizes, falls, and duct skirting size. Out of these sub tasks, the set down sizes cannot be resolved before knowing the duct skirting. The design development discussions started at the beginning of the DIP and continued till the 11th meeting.	2	11
Task 2	Helix stairs façade design	Helix stairs task comprised a façade type surrounding a double helix stair with dual landings on opposite sides of three levels. This design task lasted for the whole duration of the detailed design phase because it was added to the tower facade scope as mentioned by the project engineer. Therefore, at the beginning it needed cost adjustment and design intent confirmation as some of the stairs design parameters were not yet fixed	2	21
Task 3	Facade Panels modulation	Panels modulation was related to the design intent because of the building geometric shape in terms of curves length and orientation. This task included figuring out how many façade types to be modelled in 3D and used for manufacturing drawings.	3	13
Task 4	Ledge and soffit cladding	Ledge and soffit cladding task was one of the design tasks that lasted for the whole detailed design phase because of there was uncertainty about the cladding material choice and its fire engineering approvals. Other design issues were discussed such as junction detail between curved fascia and ledge cladding to ensure weather proofing requirements are met, gaskets material and installation, and matching cladding colour with blinds.	3	21

Task 5	CCF drip edge	CCF drip edge design task need cost adjustment because client requires a cost neutral solution. Other parties needed to evaluate subcontractor's proposed solutions to match design intent and provide a cleaner outside look of the facade within the cost limits. The drip edge was first discussed in the duration of 8th meeting and lasted for 4 consecutive meetings.	8	12
Task 6	Winter garden junction	Winter garden junction was one of the critical design tasks because of the transition between three different façade types. It generated several design issues related to panels curvature dimensions, helix stairs transition panels, mullion sizes, and connections detailing for weather proofing requirements. However, the winter garden junction task discussion started later in the 6th meeting and was resolved in the 13th meeting.	6	13
Task 7	Winter garden external facade	Winter garden external facade configuration level 9-16 included a number of connections that were discussed such as framing system, head detail, access the sub head, access to the blind hatch, additional ledge and soffit cladding and curves at transitions into winter gardens. The discussion of this design task started early in the 2nd meeting and lasted till the 18th meeting. Winter garden internal facade configuration level 9-16 had a number of components discussed in the meetings such as confirmation of design intent, configuration of stairs, partitions to enclose stairs, and scope adjustment. The duration of this design task lasted from the second meeting and was resolved in the 8th meeting.	2	14
Task 8	Winter garden internal facade	Winter garden internal facade configuration level 9-16. Confirmation on design intent and configuration of stairs, and partitions to enclose the stairs, general arrangements and section showing grills was needed for scope register and documentation.	3	8
Task 9	Roof top façade panels	Roof top facade design task was discussed at the very beginning of the DIP phase (meeting 2) for three consecutive meetings because of scope adjustment resulted from adding some elements such as cladding and balustrade to match the winter gardens facade. The roof top facade discussion was resumed again in the 15th meeting to resolve design issues such as hop location, brackets connection details, and confirming final roof levels.	2	20
Task 10	East facade elevation panels	East facade elevation on level 7 required confirmation from the architects about the scope of their facade because it was one of transition facade panels between the tower and podium	3	8
Task 11	Visual mock-up	Visual mock-up and performance testing strategy resembled two submissions that were required from the subcontractor. These two items were present in all meetings agenda to evaluate the visual look of facade panels and subcontractor's proposed testing strategies before being approved by main contractor, architects, and	2	12

Task 12	Performance prototype for testing	facade consultant. They were not design focused tasks but required co-ordination between participants. For instance, participants needed to agree on facade elements included in the visual mock and viewing date.	2	21
Task 13	Overflows drainage	Overflows drainage for level 17 task was raised by the main contractor in the 5th meeting because participants had to agree on a suitable drainage strategy	5	13
Task 14	Facade access strategy	Facade access strategy was brought up in meetings 9-21 because it required coordination between facade design team and another subcontractor who was responsible for developing the facade access strategy. Tasks discussed were related to facade cleaning system requirements such as track solution and its installation, and confirmation fixing locations in the cladding joints.	10	18
Task 15	winter garden facade ventilation grilles	Winter garden facade ventilation grilles material selection needed confirmation to use linear perforated sheet. Other requirement was needed such as pressure drop calculations and dimensions.	8	16
Task 16	Balustrade on level 17	Required design intent sketch for subcontractor to follow. Confirmation on max cantilever of glass to be 400mm, 100mm gap under the glass, stainless steel stanchion and integrated handrail	10	19
Task 17	Door hardware	Included hardware schedule with security and functional requirements	12	21
Task 18	Skylight glass	Updated configuration around the skylight was needed to use concave curve section of CCF panels adjacent to the skylight	2	4
Task 19	CCF blinds	This task is related to facility management and the mechanisms of operating the blinds. Team needed to understand how the operable blinds work and manual override options	17	17

Appendix II - Case study A – Key Participants' Rating Table

Survey question: Can you please rate your collaboration experience in meeting [insert date] using the scale 1–9 (where 1=very poor, 5=neutral, 9=excellent).

Note: Survey started in meeting 2

Meetings M1-M21	***C1 (main contractor)***	***F1 (façade engineer)***	***R2 (architect)***	***L1 (client)***	***T2 (subcontractor)***
Mtg 1					
Mtg 2	7	7	6	8	6
Mtg 3	7	7	4	8	7
Mtg 4	8	6	6	8	7
Mtg 5	7	5	7	8	7
Mtg 6	8	6	7	8	6
Mtg 7	6	6	7	7	6
Mtg 8	5	7	7	7	6
Mtg 9	6	7	7	7	7
Mtg 10	7	6	7	7	7
Mtg 11	6	6	6	7	6
Mtg 12	6	7	7	7	5
Mtg 13	6	6	7	9	6
Mtg 14	6	6	7	9	6
Mtg 15	6	4	6	9	7
Mtg 16	6	7	7	9	7
Mtg 17	7	7	3	8	7
Mtg 18	6	7	7	9	7
Mtg 19	7	7	5	8	7
Mtg 20	8	7	7	8	7
Mtg 21	7	7	7	8	7

Appendix II - Case study A – Single Interactions Table

Interaction categories	1. Shows solidarity	2. Shows tension release	3. Agrees	4. Gives suggestion	5. Give analysis	6. Gives confirmation	7. Gives information	8. Ask for information	9. Asks for confirmation	10. Ask for analysis	11. Asks for suggestion	12. Disagrees	3. Shows tension	14. Shows antagonism	Total N (%)
Meeting 1 N (%)	0 (0.0)	0 (0.0)	3 (5.5)	9 (16.4)	4 (7.3)	9 (16.4)	9 (16.4)	14 (25.5)	4 (7.3)	2 (3.6)	1 (1.8)	0 (0.0)	0 (0.0)	0 (0.0)	55 (100.0)
Meeting 2 N (%)	0 (0.0)	0 (0.0)	8 (5.9)	16 (11.8)	31 (22.8)	22 (16.2)	17 (12.5)	15 (11.0)	12 (8.8)	9 (6.6)	6 (4.4)	0 (0.0)	0 (0.0)	0 (0.0)	136 (100.0)
Meeting 3 N (%)	2 (0.8)	0 (0.0)	6 (2.5)	12 (5.1)	68 (28.7)	54 (22.8)	28 (11.8)	15 (6.3)	12 (5.1)	28 (11.8)	8 (3.4)	0 (0.0)	4 (1.7)	0 (0.0)	237 (100.0)
Meeting 4 N (%)	0 (0.0)	0 (0.0)	9 (5.0)	19 (10.5)	50 (27.6)	26 (14.4)	36 (19.9)	13 (7.2)	11 (6.1)	13 (7.2)	4 (2.2)	0 (0.0)	0 (0.0)	0 (0.0)	181 (100.0)
Meeting 5 N (%)	0 (0.0)	0 (0.0)	7 (4.0)	11 (6.4)	40 (23.1)	28 (16.2)	24 (13.9)	22 (12.7)	9 (5.2)	19 (11.0)	11 (6.4)	1 (0.6)	1 (0.6)	0 (0.0)	173 (100.0)
Meeting 6 N (%)	1 (0.4)	1 (0.4)	14 (5.3)	22 (8.4)	77 (29.3)	39 (14.8)	29 (11.0)	27 (10.3)	17 (6.5)	24 (9.1)	10 (3.8)	1 (0.4)	1 (0.4)	0 (0.0)	263 (100.0)
Meeting 7 N (%)	0 (0.0)	1 (0.4)	7 (2.7)	17 (6.5)	65 (24.8)	48 (18.3)	43 (16.4)	34 (13.0)	15 (5.7)	26 (9.9)	4 (1.5)	0 (0.0)	2 (0.8)	0 (0.0)	262 (100.0)
Meeting 8 N (%)	0 (0.0)	0 (0.0)	4 (2.0)	8 (4.0)	48 (23.9)	36 (17.9)	32 (15.9)	21 (10.4)	19 (9.5)	24 (11.9)	7 (3.5)	0 (0.0)	2 (1.0)	0 (0.0)	201 (100.0)
Meeting 9 N (%)	0 (0.0)	2 (1.0)	10 (5.2)	15 (7.8)	28 (14.6)	30 (15.6)	39 (20.3)	24 (12.5)	15 (7.8)	18 (9.4)	6 (3.1)	2 (1.0)	3 (1.6)	0 (0.0)	192 (100.0)
Meeting 10 N (%)	0 (0.0)	0 (0.0)	6 (5.1)	10 (8.5)	16 (13.6)	20 (16.9)	27 (22.9)	16 (13.6)	10 (8.5)	8 (6.8)	1 (0.8)	2 (1.7)	2 (1.7)	0 (0.0)	118 (100.0)
Meeting 11 N (%)	0 (0.0)	1 (0.6)	2 (1.3)	10 (6.5)	29 (18.8)	22 (14.3)	24 (15.6)	31 (20.1)	16 (10.4)	16 (10.4)	3 (1.9)	0 (0.0)	0 (0.0)	0 (0.0)	154 (100.0)
Meeting 12 N (%)	0 (0.0)	3 (2.2)	2 (1.4)	10 (7.2)	21 (15.2)	17 (12.3)	29 (21.0)	21 (15.2)	16 (11.6)	16 (11.6)	1 (0.7)	1 (0.7)	1 (0.7)	0 (0.0)	138 (100.0)
Meeting 13 N (%)	4 (1.9)	1 (0.5)	12 (5.8)	15 (7.3)	38 (18.4)	19 (9.2)	44 (21.4)	30 (14.6)	10 (4.9)	21 (10.2)	4 (1.9)	3 (1.5)	3 (1.5)	2 (1.0)	206 (100.0)
Meeting 14 N (%)	2 (0.5)	14 (3.8)	22 (5.9)	25 (6.7)	62 (16.7)	63 (17.0)	70 (18.9)	37 (10.0)	28 (7.5)	28 (7.5)	12 (3.2)	6 (1.6)	1 (0.3)	1 (0.3)	371 (100.0)

Meeting 15 N (%)	1 (0.3)	7 (2.3)	12 (3.9)	21 (6.8)	41 (13.2)	41 (13.2)	72 (23.2)	53 (17.0)	26 (8.4)	17 (5.5)	8 (2.6)	7 (2.3)	5 (1.6)	0 (0.0)	311 (100.0)
Meeting 16 N (%)	0 (0.0)	2 (0.8)	21 (7.9)	15 (5.7)	41 (15.5)	31 (11.7)	59 (22.3)	55 (20.8)	12 (4.5)	18 (6.8)	6 (2.3)	5 (1.9)	0 (0.0)	0 (0.0)	265 (100.0)
Meeting 17 N (%)	0 (0.0)	0 (0.0)	4 (2.8)	10 (6.9)	37 (25.5)	13 (9.0)	27 (18.6)	26 (17.9)	7 (4.8)	16 (11.0)	4 (2.8)	0 (0.0)	1 (0.7)	0 (0.0)	145 (100.0)
Meeting 18 N (%)	2 (1.1)	3 (1.7)	12 (6.8)	10 (5.6)	30 (16.9)	26 (14.7)	32 (18.1)	22 (12.4)	17 (9.6)	11 (6.2)	8 (4.5)	4 (2.3)	0 (0.0)	0 (0.0)	177 (100.0)
Meeting 19 N (%)	0 (0.0)	3 (1.2)	16 (6.6)	9 (3.7)	38 (15.8)	26 (10.8)	70 (29.0)	41 (17.0)	11 (4.6)	16 (6.6)	9 (3.7)	2 (0.8)	0 (0.0)	0 (0.0)	241 (100.0)
Meeting 20 N (%)	0 (0.0)	3 (1.0)	16 (5.1)	25 (8.0)	48 (15.4)	50 (16.1)	70 (22.5)	35 (11.3)	20 (6.4)	20 (6.4)	12 (3.9)	10 (3.2)	2 (0.6)	0 (0.0)	311 (100.0)
Meeting 21 N (%)	2 (0.6)	1 (0.3)	12 (3.7)	15 (4.6)	71 (21.8)	44 (13.5)	68 (20.9)	58 (17.8)	17 (5.2)	21 (6.5)	5 (1.5)	7 (2.2)	4 (1.2)	0 (0.0)	325 (100.0)
Aggregate N (%)	14 (0.3)	42 (0.9)	205 (4.6)	304 (6.8)	883 (19.8)	664 (14.9)	849 (19.0)	610 (13.7)	304 (6.8)	371 (8.3)	130 (2.9)	51 (1.1)	32 (0.7)	3 (0.1)	4462 (100.0)

Appendix II - Case study A – Sequential interactions Table

Key: AI = asks for information, GI = gives information, AC = asks for confirmation, GC = gives confirmation, AO = asks for analysis, GO = gives analysis, AS = asks for suggestions, GS = gives suggestion, AE = agrees, DE = disagrees, TR = shows tension release, ST = shows tension, SS = shows solidarity, and SA = shows antagonism

Sequential interactions	Mtg. 1 N(%)	Mtg. 2 N(%)	Mtg. 3 N(%)	Mtg. 4 N(%)	Mtg. 5 N(%)	Mtg. 6 N(%)	Mtg. 7 N(%)	Mtg. 8 N(%)	Mtg. 9 N(%)	Mtg. 10 N(%)	Mtg. 11 N(%)	Mtg. 12 N(%)	Mtg. 13 N(%)	Mtg. 14 N(%)	Mtg. 15 N(%)	Mtg. 16 N(%)	Mtg. 17 N(%)	Mtg. 18 N(%)	Mtg. 19 N(%)	Mtg. 20 N(%)	Mtg. 21 N(%)	Aggregate N(%)
AI - GI	6 (15)	2 (1.75)	5 (2.22)	6 (3.77)	6 (3.97)	9 (3.52)	12 (4.88)	3 (1.65)	6 (3.59)	5 (4.81)	8 (5.76)	12 (9.16)	15 (8.67)	17 (5.31)	17 (6.27)	21 (8.47)	17 (12.14)	16 (9.76)	17 (6.91)	12 (3.56)	18 (5.63)	230 (5.56)
GO - GO	0 (0.00)	9 (7.89)	21 (9.33)	18 (11.32)	7 (4.64)	20 (7.81)	14 (5.69)	12 (6.59)	2 (1.20)	3 (2.88)	5 (3.60)	3 (2.29)	12 (6.94)	11 (3.44)	12 (4.43)	0 (0.00)	10 (7.14)	8 (4.88)	10 (4.07)	16 (4.75)	27 (8.44)	220 (5.32)
AO - GO	0 (0.00)	5 (4.39)	13 (5.78)	10 (6.29)	8 (5.30)	15 (5.86)	19 (7.72)	12 (6.59)	5 (2.99)	4 (3.85)	11 (7.91)	9 (6.87)	12 (6.94)	22 (6.88)	7 (2.58)	10 (4.03)	13 (9.29)	7 (4.27)	5 (2.03)	7 (2.08)	7 (2.19)	201 (4.86)
AC - GC	0 (0.00)	2 (1.75)	3 (1.33)	4 (2.52)	2 (1.32)	9 (3.52)	14 (5.69)	8 (4.40)	11 (6.59)	7 (6.73)	7 (5.04)	7 (5.34)	3 (1.73)	12 (3.75)	12 (4.43)	7 (2.82)	3 (2.14)	4 (2.44)	8 (3.25)	12 (3.56)	9 (2.81)	144 (3.48)
GI - GO	1 (2.50)	3 (2.63)	6 (2.67)	4 (2.52)	4 (2.65)	11 (4.30)	8 (3.25)	7 (3.85)	2 (1.20)	4 (3.85)	4 (2.88)	2 (1.53)	5 (2.89)	6 (1.88)	6 (2.21)	15 (6.05)	10 (7.14)	5 (3.05)	12 (4.88)	11 (3.26)	16 (5.00)	142 (3.44)
GI - AI	5 (12.50)	3 (2.63)	2 (0.89)	5 (3.14)	3 (1.99)	4 (1.56)	8 (3.25)	3 (1.65)	5 (2.99)	2 (1.92)	6 (4.32)	7 (5.34)	8 (4.62)	7 (2.19)	3 (1.11)	25 (10.08)	7 (5.00)	11 (6.71)	7 (2.85)	8 (2.37)	10 (3.13)	139 (3.36)
GO - AO	0 (0.00)	1 (0.88)	10 (4.44)	4 (2.52)	5 (3.31)	11 (4.30)	14 (5.69)	16 (8.79)	5 (2.99)	2 (1.92)	4 (2.88)	5 (3.82)	5 (2.89)	9 (2.81)	3 (1.11)	0 (0.00)	10 (7.14)	3 (1.83)	4 (1.63)	8 (2.37)	5 (1.56)	124 (3.00)
AI - GC	3 (7.50)	4 (3.51)	6 (2.67)	3 (1.89)	9 (5.96)	6 (2.34)	11 (4.47)	3 (1.65)	6 (3.59)	7 (6.73)	8 (5.76)	5 (3.82)	3 (1.73)	7 (2.19)	8 (2.95)	10 (4.03)	1 (0.71)	4 (2.44)	6 (2.44)	6 (1.78)	10 (3.13)	126 (3.05)
GO - GC	1 (2.50)	3 (2.63)	12 (5.33)	6 (3.77)	5 (3.31)	8 (3.13)	5 (2.03)	5 (2.75)	2 (1.20)	2 (1.92)	3 (2.16)	3 (2.29)	1 (0.58)	10 (3.13)	7 (2.58)	0 (0.00)	2 (1.43)	6 (3.66)	12 (4.88)	8 (2.37)	19 (5.94)	120 (2.90)
GC - GO	0 (0.00)	3 (2.63)	17 (7.56)	5 (3.14)	3 (1.99)	7 (2.73)	9 (3.66)	5 (2.75)	8 (4.79)	0 (0.00)	3 (2.16)	3 (2.29)	2 (1.16)	9 (2.81)	9 (3.32)	3 (1.21)	0 (0.00)	5 (3.05)	11 (4.47)	9 (2.67)	6 (1.88)	117 (2.83)
AI - GO	0 (0.00)	2 (1.75)	2 (0.89)	1 (0.63)	3 (1.99)	9 (3.52)	5 (2.03)	6 (3.30)	6 (3.59)	3 (2.88)	3 (2.16)	4 (3.05)	3 (1.73)	7 (2.19)	8 (2.95)	12 (4.84)	7 (5.00)	5 (3.05)	5 (2.03)	8 (2.37)	17 (5.31)	116 (2.81)
GI - GC	1 (2.50)	1 (0.88)	6 (2.67)	3 (1.89)	3 (1.99)	4 (1.56)	11 (4.47)	4 (2.20)	3 (1.80)	2 (1.92)	3 (2.16)	2 (1.53)	1 (0.58)	13 (4.06)	8 (2.95)	12 (4.84)	1 (0.71)	3 (1.83)	10 (4.07)	12 (3.56)	10 (3.13)	113 (2.73)
GI - GI	3 (7.50)	2 (1.75)	5 (2.22)	6 (3.77)	2 (1.32)	1 (0.39)	3 (1.22)	3 (1.65)	8 (4.79)	2 (1.92)	2 (1.44)	3 (2.29)	6 (3.47)	14 (4.38)	4 (1.48)	9 (3.63)	4 (2.86)	2 (1.22)	7 (2.85)	13 (3.86)	10 (3.13)	109 (2.64)
GC - AI	2 (5.00)	2 (1.75)	2 (0.89)	2 (1.26)	6 (3.97)	7 (2.73)	8 (3.25)	2 (1.10)	2 (1.20)	6 (5.77)	4 (2.88)	5 (3.82)	4 (2.31)	7 (2.19)	10 (3.69)	8 (3.23)	4 (2.86)	4 (2.44)	5 (2.03)	3 (0.89)	15 (4.69)	108 (2.61)
GO - AI	0 (0.00)	1 (0.88)	6 (2.67)	2 (1.26)	4 (2.65)	7 (2.73)	7 (2.85)	3 (1.65)	4 (2.40)	3 (2.88)	5 (3.60)	4 (3.05)	4 (2.31)	5 (1.56)	8 (2.95)	0 (0.00)	9 (6.43)	5 (3.05)	5 (2.03)	3 (0.89)	14 (4.38)	99 (2.40)
GC - GI	1 (2.50)	2 (1.75)	5 (2.22)	3 (1.89)	0 (0.00)	3 (1.17)	7 (2.85)	5 (2.75)	2 (1.20)	2 (1.92)	0 (0.00)	1 (0.76)	1 (0.58)	7 (2.19)	4 (1.48)	5 (2.02)	2 (1.43)	2 (1.22)	9 (3.66)	14 (4.15)	13 (4.06)	88 (2.13)
GC - GC	0 (0.00)	2 (1.75)	4 (1.78)	1 (0.63)	1 (0.66)	5 (1.95)	3 (1.22)	7 (3.85)	3 (1.80)	4 (3.85)	2 (1.44)	1 (0.76)	1 (0.58)	11 (3.44)	6 (2.21)	5 (2.02)	1 (0.71)	7 (4.27)	4 (1.63)	14 (4.15)	5 (1.56)	87 (2.11)

GI - AO	0 (0.00)	1 (0.88)	1 (0.44)	2 (1.26)	3 (1.99)	3 (1.17)	2 (0.81)	1 (0.55)	3 (1.80)	1 (0.96)	4 (2.88)	4 (3.05)	8 (4.62)	9 (2.81)	2 (0.74)	11 (4.44)	6 (4.29)	4 (2.44)	2 (0.81)	6 (1.78)	4 (1.25)	77 (1.86)
GO - GS	0 (0.00)	3 (2.63)	3 (1.33)	5 (3.14)	4 (2.65)	9 (3.52)	5 (2.03)	2 (1.10)	1 (0.60)	2 (1.92)	5 (3.60)	3 (2.29)	1 (0.58)	4 (1.25)	3 (1.11)	0 (0.00)	5 (3.57)	1 (0.61)	2 (0.81)	7 (2.08)	4 (1.25)	69 (1.67)
GO - AC	0 (0.00)	3 (2.63)	4 (1.78)	7 (4.40)	1 (0.66)	8 (3.13)	3 (1.22)	3 (1.65)	3 (1.80)	0 (0.00)	3 (2.16)	3 (2.29)	1 (0.58)	9 (2.81)	4 (1.48)	0 (0.00)	2 (1.43)	1 (0.61)	3 (1.22)	5 (1.48)	3 (0.94)	66 (1.60)
GS - GC	0 (0.00)	5 (4.39)	4 (1.78)	5 (3.14)	1 (0.66)	6 (2.34)	4 (1.63)	1 (0.55)	0 (0.00)	0 (0.00)	2 (1.44)	1 (0.76)	1 (0.58)	4 (1.25)	5 (1.85)	8 (3.23)	1 (0.71)	0 (0.00)	7 (2.85)	8 (2.37)	3 (0.94)	66 (1.60)
GO - GI	0 (0.00)	2 (1.75)	3 (1.33)	0 (0.00)	3 (1.99)	2 (0.78)	6 (2.44)	5 (2.75)	3 (1.80)	1 (0.96)	2 (1.44)	1 (0.76)	3 (1.73)	4 (1.25)	2 (0.74)	0 (0.00)	2 (1.43)	3 (1.83)	5 (2.03)	7 (2.08)	8 (2.50)	62 (1.50)
GC - AO	0 (0.00)	2 (1.75)	8 (3.56)	2 (1.26)	4 (2.65)	2 (0.78)	5 (2.03)	3 (1.65)	4 (2.40)	2 (1.92)	3 (2.16)	2 (1.53)	1 (0.58)	6 (1.88)	0 (0.00)	4 (1.61)	0 (0.00)	2 (1.22)	3 (1.22)	3 (0.89)	6 (1.88)	62 (1.50)
GC - AC	0 (0.00)	1 (0.88)	2 (0.89)	2 (1.26)	0 (0.00)	1 (0.39)	5 (2.03)	3 (1.65)	2 (1.20)	3 (2.88)	3 (2.16)	1 (0.76)	0 (0.00)	4 (1.25)	11 (4.06)	7 (2.82)	0 (0.00)	0 (0.00)	1 (0.41)	6 (1.78)	9 (2.81)	61 (1.48)
AO - GC	0 (0.00)	1 (0.88)	7 (3.11)	2 (1.26)	2 (1.32)	1 (0.39)	3 (1.22)	4 (2.20)	3 (1.80)	1 (0.96)	2 (1.44)	3 (2.29)	4 (2.31)	5 (1.56)	3 (1.11)	3 (1.21)	1 (0.71)	2 (1.22)	3 (1.22)	4 (1.19)	3 (0.94)	57 (1.38)
GC - GS	3 (7.50)	1 (0.88)	2 (0.89)	4 (2.52)	2 (1.32)	4 (1.56)	3 (1.22)	0 (0.00)	1 (0.60)	3 (2.88)	3 (2.16)	2 (1.53)	3 (1.73)	6 (1.88)	2 (0.74)	3 (1.21)	1 (0.71)	2 (1.22)	8 (3.25)	5 (1.48)	2 (0.63)	60 (1.45)
GI - GS	2 (5.00)	2 (1.75)	3 (1.33)	5 (3.14)	2 (1.32)	1 (0.39)	6 (2.44)	3 (1.65)	1 (0.60)	1 (0.96)	1 (0.72)	2 (1.53)	7 (4.05)	3 (0.94)	5 (1.85)	5 (2.02)	0 (0.00)	1 (0.61)	2 (0.81)	5 (1.48)	1 (0.31)	58 (1.40)
GI - AC	0 (0.00)	2 (1.75)	4 (1.78)	1 (0.63)	2 (1.32)	2 (0.78)	3 (1.22)	3 (1.65)	3 (1.80)	4 (3.85)	2 (1.44)	6 (4.58)	1 (0.58)	2 (0.63)	4 (1.48)	4 (1.61)	1 (0.71)	1 (0.61)	2 (0.81)	5 (1.48)	2 (0.63)	54 (1.31)
AI - AI	4 (10.00)	1 (0.88)	2 (0.89)	1 (0.63)	1 (0.66)	0 (0.00)	2 (0.81)	3 (1.65)	0 (0.00)	0 (0.00)	5 (3.60)	1 (0.76)	2 (1.16)	3 (0.94)	5 (1.85)	6 (2.42)	2 (1.43)	1 (0.61)	5 (2.03)	2 (0.59)	3 (0.94)	49 (1.19)
AO - GI	0 (0.00)	1 (0.88)	2 (0.89)	1 (0.63)	4 (2.65)	2 (0.78)	3 (1.22)	2 (1.10)	5 (2.99)	1 (0.96)	1 (0.72)	2 (1.53)	2 (1.16)	2 (0.63)	2 (0.74)	1 (0.40)	2 (1.43)	2 (1.22)	3 (1.22)	3 (0.89)	2 (0.63)	43 (1.04)
GO - AE	0 (0.00)	3 (2.63)	3 (1.33)	4 (2.52)	3 (1.99)	7 (2.73)	2 (0.81)	1 (0.55)	2 (1.20)	0 (0.00)	0 (0.00)	0 (0.00)	3 (1.73)	4 (1.25)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	5 (1.48)	0 (0.00)	39 (0.94)
GS - GO	0 (0.00)	1 (0.88)	2 (0.89)	5 (3.14)	6 (3.97)	6 (2.34)	3 (1.22)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.72)	1 (0.76)	0 (0.00)	0 (0.00)	2 (0.74)	2 (0.81)	1 (0.71)	1 (0.61)	1 (0.41)	5 (1.48)	2 (0.63)	39 (0.94)
GO - AS	0 (0.00)	1 (0.88)	2 (0.89)	0 (0.00)	4 (2.65)	5 (1.95)	2 (0.81)	2 (1.10)	3 (1.80)	0 (0.00)	1 (0.72)	1 (0.76)	1 (0.58)	5 (1.56)	3 (1.11)	0 (0.00)	0 (0.00)	5 (3.05)	3 (1.22)	1 (0.30)	0 (0.00)	39 (0.94)
AS - GO	0 (0.00)	1 (0.88)	3 (1.33)	0 (0.00)	7 (4.64)	4 (1.56)	1 (0.41)	3 (1.65)	3 (1.80)	0 (0.00)	1 (0.72)	1 (0.76)	0 (0.00)	1 (0.31)	1 (0.37)	1 (0.40)	0 (0.00)	2 (1.22)	4 (1.63)	4 (1.19)	1 (0.31)	38 (0.92)
AC - GO	0 (0.00)	3 (2.63)	4 (1.78)	2 (1.26)	1 (0.66)	3 (1.17)	0 (0.00)	5 (2.75)	1 (0.60)	0 (0.00)	1 (0.72)	0 (0.00)	1 (0.58)	3 (0.94)	3 (1.11)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.59)	5 (1.56)	35 (0.85)
GS - AI	2 (5.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	1 (0.39)	2 (0.81)	1 (0.55)	1 (0.60)	1 (0.96)	1 (0.72)	1 (0.76)	4 (2.31)	2 (0.63)	1 (0.37)	3 (1.21)	3 (2.14)	2 (1.22)	2 (0.81)	2 (0.59)	4 (1.25)	34 (0.82)
GS - GI	0 (0.00)	3 (2.63)	1 (0.44)	1 (0.63)	1 (0.66)	1 (0.39)	1 (0.41)	0 (0.00)	1 (0.60)	1 (0.96)	2 (1.44)	2 (1.53)	0 (0.00)	1 (0.31)	3 (1.11)	1 (0.40)	1 (0.71)	3 (1.83)	0 (0.00)	7 (2.08)	0 (0.00)	30 (0.73)
AC - GI	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.26)	1 (0.66)	1 (0.39)	1 (0.41)	2 (1.10)	2 (1.20)	1 (0.96)	2 (1.44)	1 (0.76)	1 (0.58)	2 (0.63)	2 (0.74)	3 (1.21)	0 (0.00)	0 (0.00)	0 (0.00)	5 (1.48)	3 (0.94)	29 (0.70)
GS - AE	0 (0.00)	1 (0.88)	0 (0.00)	2 (1.26)	0 (0.00)	3 (1.17)	1 (0.41)	1 (0.55)	3 (1.80)	3 (2.88)	1 (0.72)	0 (0.00)	4 (2.31)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	1 (0.30)	1 (0.31)	24 (0.58)
GI - AS	0 (0.00)	2 (1.75)	2 (0.89)	0 (0.00)	2 (1.32)	0 (0.00)	0 (0.00)	2 (1.10)	3 (1.80)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.16)	2 (0.63)	2 (0.74)	2 (0.81)	0 (0.00)	0 (0.00)	1 (0.41)	4 (1.19)	0 (0.00)	24 (0.58)
AE - GO	0 (0.00)	2 (1.75)	0 (0.00)	3 (1.89)	0 (0.00)	3 (1.17)	3 (1.22)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.16)	2 (0.63)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.81)	3 (0.89)	1 (0.31)	23 (0.56)
GS - AO	0 (0.00)	2 (1.75)	1 (0.44)	0 (0.00)	1 (0.66)	3 (1.17)	1 (0.41)	1 (0.55)	1 (0.60)	0 (0.00)	0 (0.00)	1 (0.76)	1 (0.58)	2 (0.63)	1 (0.37)	1 (0.40)	3 (2.14)	0 (0.00)	1 (0.41)	2 (0.59)	1 (0.31)	23 (0.56)

GI - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	1 (0.76)	0 (0.00)	3 (0.94)	3 (1.11)	5 (2.02)	1 (0.71)	3 (1.83)	2 (0.81)	1 (0.30)	1 (0.31)	21 (0.51)
AI - GS	3 (7.50)	3 (2.63)	1 (0.44)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	1 (0.55)	4 (2.40)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.37)	2 (0.81)	1 (0.71)	0 (0.00)	0 (0.00)	1 (0.30)	3 (0.94)	23 (0.56)
GO - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	1 (0.76)	2 (1.16)	2 (0.63)	2 (0.74)	0 (0.00)	0 (0.00)	0 (0.00)	3 (1.22)	6 (1.78)	2 (0.63)	20 (0.48)
AO - AO	0 (0.00)	2 (1.75)	2 (0.89)	1 (0.63)	1 (0.66)	1 (0.39)	0 (0.00)	1 (0.55)	0 (0.00)	1 (0.96)	1 (0.72)	1 (0.76)	2 (1.16)	2 (0.63)	1 (0.37)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	2 (0.59)	1 (0.31)	20 (0.48)
GC - AE	0 (0.00)	2 (1.75)	1 (0.44)	1 (0.63)	2 (1.32)	3 (1.17)	1 (0.41)	1 (0.55)	2 (1.20)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	3 (1.22)	1 (0.30)	0 (0.00)	20 (0.48)
GS - AC	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	1 (0.39)	2 (0.81)	1 (0.55)	1 (0.60)	1 (0.96)	2 (1.44)	1 (0.76)	1 (0.58)	1 (0.31)	2 (0.74)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.81)	3 (0.89)	0 (0.00)	19 (0.46)
AC - GS	0 (0.00)	2 (1.75)	0 (0.00)	2 (1.26)	0 (0.00)	3 (1.17)	0 (0.00)	1 (0.55)	0 (0.00)	1 (0.96)	2 (1.44)	1 (0.76)	0 (0.00)	0 (0.00)	2 (0.74)	1 (0.40)	0 (0.00)	0 (0.00)	1 (0.41)	3 (0.89)	0 (0.00)	19 (0.46)
AI - AC	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.63)	1 (0.66)	2 (0.78)	1 (0.41)	1 (0.55)	1 (0.60)	0 (0.00)	1 (0.72)	0 (0.00)	3 (1.73)	2 (0.63)	1 (0.37)	1 (0.40)	0 (0.00)	1 (0.61)	2 (0.81)	0 (0.00)	1 (0.31)	19 (0.46)
AI - AO	0 (0.00)	1 (0.88)	0 (0.00)	1 (0.63)	2 (1.32)	1 (0.39)	1 (0.41)	1 (0.55)	1 (0.60)	0 (0.00)	2 (1.44)	0 (0.00)	1 (0.58)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	1 (0.61)	2 (0.81)	1 (0.30)	1 (0.31)	18 (0.44)
AO - AI	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	2 (1.32)	2 (0.78)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	1 (0.72)	0 (0.00)	0 (0.00)	3 (0.94)	1 (0.37)	1 (0.40)	1 (0.71)	0 (0.00)	2 (0.81)	1 (0.30)	1 (0.31)	17 (0.41)
AS - GC	0 (0.00)	1 (0.88)	2 (0.89)	0 (0.00)	1 (0.66)	2 (0.78)	0 (0.00)	1 (0.55)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.22)	2 (0.81)	2 (0.59)	1 (0.31)	17 (0.41)
GC - AS	0 (0.00)	1 (0.88)	1 (0.44)	2 (1.26)	1 (0.66)	2 (0.78)	1 (0.41)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.37)	1 (0.40)	0 (0.00)	0 (0.00)	3 (1.22)	2 (0.59)	0 (0.00)	17 (0.41)
AS - GS	0 (0.00)	1 (0.88)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (1.22)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	3 (1.11)	2 (0.81)	0 (0.00)	2 (1.22)	0 (0.00)	3 (0.89)	0 (0.00)	16 (0.39)
GS - GS	0 (0.00)	1 (0.88)	0 (0.00)	1 (0.63)	0 (0.00)	3 (1.17)	0 (0.00)	0 (0.00)	2 (1.20)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.16)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.89)	1 (0.31)	15 (0.36)
AC - AI	0 (0.00)	1 (0.88)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	1 (0.60)	0 (0.00)	0 (0.00)	1 (0.76)	1 (0.58)	1 (0.31)	1 (0.37)	3 (1.21)	0 (0.00)	2 (1.22)	1 (0.41)	0 (0.00)	0 (0.00)	13 (0.31)
AO - GS	0 (0.00)	1 (0.88)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	1 (0.40)	2 (1.43)	0 (0.00)	1 (0.41)	5 (1.48)	1 (0.31)	13 (0.31)
AE - GI	0 (0.00)	0 (0.00)	1 (0.44)	1 (0.63)	1 (0.66)	2 (0.78)	0 (0.00)	0 (0.00)	1 (0.60)	2 (1.92)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.81)	0 (0.00)	1 (0.31)	12 (0.29)
DE - GI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	1 (0.76)	0 (0.00)	2 (0.63)	3 (1.11)	2 (0.81)	0 (0.00)	0 (0.00)	1 (0.41)	2 (0.59)	0 (0.00)	12 (0.29)
AS - GI	0 (0.00)	0 (0.00)	1 (0.44)	1 (0.63)	2 (1.32)	2 (0.78)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.16)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.81)	0 (0.00)	0 (0.00)	12 (0.29)
AE - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.66)	1 (0.39)	1 (0.41)	0 (0.00)	2 (1.20)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	3 (0.89)	0 (0.00)	11 (0.27)
TR - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.76)	0 (0.00)	0 (0.00)	5 (1.85)	1 (0.40)	0 (0.00)	0 (0.00)	2 (0.81)	0 (0.00)	2 (0.63)	11 (0.27)
GI - AE	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.26)	1 (0.66)	0 (0.00)	1 (0.41)	0 (0.00)	2 (1.20)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	1 (0.41)	2 (0.59)	0 (0.00)	11 (0.27)
AO - AC	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	3 (1.65)	2 (1.20)	1 (0.96)	0 (0.00)	2 (1.53)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	11 (0.27)
GC - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.72)	0 (0.00)	0 (0.00)	1 (0.31)	2 (0.74)	1 (0.40)	0 (0.00)	2 (1.22)	2 (0.81)	1 (0.30)	0 (0.00)	11 (0.27)
TR - GI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.94)	1 (0.37)	2 (0.81)	1 (0.71)	0 (0.00)	0 (0.00)	1 (0.30)	2 (0.63)	11 (0.27)

AC - AC	0 (0.00)	2 (1.75)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.78)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	1 (0.72)	1 (0.76)	0 (0.00)	1 (0.31)	1 (0.37)	2 (0.81)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	11 (0.27)
AE - AC	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	2 (1.10)	2 (1.20)	0 (0.00)	1 (0.72)	0 (0.00)	0 (0.00)	2 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.59)	0 (0.00)	11 (0.27)
GO - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	6 (2.21)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	1 (0.31)	10 (0.24)
AS - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	1 (0.72)	0 (0.00)	1 (0.58)	1 (0.31)	1 (0.37)	1 (0.40)	0 (0.00)	0 (0.00)	2 (0.81)	1 (0.30)	0 (0.00)	10 (0.24)
TR - GO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.72)	1 (0.76)	0 (0.00)	3 (0.94)	2 (0.74)	1 (0.40)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	9 (0.22)
AE - AO	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.26)	1 (0.66)	0 (0.00)	0 (0.00)	1 (0.55)	1 (0.60)	2 (1.92)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	9 (0.22)
GI - ST	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	3 (1.11)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	9 (0.22)
AC - AO	0 (0.00)	0 (0.00)	2 (0.89)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.72)	1 (0.76)	0 (0.00)	0 (0.00)	4 (1.48)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	9 (0.22)
GS - AS	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.10)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	1 (0.41)	3 (0.89)	0 (0.00)	8 (0.19)
AS - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	2 (1.20)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	2 (0.59)	0 (0.00)	8 (0.19)
AS - AO	0 (0.00)	1 (0.88)	2 (0.89)	2 (1.26)	0 (0.00)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	8 (0.19)
DE - GO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	1 (0.41)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.59)	1 (0.31)	8 (0.19)
AE - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	1 (0.41)	0 (0.00)	0 (0.00)	2 (1.92)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.22)	0 (0.00)	1 (0.30)	0 (0.00)	7 (0.17)
AE - GS	0 (0.00)	1 (0.88)	1 (0.44)	1 (0.63)	0 (0.00)	2 (0.78)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	6 (0.15)
GS - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	2 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	6 (0.15)
DE - GS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.16)	0 (0.00)	0 (0.00)	1 (0.40)	0 (0.00)	0 (0.00)	1 (0.41)	2 (0.59)	0 (0.00)	6 (0.15)
TR - AO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	1 (0.37)	1 (0.40)	0 (0.00)	1 (0.61)	1 (0.41)	0 (0.00)	0 (0.00)	6 (0.15)
ST - GS	0 (0.00)	0 (0.00)	2 (0.89)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	5 (0.12)
GO - ST	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	1 (0.66)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	1 (0.31)	5 (0.12)
TR - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	1 (0.40)	0 (0.00)	2 (1.22)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.12)
AE - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.16)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.12)
AI - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.76)	0 (0.00)	0 (0.00)	1 (0.37)	2 (0.81)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.12)
TR - GS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.81)	0 (0.00)	1 (0.61)	2 (0.81)	0 (0.00)	0 (0.00)	5 (0.12)
AE - GC	0 (0.00)	2 (1.75)	1 (0.44)	1 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.12)
AC - ST	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.76)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.10)

ST - GC	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.10)
AC - AE	0 (0.00)	0 (0.00)	2 (0.89)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.10)
ST - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	4 (0.10)
AC - AS	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.10)
GI - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	1 (0.31)	4 (0.10)
ST - GO	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	3 (0.07)
AE - AS	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	1 (0.66)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.07)
GS - GC	3 (7.50)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.07)
ST - GI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	1 (0.31)	3 (0.07)
SS - GO	0 (0.00)	0 (0.00)	2 (0.89)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.07)
AI - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	3 (0.07)
AO - AS	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	3 (0.07)
ST - AO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	1 (0.76)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.07)
GS - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.07)
GC - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	3 (0.07)
AS - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.74)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
TR - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
GC - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
ST - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	2 (0.05)
GS - ST	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
TR - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.40)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	2 (0.05)
DE - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.74)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
AS - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
AS - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
DE - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	2 (0.05)

ST - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	2 (0.05)
DE - GC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	1 (0.31)	2 (0.05)
AO - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	2 (0.05)
SS - GS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
DE - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	2 (0.05)
SS - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
TR - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	2 (0.05)
AO - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.71)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	2 (0.05)
AE - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	1 (0.30)	0 (0.00)	2 (0.05)
ST - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.74)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
AI - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.66)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	2 (0.05)
ST - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	1 (0.71)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
AS - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
GC - SS	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.05)
ST - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.02)
GO - SS	0 (0.00)	0 (0.00)	1 (0.44)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
DE - AO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.96)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SA - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AI - AE	0 (0.00)	1 (0.88)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SS - AO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
DE - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.02)
SS - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
TR - GC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SS - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
TR - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.02)

SS - GC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
ST - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
DE - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
ST - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.37)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AC - SA	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AE - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.60)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AE - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.41)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
TR - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.61)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AI - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.40)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AC - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AO - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.02)
Total	40 (100)	114 (100)	225 (100)	159 (100)	151 (100)	256 (100)	246 (100)	182 (100)	167 (100)	104 (100)	139 (100)	131 (100)	173 (100)	320 (100)	271 (100)	248 (100)	140 (100)	164 (100)	246 (100)	337 (100)	320 (100)	4133 (100)

APPENDIX III – CASE STUDY B

Appendix III - Case study B – Description of the Design Tasks

Task No.	Task Name	Description	Started in meeting….	Ended in meeting….
Task 1	FT09 inner façade of proposed library-North facing side	The inner façade design involved adjusting scope of work and studying engineering solutions for: structural frame size and square hollow steel (SHS) beam, glass panel size, doors width and height, and voids size for skylights. In addition, technical discussions included glass panels installation methodology, ventilation strategy, and glass replacement strategy.	1	21
Task 2	FT08 outer façade of proposed library – North facing side	The outer façade design was one of the main complex façade types. It included adjusting scope of work and investigating and discussing engineering solutions for: floor to floor glass height, glass panel width, structural system supporting glass panels (pinned vs. cantilever struts), cantilever distance from support to the glass awning, uplifting resistant calculations, and suitable orientation of patch fitting to reduce cantilever length. In addition, a feasibility study on glass size for straight panels, glass that can be curved, fabrication, shipping, glass weight, installation and required equipment, lead times, and installation duration was required to finalise these technical decisions.	1	22
Task 3	FT06a the façade for the North East side balconies	The façade design included: agreeing on ceiling and transom heights, concrete profile and set out dimensions, waterproofing detail at the top of panel, door height, and investigating using perforated sheet rather than louvres at spandrel so it can be curved.	4	21
Task 4	FT06b single helix stair façade	This façade design task included adjusting scope of work and pricing after deleting some façade areas and adjusting drawings documents.	4	21

Task 5	FT05 Façade on South side - facing main street	This façade type was one of the complex design tasks. It included investigating design solutions for: columns height, cantilever columns engineering design, columns cladding, number of glass panels per bay, performance coating, deep beam design, transom connections, and overflow strategy.	1	21
Task 6	FT04 shop front façade	The shop front façade design discussions included confirming panels width and studied the use of battens. There was a design change introduced in meeting 15 including replacing the curved glass at either side of the building entrance with a masonry wall. This design change aimed to simplify the design at these curved locations.	1	21
Task 7	FT03 Frameless shop front system	The frameless system design discussions included studying the wind beam location, dimensions, and loads, and update related drawings.	1	21
Task 8	FT02 shop front window/wall on South East corner	Design discussions included confirming the use of fixed glass shop front panels, dimensions and height, and joint details.	1	20
Task 9	Skylights	Design discussions involved requesting more clarifications about design intent, reducing the number of skylights to avoid clashing with beams, glass performance and glare caused on area below.	1	20
Task 10	BL01 glass balustrade with stainless steel handrail	Design discussions included confirming handrails, patch fittings, and crowd loading requirements.	1	20
Task 11	Visual mock- up	This task included selecting the façade types, connections for the mock-ups and glass samples.	5	20

Appendix III - Case study B – Key Participants' Rating Table

Survey question: Can you please rate your collaboration experience in meeting [insert date] using the scale 1–9 (where 1=very poor, 5=neutral, 9=excellent).

Note: Survey started in meeting 2

Meetings M1-M24	*C1 (main contractor)*	*F1 (façade engineer)*	*R2 (architect)*	*L1 (client)*	*P3 (subcontractor)*
Mtg 1					
Mtg 2	6	5	3	8	8
Mtg 3	6	5	3	8	8
Mtg 4	5	5	3	7	8
Mtg 5	6	7	3	6	8
Mtg 6	5	7	4	6	8
Mtg 7	5	5	5	6	8
Mtg 8	5	6	3	6	7
Mtg 9	7	5	4	7	7
Mtg 10	6	6	3	5	7
Mtg 11	6	4	4	7	7
Mtg 12	8	4	5	7	7
Mtg 13	6	4	5	9	7
Mtg 14	6	3	2	9	7
Mtg 15	7	4	3	8	7
Mtg 16	7	4	4	9	7
Mtg 17	6	4	4	8	7
Mtg 18	7	4	4	8	7
Mtg 19	6	5	4	9	7
Mtg 20	8	5	5	8	8
Mtg 21	7	5	5	8	8
Mtg 22	5	5	4	9	8
Mtg 23	7	5	3	8	7
Mtg 24	7	5	5	8	7

Appendix III - Case study B – Single Interactions Table

Interaction categories	1. Shows solidarity	2. Shows tension release	3. Agrees	4. Gives suggestion	5. Gives analysis	6. Gives confirmation	7. Gives information	8. Asks for information	9. Asks for confirmation	10. Asks for analysis	11. Asks for suggestion	12. Disagrees	13. Shows tension	14. Shows antagonism	Total N(%)
Meeting 1 N (%)	0 (0.0)	1 (1.5)	1 (1.5)	10 (14.9)	7 (10.4)	14 (20.9)	14 (20.9)	11 (16.4)	6 (9.0)	2 (3.0)	1 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)	67 (100.0)
Meeting 2 N (%)	0 (0.0)	1 (0.8)	4 (3.3)	17 (13.9)	28 (23.0)	8 (6.6)	25 (20.5)	10 (8.2)	8 (6.6)	9 (7.4)	3 (2.5)	5 (4.1)	4 (3.3)	0 (0.0)	122 (100.0)
Meeting 3 N (%)	0 (0.0)	1 (0.5)	1 (0.5)	11 (5.0)	55 (24.9)	19 (8.6)	48 (21.7)	31 (14.0)	7 (3.2)	25 (11.3)	5 (2.3)	13 (5.9)	5 (2.3)	0 (0.0)	221 (100.0)
Meeting 4 N (%)	1 (0.5)	12 (6.0)	0 (0.0)	10 (5.0)	29 (14.5)	24 (12.0)	44 (22.0)	27 (13.5)	4 (2.0)	22 (11.0)	3 (1.5)	16 (8.0)	8 (4.0)	0 (0.0)	200 (100.0)
Meeting 5 N (%)	0 (0.0)	4 (1.0)	1 (0.2)	13 (3.2)	95 (23.3)	41 (10.1)	107 (26.3)	67 (16.5)	18 (4.4)	40 (9.8)	7 (1.7)	9 (2.2)	5 (1.2)	0 (0.0)	407 (100.0)
Meeting 6 N (%)	0 (0.0)	0 (0.0)	7 (1.9)	11 (3.1)	66 (18.3)	35 (9.7)	102 (28.3)	73 (20.3)	14 (3.9)	38 (10.6)	2 (0.6)	4 (1.1)	8 (2.2)	0 (0.0)	360 (100.0)
Meeting 7 N (%)	0 (0.0)	0 (0.0)	0 (0.0)	4 (1.1)	66 (18.9)	40 (11.5)	113 (32.4)	68 (19.5)	14 (4.0)	20 (5.7)	3 (0.9)	14 (4.0)	7 (2.0)	0 (0.0)	349 (100.0)
Meeting 8 N (%)	1 (0.3)	6 (1.6)	8 (2.2)	15 (4.1)	63 (17.1)	43 (11.7)	84 (22.8)	57 (15.4)	28 (7.6)	26 (7.0)	4 (1.1)	24 (6.5)	10 (2.7)	0 (0.0)	369 (100.0)
Meeting 10 N (%)	0 (0.0)	5 (1.5)	6 (1.8)	10 (3.0)	62 (18.9)	44 (13.4)	93 (28.4)	46 (14.0)	30 (9.1)	19 (5.8)	9 (2.7)	4 (1.2)	0 (0.0)	0 (0.0)	328 (100.0)
Meeting 13 N (%)	1 (0.3)	5 (1.4)	9 (2.5)	16 (4.4)	57 (15.7)	50 (13.7)	101 (27.7)	52 (14.3)	31 (8.5)	32 (8.8)	6 (1.6)	2 (0.5)	2 (0.5)	0 (0.0)	364 (100.0)

Meeting 14 N (%)	0 (0.0)	12 (2.2)	3 (0.5)	16 (2.9)	90 (16.4)	89 (16.2)	129 (23.5)	85 (15.5)	33 (6.0)	42 (7.7)	12 (2.2)	10 (1.8)	27 (4.9)	1 (0.2)	549 (100.0)
Meeting 15 N (%)	3 (0.5)	28 (4.4)	9 (1.4)	29 (4.6)	104 (16.5)	115 (18.2)	146 (23.1)	85 (13.4)	45 (7.1)	42 (6.6)	14 (2.2)	5 (0.8)	7 (1.1)	0 (0.0)	632 (100.0)
Meeting 17 N (%)	0 (0.0)	16 (3.9)	12 (2.9)	18 (4.4)	72 (17.6)	68 (16.6)	121 (29.6)	45 (11.0)	20 (4.9)	27 (6.6)	1 (0.2)	5 (1.2)	4 (1.0)	0 (0.0)	409 (100.0)
Meeting 20 N (%)	2 (0.5)	6 (1.4)	10 (2.3)	16 (3.7)	87 (20.1)	79 (18.2)	102 (23.6)	48 (11.1)	47 (10.9)	27 (6.2)	4 (0.9)	4 (0.9)	1 (0.2)	0 (0.0)	433 (100.0)
Meeting 21 N (%)	1 (0.2)	5 (1.1)	10 (2.3)	21 (4.8)	104 (23.7)	71 (16.2)	94 (21.4)	53 (12.1)	27 (6.2)	38 (8.7)	11 (2.5)	2 (0.5)	2 (0.5)	0 (0.0)	439 (100.0)
Meeting 22 N (%)	0 (0.0)	5 (0.9)	9 (1.7)	33 (6.2)	126 (23.6)	63 (11.8)	110 (20.6)	54 (10.1)	45 (8.4)	42 (7.9)	15 (2.8)	21 (3.9)	10 (1.9)	0 (0.0)	533 (100.0)
Meeting 23 N (%)	0 (0.0)	3 (1.1)	12 (4.2)	16 (5.6)	78 (27.4)	36 (12.6)	47 (16.5)	34 (11.9)	22 (7.7)	31 (10.9)	5 (1.8)	1 (0.4)	0 (0.0)	0 (0.0)	285 (100.0)
Meeting 24 N (%)	4 (2.2)	5 (2.7)	14 (7.6)	16 (8.7)	40 (21.7)	23 (12.5)	24 (13.0)	20 (10.9)	10 (5.4)	19 (10.3)	7 (3.8)	1 (0.5)	1 (0.5)	0 (0.0)	184 (100.0)
Aggregate N(%)	**13 (0.2)**	**115 (1.8)**	**116 (1.9)**	**282 (4.5)**	**1229 (19.7)**	**862 (13.8)**	**1504 (24.1)**	**866 (13.9)**	**409 (6.5)**	**501 (8.0)**	**112 (1.8)**	**140 (2.2)**	**101 (1.6)**	**1 (0.0)**	**6251 (100.0)**

Appendix III - Case study B – Sequential Interactions Table

Key: AI = asks for information, GI = gives information, AC = asks for confirmation, GC = gives confirmation, AO = asks for analysis, GO = gives analysis, AS = asks for suggestions, GS = gives suggestion, AE = agrees, DE = disagrees, TR = shows tension release, ST = shows tension, SS = shows solidarity, and SA = shows antagonism

Sequential Interactions	**Mtg 1 N(%)**	**Mtg 2 N(%)**	**Mtg 3 N(%)**	**Mtg 4 N(%)**	**Mtg 5 N(%)**	**Mtg 6 N(%)**	**Mtg 7 N(%)**	**Mtg 8 N(%)**	**Mtg 10 N(%)**	**Mtg 13 N(%)**	**Mtg 14 N(%)**	**Mtg 15 N(%)**	**Mtg 17 N(%)**	**Mtg 20 N(%)**	**Mtg 21 N(%)**	**Mtg 22 N(%)**	**Mtg 23 N(%)**	**Mtg 24 N(%)**	**Aggregate N(%)**
AI - GI	3 (4.55)	4 (3.42)	23 (6.63)	31 (5.83)	34 (5.51)	27 (6.77)	19 (4.53)	12 (5.66)	25 (5.84)	23 (4.36)	14 (5.04)	4 (2.20)	10 (5.15)	30 (7.61)	33 (9.73)	26 (7.74)	21 (5.88)	20 (6.27)	359 (5.92)
GI - GI	4 (6.06)	5 (4.27)	26 (7.49)	25 (4.70)	40 (6.48)	38 (9.52)	19 (4.53)	8 (3.77)	20 (4.67)	12 (2.28)	6 (2.16)	2 (1.10)	7 (3.61)	29 (7.36)	26 (7.67)	27 (8.04)	17 (4.76)	20 (6.27)	331 (5.46)
GI - GO	0 (0.00)	5 (4.27)	13 (3.75)	19 (3.57)	23 (3.73)	25 (6.27)	24 (5.73)	10 (4.72)	23 (5.37)	32 (6.07)	9 (3.24)	4 (2.20)	6 (3.09)	20 (5.08)	15 (4.42)	22 (6.55)	10 (2.80)	22 (6.90)	282 (4.65)
AO - GO	2 (3.03)	3 (2.56)	21 (6.05)	17 (3.20)	22 (3.57)	10 (2.51)	14 (3.34)	14 (6.60)	25 (5.84)	24 (4.55)	20 (7.19)	12 (6.59)	6 (3.09)	22 (5.58)	21 (6.19)	9 (2.68)	8 (2.24)	8 (2.51)	258 (4.26)
GO - GI	1 (1.52)	6 (5.13)	11 (3.17)	19 (3.57)	18 (2.92)	16 (4.01)	17 (4.06)	10 (4.72)	21 (4.91)	23 (4.36)	7 (2.52)	6 (3.30)	8 (4.12)	18 (4.57)	15 (4.42)	21 (6.25)	11 (3.08)	19 (5.96)	247 (4.07)
GI - AI	4 (6.06)	1 (0.85)	13 (3.75)	23 (4.32)	19 (3.08)	10 (2.51)	8 (1.91)	11 (5.19)	15 (3.50)	16 (3.04)	9 (3.24)	3 (1.65)	8 (4.12)	19 (4.82)	21 (6.19)	24 (7.14)	16 (4.48)	15 (4.70)	235 (3.88)
GO - GO	2 (3.03)	8 (6.84)	4 (1.15)	7 (1.32)	16 (2.59)	17 (4.26)	10 (2.39)	12 (5.66)	18 (4.21)	28 (5.31)	15 (5.40)	4 (2.20)	9 (4.64)	22 (5.58)	10 (2.95)	13 (3.87)	11 (3.08)	10 (3.13)	216 (3.56)
AC- GC	4 (6.06)	3 (2.56)	15 (4.32)	16 (3.01)	16 (2.59)	14 (3.51)	27 (6.44)	5 (2.36)	16 (3.74)	19 (3.61)	13 (4.68)	7 (3.85)	1 (0.52)	12 (3.05)	9 (2.65)	7 (2.08)	10 (2.80)	20 (6.27)	214 (3.53)
GO - AI	2 (3.03)	2 (1.71)	15 (4.32)	14 (2.63)	18 (2.92)	6 (1.50)	10 (2.39)	6 (2.83)	12 (2.80)	12 (2.28)	13 (4.68)	7 (3.85)	1 (0.52)	22 (5.58)	21 (6.19)	17 (5.06)	10 (2.80)	7 (2.19)	195 (3.22)
GI - GC	0 (0.00)	2 (1.71)	11 (3.17)	16 (3.01)	19 (3.08)	14 (3.51)	16 (3.82)	3 (1.42)	12 (2.80)	10 (1.90)	4 (1.44)	4 (2.20)	5 (2.58)	9 (2.28)	9 (2.65)	7 (2.08)	13 (3.64)	9 (2.82)	163 (2.69)
GO - AO	0 (0.00)	1 (0.85)	9 (2.59)	14 (2.63)	12 (1.94)	6 (1.50)	10 (2.39)	11 (5.19)	16 (3.74)	16 (3.04)	15 (5.40)	8 (4.40)	1 (0.52)	12 (3.05)	9 (2.65)	6 (1.79)	8 (2.24)	5 (1.57)	159 (2.62)
GC - GI	1 (1.52)	1 (0.85)	11 (3.17)	12 (2.26)	13 (2.11)	13 (3.26)	17 (4.06)	5 (2.36)	9 (2.10)	13 (2.47)	5 (1.80)	3 (1.65)	5 (2.58)	9 (2.28)	6 (1.77)	11 (3.27)	6 (1.68)	14 (4.39)	154 (2.54)
GC - AI	3 (4.55)	0 (0.00)	8 (2.31)	19 (3.57)	21 (3.40)	13 (3.26)	13 (3.10)	3 (1.42)	14 (3.27)	8 (1.52)	4 (1.44)	4 (2.20)	3 (1.55)	8 (2.03)	4 (1.18)	9 (2.68)	10 (2.80)	9 (2.82)	153 (2.52)
AI - GO	2 (3.03)	1 (0.85)	7 (2.02)	19 (3.57)	3 (0.49)	5 (1.25)	13 (3.10)	7 (3.30)	6 (1.40)	11 (2.09)	7 (2.52)	6 (3.30)	2 (1.03)	16 (4.06)	11 (3.24)	14 (4.17)	11 (3.08)	8 (2.51)	149 (2.46)
GC -GO	0 (0.00)	4 (3.42)	7 (2.02)	12 (2.26)	20 (3.24)	9 (2.26)	13 (3.10)	1 (0.47)	17 (3.97)	12 (2.28)	11 (3.96)	3 (1.65)	3 (1.55)	7 (1.78)	5 (1.47)	5 (1.49)	12 (3.36)	7 (2.19)	148 (2.44)
AI - GC	3 (4.55)	0 (0.00)	10 (2.88)	17 (3.20)	24 (3.89)	4 (1.00)	10 (2.39)	4 (1.89)	15 (3.50)	6 (1.14)	3 (1.08)	4 (2.20)	2 (1.03)	9 (2.28)	9 (2.65)	12 (3.57)	6 (1.68)	5 (1.57)	143 (2.36)
GI - AO	0 (0.00)	4 (3.42)	10 (2.88)	11 (2.07)	10 (1.62)	8 (2.01)	8 (1.91)	4 (1.89)	9 (2.10)	6 (1.14)	8 (2.88)	2 (1.10)	4 (2.06)	11 (2.79)	11 (3.24)	8 (2.38)	5 (1.40)	6 (1.88)	125 (2.06)

GO - GC	0 (0.00)	2 (1.71)	3 (0.86)	14 (2.63)	16 (2.59)	14 (3.51)	10 (2.39)	5 (2.36)	14 (3.27)	10 (1.90)	10 (3.60)	5 (2.75)	2 (1.03)	5 (1.27)	4 (1.18)	3 (0.89)	3 (0.84)	3 (0.94)	123 (2.03)
GI - AC	2 (3.03)	2 (1.71)	13 (3.75)	5 (0.94)	11 (1.78)	8 (2.01)	15 (3.58)	1 (0.47)	7 (1.64)	10 (1.90)	4 (1.44)	2 (1.10)	1 (0.52)	5 (1.27)	3 (0.88)	9 (2.68)	3 (0.84)	10 (3.13)	111 (1.83)
GC - GC	3 (4.55)	0 (0.00)	4 (1.15)	13 (2.44)	23 (3.73)	12 (3.01)	9 (2.15)	0 (0.00)	8 (1.87)	6 (1.14)	3 (1.08)	2 (1.10)	3 (1.55)	3 (0.76)	2 (0.59)	6 (1.79)	1 (0.28)	4 (1.25)	102 (1.68)
GO - AC	1 (1.52)	1 (0.85)	5 (1.44)	7 (1.32)	5 (0.81)	3 (0.75)	15 (3.58)	3 (1.42)	7 (1.64)	13 (2.47)	6 (2.16)	3 (1.65)	1 (0.52)	8 (2.03)	2 (0.59)	2 (0.60)	8 (2.24)	5 (1.57)	95 (1.57)
AO - GI	0 (0.00)	3 (2.56)	5 (1.44)	8 (1.50)	7 (1.13)	7 (1.75)	4 (0.95)	1 (0.47)	4 (0.93)	9 (1.71)	6 (2.16)	3 (1.65)	8 (4.12)	4 (1.02)	8 (2.36)	7 (2.08)	3 (0.84)	4 (1.25)	91 (1.50)
AI - AI	1 (1.52)	1 (0.85)	5 (1.44)	6 (1.13)	8 (1.30)	4 (1.00)	4 (0.95)	6 (2.83)	3 (0.70)	6 (1.14)	3 (1.08)	1 (0.55)	5 (2.58)	5 (1.27)	7 (2.06)	8 (2.38)	7 (1.96)	5 (1.57)	85 (1.40)
GC - AO	0 (0.00)	0 (0.00)	3 (0.86)	7 (1.32)	8 (1.30)	5 (1.25)	3 (0.72)	3 (1.42)	5 (1.17)	6 (1.14)	3 (1.08)	2 (1.10)	3 (1.55)	3 (0.76)	7 (2.06)	3 (0.89)	4 (1.12)	0 (0.00)	65 (1.07)
GI - GS	2 (3.03)	2 (1.71)	2 (0.58)	6 (1.13)	5 (0.81)	8 (2.01)	4 (0.95)	0 (0.00)	3 (0.70)	7 (1.33)	3 (1.08)	5 (2.75)	3 (1.55)	4 (1.02)	3 (0.88)	0 (0.00)	3 (0.84)	0 (0.00)	60 (0.99)
GC - AC	2 (3.03)	0 (0.00)	5 (1.44)	8 (1.50)	8 (1.30)	3 (0.75)	8 (1.91)	0 (0.00)	5 (1.17)	3 (0.57)	4 (1.44)	2 (1.10)	0 (0.00)	1 (0.25)	4 (1.18)	2 (0.60)	0 (0.00)	5 (1.57)	60 (0.99)
AC - GI	1 (1.52)	2 (1.71)	3 (0.86)	6 (1.13)	5 (0.81)	2 (0.50)	6 (1.43)	1 (0.47)	3 (0.70)	8 (1.52)	3 (1.08)	1 (0.55)	1 (0.52)	4 (1.02)	2 (0.59)	4 (1.19)	3 (0.84)	2 (0.63)	57 (0.94)
GO - GS	1 (1.52)	3 (2.56)	3 (0.86)	2 (0.38)	5 (0.81)	3 (0.75)	4 (0.95)	1 (0.47)	4 (0.93)	11 (2.09)	3 (1.08)	2 (1.10)	1 (0.52)	2 (0.51)	1 (0.29)	0 (0.00)	1 (0.28)	3 (0.94)	50 (0.82)
GC - GS	4 (6.06)	2 (1.71)	4 (1.15)	3 (0.56)	4 (0.65)	4 (1.00)	4 (0.95)	2 (0.94)	3 (0.70)	5 (0.95)	2 (0.72)	2 (1.10)	1 (0.52)	2 (0.51)	1 (0.29)	1 (0.30)	4 (1.12)	1 (0.31)	49 (0.81)
GS - GI	3 (4.55)	2 (1.71)	4 (1.15)	3 (0.56)	5 (0.81)	3 (0.75)	2 (0.48)	2 (0.94)	3 (0.70)	7 (1.33)	3 (1.08)	1 (0.55)	1 (0.52)	2 (0.51)	1 (0.29)	0 (0.00)	0 (0.00)	1 (0.31)	43 (0.71)
GI - DE	0 (0.00)	2 (1.71)	1 (0.29)	4 (0.75)	2 (0.32)	1 (0.25)	0 (0.00)	3 (1.42)	0 (0.00)	4 (0.76)	0 (0.00)	0 (0.00)	4 (2.06)	1 (0.25)	2 (0.59)	4 (1.19)	8 (2.24)	1 (0.31)	37 (0.61)
AO - AI	0 (0.00)	0 (0.00)	2 (0.58)	5 (0.94)	1 (0.16)	1 (0.25)	2 (0.48)	3 (1.42)	3 (0.70)	1 (0.19)	0 (0.00)	2 (1.10)	0 (0.00)	4 (1.02)	4 (1.18)	2 (0.60)	4 (1.12)	3 (0.94)	37 (0.61)
AC - GO	0 (0.00)	0 (0.00)	2 (0.58)	2 (0.38)	8 (1.30)	1 (0.25)	4 (0.95)	0 (0.00)	4 (0.93)	5 (0.95)	3 (1.08)	1 (0.55)	0 (0.00)	0 (0.00)	1 (0.29)	1 (0.30)	2 (0.56)	2 (0.63)	36 (0.59)
GS - GC	2 (3.03)	0 (0.00)	1 (0.29)	5 (0.94)	4 (0.65)	4 (1.00)	3 (0.72)	1 (0.47)	3 (0.70)	4 (0.76)	1 (0.36)	1 (0.55)	2 (1.03)	0 (0.00)	0 (0.00)	2 (0.60)	2 (0.56)	1 (0.31)	36 (0.59)
AI - AC	0 (0.00)	0 (0.00)	2 (0.58)	3 (0.56)	8 (1.30)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	4 (0.76)	3 (1.08)	0 (0.00)	1 (0.52)	0 (0.00)	3 (0.88)	0 (0.00)	4 (1.12)	5 (1.57)	34 (0.56)
GO - AS	0 (0.00)	2 (1.71)	2 (0.58)	5 (0.94)	4 (0.65)	1 (0.25)	1 (0.24)	2 (0.94)	5 (1.17)	4 (0.76)	1 (0.36)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	1 (0.28)	5 (1.57)	34 (0.56)
GS - AE	1 (1.52)	4 (3.42)	2 (0.58)	0 (0.00)	3 (0.49)	3 (0.75)	3 (0.72)	0 (0.00)	3 (0.70)	2 (0.38)	3 (1.08)	4 (2.20)	0 (0.00)	0 (0.00)	2 (0.59)	0 (0.00)	2 (0.56)	1 (0.31)	33 (0.54)
AI - AO	2 (3.03)	2 (1.71)	1 (0.29)	3 (0.56)	3 (0.49)	2 (0.50)	1 (0.24)	1 (0.47)	0 (0.00)	1 (0.19)	2 (0.72)	1 (0.55)	5 (2.58)	3 (0.76)	3 (0.88)	1 (0.30)	1 (0.28)	0 (0.00)	32 (0.53)
GI - AS	1 (1.52)	0 (0.00)	2 (0.58)	4 (0.75)	4 (0.65)	0 (0.00)	0 (0.00)	2 (0.94)	2 (0.47)	5 (0.95)	1 (0.36)	1 (0.55)	1 (0.52)	1 (0.25)	1 (0.29)	2 (0.60)	2 (0.56)	3 (0.94)	32 (0.53)
DE - GI	0 (0.00)	1 (0.85)	1 (0.29)	2 (0.38)	0 (0.00)	3 (0.75)	1 (0.24)	2 (0.94)	1 (0.23)	6 (1.14)	1 (0.36)	0 (0.00)	1 (0.52)	3 (0.76)	0 (0.00)	4 (1.19)	4 (1.12)	1 (0.31)	31 (0.51)
AC - AC	0 (0.00)	0 (0.00)	2 (0.58)	0 (0.00)	7 (1.13)	0 (0.00)	5 (1.19)	1 (0.47)	3 (0.70)	5 (0.95)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	5 (1.40)	3 (0.94)	31 (0.51)
AO - AO	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.16)	4 (1.00)	0 (0.00)	2 (0.94)	3 (0.70)	3 (0.57)	1 (0.36)	0 (0.00)	3 (1.55)	4 (1.02)	4 (1.18)	0 (0.00)	2 (0.56)	1 (0.31)	29 (0.48)

AC - AI	1 (1.52)	1 (0.85)	4 (1.15)	5 (0.94)	1 (0.16)	2 (0.50)	3 (0.72)	0 (0.00)	1 (0.23)	4 (0.76)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	2 (0.59)	0 (0.00)	2 (0.56)	1 (0.31)	28 (0.46)
GS - AI	0 (0.00)	1 (0.85)	1 (0.29)	2 (0.38)	6 (0.97)	2 (0.50)	2 (0.48)	0 (0.00)	2 (0.47)	3 (0.57)	0 (0.00)	1 (0.55)	0 (0.00)	2 (0.51)	2 (0.59)	0 (0.00)	3 (0.84)	1 (0.31)	28 (0.46)
AO - GC	0 (0.00)	1 (0.85)	3 (0.86)	3 (0.56)	4 (0.65)	3 (0.75)	2 (0.48)	0 (0.00)	0 (0.00)	2 (0.38)	2 (0.72)	0 (0.00)	2 (1.03)	3 (0.76)	0 (0.00)	1 (0.30)	1 (0.28)	1 (0.31)	28 (0.46)
GS - GO	1 (1.52)	3 (2.56)	1 (0.29)	1 (0.19)	4 (0.65)	0 (0.00)	2 (0.48)	1 (0.47)	2 (0.47)	2 (0.38)	5 (1.80)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	2 (0.56)	3 (0.94)	28 (0.46)
AE - GO	0 (0.00)	1 (0.85)	0 (0.00)	2 (0.38)	0 (0.00)	4 (1.00)	1 (0.24)	0 (0.00)	2 (0.47)	4 (0.76)	6 (2.16)	4 (2.20)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	1 (0.28)	0 (0.00)	26 (0.43)
GS - AO	0 (0.00)	0 (0.00)	2 (0.58)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.48)	2 (0.94)	1 (0.23)	4 (0.76)	1 (0.36)	4 (2.20)	3 (1.55)	3 (0.76)	2 (0.59)	0 (0.00)	1 (0.28)	1 (0.31)	26 (0.43)
GC - TR	0 (0.00)	0 (0.00)	1 (0.29)	3 (0.56)	8 (1.30)	2 (0.50)	3 (0.72)	1 (0.47)	0 (0.00)	2 (0.38)	0 (0.00)	1 (0.55)	2 (1.03)	1 (0.25)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	25 (0.41)
GS - AC	1 (1.52)	1 (0.85)	1 (0.29)	1 (0.19)	0 (0.00)	2 (0.50)	1 (0.24)	1 (0.47)	2 (0.47)	6 (1.14)	1 (0.36)	1 (0.55)	1 (0.52)	1 (0.25)	2 (0.59)	0 (0.00)	2 (0.56)	1 (0.31)	25 (0.41)
GI - ST	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.94)	2 (0.32)	2 (0.50)	0 (0.00)	1 (0.47)	0 (0.00)	4 (0.76)	0 (0.00)	0 (0.00)	1 (0.52)	1 (0.25)	3 (0.88)	4 (1.19)	2 (0.56)	0 (0.00)	25 (0.41)
AE - GI	0 (0.00)	0 (0.00)	2 (0.58)	0 (0.00)	2 (0.32)	3 (0.75)	6 (1.43)	0 (0.00)	3 (0.70)	0 (0.00)	2 (0.72)	2 (1.10)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.84)	1 (0.31)	24 (0.40)
AS - GS	1 (1.52)	2 (1.71)	2 (0.58)	1 (0.19)	3 (0.49)	0 (0.00)	0 (0.00)	3 (1.42)	4 (0.93)	1 (0.19)	2 (0.72)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	1 (0.30)	1 (0.28)	2 (0.63)	24 (0.40)
GI - TR	1 (1.52)	0 (0.00)	1 (0.29)	5 (0.94)	8 (1.30)	2 (0.50)	1 (0.24)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	1 (0.52)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.94)	24 (0.40)
GO - AE	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	2 (0.32)	2 (0.50)	1 (0.24)	0 (0.00)	4 (0.93)	2 (0.38)	3 (1.08)	3 (1.65)	0 (0.00)	1 (0.25)	2 (0.59)	0 (0.00)	1 (0.28)	1 (0.31)	23 (0.38)
GI - AE	0 (0.00)	0 (0.00)	2 (0.58)	1 (0.19)	1 (0.16)	4 (1.00)	3 (0.72)	0 (0.00)	2 (0.47)	2 (0.38)	2 (0.72)	1 (0.55)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	2 (0.56)	2 (0.63)	23 (0.38)
DE - GO	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.16)	0 (0.00)	1 (0.24)	5 (2.36)	0 (0.00)	6 (1.14)	0 (0.00)	1 (0.55)	1 (0.52)	0 (0.00)	1 (0.29)	2 (0.60)	4 (1.12)	0 (0.00)	23 (0.38)
AI - GS	0 (0.00)	1 (0.85)	1 (0.29)	2 (0.38)	2 (0.32)	1 (0.25)	1 (0.24)	1 (0.47)	2 (0.47)	1 (0.19)	1 (0.36)	1 (0.55)	0 (0.00)	2 (0.51)	3 (0.88)	2 (0.60)	0 (0.00)	1 (0.31)	22 (0.36)
AS - GI	0 (0.00)	0 (0.00)	1 (0.29)	2 (0.38)	4 (0.65)	0 (0.00)	2 (0.48)	0 (0.00)	2 (0.47)	5 (0.95)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	2 (0.56)	2 (0.63)	22 (0.36)
ST - GI	0 (0.00)	0 (0.00)	0 (0.00)	8 (1.50)	1 (0.16)	2 (0.50)	1 (0.24)	2 (0.94)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	1 (0.52)	1 (0.25)	1 (0.29)	0 (0.00)	3 (0.84)	0 (0.00)	22 (0.36)
GO - DE	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	2 (0.32)	1 (0.25)	3 (0.72)	3 (1.42)	1 (0.23)	4 (0.76)	1 (0.36)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	4 (1.12)	0 (0.00)	21 (0.35)
GS - GS	2 (3.03)	2 (1.71)	0 (0.00)	0 (0.00)	3 (0.49)	0 (0.00)	0 (0.00)	2 (0.94)	2 (0.47)	2 (0.38)	2 (0.72)	2 (1.10)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	20 (0.33)
TR - GI	0 (0.00)	0 (0.00)	1 (0.29)	3 (0.56)	5 (0.81)	2 (0.50)	2 (0.48)	1 (0.47)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	1 (0.52)	2 (0.51)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	20 (0.33)
ST - AI	0 (0.00)	1 (0.85)	1 (0.29)	4 (0.75)	0 (0.00)	1 (0.25)	0 (0.00)	1 (0.47)	0 (0.00)	1 (0.19)	0 (0.00)	1 (0.55)	1 (0.52)	1 (0.25)	2 (0.59)	3 (0.89)	2 (0.56)	0 (0.00)	19 (0.31)
AS - GO	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.94)	3 (0.49)	0 (0.00)	1 (0.24)	0 (0.00)	2 (0.47)	1 (0.19)	1 (0.36)	1 (0.55)	1 (0.52)	2 (0.51)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	19 (0.31)
GC - AE	0 (0.00)	0 (0.00)	4 (1.15)	1 (0.19)	1 (0.16)	2 (0.50)	2 (0.48)	0 (0.00)	0 (0.00)	2 (0.38)	3 (1.08)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	18 (0.30)
AO - GS	0 (0.00)	2 (1.71)	0 (0.00)	0 (0.00)	4 (0.65)	0 (0.00)	1 (0.24)	1 (0.47)	2 (0.47)	1 (0.19)	1 (0.36)	1 (0.55)	2 (1.03)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	17 (0.28)

GO - ST	0 (0.00)	2 (1.71)	0 (0.00)	5 (0.94)	1 (0.16)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	4 (2.06)	2 (0.51)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	17 (0.28)
DE - DE	0 (0.00)	1 (0.85)	0 (0.00)	2 (0.38)	0 (0.00)	1 (0.25)	0 (0.00)	2 (0.94)	0 (0.00)	3 (0.57)	0 (0.00)	0 (0.00)	3 (1.55)	0 (0.00)	0 (0.00)	2 (0.60)	3 (0.84)	0 (0.00)	17 (0.28)
TR - GO	0 (0.00)	1 (0.85)	0 (0.00)	2 (0.38)	4 (0.65)	0 (0.00)	3 (0.72)	0 (0.00)	1 (0.23)	0 (0.00)	1 (0.36)	1 (0.55)	1 (0.52)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	15 (0.25)
TR - TR	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	3 (0.49)	7 (1.75)	0 (0.00)	0 (0.00)	1 (0.23)	0 (0.00)	0 (0.00)	1 (0.55)	1 (0.52)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	15 (0.25)
GS - DE	0 (0.00)	1 (0.85)	1 (0.29)	0 (0.00)	1 (0.16)	2 (0.50)	0 (0.00)	0 (0.00)	1 (0.23)	2 (0.38)	0 (0.00)	0 (0.00)	1 (0.52)	3 (0.76)	0 (0.00)	2 (0.60)	0 (0.00)	0 (0.00)	14 (0.23)
AO - AC	0 (0.00)	0 (0.00)	0 (0.00)	6 (1.13)	1 (0.16)	1 (0.25)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (1.12)	1 (0.31)	14 (0.23)
DE - AI	0 (0.00)	1 (0.85)	1 (0.29)	0 (0.00)	2 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.03)	0 (0.00)	2 (0.59)	3 (0.89)	2 (0.56)	1 (0.31)	14 (0.23)
TR - AI	0 (0.00)	0 (0.00)	1 (0.29)	1 (0.19)	4 (0.65)	2 (0.50)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.36)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	2 (0.63)	13 (0.21)
GO - TR	0 (0.00)	0 (0.00)	1 (0.29)	1 (0.19)	2 (0.32)	2 (0.50)	1 (0.24)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.36)	1 (0.55)	2 (1.03)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	13 (0.21)
TR - AO	0 (0.00)	0 (0.00)	1 (0.29)	3 (0.56)	3 (0.49)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.47)	1 (0.19)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	13 (0.21)
ST - GO	0 (0.00)	2 (1.71)	0 (0.00)	3 (0.56)	0 (0.00)	1 (0.25)	0 (0.00)	2 (0.94)	2 (0.47)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	13 (0.21)
GC - AS	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	3 (0.49)	0 (0.00)	1 (0.24)	0 (0.00)	3 (0.70)	2 (0.38)	0 (0.00)	0 (0.00)	1 (0.52)	2 (0.51)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	13 (0.21)
GC - DE	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	2 (1.03)	1 (0.25)	0 (0.00)	1 (0.30)	2 (0.56)	1 (0.31)	12 (0.20)
ST - GC	1 (1.52)	0 (0.00)	1 (0.29)	0 (0.00)	3 (0.49)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	4 (2.06)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	11 (0.18)
AI - ST	0 (0.00)	0 (0.00)	1 (0.29)	2 (0.38)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.59)	2 (0.60)	3 (0.84)	0 (0.00)	11 (0.18)
DE - GC	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	1 (0.16)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	2 (1.03)	0 (0.00)	1 (0.29)	0 (0.00)	3 (0.84)	0 (0.00)	11 (0.18)
TR - GC	0 (0.00)	1 (0.85)	0 (0.00)	1 (0.19)	4 (0.65)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.57)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	1 (0.30)	0 (0.00)	0 (0.00)	11 (0.18)
GC - ST	0 (0.00)	1 (0.85)	0 (0.00)	5 (0.94)	2 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	11 (0.18)
AE - AO	0 (0.00)	0 (0.00)	4 (1.15)	0 (0.00)	1 (0.16)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	1 (0.28)	1 (0.31)	11 (0.18)
AO - DE	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	3 (1.42)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	1 (0.52)	1 (0.25)	0 (0.00)	0 (0.00)	2 (0.56)	0 (0.00)	10 (0.16)
DE - GS	0 (0.00)	2 (1.71)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	1 (0.52)	2 (0.51)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	10 (0.16)
DE - ST	0 (0.00)	0 (0.00)	4 (1.15)	0 (0.00)	1 (0.16)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.36)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	10 (0.16)
AC - GS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.24)	3 (1.42)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.51)	0 (0.00)	0 (0.00)	2 (0.56)	0 (0.00)	10 (0.16)
AS - AO	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.23)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.63)	8 (0.13)
AC - AO	0 (0.00)	1 (0.85)	1 (0.29)	0 (0.00)	2 (0.32)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	1 (0.29)	0 (0.00)	0 (0.00)	1 (0.31)	8 (0.13)

AS - GC	0 (0.00)	1 (0.85)	0 (0.00)	0 (0.00)	2 (0.32)	2 (0.50)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.36)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	8 (0.13)
AE - AI	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.23)	1 (0.19)	2 (0.72)	0 (0.00)	2 (1.03)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	8 (0.13)
AS - AI	0 (0.00)	1 (0.85)	0 (0.00)	0 (0.00)	3 (0.49)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.36)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	8 (0.13)
AE - AC	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	1 (0.47)	1 (0.23)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	1 (0.28)	1 (0.31)	8 (0.13)
GS - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	1 (0.25)	1 (0.29)	1 (0.30)	1 (0.28)	1 (0.31)	7 (0.12)
ST - GS	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	2 (0.56)	0 (0.00)	7 (0.12)
AI - DE	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	1 (0.16)	0 (0.00)	1 (0.24)	0 (0.00)	2 (0.47)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	7 (0.12)
AI - TR	0 (0.00)	1 (0.85)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.24)	1 (0.47)	0 (0.00)	0 (0.00)	1 (0.36)	2 (1.10)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	7 (0.12)
AE - GS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.49)	1 (0.25)	0 (0.00)	0 (0.00)	1 (0.23)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	7 (0.12)
DE - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.23)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.51)	0 (0.00)	1 (0.30)	1 (0.28)	0 (0.00)	7 (0.12)
ST - DE	0 (0.00)	0 (0.00)	1 (0.29)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	2 (1.03)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	0 (0.00)	6 (0.10)
AE - GC	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.24)	0 (0.00)	1 (0.23)	0 (0.00)	1 (0.36)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	1 (0.30)	0 (0.00)	0 (0.00)	6 (0.10)
AE - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (1.03)	1 (0.25)	1 (0.29)	2 (0.60)	0 (0.00)	0 (0.00)	6 (0.10)
AE - AE	0 (0.00)	1 (0.85)	1 (0.29)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	1 (0.19)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	6 (0.10)
ST - AO	1 (1.52)	0 (0.00)	1 (0.29)	1 (0.19)	0 (0.00)	1 (0.25)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	6 (0.10)
GS - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	1 (0.23)	0 (0.00)	0 (0.00)	3 (1.65)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	6 (0.10)
AO - AS	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.70)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	6 (0.10)
DE - AO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	1 (0.25)	0 (0.00)	1 (0.30)	2 (0.56)	0 (0.00)	6 (0.10)
AC - ST	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.56)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.08)
AS - ST	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	2 (0.32)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	5 (0.08)
TR - DE	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.23)	0 (0.00)	0 (0.00)	3 (1.65)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.08)
ST - ST	0 (0.00)	1 (0.85)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.84)	0 (0.00)	5 (0.08)
AC - TR	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	1 (0.30)	0 (0.00)	0 (0.00)	5 (0.08)
GS - TR	0 (0.00)	1 (0.85)	1 (0.29)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.08)
AC - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	3 (1.55)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	5 (0.08)

SS - GO	0 (0.00)	1 (0.85)	1 (0.29)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	5 (0.08)
ST - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (1.55)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	4 (0.07)
AS - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	1 (0.31)	4 (0.07)
AS - AS	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	2 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.07)
DE - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	2 (1.10)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.07)
DE - TR	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.56)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	4 (0.07)
AO - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	1 (0.23)	0 (0.00)	1 (0.36)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
GI - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
TR - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.23)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	3 (0.05)
AC - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.48)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
TR - GS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.57)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
AE - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.36)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	3 (0.05)
TR - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	3 (0.05)
AS - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.36)	1 (0.55)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
AC - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
AS - DE	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
GO - SS	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.38)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.05)
SS - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.03)
AO - ST	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.47)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	2 (0.03)
AI - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.03)
AI - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	2 (0.03)
AO - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.03)
ST - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.03)
AS - TR	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.03)
GC - SS	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.03)

SS - AO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
GC - GO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	1 (0.02)
AE - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
GO - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
ST - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
ST - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
DE - GO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AI - GO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.31)	1 (0.02)
AI - GO	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
GO - DE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SS - AC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.24)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
GO - GI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	1 (0.02)
SS - AI	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	0 (0.00)	1 (0.02)
GS - AE	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SS - GC	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.55)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
GS - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
TR - AS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.30)	0 (0.00)	0 (0.00)	1 (0.02)
AO - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.25)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
AE - TR	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	1 (0.02)
AO - GO	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SS - SS	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.29)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
SA - DE	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.19)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.02)
ST - SA	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.28)	0 (0.00)	1 (0.02)
Total N(%)	66 (0.00)	117 (0.00)	347 (0.00)	532 (0.00)	617 (0.00)	399 (0.00)	419 (0.00)	212 (0.00)	428 (0.00)	527 (0.00)	278 (0.00)	182 (0.00)	194 (0.00)	394 (0.00)	339 (0.00)	336 (0.00)	357 (0.00)	319 (0.00)	6063 (100.00)