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ALTERNATIVE PROJECT DELIVERY METHODS: DESIGN DYNAMICS AND IMPLICATIONS

by
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AN ABSTRACT OF THE DISSERTATION OF

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Time is a major constraint in today's competitive market. Alternative project delivery methods (APDMs) allow for a faster project completion due the earlier involvement of the builder and the concurrency of the design and construction project functions. However, starting construction with partially completed design leads to potential incompatibilities of coordination between the released deliverables and other associated unreleased elements that are usually at different design development stages, which may ultimately lead to a higher frequency of changes and rework.

There stems the significance of this research work that aims at analysing the impact of alternative design-construction (DC) modes (e.g. fast-track) under APDMs on the design information release (DIR) dynamics and the respective implications. These implications are related to the design agreement negotiation and formation process and the Architect/Engineer (A/E)'s liability exposure and indemnity. Then, given the increased time pressure exercised by the builder on the A/E under a contractor-led design-build (DB) project, and the inevitable emergence of changes that may bring about detrimental impacts on project performance, the last objective of this research work is to devise a tool that helps design-builders track the changes for the purpose of controlling their impacts.

The methodology of work includes: (1) generating the design phase properties under alternative DC modes and conceptualizing the respective alternative DIR dynamics, (2) devising the models pertaining to the A/E's staging of services and inferring the expected changes in the staffing requirement and fee proposal, (3) reviewing common law cases and developing the general framework underlying negligence claims in tort against the A/E, and (4) tracking emergent changes in a contractor-led DB delivery method and developing a BIM-enabled system that helps tracking those changes to serve the control of their impact.

The findings of this study shall assist A/E professionals and design-builders in controlling risk-related matters brought about by APDMs. For instance, it informs design managers about the need for a design team's re-structuring to accommodate for alternative DIR dynamics. Moreover, it alerts designers about a potentially increased liability exposure emanating from the reduced certainty on the DIR's coordination quality. Accounting for the quality of design documentation, while keeping in mind the persisting liability burden, is expected to impact the capability and willingness of the A/E to deal with (or accept to abide by) a certain pattern or extent of design information release that is in satisfaction with the construction priorities or preferences imposed by a DB contractor. From a design-builder's perspective, monitoring time and budget performance in view of potential claims induced by emergent changes leads to a better assessment and planning for potential risks.

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Kalach, M., Abdul-Malak, M.A. and Srour, I.,(2020). "BIM-enabled Streaming of Changes and Potential Claims Induced by Fast tracking Design-Build Projects" *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, Under Review.

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LIST OF ACRONYMS

Acronym	Description
PDM	Project delivery method
APDM	Alternative project delivery method
DBB	The design-bid-build delivery method
CMAR	The construction manager at-risk delivery method
CMR	The construction manager at-risk entity
CMa	Agency construction management approach, or the phased DBB with agency CM
DB	The design-build delivery method
DIR	Design information release
A/E	Architect/Engineer
DC	Design-construction
SD	Schematic design
DD	Design development
CD	Construction documentation
LOD	Level of development
BIM	Building information modeling/model

CHAPTER 1

INTRODUCTION

1.1 Preamble

Several alternatives to the lengthy process of the traditional design-bid-build (DBB) delivery method have evolved over the years to suit the increasing needs and complexities of the construction industry. Owners opt for alternative project delivery methods (APDMs) for the main reason of compressing the project schedule, i.e., reducing the overall project delivery time, (Lopez del Puerto et al., 2008, Culp, 2011, Touran et al., 2011, Sullivan et al., 2017, Antoine et al., 2019) or delivering projects at a more intense pace (Antoine et al., 2019). Design-build (DB), in particular, has gained momentum and popularity among project owners as it offers them the unique added advantage of a single point of responsibility and accountability for design and construction services.

The potential timesaving advantage under APDMs, such as the construction manager at-risk (CMAR) or the DB, is attributed to (a) having design and construction fast-tracked/overlapped, as compared to the DBB in which a full design completion is needed before starting construction, and (b) the cooperation between the designer and the builder (Touran et al., 2011, El Asmar and Ariaratnam, 2018). Moreover, it is argued that the project schedule in CMAR is compressed to a more modest degree than in DB, because in DB (a) the degree of overlap is more pronounced since design and construction are obtained from a single entity (Touran et al., 2011), and (b) less detailed documentation is required (Quatman and Dhar, 2003, Culp, 2011).

Despite the aspired advantage of shortening the overall project duration, the design phase of fast-track projects faces many challenges, and front-end planning is often sacrificed in favor of starting the construction work as soon as possible (Deshpande et al. 2012). For instance, owing to the iterative nature of the design process, design problems are argued to emanate from having the design and construction phases executed in parallel with a minimal lag time, therefore having the design phase driven by the needs of the construction work (Deshpande et al. 2012).

The challenges further increase in a contractor-led DB setup for the following reasons: (a) the builder's considerable control over the details and sequence of design documents preparation and the related decision-making process (American Bar Association (ABA) 2003; Touran et al. 2011), (b) the details of the design, and the resultant quality, being constrained by the budget and the schedule as guaranteed by the design-builder (Gransberg and Molenaar 2004), (c) the owner's loss of direct control over the detailed design (Gransberg et al. 2008), and (d) the builder's presumed control over the design process and the designers' compensation, potentially influencing designers to exercise "shortcuts" in order to lower cost, or compromise on materials quality and long-term maintenance considerations (Brierley et al. 2010; McGreevy et al. 2005). Moreover, the contractor-led DB approach not only rids the A/E professionals of their independent role, but it also induces a new role of design manager for the contractor during the design phase (Chan et al. 2005). That is, the design-builder may face an immense challenge as most contractors are not trained to manage the design process even though they know the suitable timing (i.e., from a construction schedule's perspective) of the required design information (Chan and Yu 2005). Furthermore, DB is characterized by an inherent "culture clash"; that is, while designers traditionally believe they must protect (1) owners from contractors cutting corners and overpricing changes and (2) the integrity of their design rather than solving contractors' cost issues, contractors believe that designers overdesign everything and expect them to cover up design flaws (McGreevy et al. 2005). Contractors, when in control over the design process and the designers' compensation, are likely to influence them to exercise "shortcuts" in order to lower cost, instead of seeking value engineering design (McGreevy et al. 2005).

That said, schedule compression under APDMs is well established in the literature and is mainly realized by way of overlapping the design and construction phases. Starting construction with partially completed design increases the uncertainty and complexity associated with the design work (Lee et al., 2005, Zerjav et al., 2011, Deshpande et al., 2012) and leads to a higher frequency of rework (Moazzami et al., 2011). Moreover, given that the DB approach induces new roles for the A/E as well as for the contractor, it further adds to the complexity of the design phase and, therefore, the release of design information under such circumstances becomes more critical. On the one hand, different modes of overlap may be obtained under various APDMs, depending on the characteristics of each method. While a plethora of scholars studied the overlap between design and construction activities/tasks or within design activities/tasks, with some referring to fast-track projects (reflecting a general case of design and construction being overlapped/ fast-tracked), none of these studies is applied in the context of a specific APDM. Namely, the features that characterize APDMs were not previously discussed in literature work addressing the overlapping mechanism. On the other hand, A/E professionals are susceptible to different forms of professional liabilities, depending on the roles and responsibilities assumed by them (i.e., either as independent consultants appointed by owners or as subcontractors acting under design-builders) in connection with the rendering of design and other related services. Undoubtedly, DB does not change the fundamental role of the designer with respect to developing the design and preparing the construction documents. However, the dynamics of the legal relationship between the design-builder and the A/E in the DB setting are observed to be far different than the dynamics of the relationship between owners and designers on traditional DBB projects (Staak 2012). Yet, the relevant body of knowledge is found to be lacking work that can provide designers with a clear mapping of liability exposures stemming from the different services furnished by them under different capacities.

To bridge this gap, this research work investigates the impact of alternative DC modes (e.g. fast-track) under APDMs on the release of design deliverables and the respective implications on the Architect/Engineer's role and liabilities on the one hand, and the design-builder's time and budget performance on the other hand. This is mainly achieved by conceptualizing the possible alternative design information release (DIR) dynamics under alternative design-construction (DC) modes, and then benchmarking these dynamics against the well-established release of design deliverables under the sequential DC mode of the DBB method. Then, this study examines the implications of these alternative dynamics on the A/E's needed resources staffing and liability exposure and indemnity. Finally, given the increased uncertainties and challenges associated with the undertaking of the design phase in fast-track DB projects and the inevitable emergence of changes that may bring about negative impacts on the project performance, the last objective of this research work is to devise a tool that helps tracking those changes to serve the control of their impacts.

1.2 Organization of the dissertation

The organization of the dissertation is presented in Figure 1. Chapter 2 provides research background and related works to the topics covered in this study mainly, the overlapping mechanism in the construction industry and the associated tradeoffs, the definitions and characteristics of project delivery methods (PDMs), the role and liabilities of the design professional under alternative delivery methods, and Building Information Modeling (BIM) and change management. Chapter 3 discusses the research motivation, objectives, and contributions. Chapter 4 presents and explains the overall research design and the individual research methodologies and methods developed with respect to each of the four main research modules covered in this research study. Research Modules 1, 2, and 3 are covered in Chapter 5, Chapter 6, and Chapter 7, respectively; these include the conceptualization of the design information release (DIR) dynamics under alternative design-construction (DC) modes, and the implication of these alternative dynamics on (1) the A/E's required staffing and the respective design agreement negotiation and (2) the A/E's liability exposure and indemnity. Module 4 includes the development of a change tracking system for DB projects and is covered in Chapter 8 and Chapter 9. Namely, this module starts with investigating BIM applicability, in terms of usefulness and degree of relevance, to DB projects in Chapter 8. Then, Chapter 9 focuses on the BIM-enabled streaming of changes induced by fast tracking DB projects and includes the development of a BIM-based plugin that helps tracking changes in serving the control of their impact. Lastly, Chapter 10 concludes with a summary of the work presented, recommendations, and future research.

Figure 1. Organization of the dissertation

CHAPTER 2

RESEARCH BACKGROUND AND RELATED WORK

2.1 Project Contracting/Delivery Methods Characteristics

Project delivery describes the system used by the project owner to plan, design, construct, operate, and maintain facilities by entering into legal agreements with one or more entities or parties. Gordon (1994) defined a contracting method along four aspects: the extent of scope, the organization (i.e., the lead business entity), the type of contract and the contract award method (Figure 2). Each of these aspects includes several options/components. The number of possible combinations of these components gives a multiplicity of variations of alternative contracting methods.

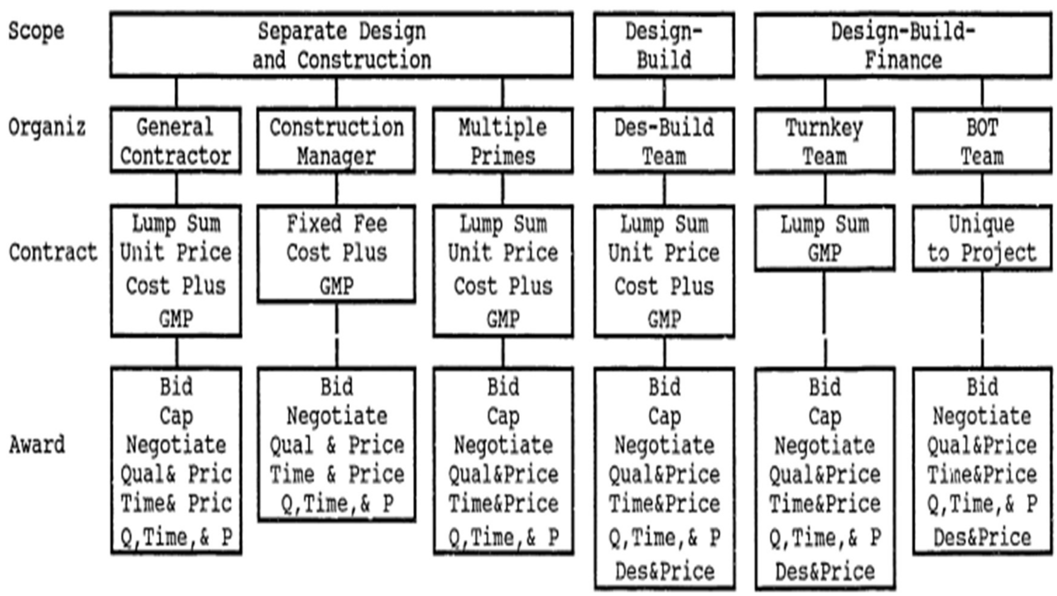


Figure 2. Construction contracting method components (Gordon 1994)

A project delivery method (PDM) is one that (a) defines the roles and responsibilities of the parties involved in a project and (b) establishes an execution framework in terms of sequencing of design, procurement, and construction (Oyetunji and Anderson 2006). The American Institute of Architects (AIA) and the Associated General Contractors of America (AGC), emphasized on the multiplicity of definitions of project delivery methods, yet on the lack of industry-wide accepted ones. These definitions which are developed by groups, organizations, and individuals, used different characteristics, none of which is entirely right or entirely wrong. That is, a primer on project delivery was produced by these two organizations, offering basic definitions aiming to help owners better understand their options. This primer distinguished between the "delivery" and "management" aspects of project delivery, referring to delivery as "the method for assigning responsibility to an organization or an individual for providing design and construction services," and to management as "the means for coordinating the process of design and construction" (AIA and AGC 2011). El Asmar e*t al.* (2013) define a project delivery method as a means that regulates the relationships and the time of engagement of the different project stakeholders, in order to deliver the built facility. According to Franz and Leicht (2016), the common characteristics that are frequently used in literature to differentiate among the PDMs include: (a) the allocation of design and construction responsibilities, regularly expressed in the number of contracts held by the owner, (b) the timing of involvement of the general contractor (GC) with respect to the design stages, (c) the methods used for soliciting bids or proposals from the GC; (d) the selection criteria of the GC, and (e) the payment methods for the GC. The authors argued that project delivery methods in the building construction industry are concerned with both the organization of the participants and the management of the process, which are social concerns with complex categorical relationships more than engineering problems. Therefore, they identified five classes as an alternative and more consistent structure for describing project delivery methods in future research. Compared to existing classifications of project delivery methods, these classes are data-driven typologies that represent how participants are procured and organized into a project team (Franz and Leicht 2016). The identified classes were then aligned with the twelve variations of PDMs that were previously proposed by the Construction Industry Institute (CII) as illustrated in Table 1.

Table 1. Alignment of Observed Classes with Existing Variations of PDMs (adapted from Franz and Leicht 2016)

Observed classes	Existing project delivery method variations (CII, 2003)	Description (CII, 2003)	Additional characteristics conveyed by class membership
Class I	Traditional design-bid-build (DBB)	Sequential design and construction, GC procurement begins with construction, owner contracts separately with designer and builder	Lump sum contract
	DBB with staged development		
Class II	DBB with construction manager (CM)	Sequential design and construction, builder procurement begins with construction or during late design, owner contracts separately with designer and builder	Lump sum contract, builder and specialty trades are prequalified
	DBB with project manager		
	DBB with early procurement		
	DBB with early procurement and CM		
Class III	Construction management at risk (CMR)	Overlapped design and construction, builder procurement begins during early design, owner contracts separately with design and builder	Cost reimbursable contract, builder and specialty trades are prequalified
	Fast track		
	Parallel primes		
Class IV	Design-build (DB)	Overlapped design and construction, builder procurement begins during early design, owner contracts with a single design-build entity	Specialty trade procurement begins during early design, Lump sum contract, design-builder and specialty trades are prequalified
	Turnkey		
Class V	Multiple DB	Overlapped design and construction, builder procurement begins during early design, owner contracts with a one or more designers and builders	Specialty trade procurement begins during early design, cost reimbursable contract, builder and specialty trades are prequalified
	Integrated project delivery (IPD)[a]		

[a]IPD was not included in the CII (2003) listing of project delivery methods, but was added to this table for completeness.

2.2 PDM Comparison Criteria and Selection Process

Several alternatives to the lengthy process of the traditional design-bid-build (DBB) delivery method have evolved over the years to suit the increasing needs and complexities of the construction industry. Owners opt for alternative project delivery methods (APDMs) for the main reason of compressing the project schedule, i.e., reducing the overall project delivery time, (Lopez del Puerto et al. 2008; Culp 2011; Touran et al. 2011; Sullivan et al. 2017; Antoine et al. 2019) or delivering projects at a more intense pace (Antoine et al. 2019).

Before choosing a PDM, owners must gain an initial understanding of the project, including a realistic cost range, schedule constraints, and design parameters. The selection process often followed a "process of elimination", i.e. paring away obviously inappropriate methods until reasonable alternatives prevail. To eliminate inappropriate organizations, Gordon (1994) specified three types of drivers that must be assessed: (a) project drivers (e.g., time constraints, flexibility needs, preconstruction service needs, design process interaction and financial constraints), (b) owner drivers (e.g., construction sophistication, current capabilities, risk aversion, restriction on methods and other external factors) and (c) market drivers (e.g., availability of appropriate contractors, current state of the market and package size of the project). Likewise, Qiang et al. (2015) identified three groups of factors governing and impacting the choice of a specific project delivery system, namely, internal project conditions (e.g. client's ability, client's preference), external project conditions (e.g. contractor related factors, consultant related factors, project characteristic and external project environment) and project performance objective factors (e.g. project process performance and project outcome performance).

Existing studies on PDM selection are mostly based on analysis of influencing factors and carry out comprehensive evaluation to assess a PDM by relying on experts' subjective opinions (Wang *et al.* 2013). Nevertheless, in literature, several ways and means are suggested for projects' owners/developers by way of more objectively selecting the most appropriate delivery approach for a project in question. For instance, scientific decision-making techniques such as the fuzzy approach (Mostafavi and Karamouz 2010; Martin *et al.* 2016), the analytical hierarchy process (AHP) (Al Khalil 2002; Mahdi and Alreshaid 2005; Mafakheri *et al.* 2007, Barati *et al.* 2015), the information entropy and unascertained measure model (Li *et al.* 2015) or internet technologies such as the creation of an electronic module called "e-Adviser" (Ng and Cheung 2007) were introduced as alternatives to the classical "method of elimination" that used to be implemented traditionally.

Breaking through the traditional research methods, an objective assessment and selection framework of the Design Build (DB) method, based on its value-added advantages as compared to Design-Bid-Build (DBB) was presented by Wang *et al.* (2013). The authors defined the concept of Value-added as the increase in project value resulting from project cost reduction and the time savings under DB compared to DBB, with fixed requirements of project function, scale and quality (Wang *et al.* 2013). The framework was based on the two distinct differences between the two approaches: (a) the integration of design and construction and (b) the single contractual relationship between the owner and the design builder. The study presented a scientific decision-making analysis of DB application and adoption.

The traditional comparison of cost, time and quality metrics of the different PDMs have been the subject of many construction research studies. For instance, El

Asmar *et al.* (2013) evaluated the performance of 35 IPD projects in comparison to projects delivered using other PDMs and showed statistically significant performance outcomes in the case of IPD. Sullivan *et al.* (2017) analyzed two decades of literature covering different PDMs comparison [namely the design-build (DB) and the construction manager at-risk (CMAR)] in various project types (e.g., transportation, buildings, military projects, etc.). The results showed that: (a) no single delivery method consistently performs better on unit cost, (b) CMAR and DB were the most accurate in controlling the schedule variation of a project, and (c) DB was superior in delivery speed in all explored studies and continues to increase its advantage over time. However, such comparison metrics govern the traditional decision-making process regarding the most suitable delivery method of the built project (Sullivan *et al.* 2017). Tran et al. (2017) compared the performance of highway DBB and DB projects and found that DB projects statistically provided a higher construction intensity (i.e., more work put in place) than DBB for new construction and reconstruction work types. Similarly, Chini et al. (2018) found that the greatest advantage of DB is the timesaving it offers, since it entails a faster delivery speed as well as a faster construction speed. El Asmar and Ariaratnam (2018) analyzed the performance of APDMs for water and wastewater infrastructure projects. The authors found that the DBB had the slowest project delivery speed (i.e., how fast a project is being designed and constructed in relation to its size), defeated by the CMAR, with the DB presenting the best speed performance (El Asmar and Ariaratnam 2018).

As clients increase the expectations they have regarding the performance of their intended facilities and face increasing cost and schedule constraints, the industry as a whole will need to develop more effective and efficient methods of delivering these assets. New pressures on long-term operating costs and environmental impacts will further drive the need for better designs and construction methods (Kilinc *et al.* 2015). Unlike conventional building development where the environmental effects of a built project are often disregarded, green building (GB) strategies focus on the improved environmental performance. A recent study by Ahmad *et al.* (2017) explored the effect of different PDMs on the green performance of GB projects using a systematic research review. To this end, the study defined GB projects as innovative projects and their level of green performance as an indication of their level of innovation. The authors argued that coordination among project team members is strongly influenced by the PDM which by itself impacts project innovation. Depending on the extent of innovative features incorporated, each PDM was found to have the capacity to produce successful results (Ahmad *et al.* 2017).

On the other hand, risk management in construction projects is also influenced by the procurement options (Osipova and Eriksson 2011). To this end, Osipova and Eriksson (2011) clarified how to improve risk management by adopting appropriate procurement options in terms of project delivery method, form of payment, and use of collaboration or partnering arrangements.

Inherent with the fast-track alternative is the time saving resulting from the compressed schedule due to the degree of overlap between design and construction providing the salient advantage over the sequential option. Moreover, the pursuit of faster fast-track or “flash-track” alternative could be deemed necessary in certain circumstances such as emergency rebuilds, competitive market advantage, and regulatory compliance (Austin *et al*. 2015). Whereas fast tracking can be defined as a time-driven process that by necessity requires some degree of concurrency between engineering, procurement, and construction, flash tracking is defined as a time-driven project, which by necessity requires a heightened degree of concurrency between these functions (Austin *et al.* 2015). To be noted that not all organizations can pursue executing flash-track projects. That is, readiness assessment algorithms were developed by Pishdad-Bozorgi *et al.* (2016) to enable an organization to assess its readiness to execute time-critical or flash-track projects.

On the one hand, through focusing on the relationships and interdependencies between 47 essential flash-track practices, it was identified that personnel selection, contractually aligning project participants and establishing fully integrated teams, as being from the most central and core flash-track enablers (Pishdad-Bozorgi *et al.* 2017). On the other hand, integration of participants (a) holds the potential to mend construction industry fragmentation, which often results in poor performance (Mesa *et al.* 2016) and (b) leads to innovative solutions thereby presenting a better project environmental performance (Ahmad *et al.* 2017). In contrast, traditional lump-sum contract is the most detrimental to innovation, involving the highest cost risk, the highest occurrence of adversarial relationships, lowest integration level across the supply chain, and poorest innovation outcomes (Ahmad *et al*. 2017). Moreover, disintegration of the construction process and the resulting adversarial relationship associated with the traditional multiple contracts have caused construction professionals to advocate for more relaxing relational contracts that incorporate higher levels of cooperation and integration.

Collaboration under a relational contracting arrangement involves an equitable sharing of risks and rewards in order to reduce adversarial relationships and align the interests of different parties. The establishment of long-term partnership agreements has been an example of developing trust between organizations who work repeatedly together (Fenner *et al.* 2006, Ahmad *et al.* 2017). Lahdenperä (2012) compared the three-different relational contracting (RC) arrangements: 1) Project Partnering (PP), 2) Project Alliancing (PA), and 3) Integrated Project Delivery (IPD). It was concluded that all incorporate common features but to a varying degree, such as the early involvement of the main parties, transparent financial system, shared risks and awards, joint decision-making, and collaborative agreement among multiple parties. Moreover, the core philosophy in these types of relational contracting is to generate a cooperative and trustful climate for the benefit of the project. Besides, early involvement of participants and availability of opportunities for open dialogue and collaboration was proved to enhance the risk management process (Osipova and Eriksson 2011). However, while PDMs define risk allocation formally, the use of incentives and collaboration or partnering arrangements helps in establishing a collaborative approach to risk management (Osipova and Eriksson 2011). To this end, Boukendour and Hughes (2014) suggested a fair risk-sharing formula that incentivizes the partners to truthfully propose their target costs. The importance of such incentive formula is to remove any suspicion as well as increase trust and collaboration among the contracting parties during advanced stages of the project (Boukendour and Hughes 2014).

2.3 Design Stages: Standard Definitions

Standard forms of architecture and engineering services are offered by many organizations in order to define, among other services, the scope of the design services to be provided, the different design stages, the expected design deliverables, and the role of the A/E professional according to these stages. For instance, the American Institute of Architects (AIA), divides the design stages into “schematic design”, “design development”, and “construction documents” stages; whereas the scope of the architect’s basic services includes the typical structural, mechanical, and electrical engineering services as well (AIA 1997; AIA 2017). The family of documents offered by the AIA includes the most commonly used form of owner-architect agreement in the United States, i.e., AIA − document B141 − 1997 (Xia 2010). To this end, Table 2 presents a brief description of the design stages and the required deliverables at the end of each stage, as per the AIA-1997 and the latest AIA-2017 versions. Another American-based set of contracts, offered by the Engineers Joint Contract Documents Committee (EJCDC), divides the Engineer’s basic services in the design phase to the “study and report phase”, the “preliminary design phase” and the “final design phase” (EJCDC 2008). Alternatively, the Royal Institute of British Architects (RIBA) lists the design stages by letter C, D, E and F, corresponding to the “concept design”, the “design development”, the “technical design” and the “production information” stages, respectively (RIBA Outline Plan of Work 2007). In its latest release, i.e., the 2013 version, design stages are listed by numbers, whereas Stage 2, 3 and 4 corresponds respectively to the “concept design”, the ”developed design”, and the “technical design” stage (RIBA Plan of Work 2013). To this end, Figure 3 displays the design stages’ description as adapted from the RIBA plan of work 2007 and 2013. Moreover, other country-specific designations may also be encountered. For instance, in the People's Republic of China, the design phase consists of the “scheme design”, the “preliminary design”, and the “working drawing” stages (Xia 2010).

Despite the different terminologies, the above-listed standard forms include the same core description of the design stages and support the argument that design information matures progressively with an increasing level of detail in design deliverables uniformly across all design elements. Therefore, design stages are rather observed as milestones to track the progression of the design process. The family of documents offered by the AIA includes the most commonly used form of owner-architect agreement in the United States (Xia 2010). Therefore, schematic design (SD), design development (DD) and construction documentation (CD) may be regarded as the fundamental and logical design stages expected from the A/E to carry-out sequentially under a traditional design process and thus are adopted throughout this research study.

As for alternative PDMs, the AIA acknowledges the benefits, as well as the risks, stemming from the use of phased or fast-track schedules. These risks include the incurred additional costs to revise, re-coordinate, redesign and reconstruct portions of the work. However, there is no direct indication as to the mode of concurrency of design stages (B132 – 2009 - § 5.4.1 and B133 – 2014 - § 5.4.1). On the other hand, the RIBA plan of work (2007) illustrates the possible sequencing of stages for the various PDMs. For instance, “a fully designed project single stage tender” (i.e., the traditional method), is illustrated by sequential design stages and sequential design and construction phases. As for the considered alternative PDMs, design and construction phases become overlapped and the design stages become overlapped as well. Moreover, in addressing the changes with respect to the procurement method, the RIBA’s 2013 version re-emphasized on the resultant overlapping/concurrency of certain stages and on the changes in the information exchanges at a stage completion (RIBA 2013).

Table 2. Design Stages as Adapted from the AIA's Standard Form of Architect's Services

Architect's Design Services		AIA−B141−1997	AIA−B201−2017
SD*	Description	**§ 2.4.2.1** The Architect shall provide schematic design documents based on the mutually agreed-upon program, schedule, and budget for the cost of the work. The documents shall establish the **conceptual design** of the project illustrating the scale and relationship of the project components.	**§ 2.2.4** Based on the project requirements agreed upon with the Owner, the Architect shall prepare and present, for the Owner's approval, a **preliminary design** illustrating the scale and relationship of the project components. **§ 2.2.5** Based on the Owner's approval of the preliminary design, the Architect shall prepare **schematic design documents** for the Owner's approval.
	Deliverables	**§ 2.4.2.1** Required: Conceptual site plan, if appropriate, and preliminary building plans, sections and elevations. Preliminary selections of major building systems and construction materials shall be noted on the drawings or described in writing. Optional: Study models, perspective sketches, electronic modeling or combinations of these media.	**§ 2.2.5** Required: Drawings and other documents including a site plan, if appropriate, and preliminary building plans, sections and elevations. Preliminary selections of major building systems and construction materials shall be noted on the drawings or described in writing. Optional: Combination of study models, perspective sketches, or digital modeling.
DD*	Description	**§ 2.4.3.1** The architect shall provide design development documents based on the approved schematic design documents and updated budget for the cost of the work. The design development documents shall illustrate and describe the **refinement of the design** of the Project, establishing the scope, relationships, forms, size and appearance of the Project.	**§ 2.3.1** Based on the Owner's approval of the schematic design documents, and on the Owner's authorization of any adjustments in the Project requirements and the budget for the cost of the work, the Architect shall prepare design development documents for the Owner's approval. The design development documents shall illustrate and describe the **development of the approved schematic design documents**
	Deliverables	**§ 2.4.3.1** Plans, sections and elevations, typical construction details, and equipment layouts. Specifications that identify major materials and systems and establish in general their quality levels.	**§ 2.3.1** Drawings and other documents including plans, sections, elevations, typical construction details, and diagrammatic layouts of building systems to fix and describe the size and character of the Project as to architectural, structural, mechanical and electrical systems, and other appropriate elements. The design development documents shall also include outline specifications that identify major materials and systems and establish, in general, their quality levels.
CD*	Description	**§ 2.4.4.1** The Architect shall provide construction documents based on the approved design development documents and updated budget for the cost of the work. The construction documents shall **set forth in detail the requirements for construction of the project.**	**§ 2.4.1** Based on the Owner's approval of the design development documents, and on the Owner's authorization of any adjustments in the project requirements and the budget for the cost of the work, the Architect shall prepare construction documents for the Owner's approval. The construction documents shall illustrate and describe the **further development of the approved design development documents.**
	Deliverables	**§ 2.4.4.1** Drawings and specifications that establish in detail the quality levels of materials and systems required for the project.	**§ 2.4.1** Drawings and Specifications setting forth in detail the quality levels and performance criteria of materials and systems and other requirements for the construction of the work. The Owner and Architect acknowledge that**, in order to perform the work, the Contractor will provide additional information,** including shop drawings, product data, samples and other similar submittals, which the Architect shall review in accordance with Section 2.6.4.

*SD: Schematic design; DD: Design development; CD: Construction documents

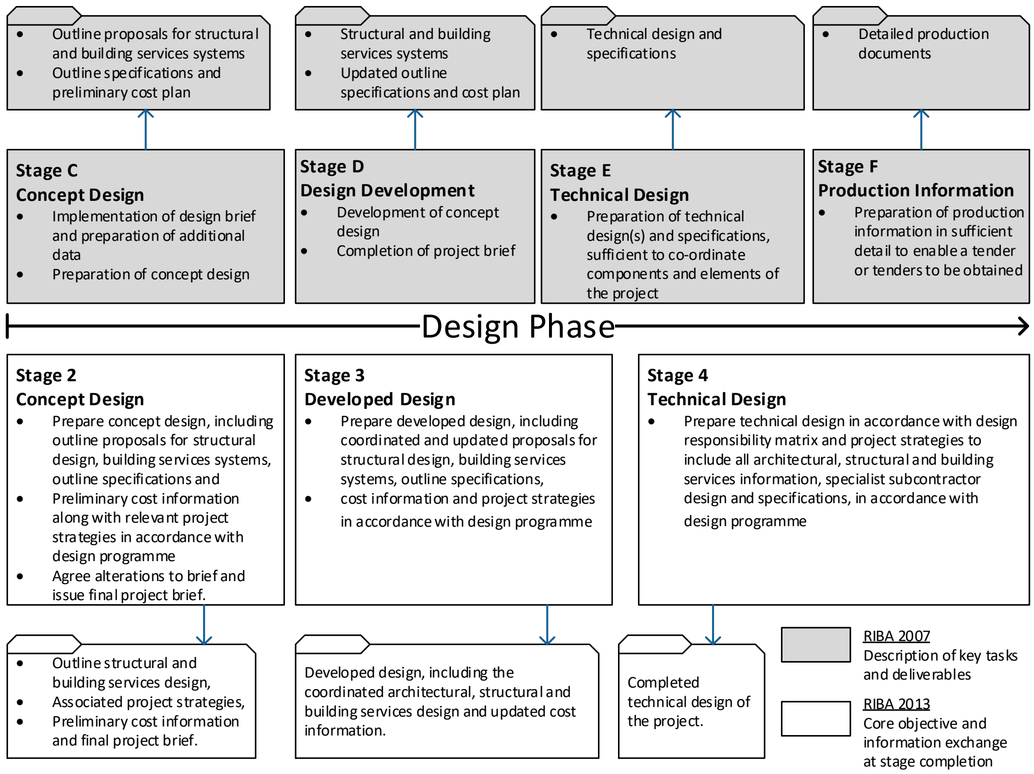


Figure 3. Design stages as adapted from the RIBA plan of work

2.4 The design phase under alternative project delivery

Despite the aspired advantages of adopting any of the APDMs in shortening the overall project duration, the successful execution of the design phase of such projects is challenging (Deshpande et al. 2012). For instance, owing to the iterative nature of the design process, design problems are argued to emanate from having the design and construction phases executed in parallel with a minimal lag time; therefore, having the design phase driven by the needs of the construction work (Deshpande et al. 2012). The practice of overlapping design and construction (a) may increase the uncertainty and complexity of the project (owing to iterative cycles resulting from errors and rework), as compared to when those phases are implemented sequentially (Lee et al. 2005), (b) causes additional complexity to the design process (Zerjav et al. 2011), and (c) may lead to unexpected project outcomes (Alhomadi et al. 2011). Yet, a project with overlapped design and construction phases can successfully achieve its original objectives by (a) avoiding aggressive overlapping, (b) planning properly and realistically, (c) using experienced teams, and (d) learning from previous similar projects (Alhomadi et al. 2011). The design phase challenges are further increased in a contractor-led DB setup for the following reasons: (a) the details of the design, and the resultant quality, being constrained by both the budget and the schedule as guaranteed by the design-builder (Gransberg and Molenaar 2004), (b) the builder's presumed control over the design process and the designers' compensation, potentially influencing designers to exercise "shortcuts" in order to lower cost, or compromise on materials quality and long-term maintenance considerations (McGreevy et al. 2005; Brierley et al. 2010), and (c) the increased time pressure exercised by the builder on the A/E, being his/her design subcontractor (Stipanowich 2015). Moreover, the contractor-led DB approach not only rids the A/E professionals of their independent role, but also induces a new role of design manager for the contractor due to his/her involvement in the design phase (Chan et al. 2004). However, managing a role for the first time revealed as being among the primary contributors to project complexity (Jarkas 2017). That is, the design-builder may face a big challenge as most of the contractors are not trained to manage the design process even though they know the suitable timing (i.e., for the construction schedule) of the required design information (Chan and Yu 2005).

2.5 Role, Risks and Liabilities of the Design Consultant under APDMs

2.5.1 *The A/E's Engagement*

Architecture/Engineering (A/E) professionals undertake a seminal role throughout the lifecycle of any construction project. A thorough understanding of the basis of engagement of these professionals, and the respective agreement formation, is therefore of paramount importance for a successful delivery of the project in question. To this effect, the need for comprehensive contract documents that carefully address the various legal, financial and technical aspects of the project, was addressed long ago by Clough (1986). However, despite their fundamental importance, contracts remain poorly understood and many research studies have called for the development of a conceptual foundation that provides a better understanding of contracts (Galloway 2004, Kumaraswamy 2006, Puddicombe 2009). Moreover, the concerned parties are advised to thoroughly review the different elements of the agreement before signature, in order to ensure a clear understanding of each party's duties and responsibilities and provide a higher chance of mitigating conflicts (Puddicombe 2009, ASCE 2012a). Here comes the role of (a) the pre-contract negotiation phase as a means of "avoiding and mitigating delay and disruption claims conflict" (Aibinu 2009) and (b) using standard forms of agreement due to the several advantages they provide. Standard forms of agreements for professional A/E services are generally concerned with: (a) defining the scope of design services to be provided, the schedule/time of performance for the contracting parties, the fee/compensation for professional services; and the owner's responsibilities, and (b) addressing the different terms and conditions including procedures for amending the agreement, definition for the standards of performance, and insurance coverage requirement, among many others (ASCE 2012a). The American Society of Civil Engineers (ASCE 2012a) recommends owners to include in the contract provisions that proactively deal with delays in order to alleviate their detrimental.

On the one hand, it is crucial for both parties, i.e., the owner and the A/E professional, to fix in the agreement and with reasonable limits the time allowed for the

A/E professional to perform its various services (Davis 1986). This is mainly due to (a) the interest of the owner in the project completion dates and (b) the effect of these durations on the A/E professional's incurred costs (Davis 1986). On the other hand, the A/E's scope of services must be carefully written because of their argued implications on professional liability and on quality control (Walter 1987). Moreover, fees for such rendered services must be adequate for the A/E in order to devote the needed time and attention for a careful design and checking (Walter 1987). Furthermore, the procurement method of A/E professionals may substantially impact their organizational resources (Bausman *et al.* 2014), and hence the need for qualification-based selection (QBS) methods is highlighted in the literature. For instance, a study by Kasma (1987) recommended a QBS method that involves negotiating the agreement with the selected firm on the basis of a definitive scope of work and period of performance. The author called for providing established fee schedules or curves for the purpose of providing comparisons but not as a basis of justification of any proposed fees (Kasma 1987). This is supported by the research of McGeorge (1988), concluding that attention needs to be given to the procedures of selection and to the basis of fee payment for A/E professionals. Likewise, the research findings of Christodoulou (2004) included recommending a QBS that is based on the negotiation of a fair and reasonable compensation for such services. For instance, the American Institute of Architects (AIA 2001) suggests the use of hourly-based compensation as a reasonable approach if the full extent of the A/E's basket of services cannot be determined in advance. This needs to be complemented by the development of new methodologies and pricing strategies that adequately reflect the increased efficiencies in engineering hours logically resulting from the technological development (Sturts *et al.* 2005).

The crafting of the contract document between the owner and the A/E should take into account the project context as reflected by the adopted delivery method. For example, the construction industry is often faced with the challenge of shortening the project completion time. That is, the traditional sequential method of delivering construction projects is being increasingly replaced with alternative delivery methods. Overlapping design and construction activities and the use of early information from the precedent activities, which are common practices implemented in alternative PDMs, provide the potential of achieving a reduced completion time. However, these practices are commonly associated with design and construction rework, which may impact the contemplated design durations figures.

On the one hand, when fast-tracking the design and construction phases, high performance design teams become required (Otter and Prins 2001). Under such circumstances, a higher involvement of A/E professionals during the construction phase is expected as well, thereby requiring adjustments in fee and staffing requirements (Miles and Ballard 2001). On the other hand, Chua and Hossain (2011) studied the impact of utilizing early information on redesign and total design duration. Providing valuable insight to project managers, their findings revealed that the total amount of potentially induced redesign may adversely impact loss of productivity − thereby requiring additional resources − and overall design completion for a project with limited resources (Chua and Hossain 2011). Likewise, Hossain *et al.* (2012) and Hossain and Chua (2014) recognized the need for a well-planned overlapping strategy, in order to avoid having excessive redesign instead of a reduced design duration. For instance, Hossain *et al.* (2012) proposed an integrated framework to optimize the concurrent execution of design activities while maintaining minimum redesign. Likewise, a four-step process for scheduling the design phase of fast-tracked construction projects was developed by Srour *et al.* (2013). Their work is deemed useful to project managers and to group leaders who are in charge of staffing each of the major design disciplines. Dehghan and Ruwanpura (2014) argue that the overlapping process is "inherently risky because it increases uncertainties and can result in more changes and rework". Therefore, their research proposed a time-cost trade-off model in order to gain maximum advantages from early project completion.

Construction projects may well be associated with several sources of uncertainty. For instance, the quality and completeness of information, the diversity of interests and the exposure to external influences are among many other events that may all lead to aspects of uncertainty, with some being potentially viewed and treated as risks, therefore threatening the achievement of the project objectives (Atkinson 2006). To this effect, the management of uncertainty is regarded by Atkinson (2006) as a necessary condition for effective project management, thereby calling for the need for more sophisticated efforts that recognize and manage the several important sources of uncertainty. For instance, acknowledging that projects may start with broadly defined information that get refined as the project progresses, a research by Carmichael and Karantonis (2015) suggested the use of "convertible contract", i.e., changing contract terms as a project progresses, as a means to tailor a contract to a project's situation. A study by Demirel *et al.* (2017) suggested the need for some flexibility requirement in public-private-partnership (PPP) contracts due to being typically implemented in contexts of great uncertainty. Their research define flexibility as the ability of a contract to deal with changing circumstances. Their main findings revealed that the timely recognition, i.e., in the pre-contract phase of projects, of potential changes, combined with the availability of flexible coping mechanisms, help the different stakeholders better understand the challenges that they may face in fulfilling their objectives (Demirel *et al.* 2017).

2.5.2 *Risks and Liabilities of the Design Consultant*

With the substantial increase in the degree of integration between design and construction and the growing complexity in construction projects, new roles have emerged, involving new risks and liabilities. In fact, the old concept of the master builder is resurfacing with the partial integration of design and construction under the design-build (DB) delivery approach and the more contemporary methodology of integrated project delivery (IPD). Burr and Jones (2010) investigated the evolving role of the architect in the construction process with respect to these emerging new delivery methods, and suggested that the successful architect of the future could be one who strives to reclaim lost responsibilities, explores new alternative services, and promotes a higher level of collaboration with the build team. However, Piyadasa and Hadikusumo (2014) describe the consulting services done by consultants under alternative project delivery methods as being non-standard forms of, or innovative, consulting services and argue how these non-standard forms entail consultants to assume atypical risks. By contrast, unwillingness to take on risks outside the consultant's core activities would inevitably lead to loss of business opportunities. One of their key findings is that risk in these non-standard forms is influenced by additional factors not prevalent in standard consulting services, including having contractors as their clients and ill-defined scope of services and deliverables, with the most severe potential impact being the loss of design professional's reputation and/or goodwill.

On the other hand, Fredrickson (1998) addressed long ago, the concerns designers may have under the DB approach regarding (a) how much design effort they will be required to put and (b) their professional responsibility. The author further suggested guidelines to determine what amount of design is needed at each stage of a design-build project to improve its chances of success. For example, in design-bid-build work, designers understand that the contractor's economic goals are not generally consistent with the owner's goals. Therefore, designers prepare plans and specifications assuming that "the least qualified constructor" may perform the work and go to extremes to make certain that even the most basic information is available, with that protective information being added with the aim of preventing claims (Fredrickson 1998). The DB approach effectively flips the role of the designer, in that the designer now works directly for the builder who has goals very different from those of the owner, primarily focusing on cost, production, schedule, and efficiency. As a design subcontractor to the contractor, the designer must support the priorities of this new client while still fulfilling its professional responsibilities. Such a fast–track delivery approach requires the designer to meet deadlines in respect of construction priorities while still following an overall comprehensive project design plan.

Construction projects are temporary social systems, completed usually by a group of people who must interact for many purposes. Under a project organizational structure where design and construction services are undertaken as separate scopes by separate entities (e.g., design-bid-build (DBB) approach), the architecture/engineer (A/E) design consultant maintains a direct contract with the owner and, as such, assumes contractual legal liabilities towards it. This system is traditionally known for the inherent quasi-adversarial relationship between the designer and the contractor.

Alternatively, under other structures such as those where the design consultant is to operate directly under a DB contractor, an engineering-procurement-construction (EPC) contractor, or a build-operate-transfer (BOT) concessionaire, the design consultant is no more in direct contact/contract with the owner and – as such – assumes a different role/status, a design subcontractor to the main contractor. However, although there is no contract between the designer and the owner, the former must be cognizant of tort liability. In many jurisdictions, the design professional may be liable not only to the party with whom it contracted but to third parties (such as the owner) who could foreseeably be injured by the designer's negligence. Therefore, the design professional may be liable both to the owner and to the design builder (Walters et al. 2015). Further complications of risk allocation in regards to professional liability stem when the owner retains a design criteria consultant (DCC) who is likely to perform conceptual-level design services before the design builder is appointed (Drewry and Toops 2008).

Owners opt for DB for the biggest advantage of dealing with a single source of responsibility for design and construction, the increased risk that the DB approach allows to be transferred to the design-builder, the opportunity to fast-track the design-construction process, and the ability to take advantage of the contractor's construction expertise in the design phase. However, DB is characterized by an inherent "culture clash"; that is, while designers traditionally believe they must protect (1) owners from contractors cutting corners and overpricing changes and (2) the integrity of their design rather than solving contractors' cost issues, contractors believe that designers overdesign everything and expect them to cover up design flaws (McGreevy *et al.* 2005). Contractors, when in control over the design process and the designers' compensation, are likely to influence them to exercise "shortcuts" in order to lower cost, instead of seeking value engineering design (McGreevy *et al*. 2005). Undoubtedly, DB does not change the fundamental role of the designer with respect to developing the design and preparing the construction documents. However, most other aspects of DB are likely to be different for the designer. The designer's lack of independence in a DB setup may create problems due to the potential pressure exercised by the builder on the A/E in order to focus on construction costs; this may downplay the owner's needs, materials quality, and long-term maintenance considerations (Hatem 2006). On the one hand, the dynamics of the legal relationship between the design-builder and the A/E in the DB setting are observed to be far different than the dynamics of the relationship between owners and designers on traditional DBB projects (Staak 2012). On the other hand, it is argued that DB creates some unique challenges for the A/E; while some are consistent with those of the DBB approach, other ones differ and involve some practical challenges and associated impacts on its role, thereby affecting the level of assumed risks (Staak 2012).

Tort actions are third-party liability actions, related to malpractice, and are not as limited in scope as contract actions may be (Jensen and Land 1983). Singh (2003) views tort as harm and damages as harm that is measurable in monetary terms. In the context of construction projects, delays, contract changes, and defective performance can cause potential physical and/or economic harm to the owner, the contractor, or even to the users (Singh 2003). However, to prevail in tort, negligence must be proven to have occurred, and that it was the contributing cause of the loss/damage (Jensen *et al.* 1983, Bakos and Hake 1987, Day 1993, Singh and Sakamoto 2001, Caine and Thomas 2013).

Historically, courts started to abandon the privity requirement in the 1950s, thus holding A/Es liable to third parties. When coupled with the liability crisis in the mid 1980s, the exposure to professional liability became, and continues to be, a concern for A/E professionals, and it has since been addressed extensively (White 1959, Earley 1977, Jensen and Land 1983, Holland 1985, Bakos and Hake 1987, Horne 1990, Lunch 1990, Day 1993, Stein and Hiss 2003, Caine and Thomas 2013). For instance, the exposure of the A/E to intentional tort liability when assuming the role of a judge on disputes was addressed by Stein and Hiss (2003). Conversely, the exposure to unintentional tort liability in its role as a designer was later presented by Caine and Thomas (2013).

It becomes evident that A/E professionals are susceptible to different forms of professional liabilities, depending on the roles and responsibilities assumed by them in connection with the rendering of design and other related services. However, the relevant body of knowledge seems to be lacking work that can provide designers with a clear mapping of liability exposures stemming from the different services furnished by them under different capacities.

2.6 The Overlapping Mechanism and Information Exchange

Overlapping project activities is considered as an effective and well-known method to reduce the time for completion of projects. However, when it comes to overlapping between design and construction, essential factors such as cost, and quality have to be better thought of so that negative time-related tradeoffs are reduced. In attempt to understand the trade-off between time reduction and cost increase upon overlapping different design activities, Dehghan and Ruwanpura (2014) have introduced a model that explains the mechanism and characteristics of such overlap (Figure 4). They focused on analyzing the effect of predecessors and concurrent activities aiming to give insights on solving the overlapping time-cost tradeoffs and identifying the optimum degree of concurrency during the design phase. Further on, the research developed to identify the optimal overlapping strategy during the design phase of a project (Dehghan and Ruwanpura 2015). Accordingly, an algorithm was developed to optimize the path network of the design plan, taking into account critical and non-critical design activities (Dehghan and Ruwanpura 2015). On similar track, an algorithm or so called as a 'temporary scheduling tool' was developed to calculate the shortest possible path during design, where dependency structure matrix (DSM) was used to map the overlapping activities (Srour *et al.* 2013). Using different research methodology, discrete-event simulation has been used to model the overall design process while considering the probabilistic nature of design activities. The outcome was to predict the overall expected duration and the amount of rework. Then, optimization was performed via the developed model, and it mapped out the eliminations of the unnecessary rework without significant delay in the design phase (Hossain *et al.* 2012).

Besides, other research studies have focused on the concurrency across design and construction works instead of the overlap within the design phase. Overlapping between design and construction works usually imposes a challenge to identify the optimal fast track. A study showed using an optimization model that information exchange between upstream and downstream activities are the main drivers for the optimal fast track. Also, while considering such information exchange, substantial time savings can be gained (Khoueiry *et al.* 2013).

Continuing with design-construction overlapping, simulation analyses showed that the time reduction and amount of rework mainly depend on the accuracy of upstream early information and sensitivity of downstream activities (Hossain and Chua 2014). The basis of such analyses was an integrated model incorporating the mechanism of upstream evolution and downstream sensitivity criteria. The study also showed that unplanned concurrency doesn't necessarily reduce the initial duration but may induce unplanned rework instead (Hossain and Chua 2014). For better understanding the sensitivity of downstream activities as an important criterion for the optimal overlap, a research study has analyzed the factors that assess the level of sensitivity in construction activities to upstream design information (Blacud *et al.* 2009). It was revealed that the level of transformation, lead time, modularity and the interaction of built components are essential factors for assessing the sensitivity of construction activities (Blacud *et al.* 2009). Additionally, another study has proven the effectiveness of aligning the overlapping techniques such as freezing design criteria, overdesign, and early release of preliminary design with the characteristics of upstream and downstream activities such as evolution of design information and sensitivity (Bogus *et al.* 2006).

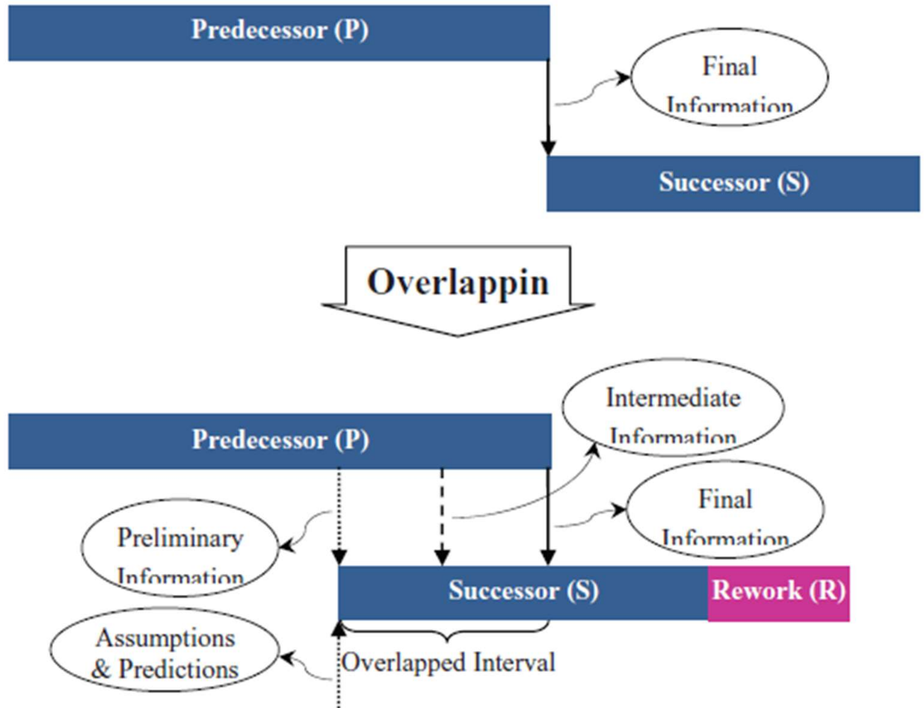


Figure 4. The mechanism of activity overlapping (Dehghan and Ruwanpura 2014)

As for the nature of the information exchanged between pairs of overlapped/concurrent activities, it is well established that it progresses from preliminary to intermediate to become final at the design completion of the corresponding task/activity releasing information, i.e. otherwise designated by upstream activity (Terwiesch et al. 2002; Dehghan and Ruwanpura 2011). As such, design information progresses from a low-to-medium level of upstream knowledge, and the earlier the downstream activity starts, i.e., the higher the intensity of the overlapping zone, the higher the expected risk of future changes (Terwiesch et al. 2002). Terwiesch et al. (2002) distinguished between the precision (or the accuracy) of the information exchanged and the stability of that information (or the likelihood of it being changed at a later stage), to develop alternative coordination strategies for managing interdependent tasks. Similarly, Dehghan and Ruwanpura (2011) illustrated the release of preliminary information from a predecessor activity to a successor one, as progressing from preliminary, i.e., at the early start of the overlapping zone, to final information at its end. When the predecessor releases its final design information, changes and adjustments may be needed in the successor activity in order to compensate for any incompatibility between the preliminary information used and the final one obtained (Dehghan and Ruwanpura 2011).

Several methodologies have been proposed in order to gain maximum advantages of the overlapping mechanism and minimize design and/or construction rework (Pena-Mora and Li, 2001, Bogus et al., 2006, Bogus et al., 2011, Hossain et al., 2012, Khoueiry et al., 2013, Srour et al., 2013, Dehghan et al., 2015, Hossain and Chua, 2014, Dehghan and Ruwnapura, 2014). For instance, optimization approaches that incorporate the concepts of upstream design evolution and downstream (i.e., construction work) sensitivity criteria were developed to optimize the project schedule while maintaining minimum rework (Khoueiry et al., 2013, Hossain and Chua, 2014). Alternatively, other studies were limited to the design phase, thereby focusing on the overlap between design activities using dependency information or the concept of downstream design sensitivity to upstream design evolution (Bogus et al., 2006, Bogus et al., 2011, Hossain et al., 2012, Srour et al., 2013, Dehghan and Ruwnapura, 2014). The previously listed studies looked at the overlap either between design and construction activities/tasks or within design activities/tasks. While some do refer to fast-track projects (reflecting a general case of design and construction being overlapped/ fast-tracked), none of these studies is applied in the context of a specific

APDM. Namely, the features that characterize APDMs were not previously discussed in literature work addressing the overlapping mechanism.

2.6.1 ***Design documentation quality***

The quality of design documents may be assessed by measuring the extents of *design* attributes and *documentation* attributes. These attributes were originally identified by Tilley et al. (1999). The former set of attributes corresponds to functionality, constructability, innovation, or aesthetics; while the latter set of attributes includes accuracy, completeness, coordination, final checking, and certainty, among others (Tilley et al. 1999). Acknowledging that the overall project success may depend on several factors (Chan et al. 2004), design and documentation quality constitutes a major influence on the overall performance and efficiency of construction projects (Tilley 2005). For instance, the decline in the quality of design documents was reported as being a major cause of cost overruns according to the survey conducted by the FMI Corporation and the Construction Management Association of America (2004) . Moreover, study findings by Pesek et al. (2019) revealed that both the contractors and the owners recognized that document deficiencies regularly increased project cost and duration.

Regardless of which project delivery method (PDM) is adopted, an efficient construction process and a successful overall project completion serve the interests of all project participants. Critical to such desired success is releasing high quality design documents. However, overlapping or fast-tracking design and construction does not afford an ideal level of coordination when integrating the detailed design, thereby increasing the challenges of producing comprehensive construction documents. For instance, a study by Andi and Minato (2003) revealed that when limited time is allocated to carry out design work, coupled with the reduced level of design fees, design documents quality-related deficiencies may well arise and affect the efficiency of the construction process. Moreover, the decline in the quality of design documents was reported as being a major cause of cost overruns according to the survey conducted by the FMI Corporation and the Construction Management Association of America (CMAA). Namely, 63% of owners concurred that the quality declined to a point where electrical and mechanical subcontractors are completing the design through the shop drawings (FMI Corporation and CMAA 2004). Likewise, Nepal *et al.* (2006) demonstrated that the advantages aspired to when working under schedule pressure, may be offset by the negative effects of the declined quality of the work. Owing to the "gradual erosion of architectural roles in favor of the subcontractor and contractor", along with the unsustainable reduction of design fees, Forbes (2014) argues that architecture/engineering (A/E) professionals cannot afford to dedicate the needed time to fully explore all the detail complexities of the design; thus, resulting in sub-optimally complete construction documents. The inability to devote the sufficient time for the design that would otherwise be afforded in the design-bid-build (DBB) setting is further exacerbated under the DB delivery method due to time pressure exercised by the builder on the A/E, being his design subcontractor (Stipanowich 2015).

To this end, the DB delivery method further increases the challenges encountered in the design phase. For instance, the details of the design in a DB setup, and the resultant quality, are said to be constrained by both the budget and the schedule as guaranteed by the design-builder (Gransberg and Molenaar 2004). The International Federation of Consulting Engineers (FIDIC) emphasized that a designer employed by a construction contractor must understand that he may be pressured to sacrifice the quality for the profitability of the project and must expect fee negotiations after selection (FIDIC 2005). Moreover, the DB approach not only rids the A/E professionals of their independent role, but also induces a new role of design manager for the contractor due to his involvement in the design phase (Chan and Yu 2005). However, managing a role for the first time revealed as being among the primary contributors to project complexity (Jarkas 2017). That is, the design-builder may face a big challenge as most of the contractors are not trained to manage the design process even though they know the suitable timing (i.e., for the construction schedule) of the required design information (Chan and Yu 2005). Moreover, the builder's presumed control over the design process and the designers' compensation in DB, may influence designers to exercise "shortcuts" in order to lower cost, rather than seeking value engineering design (McGree*vy et* al. 2005). For instance, the designer's "lack of independence" is said to be translated by a potential pressure exercised by the builder on the A/E in order to focus on construction costs and to compromise on materials quality and long-term maintenance considerations (Hatem 2006).

2.6.2 *Rework and changes*

Whether it is design- or construction-related, rework is a common phenomenon in the life cycle of any construction project, inclusive of those delivered under the traditional DBB, and various reasons may cause it (Forcada et al. 2014; Ye et al. 2015). However, when it comes to APDMs, more reasons may prevail; these include: (a) the overlapping/concurrency of activities and their progression in parallel based on preliminary information (Khoueiry et al. 2013; Srour et al. 2013; Dehghan et al. 2015), (b) the schedule pressure (Nepal et al. 2006), (c) the incorporation of changes and/or feedbacks in the design of overlapped tasks (Arundachawat et al. 2009), and (d) design decisions being made with partially available information and implemented at the site rapidly (Deshpande et al. 2012). To this effect, several methodologies have been proposed in order to gain maximum advantages of the overlapping mechanism and minimize design and/or construction rework (Peña-Mora and Li 2001; Bogus et al. 2006; Bogus et al. 2011; Hossain et al. 2012; Khoueiry et al. 2013; Srour et al. 2013; Dehghan and Ruwnapura 2014; Hossain and Chua 2014; Dehghan et al. 2015). The previously listed studies looked at the overlap either between design and construction activities/tasks or within design activities/tasks. While some do refer to fast-track projects (reflecting a general case of design and construction being overlapped/ fast-tracked), none of these studies is applied in the context of a specific PDM. Namely, the features that characterize APDMs were not previously discussed in literature work addressing the overlapping mechanism.

Fazio *et al.* (1988) pointed out long ago to the common difficulties that may be encountered in the design phase of fast-track projects. That is, due to the frequently "rushed" design phase, and the rearrangement of the design procedures and sequences, the authors emphasized on the increased coordination problems between work packages and the increased probability of encountering errors and omissions. Likewise, a study by Williams (1995) revealed that the reduced overall project duration resulting from the fast-track technique, is normally associated with an increased level of assumptions, a decreased volume and quality of design information, and the potentially unavailable time for design optimization. Therefore, his research findings called for the need to budget for rework.

Rework in fast-track projects may result from any or all of the following reasons: (a) the overlapping/concurrency of activities and proceeding in parallel based on preliminary information (Loch and Terwiesch 1998; Cho and Eppinger 2001; Terwiesch *et al.* 2002), (b) the schedule pressure (Nepal *et al.* 2006), (c) the incorporation of changes and/or feedbacks in the design of overlapped tasks (Arundachawat *et al.* 2009), and (d) design decisions being made with partially available information and implemented at the site rapidly (Deshpande *et al.* 2012). To this effect, owing to the iterative nature of the design process, design problems are argued to emanate from having the design and construction phases executed in parallel with a minimal lag time; therefore, having the design phase driven by the needs of the construction work (Deshpande *et al.* 2012).

Research studies recognized rework as being a normal consequence of overlapping design activities, thereby several methodologies have been proposed in order to gain maximum advantages of this mechanism. For instance, Hossain *et al.* (2012) advocated the need for a well-planned overlapping strategy to prevent having excessive design rework resulting from the use of early information. Their research work offered an integrated framework that optimizes the scheduling of concurrent design activities, while maintaining minimum redesign. Alternatively, Srour *et al.* (2013) argued that the degree of dependency between pairs of design activities dictates the extent to which they may be overlapped. Therefore, the authors presented a methodology for scheduling overlapped design activities of fast-tracked construction projects based on dependency information. Dehghan and Ruwanpura (2014) viewed the overlapping mechanism as being “inherently risky” which necessitates a trade-off between benefits and losses; therefore, the authors developed a model that formulates design activity overlapping time-cost tradeoff.

2.7 Change Management

Design changes are commonly encountered in construction projects. A change is different from an act of rework, although both acts are performed by way of deleting, adding or replacing components (Park 2002). Rework is the act of achieving what was originally intended in the plans and specifications but without triggering another change (Park 2002). On the other hand, a change represents a deviation from the original design and may trigger subsequent changes (Park 2002). Changes can be either emergent (arising from the state of the design itself, e.g. errors) or initiated from the outside (e.g. client requests) (Eckert et al. 2004). Design changes may be caused by factors that can be client-related (e.g., change of requirement/specification), designer-related (e.g., lack of coordination among disciplines, non-compliance with authority requirements), and/or contractor-related (e.g., shortage of materials, rectification of construction mistakes), as well as other external or site-related factors (Yap et al. 2017). Changes may have a direct or indirect impact on various aspects of a project. While some may be positive and benefit the project, most changes cause interruptions to the work as well as time and cost overruns (Sun and Meng 2009). Namely, a design change (irrespective of the project delivery method in place) may cause rework, disruptions, and delays to the work progress of many of the parties involved in the design and construction processes, thereby causing a ripple effect (Sun and Meng 2009, Moayeri et al. 2016). For instance, a change may require revisions or re-design (under a severe scenario) to the construction drawings, construction changes for built components, and reordering of materials that have been already delivered to the site (Yap et al. 2017). This contributes to loss of productivity and time extension issues, direct and indirect cost increases, and strained relationships resulting from claims and disputes (Sun and Meng 2009).

When it comes to fast-track DB projects emergent changes are almost inevitable and difficult to avoid. This is due to the previously-stated challenging design process, the overlapping/concurrency of design and construction activities and their progression in parallel based on preliminary information (Moazzami et al. 2011), and the incompatibility of coordination – and the respective premature release − of design deliverables. In particular, throughout the design development of fast-track projects, changes may emerge in order to: (1) rectify errors committed within the scope of work or (2) account for a varied design parameter, omissions, unfulfilled assumptions, or lack of coordination (Mejlænder-Larsen 2017). Furthermore, fast-tracking leads to an increased level of uncertainties which make the construction dynamic and unstable, mostly by creating non value-adding change iterations among construction processes (Park 2002). When coupled with a lack of proper planning, those change iterations can cause disruptions to the construction process and may lead to more changes as a result of the reaction by management to rectify the problem (Park 2002). In addition, it is argued that under time constraints, the parties' preference of change to rework (e.g., construction managers tend to avoid rework on problematic tasks by changing the scope of work) can reinforce the change impact (Park 2002), and that the compressed schedule and overlapping of phases increase the ripple effects of changes and may counterbalance the time saving achieved by overlapping strategies (Pena-Mora and Park 2001).

Proper management of design changes is critical to the efficient delivery of construction projects; this requires a timely identification and coordination of changes and a proper analysis of their impacts. Change management practices range from conventional paper-based procedures to more automated database management systems. Karimidorabati et al. (2016) evaluated and compared the different automation levels of change-management processes. Their study proved the benefits of integrating automated change-management processes with Building Information Modeling (BIM) in improving compliance and real-time traceability, while reducing the costs of staff involved in document and process management. BIM platforms provide the opportunity to manage the whole process within a single tool and in a clear and transparent way, and hence BIM is being increasingly adopted in the construction industry owing to the benefits of delivering cost savings, and improving productivity and operations efficiencies, among other well-established advantages (Daniotti et al. 2020). However, study findings by Mehrbod et al. (2019a) revealed that even when BIM tools are readily available, industry practitioners are facing many challenges that hinder coordination processes. That is, project teams continue to rely on manual analysis of 2D drawings to resolve coordination issues (Mehrbod et al. 2019a). For instance, BIM provides the functionality of automatically detecting “clashes”, i.e., spotting congested areas (i.e., where there are insufficient space for access, insulation, etc.) or spaces that are shared between two or more elements (Eastman et al. 2011, Ch.6, page 216). However, these clashes represent only the geometrically identifiable conflicts. Alternatively, design coordination issues, which rather stem from design discrepancies, design errors, and missing items (Mehrbod et al. 2019b), encompass the broader concept of clashes or the more complex type of conflicts between systems that is either undetectable through an automatic clash detection or else requires further analysis (Mehrbod et al. 2020). To this end, the findings by Mehrbod et al. (2020) described the needed BIM-based design coordination process as a cyclic process of three interconnected steps: identifying, resolving, and then documenting design coordination issues. These coordination issues, despite the availability of BIM tools and their well-established advantages, often remain undetected or poorly documented owing to the inefficiencies of the coordination strategies that are being implemented (Mehrbod et al. 2020).

Moreover, while BIM based tools facilitate the coordination processes, they are found to be of a limited support in managing design changes across several discipline-specific BIM models. To this end, Pilehchian et al. (2015) developed a conceptual graph-based approach to represent, coordinate, and track changes for a fast-track project implemented within a collaborative multi-disciplinary BIM environment. Namely, the authors developed an ontology of design changes that represents the changed component attributes, the dependencies among components, and the change impacts. By visually mapping dependencies between the components' attributes, an example of a dependency matrix is then formulated such that it assists in automating the propagation of changes. In contrast, Moayeri et al. (2016) developed a BIM-based quantification model that quantifies the ripple effects of an intended design change and calculates its impact on the project's schedule. The developed model analyzes the impact of a change on the duration of each project component, as well as on the overall project duration. Then, Moayeri et al. (2017) presents a BIM-based visualization model that allows owners to see the ripple effects of a requested design change before making a decision, by displaying the "as-changed" and "as-planned" models and visually highlighting the sequence of impacted components and their respective dependencies. These automated changes occur according to a micro-level, predefined work breakdown structure that is used by the authors to reflect the existing connectivity and pre-defined relationships among the components of the BIM model for scheduling purposes. The previous BIM-based models deal with owner-requested design changes under a traditional delivery process, particularly examining the time impact of changes made after the completion of the design phase – but before the start of construction – on the project's schedule (Moayeri et al. 2016; Moayeri et al. 2017). On the other hand, Mejlænder-Larsen (2017) introduced a change management process developed by an engineering, procurement, and construction (EPC) contractor for handling design changes, including those that are initiated by the engineering team and the external changes originated by the client. The process relies on BIM for identifying the design status of elements and on a web-based change control system that efficiently reports, follows up, and archives project design changes. However, the process neither tackles the propagation of such changes within the EPC contractor's own organization, nor does it offer a method for identifying the affected disciplines.

The previous studies were concerned with either the identification of the chain impact of a certain change and/or the analysis of the respective time and/or cost-related impacts. Besides schedule delays and cost overruns, rework and excessive claims are the most common direct and indirect negative impact of changes, respectively (Yap et al. 2017). For instance, Ibbs et al. (2007) studied the impact of changes on labor productivity in order to reliably quantify and successfully claim lost productivity. Moazzami et al. (2011) argue that in fast-track DB projects the potential incompleteness of bid packages submitted to subcontractors causes unavoidable rework and changes, which turn into a major source of conflicts in the absence of adequate procedures for dealing with extra work. Similarly, Yap et al. (2017) showed that rework induced from the design changes is detrimental to project performance and suggested recommendations on how to overcome the problem with project-based learning and effective communication. That is, capturing and sharing of reusable project experiences is deemed essential towards maximizing the benefits of past experiences (lessons learned), shortening the learning curve and adding value to future projects (Yap et al. 2017).

Considerable research efforts have been dedicated in the last decade to exploring the potentials of BIM in dealing with claims. For instance, Gibbs et al. (2013) showed that BIM can assist with construction delay claims through the ease of access to coordinated contemporaneous project information and the visualization of the fourth dimension (time) and fifth dimension (cost), if employed on a project since inception coupled with appropriate record-keeping procedures. Moreover, El Hawary and Nassar (2016) found that using BIM technology in construction projects has a great potential in reducing certain construction claim causes (e.g., errors in design drawings and variation in quantities), especially in large complicated projects. However, the likelihood of some construction claim causes (such as differing site conditions and unexpected increases in material prices) is not reduced or avoided as a result of utilizing BIM technology. On the other hand, Marzouk et al. (2018) proposed a BIM-based claims analysis and evaluation model that allows a project's party to foresee potential claims and take necessary measures to possibly avoid them. This is achieved through monitoring delayed activities and proactively generating the respective claim cause responsibility matrix and a 5D-BIM model (time and cost dimensions included) for visualizing and foreseeing projects' areas of potential claims. Others explored the feasibility of introducing 'Contract BIM' by translating contract provisions into computable rules and applying these rules as part of the BIM for claim management purposes (Shahhosseini and Hajarolasvadi 2018). Most recently, Ali et al. (2020) studied the provisions for extension of time (EOT) under traditional construction contracts in order to have a clear understanding of all permissible EOT events and then developed a BIM-based claims management system, consisting of a plugin developed in Autodesk Revit, in order to manage EOT claims.

2.8 Building Information Modeling (BIM) Relevance to Project Delivery

Whereas traditional building design is largely reliant upon two-dimensional (2D) technical drawings (plans, elevations, sections, etc.), BIM goes beyond the notion of a 3D volumetric model or drafting tool. BIM is said to be a process enabling close collaboration and encouraging integration of the roles of all stakeholders on a project (Azhar et al. 2012). Azhar et al. (2012) further argued that traditional DBB project delivery systems have limited relevance when it comes to BIM-based projects, in contrast with the integrated project delivery (IPD) system, which is a natural companion to BIM. This is supported by Minagawa and Kusayanagi (2015) who found that a DB contract offers a good strategy for effectively utilizing BIM, and Eastman (2011) who emphasized that only partial benefits of BIM could be realized if no collaboration exists during the design phase. Hence, the DB system provides an excellent opportunity to exploit BIM, whereas the DBB system presents the greatest challenge to its use, because the contractor does not participate in the design process of the latter and must thus build his own building model after the design is completed (Eastman 2011).

The application of BIM to support an optimal cross-disciplinary and cross-phase collaboration opens a new dimension in the roles and relationships among the building actors as well as new roles of BIM manager (Eastman 2011; Sebastian 2011), BIM coordinator (Aibinu and Papadonikolaki 2016) or system integrator (Eastman 2011). Regardless of the title, this BIM professional does not take decisions concerning the design process and the rendered engineering solutions. Instead, their role is mainly concerned with developing the model, defining its structure and detailing level, merging, and detecting clashes (Sebastian 2011).

Kassem et al. (2013) defined a BIM framework as "a theoretical structure explaining or simplifying complex aspects of the BIM domain by identifying meaningful concepts and their interrelationship" and BIM workflows as "structured information (e.g., process maps) intended for operational applications of BIM concepts and tools." While the majority of existing BIM frameworks and workflows are either intended to build broad understanding and adoption at industry level or specific for BIM usage in large enterprises, Kassem et al. (2013) developed a practice-oriented BIM framework and BIM workflows that can be applied and adopted at the project level. The developed framework is reported to increase the efficiency of the workflow of the design process.

Research efforts examining ways of managing design and taking into consideration the involved workflows are not new. However, the involvement of BIM adds new insights to the process. For example, Tsai et al. (2014) presented a workflow for the specific use of BIM models in design-build projects, by selecting a large engineering, procurement, and construction (EPC) firm and implementing an in-house BIM tool as an example case. In the proposed workflow, BIM models became the facilitating tool, replacing the traditional use of 3D models and paper-based schedules and resulting in an increase in the efficiency of communication between the owners and the engineers from different departments. Al Hattab and Hamzeh (2013) compared information flow processes on traditional 2D CAD projects with BIM-based projects in the conceptual and schematic design stages. Their study established for a potential improvement in design efficiency through the use of BIM, due to its high ability for transforming the traditional design phase into a lean design process.

2.9 Design Evolution and Level of Development (LOD)

To efficiently manage the process of working in a BIM environment, the industry has adopted a formal language for describing the level of completeness of a digital modeled element (ME) at a given point in time, referred to as the "Level of Development" (LOD). The Model Progression Specifications (MPS) explicitly define the LOD required from designers and fabricators for each object type through each project phase (Bedrick 2008). Recent work advocating and explaining the concepts of LOD and MPS include AIA's G202-2013 document and the Level of Development Specification by the BIM Forum (Hooper 2015). AIA provided the basic LOD definitions, specifying the minimum content requirements and associated authorized uses for each ME at five progressively detailed levels of completeness (LOD 100, 200, 300, 400 and 500) along with a standardized responsibility matrix (AIA 2013).

Based on AIA's definitions, the BIM forum clarified what the designations mean for a comprehensive range of building systems, and it further highlighted the need for an LOD that would define a ME that is sufficiently developed to enable detailed coordination between disciplines. The requirements for this level, which are higher than those for 300 but not as high as those for 400, were designated as LOD 350 (BIM Forum 2016). Figure 5, adapted from these two references, presents an illustration of the design evolution of a steel column along different LODs.

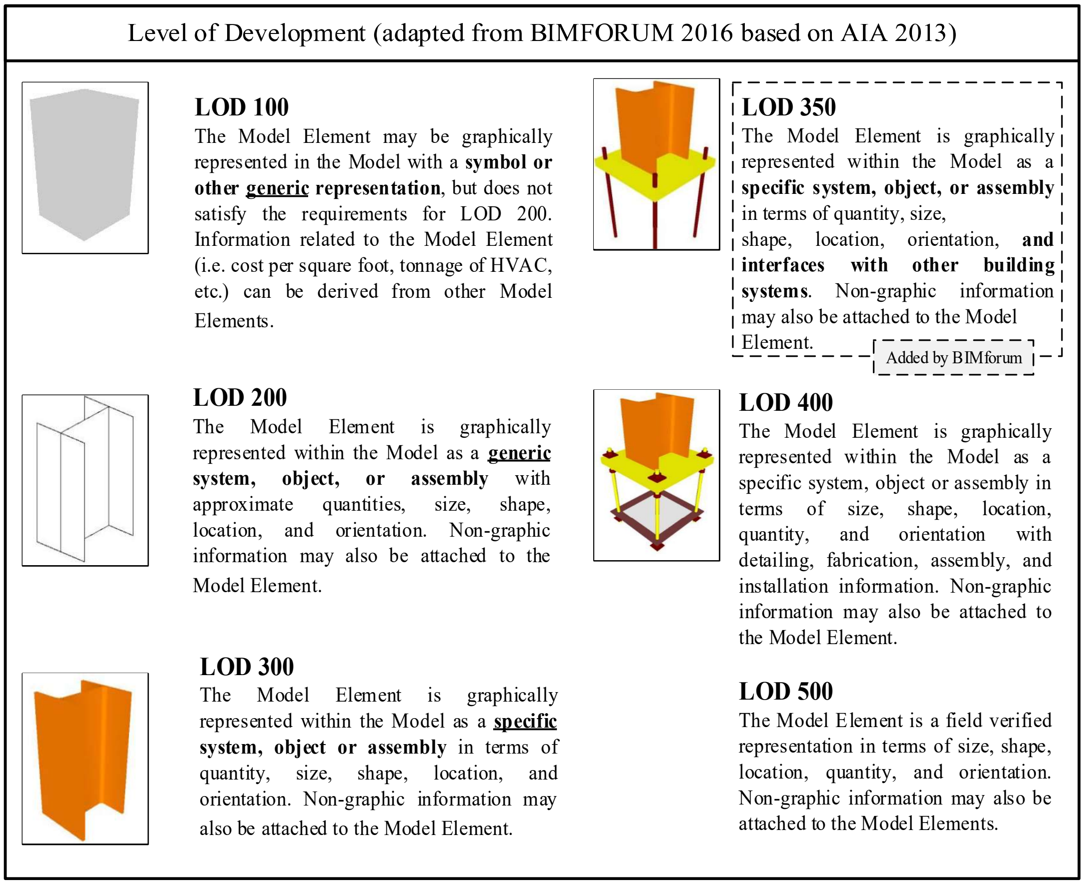


Figure 5. Design evolution with LOD levels

New insights into design management were offered by Hooper (2015), who explored alternative ways in which LOD can be used to support model progression and automatically verify a model's content against the intended use. Likewise, Abou Ibrahim and Hamzeh (2017) developed new metrics to measure information flow in BIM projects. The developed metrics reflect the design maturity of an entire BIM model or of any ME, thereby enhancing the planning and control of the design process. Nonetheless, it is worth mentioning that LODs are not necessarily defined by design phases (Autodesk 2017; BIM forum 2016). Rather, design phase completion, as well as any other milestone or deliverable, can be defined through the LOD language. Design progression in BIM, from the conceptual stage to the construction documentation stage, happens at different rates, and at an element level rather than at a model level. Completion of the schematic design stage, for example, can be manifested by a model including many elements at LOD 100 or 200, and some elements at LOD 300 and possibly 400 (BIM forum 2016).

CHAPTER 3

RESEARCH MOTIVATIONS, OBJECTIVES AND CONTRIBUTIONS

3.1 Research Statement and Motivation

The construction industry makes a vital contribution to the social and economic development of every country and has a major impact on its environment. Aiming for a successful built project, owners/developers are increasingly realizing that focusing on the delivery process of the project may be as important as focusing on its technical aspect.

Delivering construction projects using the sequential process of the design-bid-build (DBB) method is lengthy and lacks the constructability inputs of the builder. However, standard forms of agreement for this so-called traditional method, present a wide base of commonalities as to the sequential evolution of the overall design. Design stages, and despite the several terminologies used by the various forms of design agreements, are therefore observed as milestones to track the progression of the design, thereby offering a systematic and well-established A/E's role in rendering design deliverables. Accordingly, this approach affords a compatible coordination for the various design elements (DEs) due to the one-time packaging of design deliverables.

In contrast, APDMs, such as the construction manager at-risk (CMAR) or the design-build (DB), allow for a faster project completion due to the aspired timesaving associated with the earlier involvement of the builder and the concurrency of the design and construction project functions, but lead to (a) less certainty on the timing and coordination quality of released design information and (b) a reduced level of A/E's control over the numerous involved milestones. To this end, starting construction with partially completed design leads to potential incompatibilities between the released deliverables and other associated unreleased elements that are usually at different design development stages. Moreover, more uncertainty prevails when the design consultant assumes the role of a design subcontractor, under a contractor-led DB delivery method, caused by the A/E's reduced level of control over the required detail level for the design information release (DIR), when combined with the lack of owner's review requirements. Accordingly, sub-optimally detailed releases for construction become commonly expected.

Therefore, compared with the traditional mode of design delivery, when alternative methods are used, design professionals face the challenges of releasing design deliverables under atypical circumstances, thereby causing vagueness and unclear expectations concerning their role and the corresponding liabilities.

To this end, a thorough review of the archived literature and relevant body of knowledge revealed the lack of, and justified the need for, a research study that provides designers as well as design-builders (in the case of DB) with a holistic and thorough understanding of the implications of releasing design information under APDMs. These implications are mainly with respect to the A/E's role and liabilities on the one hand, and the design-builder's time and budget performance on the other hand. Accordingly, several research questions surfaced and are highlighted in the following section:

3.2 Research Questions

1-How alternative DC modes (e.g. fast-track) under alternative project delivery methods may impact the dynamics of the released design information?

2- As the A/E's bundle of commitments varies in both scope and degree of inherent uncertainties under the various PDMs in use, how the A/E's spectrum of engagement will differ with each method? And what are the respective implications on the agreement negotiation and formation process?

3- Given the multiple approaches for the procurement of construction projects, will the risks of the designers' exposure to professional liabilities differ with respect to their assumed roles and responsibilities in connection with the rendering of design and other related services? And what are the means for mitigating such risks?

4- How the incompatible coordination may impact the emergence of design and construction changes in DB?

5-Knowing the advantages that Building Information Modeling infused into the construction project delivery process, how can BIM help in tracking the emergence of changes to ultimately serve the control of their impact?

3.3 Research Goals

In attempting to find answers to the previously highlighted research questions, this research study aims to:

1- Analyze the impact of alternative DC modes under alternative project delivery methods (APDMs) on the design information release (DIR).
2- Understand the dynamics and the respective implications of the DIR under alternative design-construction (DC) modes (e.g., fast-track).

3- Examine the A/E's spectrum of engagement under APDMs and the respective implications on the design agreement negotiation and formation process.

4- Investigate the types and extents of the professional liabilities inherent in the A/E assuming either of the two contrasting capacities, an independent consultant appointed by owners or a design subcontractor acting under design-builders, for rendering the contracted deliverables.

5- Investigate the different types of insurance policies that can be procured for indemnifying against professional liabilities in construction projects and identify the different possible options for risk mitigation.

6- Investigate the change in respect of the way professional liability indemnity (PLI) coverage is to be procured and administered under a multi-tiered DB approach.

7- Investigate the applicability, in terms of usefulness and degree of relevance, of BIM to the DB method.

8- Investigate the implications of the potential incompatibilities of coordination, under the DB method, on the emergence of design and construction changes.

9- Examine the types of coordination that are needed for a timely identification of changes.

10- Demystify BIM potentials in tracking and monitoring changes in DB projects.

3.4 Research Contributions

The outcomes of this research work include:

1- Providing a conceptualization of the constructs of the inferred pattern and packaging of the design information release (DIR) under the different PDMs.

2- Offering a better understanding of the several potential sources of uncertainties associated with the alternative delivery methods and identifying the parameters/factors that the A/E needs to deal with in order to realistically strategize and organize for its involvement/engagement throughout the project.
3- Inferring the changes in staffing requirement and fee structure under APDMs.
4- Assisting the A/E in better approaching the agreement negotiation and formation process in a more informed way under APDMs.
5- Developing the constructs illustrating the liability exposure of the A/E when acting as independent consultant or as a design subcontractor.
6- Providing a framework that encompasses the different paths/possibilities for a negligence claim against the A/E to prevail or fail, whether acting as an independent consultant or as a design subcontractor.
7- Highlighting the persisting liability burden on the design professional and its potential role on the design professional's performance when rendering its design services as a design subcontractor and while being constrained by the design-construct priorities as envisioned by the design-builder.
8- Emphasizing the power of BIM in: (1) tracking the evolution of design elements (DEs) over time, (2) tracking the rework resulting from the incompatible and deferred coordination under the DB method, and (3) providing documented historical data on rework when applied systematically.
9- Developing a BIM-enabled synthesized framework that aids design-builders proactively plan and control their work in expectation of potential claims emanating from the emerging changes.

10- Devising a Revit Plugin extension that helps with the dynamic tracking and monitoring of design and construction changes to ultimately serve the pro-active control of their impact.

CHAPTER 4

RESEARCH METHODOLOGY

Time is a major constraint in today's competitive market. Alternative project delivery methods (APDMs) allow for a faster project completion due to the aspired timesaving associated with the earlier involvement of the builder and the concurrency of the design and construction project functions. However, starting construction with partially completed design leads to incompatible coordination between the released deliverables and other associated unreleased elements that are usually at different design development stages. Design problems are therefore argued to emanate from having the design phase driven by the needs of the construction work, thereby increasing the challenges and uncertainties associated with the design services performance pattern, and potentially leading to a higher frequency of changes and rework. The challenges further increase in a contractor-led design-build (DB) setup owing to the increased time pressure exercised by the builder on the Architect/Engineer (A/E) − being his/her design subcontractor − and the respective considerable control retained over the required sequencing and detailing of the released deliverables. There stems the significance of this research work that aims at analyzing the impact of alternative DC modes under APDMs on the design information release (DIR) dynamics and the respective implications. These implications are mainly with respect to the A/E's role and liabilities on the one hand, and the design-builder's time and budget performance on the other hand. As the research aimed at the generation of holistic perspectives and new frameworks that can help better understand and describe these implications, an integrative approach was adopted for reviewing and synthesizing the representative literature that was encountered. To this end, the overall methodology, as shown in Figure 6, starts with an in-depth integrative literature review that feeds into the first stages of each of the four displayed research modules. These modules include the main steps followed to achieve the intended objective of each. That is, the overall methodology includes four steps: (1) visualize the pattern and packaging of DIR under alternative design-construction modes (covered in Module 1), (2) conceptualize the models pertaining to the design consultant's staging of services and infer the expected changes in the staffing requirement and fee proposal (covered in Module 2), (3) examine the implications of APDMs on the exposure of the design consultant to professional liabilities (covered in Module 3), and (4) track emergent changes resulting from the incompatible and deferred coordination under the DB method using the Building Information Modeling (BIM) platform and devise a Revit Plugin extension that helps with the dynamic tracking and monitoring of design and construction changes and serves the pro-active control of their impact (covered in Module 4).

Merely, this research starts by conceptualizing the pattern and packaging of design information under APDMs. By providing a theoretical basis (i.e., the outcome of research Module 1) for (1) comparing the role of the A/E from the perspective of the different modes of producing design deliverables and (2) analyzing the design documentation quality-related potential deficiencies, the inferred critical implications on the A/E's agreement negotiation, on the A/E's liability exposure, and on the emergence of design and/or construction changes were further addressed in Module 2, Module 3, and Module 4, respectively. The detailed methodology adopted for each of these research modules is further discussed in the following subsections.

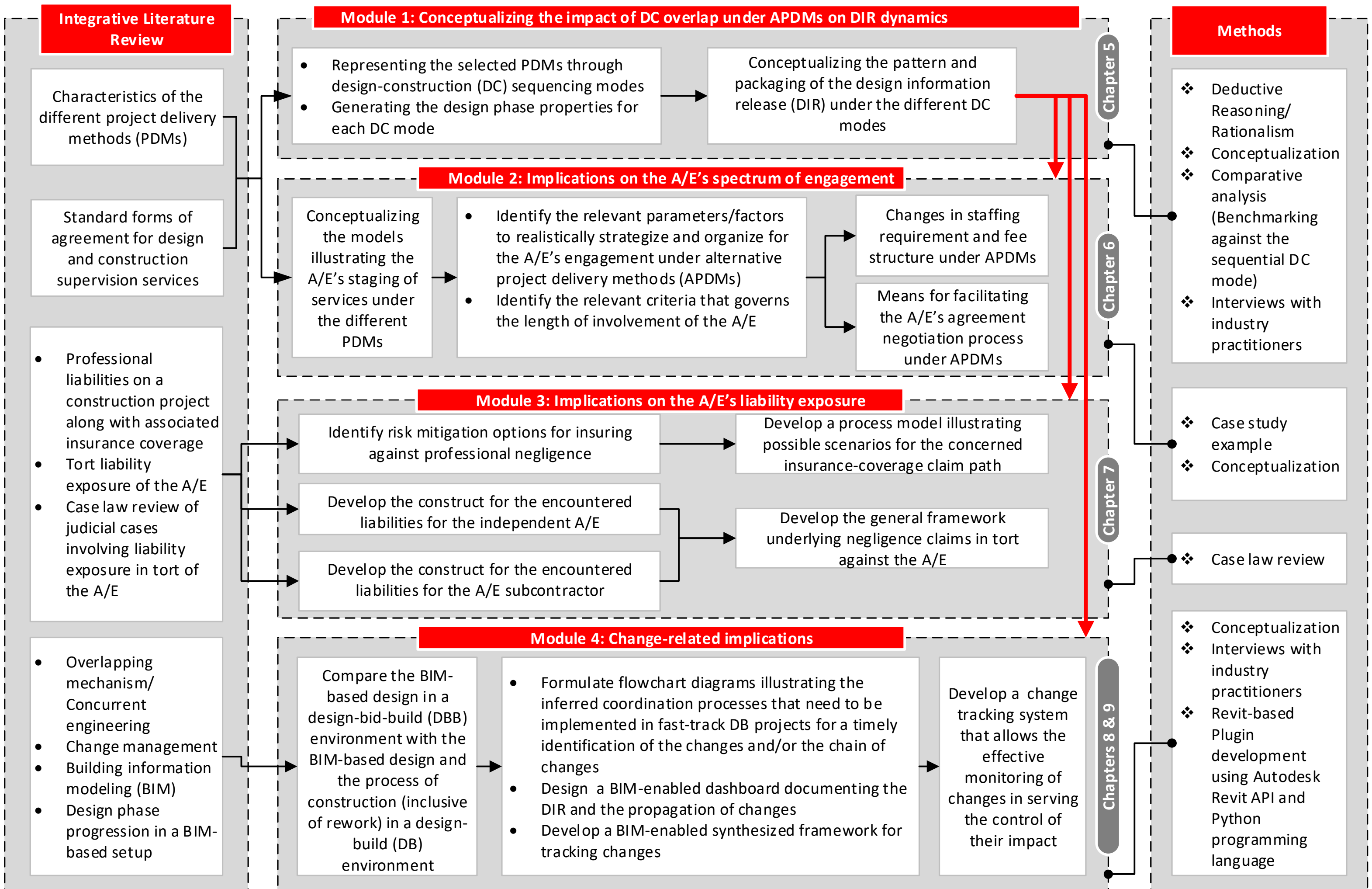


Figure 6. Overall research methodology and methods

4.1 Research Module 1: Examining the DIR dynamics

In order to investigate the research question corresponding to Module 1, i.e., how alternative DC modes under APDMs may impact the release of design deliverables, three main research stages were performed followed by a discussion of the practical implications of the study findings, as illustrated in Figure 7. At a high level, this figure shows the activities that were developed at each stage, along with the corresponding method used, in order to reach the study findings (Stage 3); thereby answering the research question. Namely, the first stage starts with explaining the rationale underlying the selection of the adopted PDMs along with defining the characteristics of each, as illustrated in Figure 7 (boxes “a” and “b”, respectively). These characteristics reinforced and supported the factors (Figure 7, box “c”) that are recognized, through established (in practice and in literature) principles pertaining to the delivery of construction projects under APDMs, to commonly exist and impact the release of design deliverables (e.g., the degree of control/pressure that could be potentially exercised by the builder). Then, using a deductive reasoning approach the selected PDMs are represented through corresponding DC modes, whereby the respective design phase properties are generated for each (Figure 7, box “d”). This method of rationalism requires that deductions logically rely on clearly stated reasons (in this case the identified factors), or general knowledge (Sargent, 2013, Koskela et al., 2019, Fischer and Gregor, 2011). These identified factors and generated design properties (at Stage 1) informed the conceptualization of the constructs illustrating the dynamics (i.e., the pattern and packaging) of the DIR under each of the identified modes (Stage 2). Namely, the construct illustrating the DIR under the sequential DC mode is first conceptualized (Figure 7, box “e”) for benchmark purposes. Then, a simplified model of DIR under an overlapped DC mode is conceptualized (Figure 7, box “f”). This simplified model, along with the identified factors and generated design properties corresponding to each of the alternative DC modes, inform the conceptualization of the alternative constructs (Figure 7, box “g”). Finally, at Stage 3 the findings of this module are analysed and summarized. Per se, a comparative analysis is made through benchmarking the conceptualized alternative constructs against the one pertaining to the sequential DC mode. A detailed description of the work carried out at each stage is provided in Chapter 5.

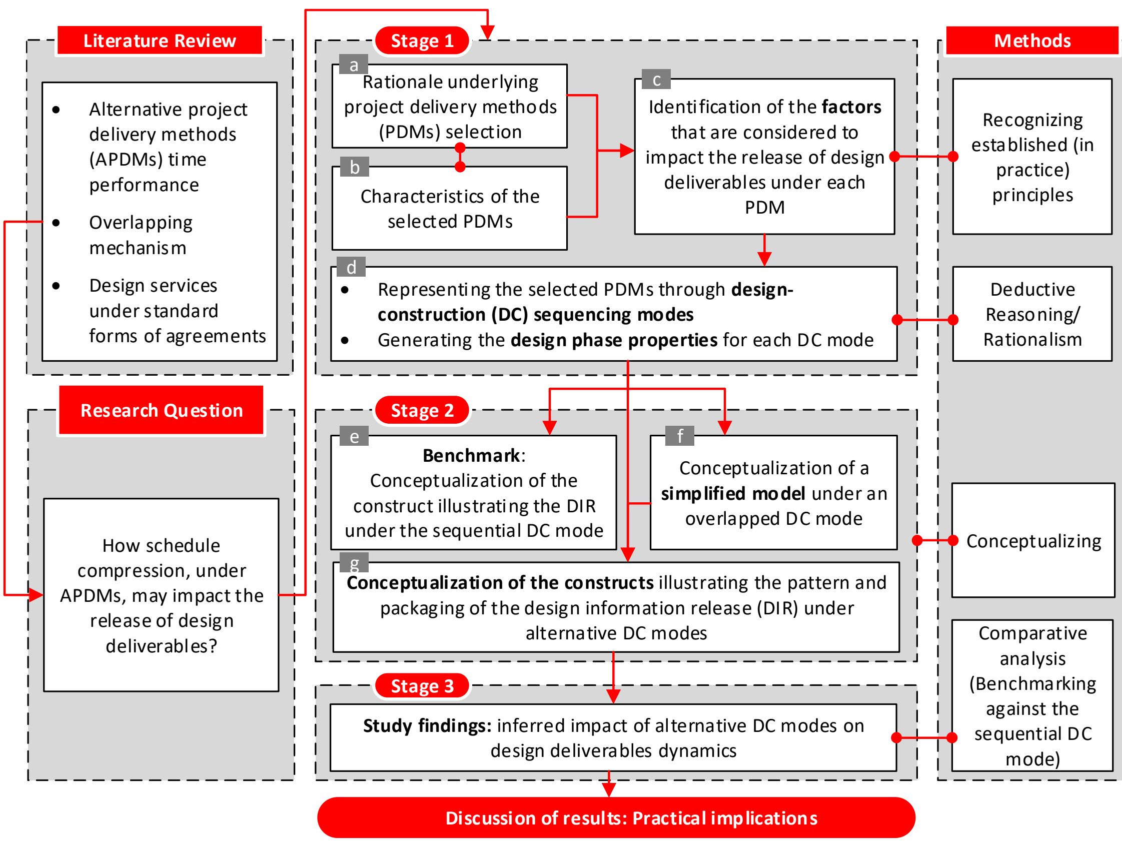


Figure 7. The stages of the adopted methodology in Module 1

The outcome of this module established for the inferred critical implications of releasing design information under the circumstances associated with APDMs.

4.2 Research Module 2: Examining the implications on the A/E's spectrum of engagement

Contracts define the roles and responsibilities of the concerned parties and specify the mechanisms that may be triggered in response to several circumstances and adversities whose contemplated occurrence has been commonly anticipated. To this end, as the A/E's bundle of commitments varies in both scope and degree of inherent uncertainties under the various PDMs in use, there stems the objective of this research module that aimed at addressing the implications of the A/E's engagement under APDMs on the respective design agreement negotiation and formation process. As shown in Figure 8 , the methodology followed for that purpose entails numerous stages. Stage 1 corresponds to the review of the relevant literature concerned with the different PDMs in use and of standard forms of agreement (this is a common stage between modules 1 and 2). The outcome of this stage provided the justification for needed research work that addresses the pre-contract negotiation phase in view of the varied circumstances underlying each delivery method. Based on the properties that were found to characterize each PDM, a conceptualization of the A/E's staging of involved services under each delivery method was accordingly constructed (Stage 2). The formulated models helped infer the relevant parameters and criteria that A/E professionals need to deal with in order to realistically strategize and organize for their engagement under each of the considered PDMs. These inferred parameters and criteria fed into the conceptualization of two strategies, as shown under Stage 3. The first strategy pertains to the implications of APDMs on staffing requirements, which in turn represent a requisite to setting up the fee structure. Finally, through deducing the expected changes in the required staffing pattern, the second strategy points out the relevant terms, conditions, and mechanisms that shall be designed and/or negotiated in a way that protects A/E professionals against the potential uncertainties associated with APDMs. A detailed description of the work carried out at each stage is provided in Chapter 6.

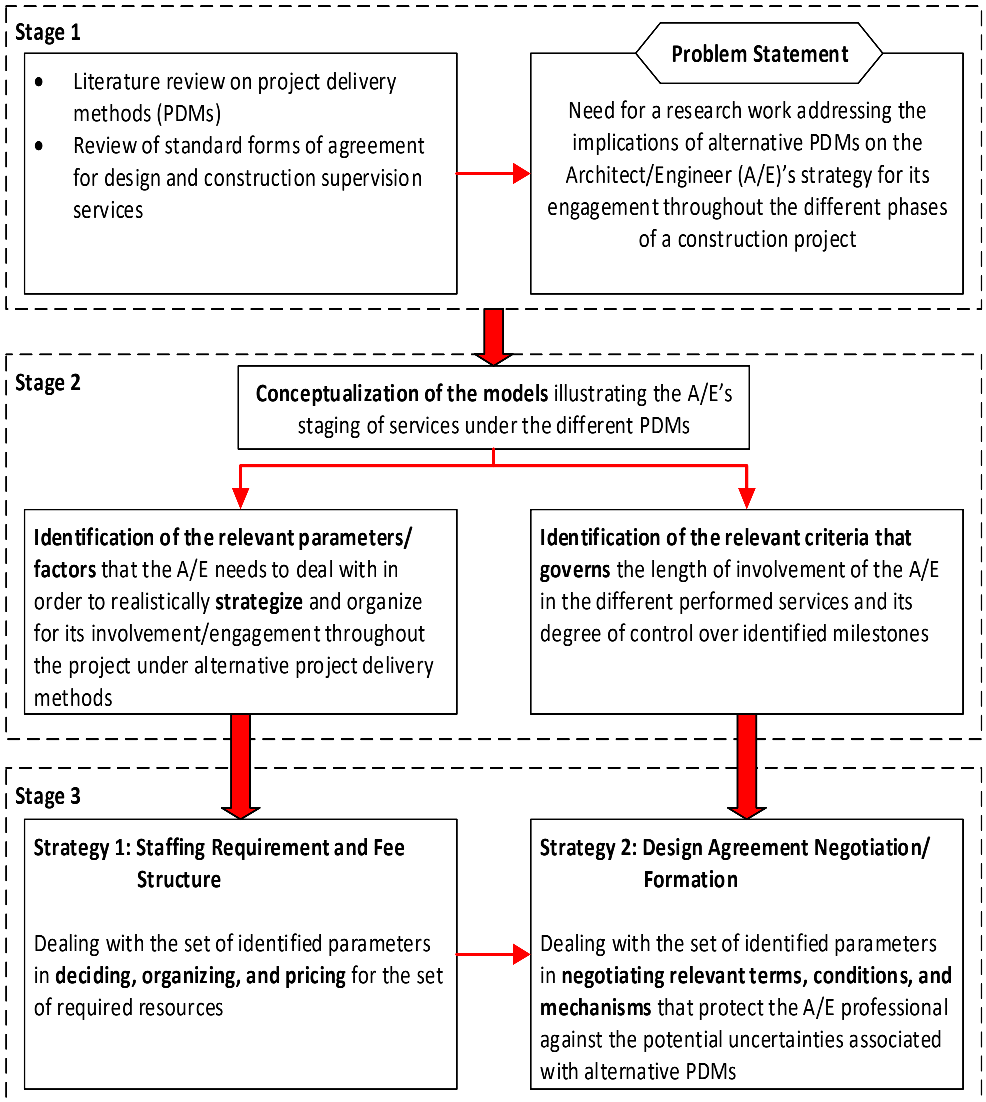


Figure 8. The stages of the adopted methodology in Module 2

4.3 Research Module 3: Examining the implications on the A/E's liability exposure and indemnity

This module aims to investigate the types and extents of the professional liabilities inherent in the A/E assuming either of the two contrasting capacities, an independent consultant or a design subcontractor, for rendering the contracted deliverables. The adopted methodology involves a number of interrelated steps, as shown in Figure 9.

This module 3 involved a literature review that was undertaken in two stages. To this end, Stage 1 consisted of a literature review on the various types of professional liabilities on a construction project along with the associated insurance coverages. This resulted in (a) identifying the different areas of liabilities that are carried by construction professionals according to the various assumed roles and (b) highlighting the different elements of tort liability in contrast to contractual liabilities. In Stage 2, a thorough review of the relevant literature, complemented with a structured review of case law involving liability exposure in tort of A/E professionals, was carried out. Whereas it was found that the recovery in tort for physical damages/injuries (i.e. bodily injuries (BI) and property damage (PD)) is relatively straightforward, the recovery of economic damages (ED) is subject to the application of the economic loss doctrine (ELD) and the varying practices in different jurisdictions. That is, Stage 2 resulted in the identification of (a) the different parties to whom an A/E can be held liable and (b) the different circumstances for the encountered liabilities. Stages 1 and 2 triggered the need for (a) research work addressing tort liability exposure of the A/E in its status/role as a design subcontractor and (b) a holistic construct underlying negligence claims in tort against the A/E. To this end, several cases that were found to be touching on claims for ED were fully scrutinized and relied upon to serve the purpose of either (a) shedding light on the liability exposure of the A/E in its independent role or in its role as a design subcontractor or (b) supporting a recognized exception to the application of the ELD. Consequently, at Stage 3, two constructs for the encountered liabilities were developed: one mapping the cases for the DBB setting and one mapping the cases for the DB setting. Finally, as informed by a synopsis of the circumstances of the encountered liabilities, along with the varying practices for the application of the ELD that may be adopted by the various states (jurisdictions), a general framework underlying negligence claims against the A/E is accordingly presented (Stage 4). Depending on the type of damages suffered, and the possible identity of the claimant (in the case of ED) which varies according to the project delivery method in place (i.e., DBB or DB), the framework encompasses the different deduced constructs reflecting the different paths/possibilities for a negligence claim against the A/E to prevail or fail. A detailed description of the work carried out at each stage is provided in Chapter 7.

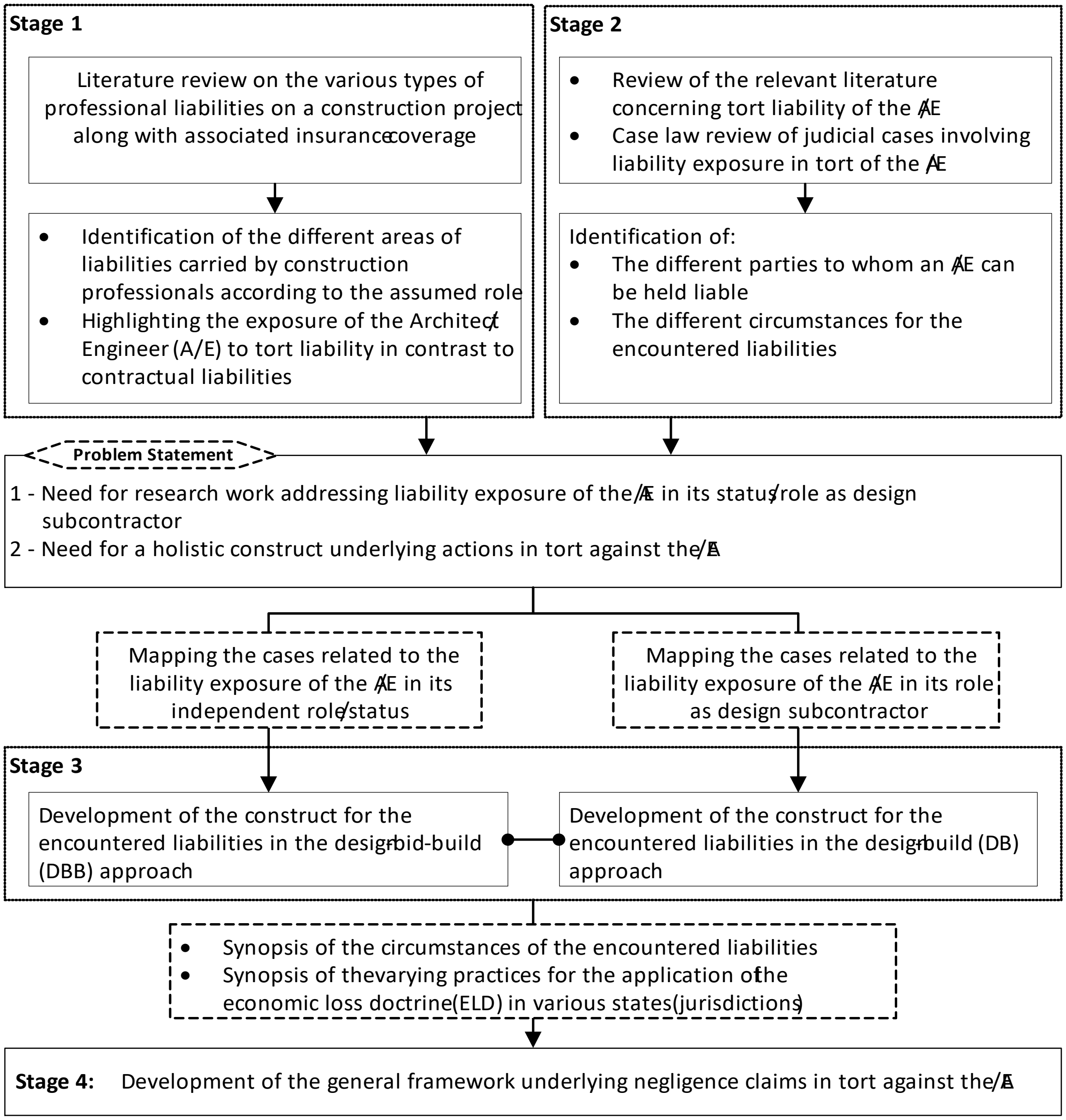


Figure 9. The stages of the adopted methodology in Module 3

4.4 Research Module 4: Change-related implications

Given the increased uncertainties and challenges associated with the undertaking of the design phase in fast-track DB projects and the inevitable emergence of changes that may bring about negative impacts on the project performance, the last objective of this research work is to devise a tool that helps tracking those changes to serve the control of their impacts.

On the one hand, a management tool is described as a tactic or process that provides guidance for managing a project (Molenaar et al. 2019); and it consists of forms, spreadsheets, flow charts, or guidelines that can be used to perform a specific task (Papajohn et al. 2019). On the other hand, the use of the DB delivery system and BIM tools in the construction industry has been growing rapidly in recent years due to the increasing demand for more efficient construction project management. The successful implementation of these tools by engineering firms, however, is still not being achieved consistently. To this end, this module starts with first examining the applicability of BIM to DB projects (covered in Chapter 8), with a focus on the interface between the design and construction deliverables. To achieve this target, two process models were formulated; one maps the BIM-based design in a DBB environment, and the other maps the BIM-based design and the process of construction (inclusive of rework) in a DB environment. The conceptualization of these two models was informed by a literature review on design management and information flow with a focus on the DB system, along with a review of BIM implementation methodologies and the associated tools enabling information flow during design. After that, a comparison between the two models is carried out for the purpose of assessing the potential advantages of BIM application under the DB delivery system. This comparison serves in identifying the different aspects of coordination in these two delivery systems and emphasizes the envisioned roles of BIM in providing documented historical data on rework and changes when applied systematically.

Then, the objectives are (a) to devise the coordination processes that are needed for a timely identification of changes and (b) to track the propagation and the respective impact of such changes (covered in Chapter 9). To achieve these objectives, the first step consisted of examining the design phase progression in a BIM-based setup. This step was essentially informed by the literature. Nevertheless, in order to get a sufficient knowledge about BIM current capabilities with respect to the identification and coordination of changes, the author sought guidance from BIM practitioners with respect to the BIM-based workflow employed in four of the top design and construction firms in the Middle East and North Africa (MENA) region. Consequently, two flowchart diagrams illustrating the inferred coordination processes that need to be implemented in fast-track DB projects are formulated. These flowcharts help in the timely identification of the changes and/or the chain of changes and feed into the development of an information display tool that visually documents the time-based coordination outcomes. That is, a BIM-enabled dynamic dashboard is accordingly designed to (a) allow for the continuous and simultaneous monitoring of design and construction progress and (b) keep track of design changes propagation. Besides, the parameters for a model element (ME), which would be stored in the BIM model, are defined. This BIM-maintained database helps in tracing the responsibility matrix of the changes and their respective impact. These steps feed into the development of a BIM-enabled synthesized framework that aids design-builders proactively plan for their work in view of the effectively streamed changes and the potentially resulting claims that are bound to emerge due to the fast-track nature of DB projects. Finally, the implementation of the proposed framework is validated through the development of a Revit plugin with hands-on support from one of the consulted BIM professionals. The plugin allows the automated and flawless documentation of the previously defined data and the automatic extraction of the designed dashboard.

The methodology followed with respect to the plugin development is illustrated in Figure 10. Namely, as most of the BIM platforms and tools provide Application Programming Interface (API) to extend their functionalities, the main BIM platform used for prototype development is Autodesk Revit 2020. Namely, the Revit API allows users to program with any.NET compliant language as a way to add extensions to the originally generated BIM model, such as VB.NET and C# as a direct .NET programming language, or IronPython and Python.NET as an implementation of the Python programming in the .NET framework. In this case, Revit API was used to develop an addon using IronPython platform, which is used to create the prototype inclusive of the user interface and software logic development owing to its power in data analysis. Although C# is the main programming language for Revit plugin development, Python was chosen for the sake of data management and for the future integration of Machine Learning and Artificial Intelligence. The developed Revit plugin is named "DB-CTS" (DB-change tracking system) and allows the effective streaming of changes to serve the control of their impact. To build the prototype of the DB-CTS, user needs are first defined in order to design the different user interfaces and the different processes. The system prototype is then constructed with Revit API and Python programming language.

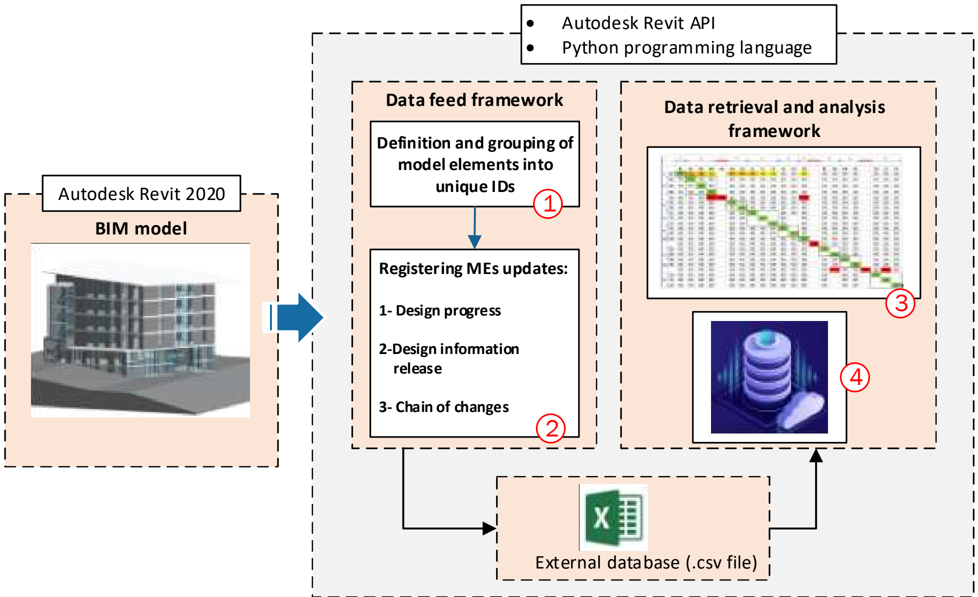


Figure 10. Methodology followed for the plugin development

CHAPTER 5

EXAMINING THE DIR DYNAMICS UNDER ALTERNATIVE DC MODES

5.1 Preamble

Schedule compression under APDMs is well established in the literature and is mainly realized by way of overlapping the design and construction phases. On the one hand, different degrees of overlap may be obtained under various APDMs, depending on the characteristics of each method. On the other hand, starting construction with partially completed design increases the uncertainty and complexity associated with the design work (Lee et al., 2005, Zerjav et al., 2011, Deshpande et al., 2012) and leads to a higher frequency of rework (Moazzami et al., 2011). To this end, several methodologies have been proposed in order to gain maximum advantages of the overlapping mechanism and minimize design and/or construction rework (Pena-Mora and Li, 2001, Bogus et al., 2006, Bogus et al., 2011, Hossain et al., 2012, Khoueiry et al., 2013, Srour et al., 2013, Dehghan et al., 2015, Hossain and Chua, 2014, Dehghan and Ruwnapura, 2014). For instance, optimization approaches that incorporate the concepts of upstream design evolution and downstream (i.e., construction work) sensitivity criteria were developed to optimize the project schedule while maintaining minimum rework (Khoueiry et al., 2013, Hossain and Chua, 2014). Alternatively, other studies were limited to the design phase, thereby focusing on the overlap between design activities using dependency information or the concept of downstream design sensitivity to upstream design evolution (Bogus et al., 2006, Bogus et al., 2011, Hossain et al., 2012, Srour et al., 2013, Dehghan and Ruwnapura, 2014). The previously listed studies looked at the overlap either between design and construction activities/tasks or within design activities/tasks. While some do refer to fast-track projects (reflecting a general case of design and construction being overlapped/ fast-tracked), none of these studies is applied in the context of a specific APDM. Namely, the features that characterize APDMs were not previously discussed in literature work addressing the overlapping mechanism. This chapter aims to investigate the impact of schedule compression and the respective overlapping of design stages under APDMs on the release of design deliverables. This is mainly achieved by conceptualizing the possible alternative design information release (DIR) dynamics, and then benchmarking these dynamics against the well-established release of design deliverables under the sequential design-construction (DC) mode of the DBB method. To that end, this research does not compare the advantages/disadvantages of the selected APDMs, neither advocates the use of a method over the other. Rather, the specific focus with respect to each of the considered APDMs is on the characteristics that allow these methods to be presented through alternative design-construction modes (as compared to the sequential mode of the DBB method). Furthermore, to be noted is that a comparison of the advantages/disadvantages of the delivery methods rather happens in terms of owners' suitability of a selected method given the set of prevailing circumstances (Al Khalil 2002). Namely, the decision-making process of projects' owners/developers with respect to the most appropriate delivery approach for a project in question is affected by the project characteristics (e.g., clarity of scope, schedule, complexity, contract pricing), owner's needs (e.g., constructability studies; value engineering studies; contract packaging; and feasibility studies), and owner's preferences (design responsibility, design control, owner's involvement after the contract's award).

5.2 Stage 1: Generation of design phase properties under alternative DC Modes

5.2.1 *Rationale underlying APDMs selection*

A project delivery method may be defined as a choice made by owners/developers concerning the pooling of functions (namely planning, design, construction, operation and finance) along with the possible associated strategies that may be used to deliver a built facility (Figure 11). The pooling defines the basket of responsibilities of a specific team, and the strategies are defined by (a) the timing of involvement of the GC or the construction manager (CM), (b) the concurrency of functions, and (c) the level of participants' integration through the type of contract implemented. As such, integration of participants, as shown in Figure 11, covers the full spectrum from the lack of integration using traditional multiple contracts (e.g., DBB) to the quasi-integration when signing relational contracts but excluding the owner, to the full integration using multi-relational contracts, where all the key participants, including the owner, signs one contract and agree to gain/pain sharing formulas. Various combinations result in various delivery methods, each tailored to meet the specific project needs and complexities. Given that collaboration of participants under relational contracts entails a whole different philosophy of financial system transparency and risk sharing in a cooperative and trustful environment (Lahdenperä, 2012), project partnering, project alliancing, and integrated project delivery are considered outside the scope of this work. Rather, the main considerations underlying the selection of APDMs form the characteristics that allow these methods to be represented through different DC modes (as contrasted to the sequential mode of the DBB).

To this end, this study is concerned with the following APDMs: (1) the CMAR, (2) the phased DBB with agency construction management (CMa), and (3) the DB. The rational underlying this selection is the early involvement of the GC and the common overlapping of design and construction functions. The phased DBB with CMa (for simplicity purposes, only the acronym CMa will be used in reference to this method) is selected due to the commonly known DC "phasing" (a more detailed description is provided in a following section). Moreover, while several structural variations of the DB method (Beard et al., 2001) exist, the contractor-led approach is selected. The reason is the perceived additional impact related to time pressure, which results out of the "lack of independence" on the part of the A/E professional. Accordingly, throughout this study, the reference to a DB team is limited to the case of a contracting firm that provides construction services while subcontracting the design-related ones. The characteristics of each of the selected methods are provided in the following sub-sections.

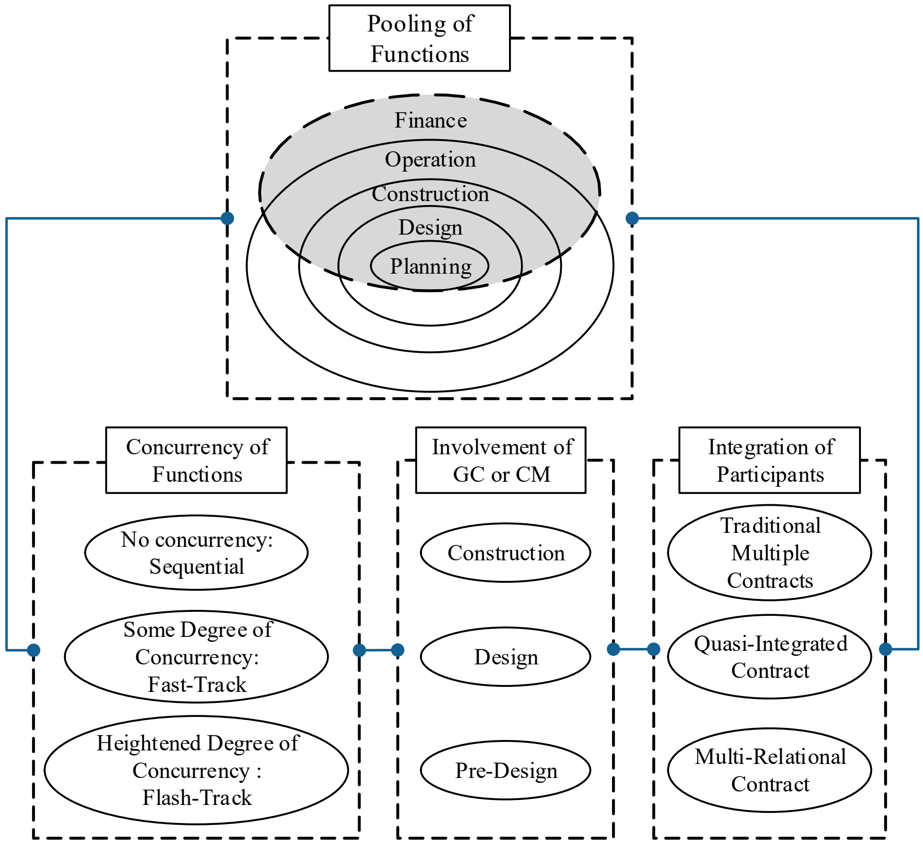


Figure 11. Multi-attribute framework for a PDM selection

5.2.1.1 The traditional DBB method

The traditional DBB delivery method is characterized by an owner signing separate agreements with the A/E and the general contractor for design and construction services, respectively (Franz and Leicht, 2016). This separation generates independency between the A/E and the GC and a system of checks and balances (Mahdi and Alreshaid, 2005). Design and construction phases are sequential (Franz and Leicht, 2016). At the end of the design phase, the A/E professional prepares and releases for bidding purposes a single package comprising the complete contract documents (Al Khalil, 2002). Providing owners with a high level of control over the detailed design, the DBB process affords the potential for an optimized design that successfully addresses the owner's requirements (Deshpande et al., 2012). Other characteristics include well-established and clearly defined and documented roles and clear quality standards produced by the complete contract documents (American Institute of Architects-Associated General Contractors of America (AIA−AGC), 2011).

5.2.1.2 The phased DBB with agency construction management method

The CMa, is otherwise referred to in the literature as the construction management for fee (Ghavamifar and Touran, 2008) or the Construction Manager as Agent method (Lopez del Puerto et al., 2008). This method involves (a) a CM acting as an agent to the owner for preparing and managing multiple bid packages (in contrast to the single bid package prepared under the DBB), which are phased over time and competitively awarded to trade contractors (in contrast to one GC under the DBB), and (b) an independent A/E for providing design services (Forbes and Ahmed, 2010). The existence of multiple trade contractors removes the single point of responsibility for construction and induces a lack of a guarantee for the overall construction price and completion time (Mahdi and Alreshaid, 2005, Lopez del Puerto et al., 2008).

5.2.1.3 The CMAR method

The CMAR delivery method is also known as the CM/GC method (Ghavamifar and Touran, 2008). It is characterized by the same organization chart of the DBB method in that the owner signs separate contracts with the A/E and the GC who is otherwise referred to as a construction manager at risk (CMR) under this method. Unlike DBB, where construction starts after the full completion of design documents, the design in CMAR is released progressively (Antoine et al., 2019). The owner contracts with the CM for pre-construction services. Then, the CM becomes at a later stage the at-risk general contractor, i.e., assuming the risk for the cost and the timely completion of the project (Antoine et al., 2019). Moreover, the CMR assumes the risks of subletting subcontract-related packages (Mahdi and Alreshaid, 2005) and the risk of guaranteeing the completion of the project for a guaranteed maximum price (GMP) based on a partially completed design (The Construction Management Association of America (CMAA), 2012). The CMR is typically engaged on the basis of a cost reimbursable contract (Franz and Leicht, 2016). The CMAR is typically faster than the DBB (Mahdi and Alreshaid, 2005) and the CMa approaches. While the top two advantages of the CM/GC were found to be the design input by the CMR and the ability to fast-track the project and accelerate the project delivery time, the top ranked disadvantage is reported to be in connection with the designer and CMR having different agendas (Shane and Gransberg, 2010). Namely, while contractors are cost-focused, designers tend to be conservative in their design for the major reason of design liability (Shane and Gransberg, 2010). Moreover, in a CM/GC process, contractors may potentially assume an owner-type role, thereby leading designers to help serve their interests (Farnsworth et al., 2016). This process affords the potential for (a) accelerated start dates, (b) phasing subcontract-related packages, and (b) an incremental construction approach characterized by the flexibility of designing a little and building a little (Farnsworth et al., 2016).

5.2.1.4 The contractor-led design-build method

The DB approach is characterized by having one party responsible towards the owner for design and construction services. Under the contractor-led DB variation, the A/E acts as a design subcontractor under the builder rather than being independent as in the previous PDMs. Design-builders may be engaged either on a lump sum fixed price contract for the completion of all design and construction services, or on a cost-plus contract with the option of a GMP. Typically, LS contracts are implemented (Franz and Leicht, 2016). Design and construction phases are overlapped (Franz and Leicht, 2016, Chen et al., 2016), thereby reducing the overall project delivery time.

Emphasized under the DB method is the builder's considerable control over the sequence of design documents preparation and the related decision-making process (American Bar Association (ABA), 2003), and the inherently dynamic environment (Koch et al., 2010). Under this approach, and as argued by Quatman and Dhar (2003), the CD stage theoretically entails less documentation than other methods "because the design-build team can agree in advance on what drawings, specifications and other documentation are needed", i.e., a less-detailed level of documentation, as a means of reducing the A/E's fees. On the other hand, it could be argued that under the circumstances of having a designer on board, working for the design-builder, the A/E may be involved in any of the construction-related professional services, thereby preparing higher-detailed level of documentation, e.g., shop-drawings or as-built documents. As such, design information under the DB method may be released in different forms depending on the purpose released for, i.e., either suiting the purpose of design progression or suiting the purpose of construction (Kalach et al., 2018b).

5.2.2 *Factors impacting the DIR under APDMs*

The above reviewed characteristics help in better framing and supporting the three identified factors (as illustrated in Figure 12) that are well-established (in practice) to likely prevail under APDMs. Namely, three factors are recognized to impact the release of design deliverables under APDMs, in contrast to the well-established release under the traditional DBB (which is displayed as the benchmark). These factors correspond to the *intensity of the DC overlap*, the *degree of control/pressure* that may be exercised by the builder on the design process, and the *level of details* in the design documents (i.e., the extent to which the design documents get to be detailed). Starting with the DC overlapping intensity, the earlier the construction starts, the higher the overlapping intensity is likely to be. As such, the overlapping intensity can be thought of to increase when moving from CMa, to CMAR, and then to DB. As for the second factor, the higher the pressure a builder may be allowed to exercise over the design progress, in order to meet the construction needs and time-schedule priorities, the higher the degree of control will potentially be. Therefore, the degree of control by the builder increases when moving from the CMAR to the DB method. As for the CMa method, and notwithstanding the lack of control by the builder, the release of bid packages is mainly controlled by the CM's strategy for packaging. Finally, while the level of design documentation details provided under the DBB and CMa methods is commensurate with execution-type drawings (because design deliverables are released for bidding), it becomes mainly dictated by the degree of control that may be exercised by the builder under the CMAR or DB method. That is, the level of details generally decreases under the CMAR due to the builder's early involvement, and even less documentation details may be provided under DB. However, for some deliverables, the required level of details may well increase to the level of shop-drawings.

Project delivery method (PDM)		Factors impacting the design information release (DIR)		
		DC overlapping intensity	Degree of control by the builder	Level of details in the design documents
Benchmark: Traditional PDM	DBB	No overlap	No control	Commensurate with execution-type drawings
Alternative PDMs (APDMs)	CMa	Increasing ↓	No control*	Commensurate with execution-type drawings
	CMAR		Increasing ↓	Generally decreasing** ↓
	DB			

*Notwithstanding the lack of control by the builder, the release of bid packages is mainly controlled by the CM's strategy for packaging

**Notwithstanding that the increased degree of control exercised by the builder generally leads to a reduced level of details in the design documents, the A/E may well be required to provide, for some deliverables, an even higher level of details (i.e., shop-drawings)

Figure 12. Factors impacting the DIR under each PDM

5.2.3 *Design phase properties under each DC Mode*

In light of the previously reviewed characteristics and identified factors, and following a deductive-reasoning approach, Figure 13 illustrates the representation of each of the methods into its corresponding DC mode, along with the generated design properties. This figure shows two different pooling of functions, either separate or pooled design and construction functions. The former category includes the traditional DBB, the multi-prime approach, the CMAR and the CMa, whereas the latter includes the DB method. That is, for each PDM, the organization chart is displayed along with the contract type and the A/E's status, the DC sequencing mode, and the generated design properties for each mode. These properties include the *process*, the *packaging*, *coordination,* and *purpose of release*.

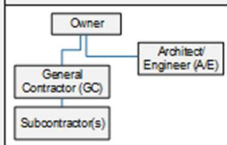
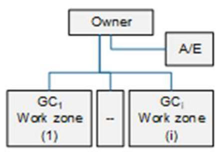
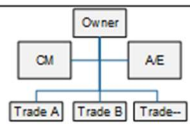
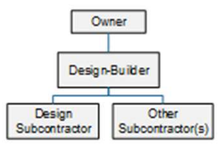
	Organization Chart	Project Delivery Method	Contract	Architect/ Engineer Status	Design and Construction Sequencing	Design Properties			
						Process	Packaging	Coordination	Purpose of Release
Separate Design and Construction Functions		Traditional DBB	Lump Sum; Unit Price	Independent	Mode 1 Sequential	Sequential Stages	Single One-time Package	Full at Project Level	Tendering Purposes
		Construction Manager at Risk (CMAR)	Cost Plus GMP	Independent	Mode 3 Fast-Track	Concurrent Stages	Successive Release of Design Information Bundles	Partial at Bundle Level	Execution Purposes
		Multi-Prime	Lump Sum; Unit Price	Independent	Mode 1 Sequential	Sequential Stages	Single One-time Package Per Work Zone	Full at Work-Zone Level	Tendering Purposes
			Cost Plus; GMP (≈ CMAR)	Independent	Mode 3 Fast-Track	Concurrent Stages	Successive Release of Design Information Bundles	Partial at Bundle Level	Execution Purposes
		Phased DBB with Agency Construction Management (CMa)	Fixed Fee or % Fee	Independent	Mode 2 Phased	Concurrent Stages	Successive Multiple Packages Per Trade	Partial at Package Level	Tendering Purposes
Pooled Design and Construction Functions		Design-Build (DB)	Lump Sum; Cost Plus GMP	Design Subcontractor	Mode 4 Fast-Track	Concurrent Stages	Gradual Release of Design Information	Variable Levels of Coordination	Satistfying Various Design and Construction Purposes

Figure 13. Design phase properties under alternative DC modes

Given that in a multi-prime approach, multiple GC – potentially overseeing various trades – sign their contracts directly with the owner to build specific work zones of the same project (Gordon, 1994), the delivery of each separate work zone is treated as in a traditional DBB delivery method or CMAR method. Starting with the traditional DBB, this method is represented by DC Mode 1. The corresponding design properties generated for DC Mode 1 are the *sequential* stages of the design process and the *single one-time package,* which is released *for tendering purposes*. Therefore, design coordination is viewed as being *full at the project level*. DC Mode 2 characterizes the *phased* DC sequence of the CMa approach. The design process is inferred to be *concurrent* allowing the *successive multiple packages* per discipline to be released for *tendering purposes*. Design coordination is therefore inferred to be *partial,* due to it being achieved at the package level. DC Mode 3 characterizes the *fast-track* DC sequencing of the CMAR approach. The design process is characterized by the inferred *concurrency or the overlapping* of design stages. As for the packaging of design, it is inferred that *bundles* of design information may be *successively released* for *execution purposes*, i.e. directly for construction, due to the potential control exercised by the CMR over the design process (as synthesized earlier). Therefore, design coordination under this mode is viewed to be *partial*, due to it being achieved at the level of the released bundle of information. As for the last DC Mode 4, the design is driven by the design-builder's schedule and is thus deduced to be released *gradually* in order to allow for an earlier start of the construction process, and an expeditious progression of construction-related activities. The term gradual is used to indicate the more frequent DIR as compared to the previously used "successive release" under DC Mode 3, stemming from the increased degree of control that may potentially be exercised by the design-builder. Design coordination under Mode 4 is conceptualized to vary according to the form of the released information and, therefore, *variable levels of coordination* are inferred to potentially exist. Moreover, the purpose of release is viewed to be *satisfying various design and construction purposes*.

5.3 Stage 2: conceptualization of the constructs

5.3.1 ***Criteria for construct definition***

The above-generated properties of the design phase along with the identified factors impacting the DIR are therefore used as key parameters in conceptualizing the possible alternative dynamics (in terms of pattern and packaging) of the DIR, as compared to traditional mode of release under DC Mode 1. Therefore, the construct of design deliverables dynamics under DC Mode 1 is first illustrated for benchmark purposes, and the possible alternative dynamics are then conceptualized. As subsequently analysed, the inferences are made with respect to the changes in the scope, frequency, and timing of the released deliverables, and – consequently – for the project's design coordination quality, under DC Mode 2, Mode 3, and Mode 4, respectively.

5.3.2 ***Benchmark: design deliverables release and packaging under DC Mode 1***

Under the traditional DBB, design and construction phases are sequential, and the design phase evolves *sequentially* from the SD through the DD and ends up at the end of the CD stage, with an increasing level of details and certainty. This sequential DC sequencing is referred to as DC Mode 1 and is considered the benchmark for the DIR. Figure 14 illustrates the construct of design deliverables dynamics under DC Mode 1. Each stage features the design work produced by the multiple disciplines involved and are presented by iterative loops. Moreover, the grey ellipse at the centre indicates the minimum SD work produced by the architecture discipline with few engineering efforts, and which is typically needed for the other disciplines to start their work. At the end of each stage, the set of deliverables is packaged as per the requirements stipulated in the design agreement, for review and approval of the owner. As such, owner's approval on a set of deliverables at the end of a specific stage officially triggers the start of the following one. Under the DC Mode 1, changes can be made to optimize and improve the design before construction starts. At the end of the CD stage, *one fully coordinated set of deliverables* is *released for tendering purposes*.

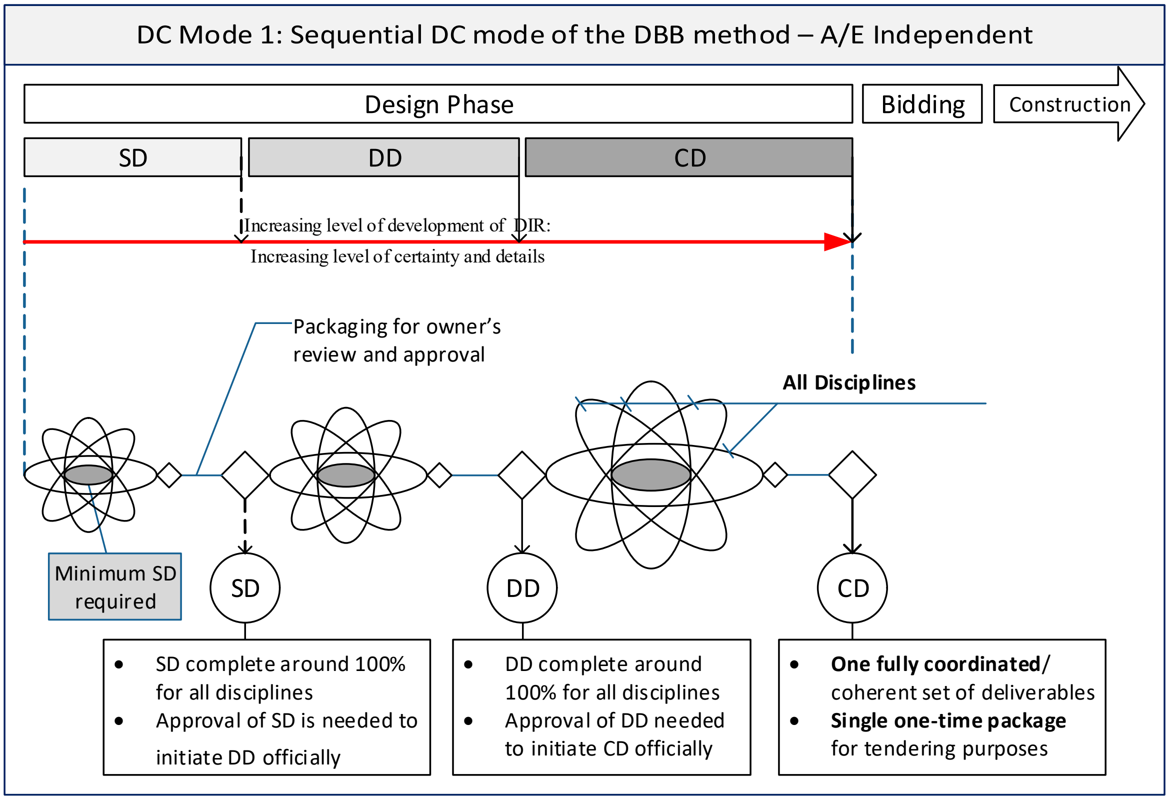


Figure 14. Construct of design deliverables dynamics under DC Mode 1

5.3.3 *Conceptualizing the possible alternative dynamics*

In order to conceptualize the possible alternative dynamics (i.e., release pattern and packaging) of the DIR under alternative DC modes, a simplified model (Figure 15) is first presented. The model illustrates the general changes in the DIR under an overlapped DC sequencing. To this end, design and construction phases are shown as overlapped, and design stages are also overlapped as a result of starting construction with a partially completed design. The full duration of each of these design stages is determined according the design stages completion by all the potentially involved design disciplines (e.g., architectural, structural, etc.). Moreover, t_1 refers to how soon the release of design deliverables may start, while t_2 is in reference to how soon the construction phase starts. This indicative model considers two associated disciplines A and B, with Discipline A releasing design deliverables for construction, but after coordinating with Discipline B. The DIR is discussed at the level of one discipline only, the one releasing design documents for construction (i.e., Discipline A).

To this end, the full length of the SD, DD and CD for Discipline A, is designated by SD_A, DD_A and CD_A, respectively. If this discipline is to release only one package, then SD_A, DD_A and CD_A will be carried out sequentially. Therefore, two cases may be encountered: the case of a single package with sequential stages and/or the case of multiple-released packages with overlapping stages, displayed by dotted hatch rectangles and by diagonally-hatched rectangles, respectively. The different coordination levels of the DIR (L_1 to L_6) that emanate from the concurrency taking place are in relation to the degree of design completion in Discipline A and in the associated Discipline B. Moreover, since any information released from an early SD stage is preliminary and matures progressively to become final at the end of the CD stage, an increasing degree of design completion in B reflects an increased certainty of the information being coordinated with A. Taking into account that other possible scenarios of the design stages overlap between A and B may also exist, the indicative model in Figure 5 considers the case where DD_A is not finalized unless and until the schematic design stage of B (SD_B) is finalized as well. Moreover, CD_A when finalized, DD_B is displayed as completed as well. Therefore, the DIR from CD_A may appear at six different coordination levels displayed by six different arrow types: (a) released from CD_A and before completion of SD_A (i.e. L_1), (b) released from CD_A having SD_A finalized (i.e. L_2), (c) released from CD_A having SD_A and SD_B finalized (i.e. L_3), (d) released from CD_A having DD_A finalized (i.e. L_4),

(e) released from CD_A having DD_A and DD_B finalized (i.e. L_5) and (f) released at the end of CD_A (i.e. L_6). That is, the several packages released for construction (i.e., from the CD stage) are conceptualized to exist at any of these coordination levels. Therefore, the *coordination* attribute of design documentation quality of these packages is defined by the level of coordination that could be afforded to a certain package at the time of being considered for release for construction. This coordination quality is dictated by the degree of design completion in the concerned other disciplines and the respective level of development, i.e., details and certainty, of the information that is the subject of coordination. Therefore, it can be safely deduced that the inferred coordination quality of the released design documents is enhanced when moving from $L_{1,CD}$ to $L_{6,CD}$.

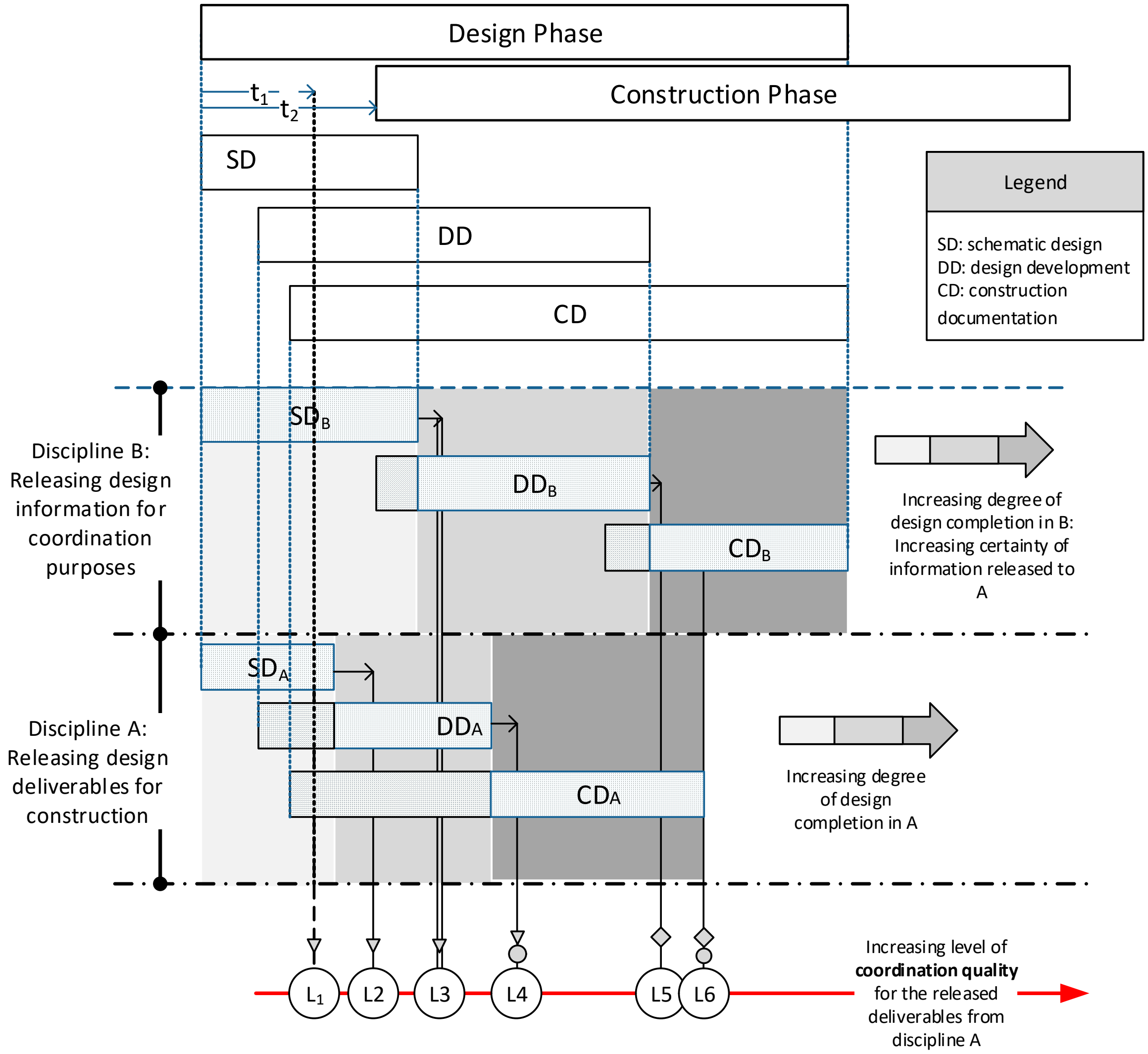


Figure 15. Simplified model for the alternative dynamics

5.3.4 *Design information release and packaging under DC Mode 2*

DC Mode 2 characterizes the *phased* DC sequence of the CMa approach. The construct of the DIR in DC Mode 2 (Figure 16) features *overlapped* design and construction phases and *concurrent SD, DD and CD stages*, but after the completion of enough SD in order to allow for an early launching of bid packages according to the CM's pre-set strategy for packaging. These stages reveal the design work offered by the different involved disciplines/sub-disciplines. These are designated by letters (e.g. A, B) in order to remain indicative and to avoid claiming the precedence of a certain discipline in releasing information for construction. For instance, a closer look at the SD stage features several overlapping boxes with indicative dimensions in order to display the overlap between the disciplines. Evidently, the SD is carried out along many disciplines at the same time.

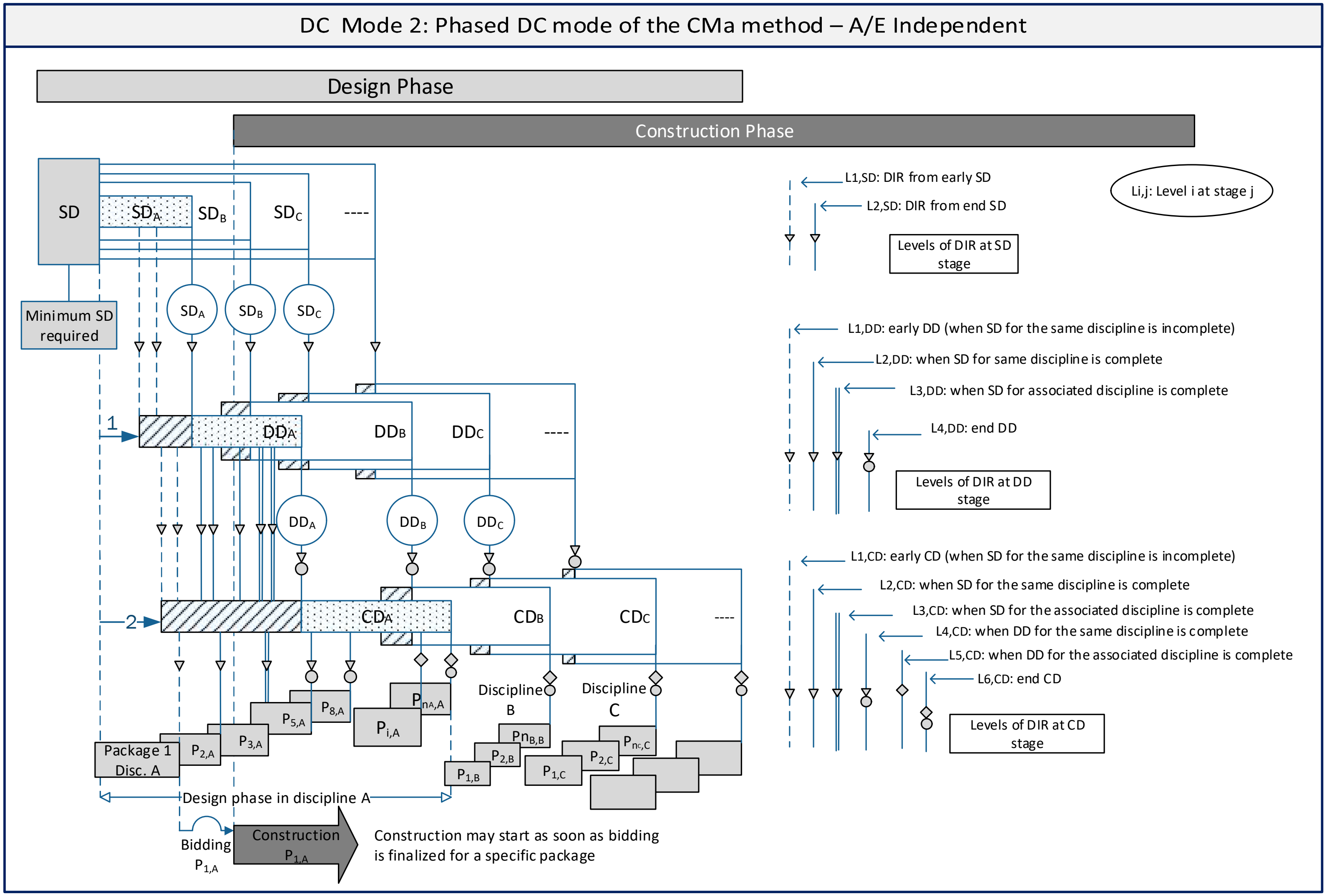


Figure 16. Construct of design deliverables dynamics under DC Mode 2

Thus, if considering the case of multiple released packages, and as soon after the completion of sufficient SD work, including the completion of the SD for the first package in discipline A ($P_{1,A}$), the DD_A may start (corresponding arrow 1). Similarly, as soon after the completion of sufficient DD work, including the completion of the DD for $P_{1,A}$, the start of the CD stage is triggered (corresponding arrow 2). When CD is completed for $P_{1,A}$, the first package in discipline A is *released for tendering purposes*. After bidding for this package, construction may start. Therefore, construction is assumed to start when bidding is done for the first completed package, which is translated by the signature of the first trade contract. Typically, under a phased approach, *packages are released on a trade-by-trade basis*, i.e., successively for trade contractors. Similar to the previously illustrated simplified model, the release of design information at the level of each design stage is presented by varying arrow shapes (see legend for these arrow shapes in Figure 16). These arrows are used to indicate the variable coordination levels of DIR.

Regarding the remaining disciplines, successive multiple packages are also presented, with a total number of packages per Discipline n_D (D designates the discipline). Emphasized under this mode is that the design packages are released according to the CM's strategy for packaging. The CM does not guarantee completion time; and, therefore, time pressure under this DC mode is expectedly less than the pressure under the fast-track environment of the following Mode 3 and Mode 4. To this end, the packages may be sizeable in order to promote competition and to have more of the good calibre of trade contractors interested in bidding.

5.3.5 *Design information release and packaging under DC Mode 3*

DC Mode 3 characterizes the *fast-track* DC sequencing of the CMAR approach. The design deliverables release under DC Mode 3 is illustrated in Figure 17. While in the previous DC

Mode 2 the CM guarantees and promises the owner with the most experienced and professional way in devising the contract packages, the CMR rather guarantees a timely completion.

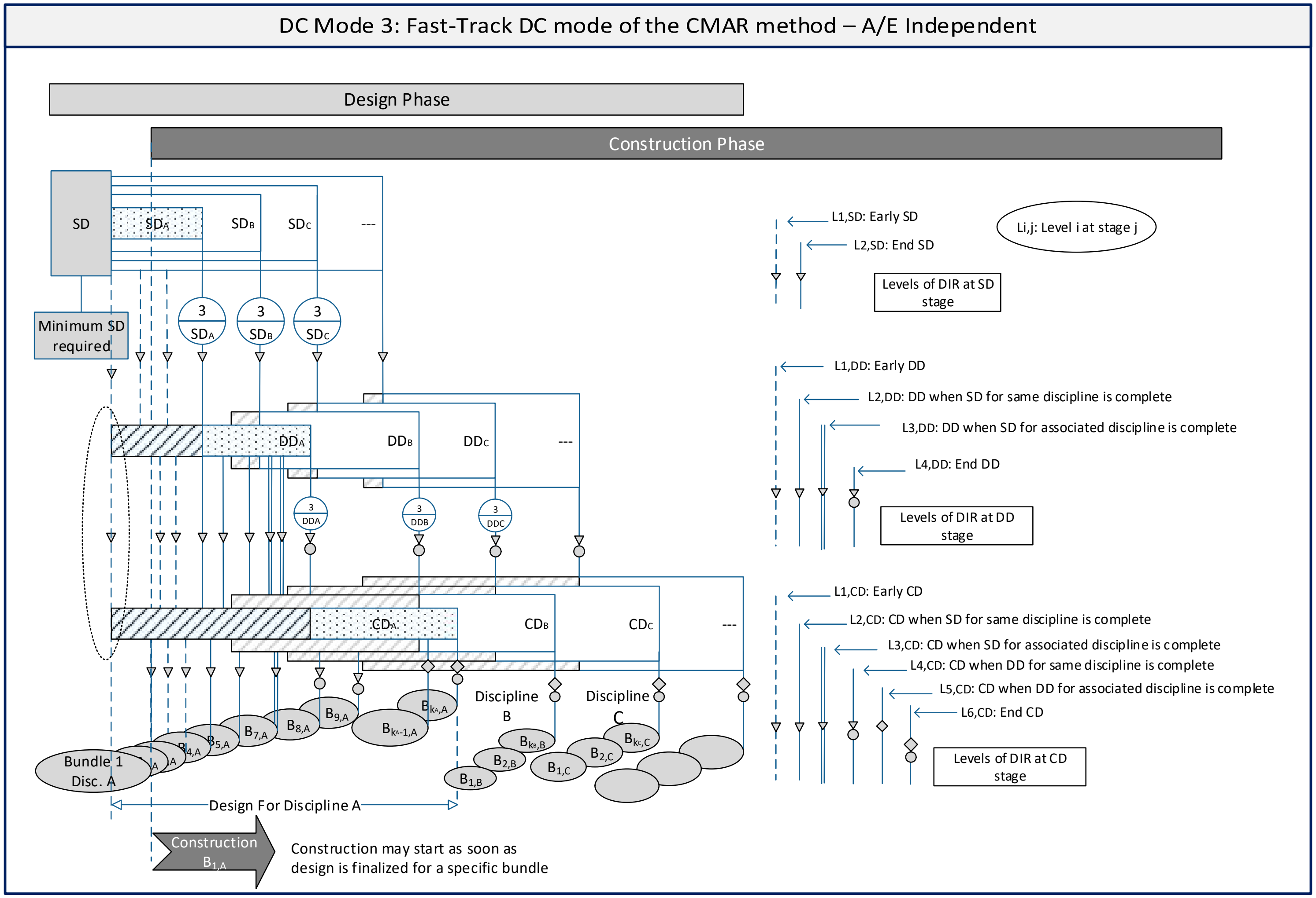


Figure 17. Construct of design deliverables dynamics under DC Mode 3

Under Mode 3, the DIR is driven by the CMR's construction schedule and, therefore, faces the pressure of being released as soon as possible in order to allow the construction works to start and to meet the several deadlines. Inherently, DC Mode 3 features a tougher environment because the production of design information is guided by the construction works deadlines rather than meeting the priorities of the CM's strategy for packaging. As such, the construct of the DIR in Mode 3 differs from the previous construct of Mode 2 in two main aspects, the scope of the released packages and the priorities it serves. Namely, from scope perspective, the bundle of design information that is released by an independent A/E to a CMR entity does not need to abide by the pervious criteria of the CMa method, i.e., having the size of the package attractive for prospective bidders. Therefore, under Mode 3, it is was inferred that DIR will be in the form of *successive bundles of information* instead of packages. Accordingly, the frequency of the DIR per discipline is reasoned to be higher. So, if "n" packages per discipline are released under Mode 2, a higher frequency of release illustrated by "K" bundles per discipline, with narrower intervals, may be released under Mode 3. Therefore, $P_{1,A}$ (in Mode 2) − theoretically speaking − could be representative of multiple bundles. Evidently, under this approach, the CMR cannot afford to wait for a bigger basket of completed design in order to carry on construction works. Thus, the DD and the CD stages may theoretically start right after the completion of a minimum SD (illustrated by a dotted ellipse), which is considered to include enough SD work that allows the CMR to price and set the schedule. Further development of the design may be still needed before the guaranteeing of the maximum price and completion time.

As for the coordination levels of DIR, the same logic discussed in the previous Mode 2 applies. But, since the bundles are *released for execution purposes*, there is no bidding phase illustrated (yet, bidding on subcontracting-related packages may well exist), and construction may start as soon as the CD stage of the first bundle of DIR in discipline A ($B_{1,A}$) is completed.

5.3.6 *Design information release and packaging under DC Mode 4*

The DB approach differs from the CMAR in two main criteria; the non-independency of the A/E being rather a design subcontractor under the design-builder and the diffusion of the DD stage which "is often abridged or even eliminated because of growing pressures from compressed schedules and reduced fees" (Quatman and Dhar, 2003). For instance, the AIA's standard form of agreement between the design-builder and the A/E (AIA-B143) (American Institute of Architects (AIA), 2014b) highlights only two stages in the design phase, the preliminary design (PD) and the CD stages. Design work under Mode 4 corresponds to the design carried out at the pre-award of the DB proposal (shown by a grey rectangle in Figure 18), the remaining PD and the CD work. Moreover, the DIR at the end of the PD stage of each discipline is shaded in order to reflect the share of design work by the owner's A/E or otherwise known as the design criteria consultant (DCC) before engaging the design-builder. The DD stage is removed, and the design information released from the PD stage is detailed directly at the CD stage prior to being released for construction. Accordingly, the construction works may start as soon as the first design information is released from discipline A. This could be as soon as the proposal award date or after the elapsing of a lag period necessary to carry additional design work in order to allow the start of the construction work, which is illustrated by the arrow designated by letter "a". The indicative scenario illustrated in Figure 18 presents a lag period between the award and the start of construction.

The DIR at the CD stage are displayed at four different coordination levels as shown in Figure 18 (due to the elimination of the DD stage). From scope perspective, these releases are different from the bundles of the previous Mode 3 which are produced by an independent

A/E. Moreover, it is assumed that, if “n” packages per discipline may be released under Mode 2, and “k” (greater than n) bundles per discipline may be released under Mode 3, then “l” (l could be even greater than k) releases may be released under Mode 4. Compared to Mode 3, a higher frequency of release is expected under Mode 4.

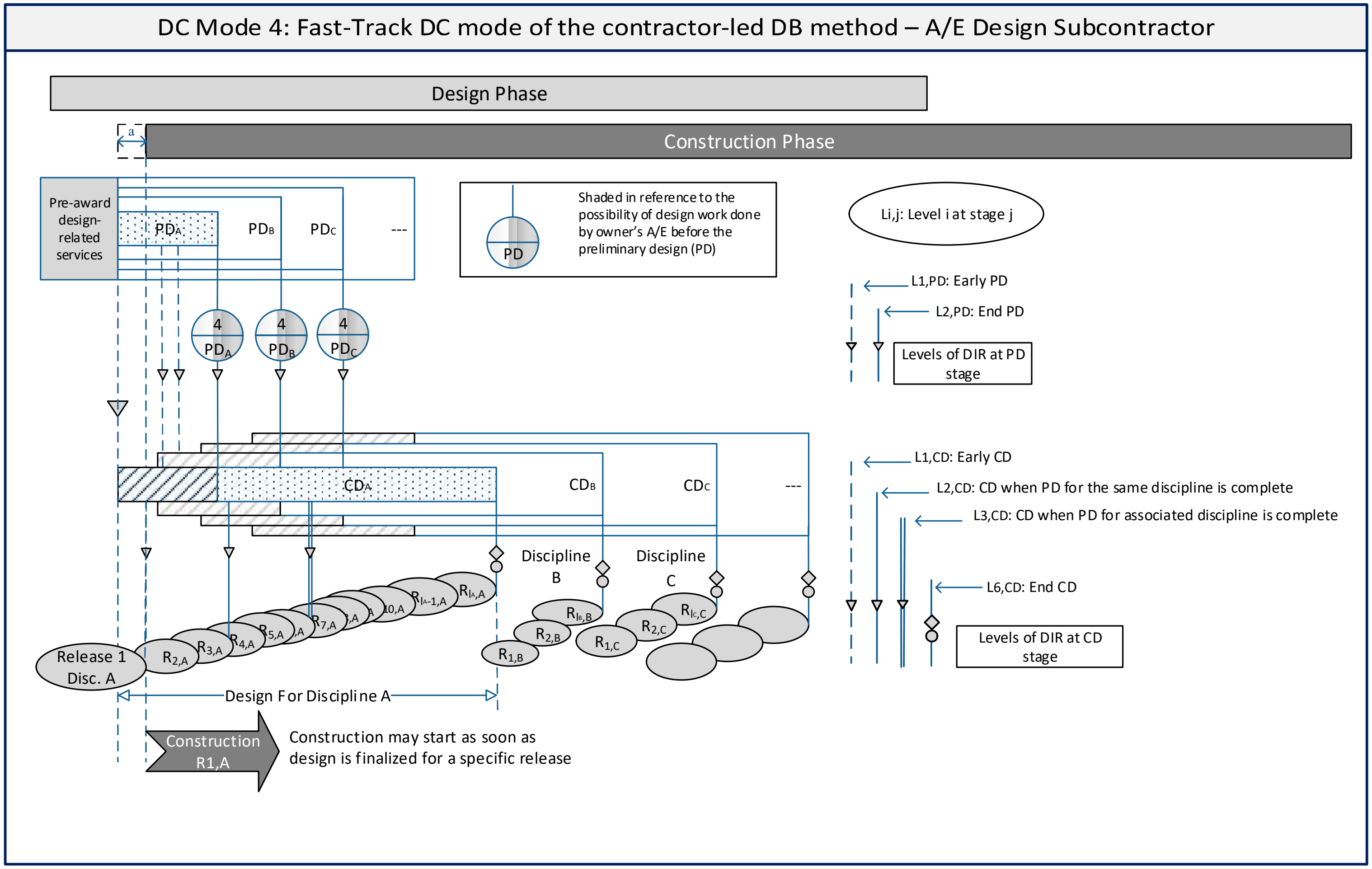


Figure 18. Construct of design deliverables dynamics under DC Mode 4

5.4 Stage 3: Module 1 findings

This research Module 1 aims at investigating how alternative DC modes, under APDMs, may impact the dynamics of the released deliverables. By benchmarking against the construct illustrating the DIR under the sequential DC mode of the DBB method (i.e., DC Mode 1), a comparative analysis was performed in order to infer the findings of the study, as summarized in Figure 19. Namely, the findings revealed that in contrast to the traditional one-time packaging of design deliverables, multiple DIR − with less certainty on their scope, timing, frequency, and coordination quality – are released under alternative DC modes. This uncertainty mainly emanates from the deduced impact of the identified factors (e.g., DC overlapping intensity and degree of pressure by the builder) on the design deliverables dynamics. Whether guided by the CM's strategy for packaging under DC Mode 2 or by the builder's schedule in Mode 3 and 4, the resultant reduced degree of control retained by the A/E over the released information dictates the extent to which design work is driven by the construction needs. That is,

- An increased time pressure on the A/E when moving from DC Mode 2 through Mode 3 to Mode 4, is translated by the *scope* of the DIR, the priority being served, and the increased *frequency* of release.
- DC Mode 3 features a tougher environment than DC Mode 2 because the production of design information is guided by the construction work's deadlines rather than meeting the priorities of the CM's strategy for packaging.
- When it comes to DC Mode 4, the releases are different from the bundles of Mode 3 which are produced by an independent A/E.

As such, if the same project is to be delivered using any of the illustrated DC modes, then the deduced changes in the DIR dynamics (as compared to the DC Mode 1 benchmark) are illustrated in Figure 19. Namely, when moving from DC Mode 2 through DC Mode 3 to DC Mode 4:

- The number of released deliverables is inferred to increase with an inherently reduced scope (due to the evident splitting of the full scope of the project's design) and an increased frequency of DIR.
- Accordingly, the project's design coordination quality is deduced to potentially decrease from DC Mode 2 through DC Mode 3 to DC Mode 4.

Design-Construction (DC) Sequencing Mode		Inferred Design Information Release (DIR) Dynamics			Inferred Project's Design Coordination Quality
		Number	Scope	Frequency	
Benchmark: Sequential DC mode	DC Mode 1	One package	Full scope	One-time	Theoretically fully coordinated set of deliverables
Alternative DC modes	DC Mode 2 DC Mode 3 DC Mode 4	↓ **Potentially increasing**	↓ **Potentially decreasing**	↓ **Potentially increasing**	↓ **Potentially decreasing**

Figure 19. Summary of Module 1 findings

5.5 Discussions: practical implications

5.5.1 *Design documentation quality-related implications*

In the traditional DC Mode 1, the single-package type of DIR and the respective theoretical full coordination at the project level give rise to an enhanced coordination quality for the released deliverables. Therefore, the risk of rework caused by coordination quality-related deficiencies can be argued to be kept to some inevitably minimum level. Inherent with the alternative DC modes is the added reason for encountering rework due to the concurrency taking place and the use of early information. However, the above-conceptualized constructs help inferring that rework is due to (a) the inability to afford the potential for a complete and compatible coordination for the DIR, or (b) sub-optimally detailed releases for the purpose of construction, as in the DC Mode 4 of the DB approach. The former case mainly stems from the incompatible design stages between the components of the release and the several associated design elements that are yet to be released, while the latter one results from the lack of an owner's review requirement preceding construction, combined with the non-independency of the A/E who is therefore afforded less control over the required detail level for the DIR.

Moreover, under alternative DC modes, the *coordination* attribute of the design documents quality, as discussed in this study, is the result of having the released information at any of the previously discussed levels spanning from L_1 to L_6. This documentation quality-related attribute is dictated by the time-variant degree of design completion of the concerned other disciplines. However, the several possible alternative dynamics of the DIR under alternative DC modes influence the possible number of design packages that may be released at each of the identified levels. For instance, an aggressive schedule compression, characterized by a higher intensity of overlap and an increased pressure by the builder, leads to an increased number of packages released at L_1 and L_2 coordination levels (for instance), as opposed to higher ones. Therefore, the aspired advantages of schedule compression – when opting for alternative DC modes − may be offset (at least partially) by a compromised documentation quality, and an increased error-prone performance of the released deliverables is therefore more likely to be encountered. While short-term risks are translated with a higher frequency of rework emanating from the incompatible coordination taking place, long-term risks may also prevail. For instance, designers, design review professionals, and project owners must be aware that any reduced certainty on the design documentation quality must be assessed against a potentially increased exposure to liabilities for design errors and omissions. Moreover, the higher the overlapping intensity is, and when coupled with improper planning and inadequate design management, the higher the risks are of an inferior design quality (e.g., increased life-cycle cost performance). Here comes the benefit of collaboration to the project delivery process, whereby management efforts can be directed towards improving the total project performance rather than focusing on meeting specific design or construction priorities. While such an approach aligns with the lean philosophy to project delivery, incrementally applying lean techniques throughout the delivery process of construction projects is argued to render promising results (Wodalski et al., 2011).

5.5.2 *The A/E role-related implications*

Under the traditional DC Mode 1 standard forms of agreement present a wide base of commonalities as to how design stages are structured throughout the design process. These stages offer a systematic and well-established A/E's role in rendering design deliverables and are observed as important milestones in the design process. In contrast, under the considered alternative DC modes, design deliverables are either phased for specific trades with respect to a CM's best strategy for packaging or released according to the builder's schedule that better serves meeting deadlines and construction priorities. Therefore, the increased uncertainty associated with the timing, frequency, and scope of the released deliverables can be inferred to cause unclear expectations concerning the planning for the A/E's needed resource staffing. As the construct of design deliverables dynamics under Mode 4 features the highest frequency of release and two vital distinct parameters, i.e., the "non-independency" of the A/E and the diffusion of the DD stage, Figure 20 shows the inferred implications of DC Mode 4 on the formation of design teams.

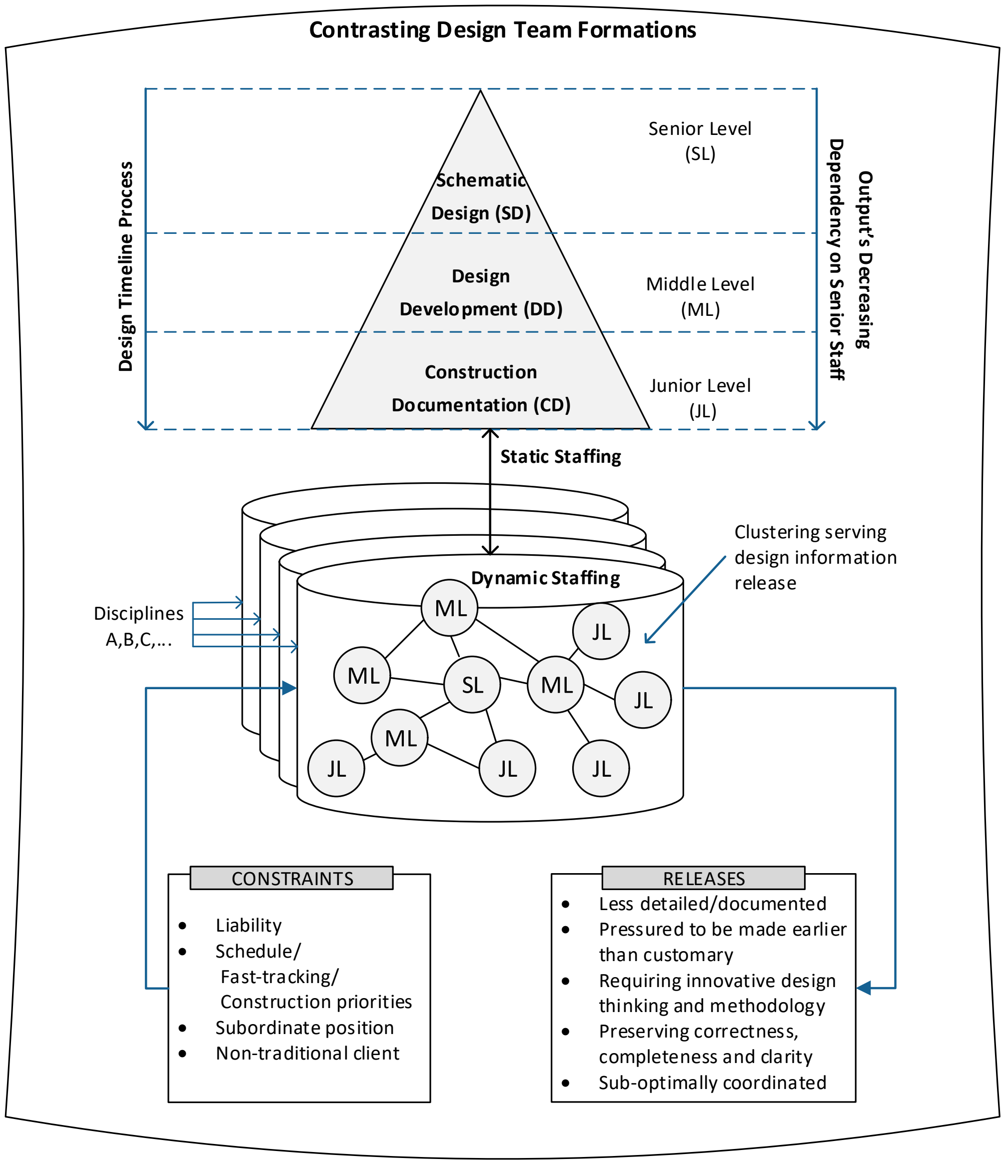


Figure 20. Design team staffing requirement under DC Mode 4

The level of work produced by the different design team members, as illustrated at the top of Figure 20, is inspired from the work of Gray and Hughes (2001) whereby the most senior staff are presented in the top of a pyramid, delegating work to their subordinates, and managing their work. In other words, design solutions are (a) worked out by the senior level (SL) staff at the SD stage (at the top of the pyramid) (b) broken down into components that are resolved by the middle-level (ML) staff at the DD stage, and (c) detailed through the lowest level junior-level (JL) staff at the CD stage. As such, the staffing needed by the A/E is conceptualized to change from the traditionally static staffing, i.e., as displayed by the decreasing dependency on senior staff as the output of design progresses from the SD towards the CD stage, to a more dynamic one illustrated by team clusters under Mode 4. This dynamic staffing is theorized to serve the specific DIR. Consequently, the needed combination of SL, ML or JL type of staff in each design discipline, at any period in the design phase, depends on the nature of the release taking place. Coupled with the pressure of schedule compression, the DIR is constrained by the burden of the design liability. Consequently, the release of design deliverables (Figure 20) is illustrated as being constrained by several issues. These include, design liability, schedule/fast-tracking/construction priorities, and working in a subordinate position to a non-traditional client in contrast to its long-standing leadership position. Therefore, to balance the effort made in producing the deliverables with the constraints inherent with the DB method, the produced documents which are conceptualized to be less detailed/ documented and pressured to be made earlier, need to be concise with a clear and careful documentation. As such, the A/E is required to be more innovative in the design thinking/methodology and this could be achieved by incorporating more practical design solutions.

5.6 Module 1 validation

Given the nature of this study, face and content validity were selected as the most appropriate non-statistical validation techniques (Lucko and Rojas, 2010, Sargent, 2013). To secure face validity of the research endeavour, in a practical field such as the construction engineering and management, the appropriate approach is through interviewing industry practitioners and seeking their opinion regarding the correctness of the study's underlying logic, and the soundness of the input-output relationships (Sargent, 2013). If the content of a study is found to fairly reflect the reality, content validity is satisfied as well (Lucko and Rojas, 2010). To this end, a purposive sampling was adopted and semi-structured interviews were performed with five industry practitioners from the top two consulting firms in the MENA region (one of which is ranked as top #6 worldwide, and the other firm is ranked as top #46, according to the Engineering News Record). The distribution of the practitioners is as follows: three professionals (one architect, one structural engineer, and one mechanical engineer, with 31, 17, and 12 years of experience, respectively) working in the top # 46 worldwide design firm, one structural engineer with 18 years of experience working in the top #6 design firm, and one structural engineer with 19 years of experience working as a freelancer design consultant for many design firms. These experts were selected owing to their experience in traditional and alternative project delivery methods. While the main purpose of the interviews was to seek the experts' opinions with respect to five tracks, i.e., (1) the validity of the identified factors at Stage 1, (2) the validity of the generated design properties for each DC mode (Stage 2), (3) the degree to which the conceptualized constructs reflect the DIR dynamics under each DC mode, (4) the validity of the findings, and (5) the work practical implications, the interviewees had the flexibility to express their opinion and give their reflections based on their own experience.

As for the three identified factors (Stage 1), the consensus of the experts was not only on the identified factors to actually exist, but also on the degree of prevalence of such factors under APDMs and on the highly experienced impact they have on the DIR. Namely, the high degree of control that may be exercised by the design-builder on the A/E was said to be "*actually translated by having representatives sent by the design-builder to our offices to rush the release of design deliverables and make sure that their requests are indeed our top priorities*." This was reported by one of the experts who also recognized the variable level of details that would be normally expected under a DB method or a CMAR approach (as reflected by the double asterisks in *Figure 12*). Namely, while a reduced level of details is commonly expected due to the builder's early involvement, a shop-drawing level detail may well be required as well. However, an interesting statement by one of the experts was to the effect that he would rather favour the extreme pressure exercised by the builder under the DB method over the very lengthy process of the DBB one, indicating: "*in DB we face extreme pressure, yet we know that all coordination issues are resolved with the same people involved and within a shorter schedule; however, in DBB, when construction starts and problems start to surface out of some missing information or due to constructability problems, we may not have the same team that was previously involved in the design, and it is always unfavourable for designers to re-visit previously submitted projects.*"

When it comes to the generated design properties, the conceptualized constructs, and the study findings, these were considered as being the very normal and logical consequence of the previously identified factors. However, one of the experts commented that the increased frequency of DIR may sometimes increase the chances to discover errors earlier. In contrast, another opinion was that "*any reduced time allocation for a certain design task, when coupled with the concurrency between design and construction, and no matter how complete the afforded coordination may be for a released package, the increased number of releases and the splitting of the full scope* *into smaller ones, would normally be at the extent of the design coordination of the project as a whole.*"

Finally, towards the end of each interview, the interviewed professional was asked whether he/she perceives any changes in the dynamics of the DIR or in the respective implications with respect to the project type. The consensus was that the conceptualized constructs for the DIR under alternative DC modes along with the reasoning and inferences made throughout the previous stages are valid for any type of construction project. The project type (e.g., buildings, roads, airports, etc.) rather dictates the number of disciplines involved, the interdependency between them, and the primacy of a certain discipline in starting the release of design deliverables. However, the other factors that were perceived as impacting the dynamics of the DIR were instead: (1) the number of design firms involved, whether one firm is providing all services in house or having multiple firms involved, and whether these are local or international, and (2) the time of involvement of the several disciplines involved when these were under different firms. Moreover, some external factors, e.g., the prevailing laws with respect to the issuance of permits and the required approval by authorities, were also seen as impacting the DIR.

CHAPTER 6

CONCEPTUALIZING THE IMPLICATIONS OF ALTERNATIVE DIR DYNAMICS ON THE A/E'S SPECTRUM OF ENGAGEMENT

6.1 Preamble

The advantage of accelerating the delivery of construction projects using alternative PDMs is inherently associated with varying degrees of uncertainties. These uncertainties mainly result from starting the different phases of the project without fully completing other preceding ones, regardless of the associated risks. On the one hand, the advantage of using standardized forms of agreements is rarely achieved with its full potential when implementing alternative PDMs because the A/E's bundle of commitments varies in both scope and degree of inherent uncertainties under each. On the other hand, and notwithstanding the widespread use and documented advantages, it was found that owners still rely on bespoke or heavily customized versions of available standard forms of agreements (Youssef *el al.* 2018). By shedding light on the relevant criteria underlying these uncertainties and owing to the need for a better understanding of the agreement negotiation and formation in light of these unveiled criteria, the relevance of this second research module stems from the need to address how these uncertainties may impact the A/E's spectrum of engagement under the different PDMs.

6.2 Staging of the Architect/Engineer's Services

Owing to the fact that time is a major constraint in every construction project, the industry is shifting towards PDMs that afford owners/developers a faster project completion. Accelerating the delivery of construction projects does not necessarily change the type of services carried out by A/E professionals; rather, it changes the staging and performance pattern of these services. As such, the following subsections illustrate the conceptualization of the models pertaining to the staging of the A/E's services in the traditional design-bid-build (DBB) method, and in the considered alternative methods, namely, the construction management at-risk, the phased construction with agency construction management , and the design-build (DB) delivery methods. As for the construction management methods, this research study adopts the terminologies used by the Construction Management Association of America (CMAA). That is, a construction manager (CM) refers to a person or a firm acting in an agency role, and a construction manager at-risk (CMR) designates a person or a firm acting in an at-risk role (CMAA 2012).

6.2.1 *The Design-Bid-Build Method*

As shown in Figure 21, the A/E's overall scope of services spans over the three sequential phases, involving design, bidding, and construction-supervision services. As for the solid arrow shown under each phase, it is to indicate the predetermined fixed duration of each of the concerned services. That is, the total length of engagement of the A/E represents the total duration resulting from the addition of the (a) design services duration, (b) bidding services duration and (c) construction supervision duration.

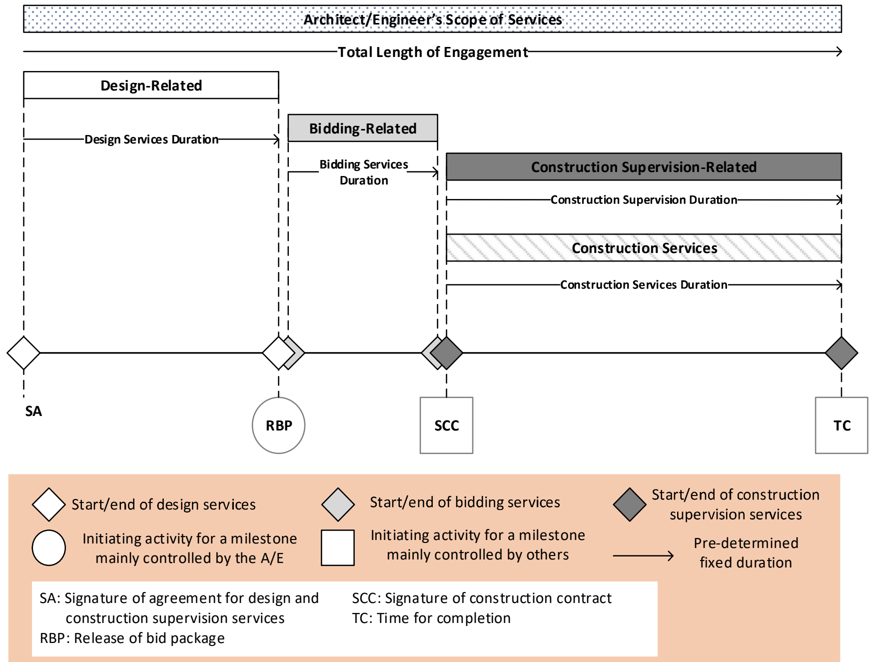


Figure 21. Conceptual model for the A/E's staging of services under the DBB setting

It should be noted that owners in a DBB setting retain control over all milestones; however, the concern here is whether the main control over a certain activity is retained by the A/E or by others. Moreover, the design services duration does not include the period related to pre-project planning; rather, it only involves the three sequential stages of schematic design (SD), design development (DD), and construction documentation (CD). Design-related services start with the signature of the agreement (SA) for the intended design and construction supervision services and end with the release of the bid package (RBP), an activity that is mainly controlled by the A/E's schedule of services. That is, the design services duration is completely independent from the construction supervision duration. As for the start of the bidding-related services, it is contingent on the RBP, and it ends with the selection of the successful bidder. However, its full duration is predetermined by the owner and the A/E at the time of the agreement signature. On the other hand, the start of construction supervision services is dependent on the signature of the construction contract, whereas the end of these services is predetermined according to the time for completion as stipulated in the construction contract, which makes both milestones to be mainly under the control of the GC.

6.2.2 *The Construction Manager At-Risk (CMAR) Delivery Method*

Acknowledging the probable existence of many other possible scenarios, the indicative model presented in Figure 22 illustrates one possibility for the conceptual model for the A/E's staging of services under the CMAR method, and this similarly applies to the models pertaining to the phased approach and DB method discussed in the following subsections. In comparison with the DBB model previously illustrated in Figure 21, the A/E's services under the CMAR model are in no doubt overlapped, and the phase pertaining to the bidding-related services under the DBB model is replaced by one that instead represents the bidding services related subcontracting by the CMR.

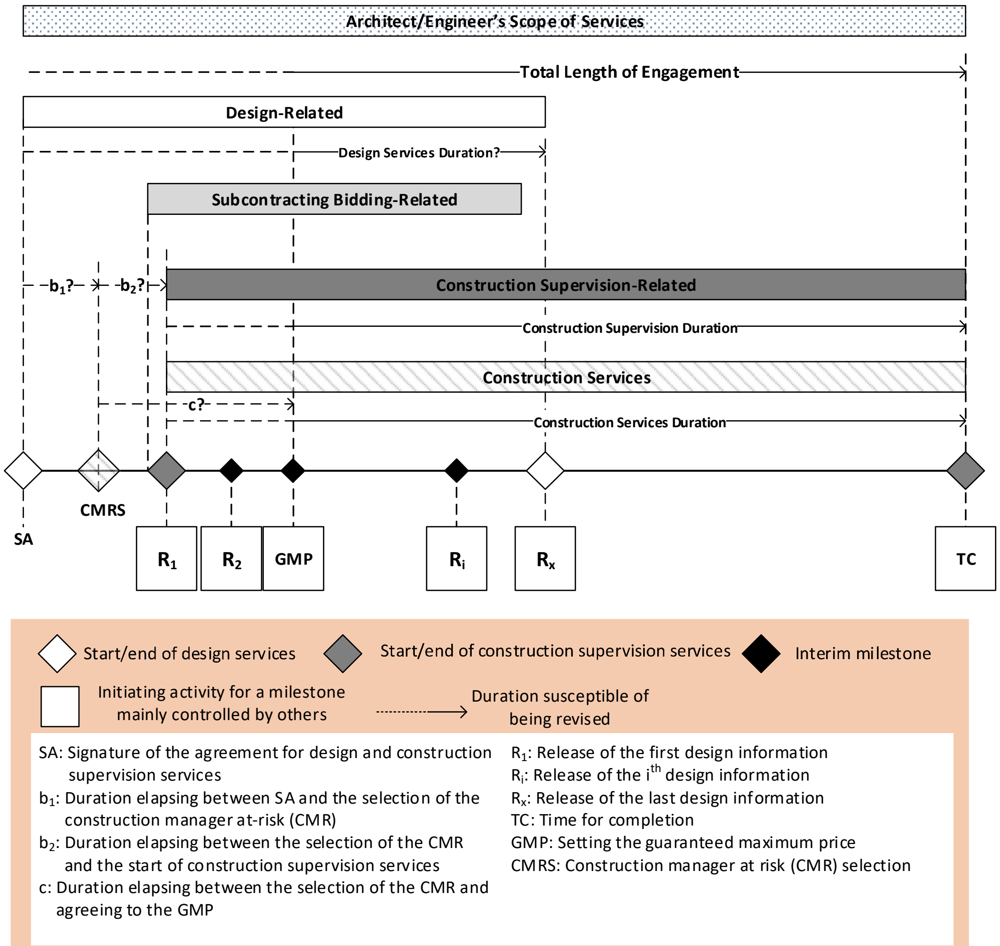


Figure 22. Conceptual model for the A/E's staging of services under the CMAR setting

The selection of the construction manager at-risk may happen at any time after the signature of the A/E's agreement, herein illustrated by the duration b_1. Design information release is now driven by the CMR's schedule for the execution of the works, and, as such, it is deduced to be taking place progressively in order to allow for an earlier start of construction work, an objective definitely aspired to under this approach. These releases are represented with square shapes to indicate that they are mainly controlled by the CMR, whereby the last release of design information (R_x) indicates the end of the design-related services. As shown, the start of the services related to construction supervision is contingent on the release of the first design information for construction (R_1), an activity that is mainly controlled by the CMR (as previously said). This start is therefore dependent on the elapsing of b_1 (period spanning between the SA and the selection of the CMR, i.e., CMRS) and b_2 (period spanning between CMRS and R_1). As for the end of these services, it is predetermined according to the time for completion as agreed in the construction contract, a milestone whose achievement is mainly under the control of the CMR. As a result, the total length of engagement of the A/E is represented by the total duration reflecting the overlap of design services duration and construction supervision duration. These duration figures are illustrated by arrows with dotted tails in order to indicate the likelihood of being susceptible to revision. This is mainly due to the fact that, at the time of the A/E's agreement signature, b_1, b_2 and c (i.e., the period between the SA and agreeing to the GMP) may all be unknown or, at least, susceptible to revision. Agreeing to the GMP represents a very important milestone and is viewed as having significant influence on fixing and/or revising previously agreed duration figures.

6.2.3 *The Phased Approach with Agency Construction Management (CMa)*

Compared to the DBB model in Figure 21, and as illustrated in the conceptual model for the A/E's staging of services under the CMa setting (Figure 23), the three types of A/E's services remain to be required, but their respective delivery periods are now overlapped. Under each of these services, the arrow representing each concerned duration figure is shown with a solid tail but with a dotted head, in order to indicate the likelihood of each of these periods being extended in view of the uncertainty pertaining to the CM's adopted strategy for work packaging. To this end, design-related services start with the SA and end with the release of the last bid package (RBP_x), an activity that is mainly controlled by the CM's strategy for packaging and the corresponding overall master schedule, also administered by the CM. As for the period designated with the letter "a" elapsing until the start of bidding-related services (illustrated by a dotted arrow), this is contingent on the planned timing for the release of the first bid package (RBP_1). These services then end upon the selection of the last trade contractor (STC_x). As it can be expected, both of these start and end milestones are mainly controlled by the CM. Concerning the start of those services related to construction supervision, the lag period designated with the letter "b" (also illustrated by a dotted arrow), it is shown to be conditional on the signature of the first trade construction contract (STC_1). The rendering of these services should be expected to practically end in concurrence with the latest of the completion times stipulated in the trade contract. Again, these milestones are mainly controlled by the CM's strategy for packaging and maintained overall master schedule.

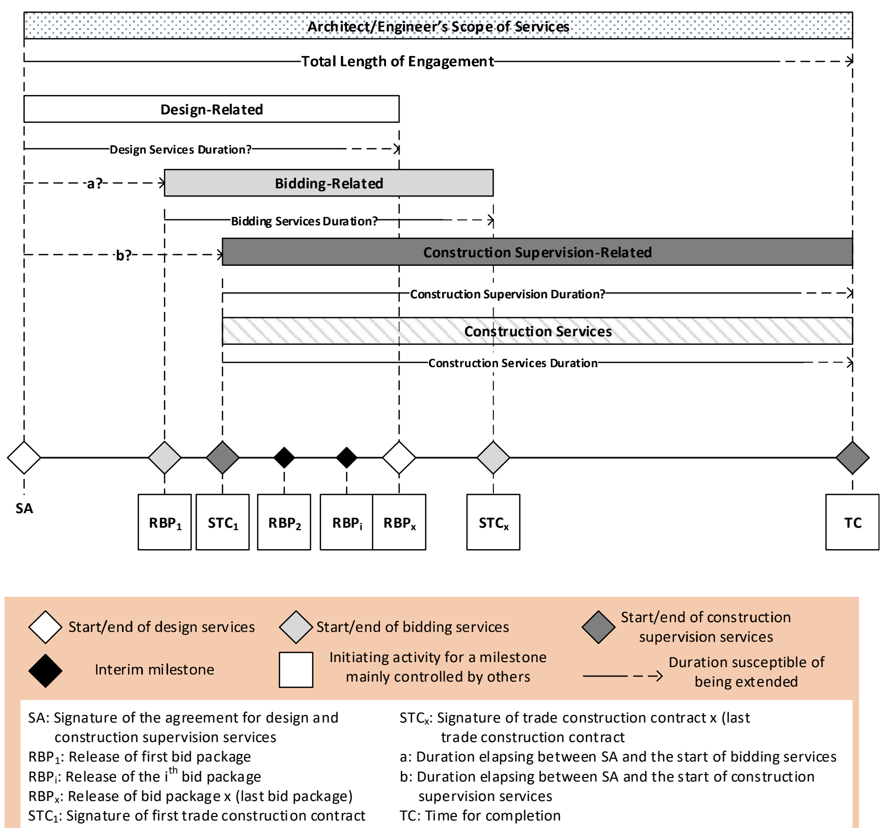


Figure 23. Conceptual model for the A/E's staging of services in the CMa setting

6.2.4 *The Design-Build (DB) Delivery Method*

Figure 24 illustrates the conceptual model of the A/E's staging of services under the DB setting. Compared to the DBB model, the design-related services performed by the design builder's A/E (i.e., otherwise referred to as the design subcontractor) are split between the pre-award phase (i.e., the DB proposal's preparation phase) and the post-award phase of the DB contract. The various types of the design subcontractor's services are shown to be largely overlapped for the post-award phase, and the bidding-related services are replaced by those services pertaining to construction subcontracts bidding, instead. In DB, it is common for the contractor to control the sequence of design documents preparation and the related decision-making process (American Bar Association 2003). This is justified by the need to have design information readily available in order to procure long-lead items and for pricing purposes (American Bar Association 2003). That is, this delivery method is characterized by its very dynamic environment resulting from the simultaneous work of the design and construction entities (Koch *et al.* 2010a).

To this effect, design information is now driven by the design-builder's schedule and is thus deduced to be released progressively, in order to allow for an earlier start of construction work. These releases are represented in square shapes so as to indicate that they are mainly controlled by the design-builder. The design services duration could extend until the end of the agreed completion time of the DB contract. As such, this duration is illustrated as an arrow with a dotted head and a solid tail, indicating the likelihood of it getting extended in view of extensions to the builder's schedule.

As for the services related to construction supervision, if any, these are limited to providing quality assurance/quality control (QA/QC) services on behalf of the builder or bridging any shortage in the builder's team for the provisioning of these services.

The start of these services (illustrated in Figure 24 by the dotted arrow designated with the letter "b") is contingent on the design-builder's schedule, and is therefore illustrated by a square shape. As for the end of these services, it could extend until the end of the time for completion stipulated in the DB contract, a milestone that is mainly under the control of the builder. As such, the total length of engagement of the A/E represents the total duration resulting from the overlapped design services duration and construction supervision duration figures. These figures are illustrated by arrows with dotted heads and solid tails, to indicate their likelihood of being extended in relation to extensions to the builder's schedule.

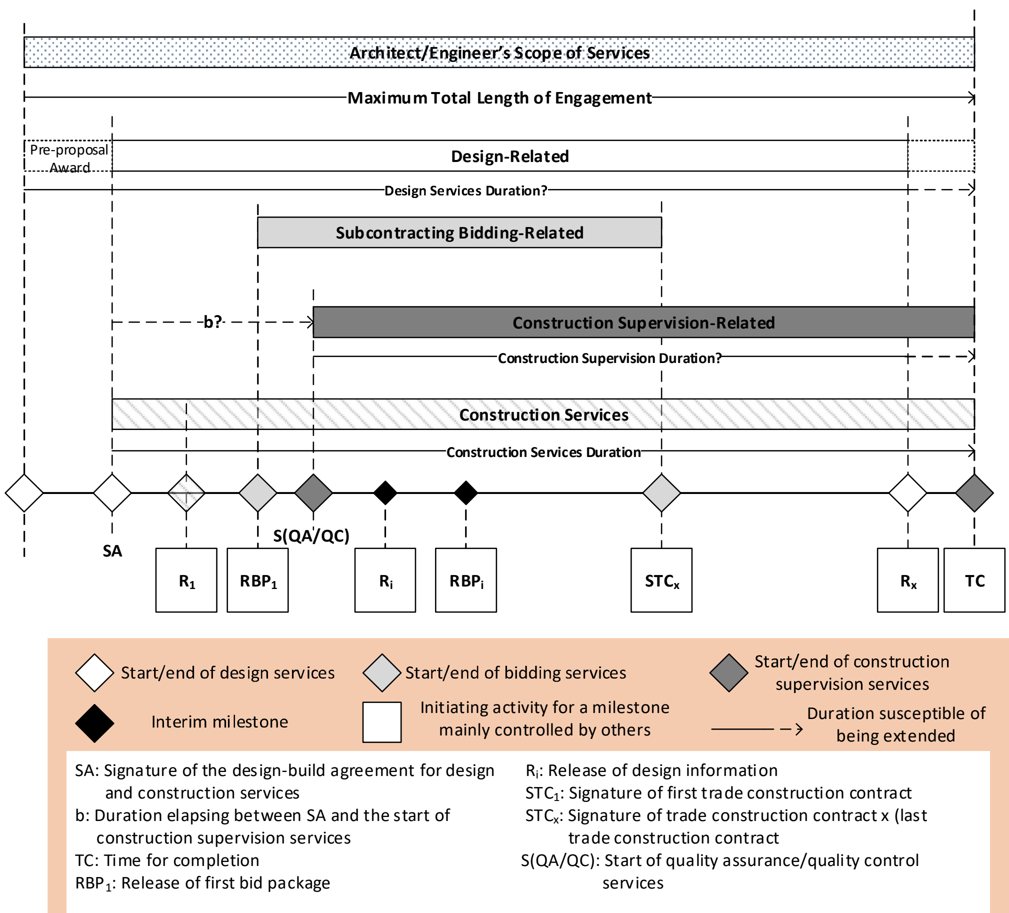


Figure 24. Conceptual model for the A/E's staging of services in the DB setting

6.2.5 *The A/E's Possible Modes of Performance*

In view of the additional PDM variations that may be available, some of which may actually prevail under one (e.g., the DB method) or more of the above illustrated PDMs, it is well recognized that, in real projects, owners may not follow a text-book approach when opting for their project organizational structures. The A/E professional may thus end up undertaking his services on one specific project under one role or several ones simultaneously, a situation that further accentuates the significance of this research work. This can be illustrated, as shown in Figure 25, through a real case study of a project constructed in the Middle East region where, under the organizational structure adopted by the project owner, the same A/E entity was required to channel its services under several modes of performance (i.e., roles) simultaneously.

Under the adopted project organizational structure, the owner hired an architecture office to act as the lead A/E design consultant, with all engineering design services being subcontracted to several other design offices. The owner also directly employed an interior design office, that was independent from the lead A/E consultant.

The overall program for this multi-hundred million United States dollars complex included three main components: (a) a luxurious multi-floor residence, for the owner's own use, (b) two longitudinal (low-rise) residential buildings (whose apartment units can be leased on a seasonal basis), and (c) a five-star hotel facility (with extravagant finishing works). The enabling works for all three components were handled by one DB contract, which was competitively awarded on a unit-price basis. The works for the owner's residence were executed under a cost-plus-a-fee contract awarded to a renowned general contracting firm, operating in the Arab Gulf and owned by one of the owner's closest long-time friends. The works for the hotel facility were contracted under the phased approach. To this end, the full package of the concrete works was executed under one trade contract, competitively awarded on a unit-price basis to a first-tier local general contracting firm. The other trade packages were successively launched, the scope of several of which was to both “design” and “build” the works involved in each package. The works for the two residential buildings were competitively contracted under one lump-sum contract to a second-tier local contracting company. The aspects related to the works’ quality were handled by (a) the lead A/E consultant, with needed input and support from all his sub-consultants and (b) the interior designer. All design- and construction-related inputs by the design professionals were channeled to concerned contractors through the entity handling project management functions.

The several A/E’s modes of performance inherent in the discussed case study along with the previously conceptualized models for the A/E’s staging of services provide a suitable platform for helping infer the relevant parameters and criteria that the A/E needs to deal with in order to realistically strategize and organize for its engagement under each of the PDMs. While providing owners with a high level of control over the design phase and A/E professionals with a high degree of control over the relevant pre-set milestones, the DBB approach affords the A/E professionals with an increased certainty as to the predetermined lengths of involvement expected to take place in the different phases of the project, to such extent that these periods can be regarded as being relatively fixed. This supports the argument that the design agreement formation process for such a delivery method is well established in practice. In contrast, given the uncertainties associated with the alternative delivery methods, mainly stemming from the uncertain duration figures and the reduced level of the A/E’s control over the numerous involved milestones, it becomes evidently crucial that a proper understanding of and accounting for such potential uncertainties be observed by the A/E professionals at the time of agreement negotiation and formation. Accordingly, the following section addresses the implications that the alternative delivery methods are likely to inflict on the staffing requirements and, subsequently, on the agreement negotiation and formation process.

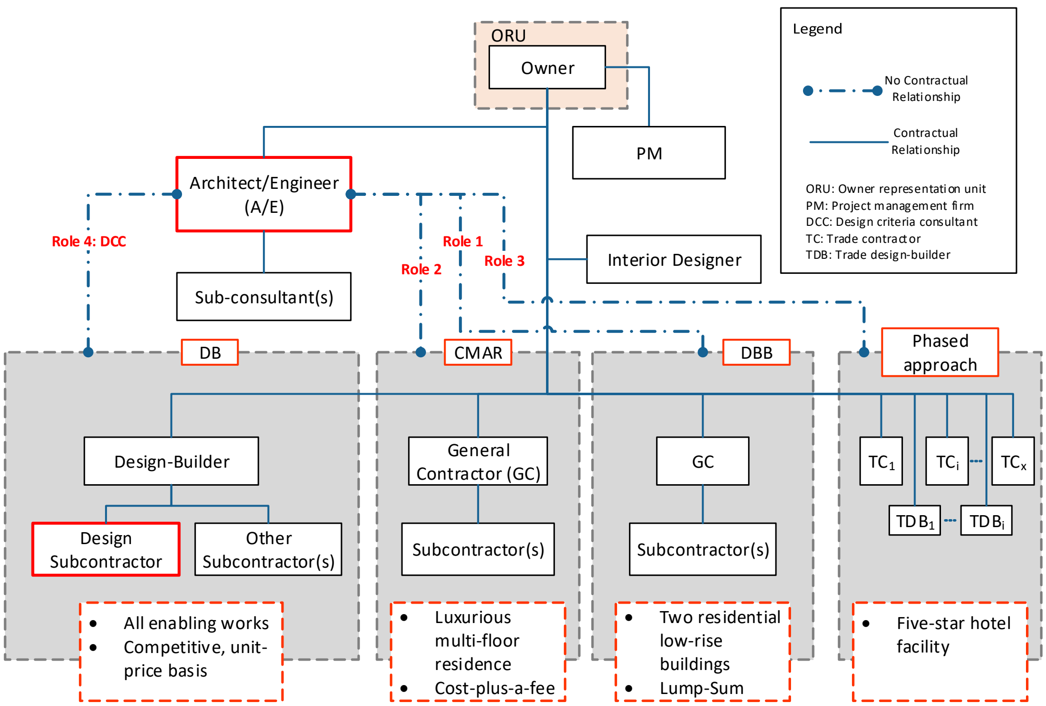


Figure 25. Case study project organizational structure

6.3 Implications on Staffing Requirements

The above-conceptualized models, depicting the various ways under which A/E professionals can be expected to render their services, have helped in deducing the relevant parameters that are thought of to be having an influence on staffing requirements. These are summarized in Table 3, where each row presents the varying attributes for each of the deduced parameters, as identified for the DBB approach as well as for the alternative PDMs considered in this study. For instance, the attribute of "sequential", designating the sequence of the A/E's full basket of services (related to the design, bidding, and construction phases) under the DBB method, naturally changes to "overlapped" under all the alternative PDMs.

Table 3. Relevant Parameters Underlying the A/E's Staffing Requirements

Relevant Parameters	**Project Delivery Method (PDM)**			
	DBB	**CMAR**	**CMa**	**DB**
Sequence of the A/E's basket of services*	Sequential	Overlapped	Overlapped	Overlapped
Sequence of design stages	Sequential	Overlapped but after the completion of enough SD to allow the CMR to price, set the schedule and guarantee completion time	Overlapped but after the completion of enough SD to allow the early launching of bid packages	Overlapped to a high degree with DD potentially eliminated
Design-construction sequencing mode	Sequential	Fast-track	Phased	Fast-track
Packaging of the A/E's instrument of services	Single bid package	Multiple releases	Multiple bid packages	Multiple releases
A/E's status and main relationship	Independent from the contractor; Direct relationship with the Owner.	Independent from the contractor; Direct relationship with the Owner.	Independent from the contractor; Mediated relationship with the Owner through the CM.	Design subcontractor to the design-builder; Direct relationship with the design-builder.
A/E's services performance pattern	Well known in advance	Becoming progressively known with considerable control retained by the A/E	Becoming progressively known with reasonable control retained by the A/E	Becoming progressively known with considerable control retained by the design-builder

*In case of DB, the design-related services could be potentially inflated due to the high possibility of carrying out some of the builder's responsibilities (e.g., shop drawings, as-built drawings, etc.)

Similarly, the sequential design stages in the DBB become overlapped under these alternative PDMs due to the early release of design information, allowing for the start of construction to be well before the completion of design. It is expected here that the overlap in the design stages takes place after achieving enough progress in the schematic design, in order to allow (a) the guaranteeing of price and completion time by the CMR, in the CMAR approach, and (b) the early launching of bid packages, in the case of the CMa method. Under the DB method, this overlap becomes more pronounced since this method is well known to be the fastest and to potentially involve the elimination of the DD stage. On the other hand, the design and construction sequencing, which is sequential in the DBB method, becomes phased in the CMa and fast-tracked in the CMAR and DB delivery methods. As for the packaging of the deliverables, the single bid package characterizing the DBB method is replaced with the release of several successive bid packages in the CMa method, and even more frequent releases in the CMAR and DB delivery methods.

The above-made deductions have accordingly paved for further inferring as to the level of staffing requirements dynamism that is expected to prevail under each of the considered alternative delivery methods, as summarized in Figure 26. Starting with the traditional DBB, the A/E's required resource allocation may be divided along three categories of professional staff: design professionals, engineering managers, and construction supervision professionals. As for the design professionals' team, design output by the senior-level staff (SLS) during the earlier stages is produced with direct support provided from the junior-level staff (JLS), and such delivered work is referred to as "aided direct output" (Gray and Hughes 2001). Conversely, design output by the JLS at the later detailed design stages is generated as a result of work delegation by the more senior to the junior design engineers and architects, where the delivered work is classified as "delegated direct output" (Gray and Hughes 2001). That is, design solutions are; (a) worked out by the SLS, (b) broken down into components that are resolved by the less senior (middle-level) staff, and (c) detailed through the lowest level. Due to its sequential nature, this method is expected to axiomatically involve a higher level of SLS requirement with an accompanying (relatively) lower requirement for JLS at the earlier design stages. In contrast, at the later stages involving the detailing of design (working drawings) for production work (i.e., CD stage), there is a need for a higher JLS requirement that is associated with a relatively lower requirement of SLS. On the other hand, the engineering managers' staff is engaged in (a) administering the agreement with the owner, (b) administering the sub-consultancy agreements (if any), (c) providing cost reviews and reporting and (d) providing contract administration services for the construction contract. As for the construction supervision professionals' staff, this group corresponds to full-time and/or part-time staff providing technical supervision for the construction contract over the full duration of construction. That said, the DBB method can be said to be requiring static staffing characterized by a decreasing dependency on SLS design professionals as design progresses toward the working drawings production stage.

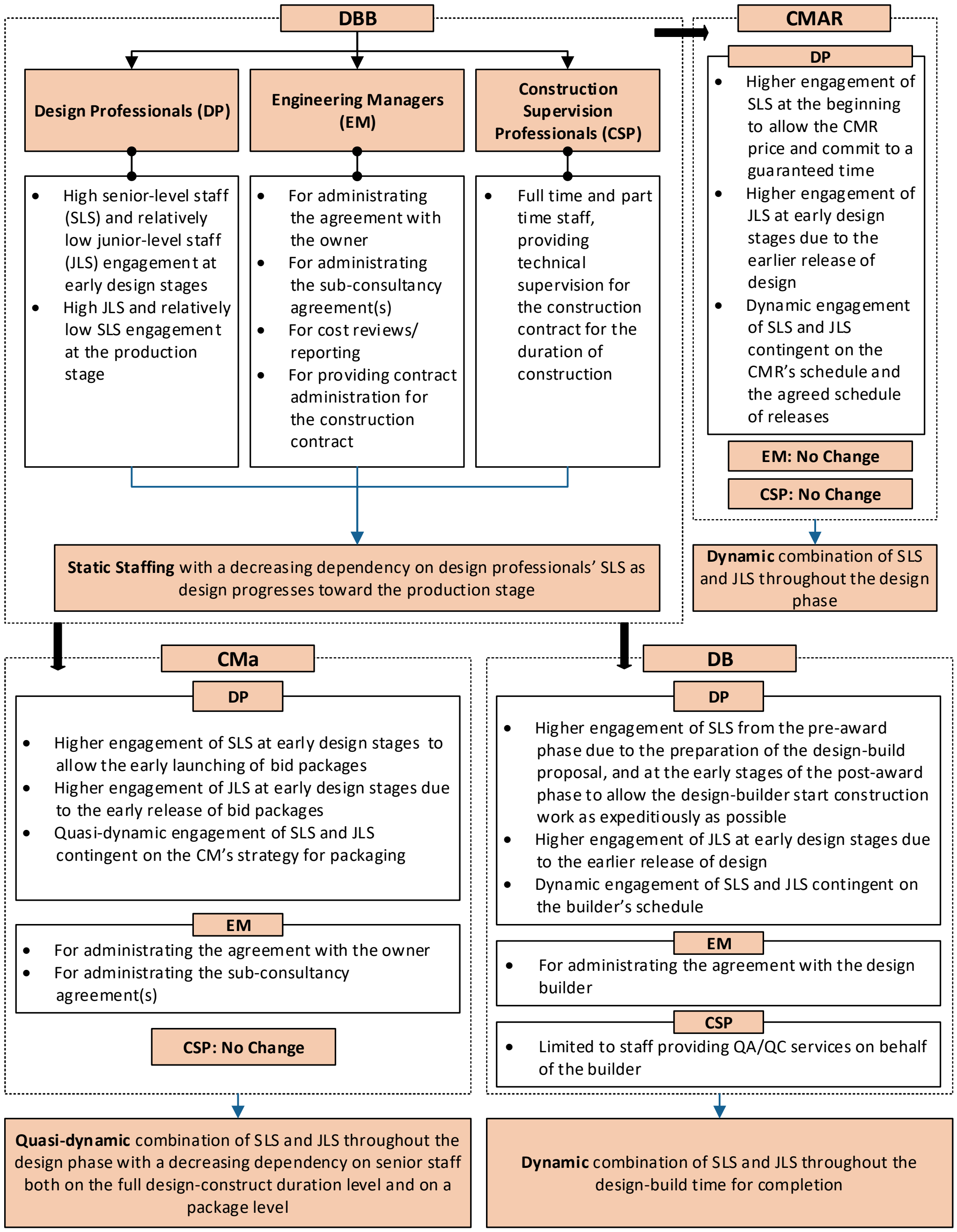


Figure 26. Deduced changes in the A/E's staffing requirements under alternative PDMs

In comparison with the DBB method, the CMAR method can be regarded as entailing a higher level of engagement of SLS at the start of the design to achieve enough progress at the schematic level. This is to allow the CMR to price and commit to a completion time, which in turn leads to a higher engagement of JLS to aid in the earlier release of design information. Coupled with the fast-track nature of this approach and having the design development potentially driven by the need to meet the priorities of the CMR's overall time schedule, the involvement of the SLS and JLS is deduced to be more on the dynamic side of the scale (as opposed to the static side of it). That is, the needed combination of senior and junior-level staff in each design discipline, depends on the nature of the release taking place. In contrast, no perceived change in the requirements for the engineering managers and construction supervision professionals' staff is contemplated. As such, the CMAR method can be highlighted as requiring a dynamic combination of SLS and JLS throughout the project's design phase.

Moving to the CMa method, and also in comparison with DBB, it can be reasoned that this method also entails a higher engagement of SLS at the start of the design, to ensure sufficient progress in SD before launching trade bid packages, which leads to a higher engagement of JLS due to the earlier release of design. Owing to the phasing of design and construction, inherently governed by the CM's strategy for packaging, the involvement of the SLS and JLS can be regarded as being quasi-dynamic. This is mainly due to the reasonably controlled progress of the design; i.e., phased design (or otherwise thought of as being sequential at a trade-level) rather than being fully sequential. With a CM on board, the engineering managers team's responsibilities are primarily limited to those dealing with the administration of the A/E's agreement with the owner and the sub-consultancy agreements (if any), as the construction contract administration responsibilities are now carried out by the CM with support provided by the A/E. Similar to the CMAR case, no change in the construction supervision professionals' requirement is envisioned. The CMa method can therefore be viewed as requiring a quasi-dynamic combination of SLS and JLS throughout the design phase, with a decreasing dependency on the senior staff both on a package level and on the full design-construction duration level.

Finally, under the DB method, a high engagement level of SLS is expected for the pre-award phase in serving the preparation of the design-build proposal, and for the early stages of the post-award phase to allow the design-builder to start construction work as expeditiously as possible. In turn, this leads to a higher level of engagement of JLS during the early design stages to produce the earlier releases of design information for construction purposes. With the fast-track nature of this method and the design-builder being in full control in respect of meeting the contractual design-construction completion time, the requirement of the A/E's involved senior and junior design staff is expected to be at the dynamic edge of the scale. Furthermore, given that less documentation (for construction) may be practiced, coupled with the potential elimination (or diffusion) of the DD stage, this may lead to a reduced level of total requirement of the JLS part of the design-related staff. Concerning the two other staff teams, the engineering managers' requirement will be limited to the staff needed for administrating the agreement with the design-builder (and any design sub-consultancy agreements), whereas the construction supervision professionals' part will involve staff needed for providing (or assisting in the rendering of) QA/QC services on behalf of the design-builder. Subsequently, it can be concluded that the major A/E's staffing implication of the DB method is also related to the design staff part, where it has been reasoned that a dynamic SLS-JLS combined requirement needs to be met throughout most of the design-construction completion time. The deduced staffing requirements dynamism, majorly prevalent at the level of the design-related staff, requires some careful consideration due to its influence on the A/E's corresponding fee structure.

Therefore, the following section depicts the inferred patterns corresponding to the previously deduced design professionals' staffing requirements.

6.4 Inferred Staffing Pattern for Design Professionals

As illustrated in the previous section, the major implications that alternative delivery methods are likely to have on the required staffing are mainly concerned with those of the design-related staff. In serving the purpose of setting up of a realistic fee structure along with a rationalized schedule of payment by A/E professionals, which can reasonably reflect the dynamic nature of the previously analyzed requirements, indicative graphs of the inferred design professionals' staffing patterns are presented in Figure 27. It can be noted that the staffing pattern under the DBB delivery method is first conceptualized, followed by the corresponding changes that are deduced to likely occur when opting for the alternative PDMs. To this end, each of the graphs shows the deduced variable levels of engagement of the design professionals' staff as the design progresses, with the x-axis and y-axis representing the duration of involvement and the invested design hours, respectively. Moreover, the diagonally-hatched area (i.e., A_1) reflects the total hours of engagement of the SLS, whereas the area with a dotted hatch (i.e., A_2) reflects the total hours of engagement of the JLS. Since these two areas are superimposed, for clarity purposes, the smallest area is always brought to the front. The height of each rectangle is, therefore, a measure of the average hours of engagement at a given design stage. That is, three horizontal dotted lines designated by letters a, b and c are used in order to highlight the total hours of involvement of the SLS at the SD stage, the JLS at the CD stage, and the SLS at the CD stage, respectively. These lines are manifested in all the four graphs to facilitate the comparison process.

Starting with the part concerned with the DBB method, the sequential grey-filled rectangles are meant to display the SD, DD and CD stages of the design phase. The indicative lengths of these rectangles represent the periods of involvement of the design professionals' -related staff for each of the stages. To this end, the decreasing dependency on SLS is shown by diagonally-hatched rectangles, with their heights diminishing while approaching the CD stage. Likewise, the increasing dependency on JLS is shown by dotted-hatched rectangles, with their heights increasing as the design progresses toward the working drawings production (i.e., CD) stage.

The pattern deductions related to the performance of design-related services under any of the considered alternative PDMs need to be thought of while considering the two main criteria of: (a) the design stages being overlapped and (b) the frequency of information release being controlled by the CM, CMR or design-builder, under the CMa, CMAR or DB delivery methods, respectively. The deduced changes in staffing patterns under CMAR correspond to one indicative possibility for the overlap in design stages along with a suggested frequency of information release as illustrated by an arrow shape. A closer look at CMAR reveals five "sub-phases" of design: (a) one with SD work, (b) one with SD and CD work, (c) one with work on SD, DD, and CD, (d) one with DD and CD work, and (e) one with work on CD. In the first sub-phase, the higher involvement of SLS is emphasized by an increase in the height of the rectangle pertaining to the SLS (corresponding arrow 1). An area presenting a high frequency of information releases (grey-shaded ellipse at the third sub-phase) is highlighted as well. This high frequency reflects the level of involvement of the JLS that is required to meet the high frequency of production (corresponding arrow 2). The last segment entails a lower engagement of JLS due to having more of the design finalized and released at earlier stages (corresponding arrow 3).

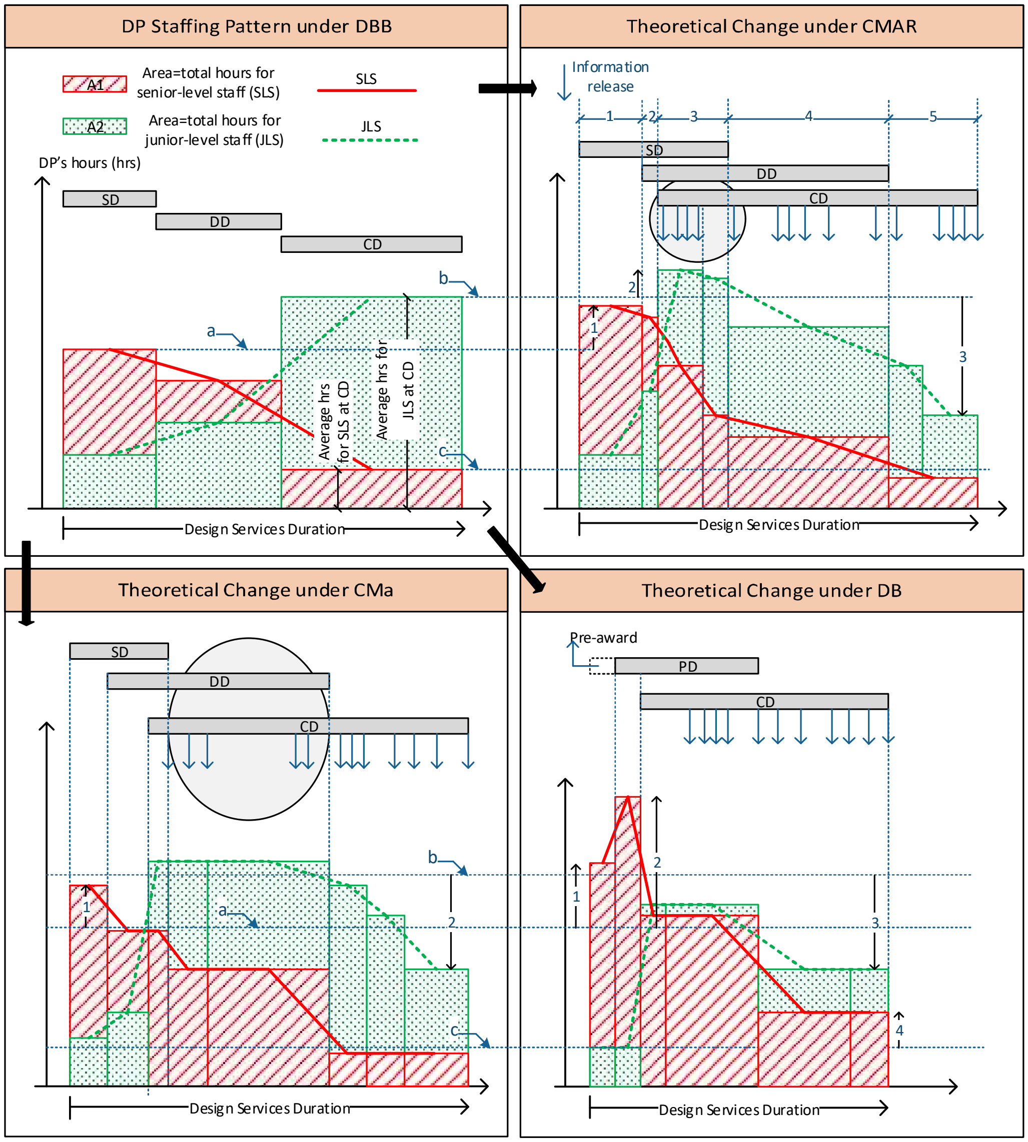


Figure 27. Envisioned changes in the staffing pattern for design professionals under alternative PDMs

Under the CMa method, the early SD stage features a high involvement of SLS to allow enough progress on SD work to serve the early launching of bid packages as previously discussed (corresponding arrow 1). Also, the CMa method is expected to feature a period of stability in the combination of staff (represented by the grey-shaded ellipse) and a lower level of involvement of the JLS toward the end of the CD stage due to having more of the bid packages finalized (corresponding arrow 2).

In the DB method, a high level of involvement of SLS is expected at the pre-award of the DB proposal (corresponding arrow 1). This involvement becomes even higher at the early post-award stage (corresponding arrow 2), and it then drops gradually as more of the design is finalized. However, higher SLS involvement is anticipated at the end of the design phase (corresponding arrow 4). This is due to the stringent coordination requirement imposed by the fast-track nature of this method, the increased likelihood of design rework occurrences, and the increased pressure typically exercised by the design-builder under such circumstances.

The spectrum of engagement of the A/E professional, in particular in terms of staffing requirements and distribution pattern of the design professional-related staff, paves the way for setting up the basis of negotiation of the design agreement under each of the PDMs. As such, the following section discusses the implications of using alternative PDMs pertaining to the agreement negotiation and formation.

6.5 Agreement Related Implications

The design agreement is a means of defining and achieving quality in the construction project (ASCE 2012b). It forms the fundamental communication tool between the owner (or the design-builder in the DB case) and the A/E professional. To this end, a careful understanding of the underlying basis of negotiating its relevant terms and conditions, in respect to the previously highlighted changes under each of the alternative PDMs, is therefore of relatively equal interest to both parties. Based on the analyses made throughout the previous sections, the implications of opting for the considered alternative PDMs on the agreement formation process are further discussed. That is, Table 4 reveals the length of involvement of the A/E in the different performed services, along with the corresponding attributes of these periods under each of the DBB, CMAR, CMa, and DB delivery methods, respectively. As such, the DBB delivery method corresponds to (a) a fixed length of involvement for the design-related services that is determined independently from the construction services duration, (b) a fixed length of involvement in bidding-related services that is determined based on a duration pre-agreed to by the owner and the A/E at the SA, and (c) a fixed length of involvement in construction supervision-related services that is determined based on an agreed construction contract duration.

Table 4. Length of Involvement of the Architect/Engineer (A/E) under Alternative PDMs

Length of involvement of the A/E in	**Project Delivery Method (PDM)**			
	DBB	**CMAR**	**CMa**	**DB**
Design-related services	Determined independently from the construction services duration; Fixed duration determined at SA.	Confirmed based on the construction services duration as guaranteed by the CMR; Duration anticipated at SA, but susceptible of being revised upon the CMR's fixed construction services duration.	Determined based on a conceived overall master schedule, administered by the CM; Duration anticipated at SA, but susceptible of being extended in view of the underlying strategy for packaging.	Determined based on the design builder's schedule; Split involvement between duration of pre-proposal related services and post-proposal related services; Duration could extend till the end of construction services duration.
Bidding-related* services	Determined based on a duration pre-agreed to by the owner and the A/E; Fixed duration determined at SA	Considered to be merged within the length of involvement in design-related services	Determined based on a conceived overall master schedule, administered by the CM; Determined at SA, but susceptible of being revised and/or extended in view of the underlying strategy for packaging.	Considered to be merged within the length of involvement in design-related services
Construction supervision-related** services	Determined based on an agreed construction contract duration; Fixed duration determined at SA.	Confirmed based on the construction services duration as guaranteed by the CMR; Duration anticipated at SA, but susceptible of being revised upon the CM's fixed construction services duration.	Determined based on a conceived overall master schedule, administered by the CM; Determined at SA, but susceptible of being extended in view of the underlying strategy for packaging and in view of construction works being carried out by trade contractors.	Determined based on an overall schedule set by the design-builder.

* In case of CMAR, these services are considered to be limited to providing technical input that relates to subcontracting specialty design; and in case of DB, these services are considered to be limited to providing technical input for subcontracted packages (construction and/or design and construction packages).

** In case of DB, these services, if available, are limited to QA/QC services performed on behalf of the design-builder.

If the owner opts for a CMAR delivery method, the length of involvement of the A/E in the different services, although anticipated at the SA, may not be confirmed until the construction services duration becomes guaranteed by the CMR. As such, A/E professionals need to account for periods of involvement that are “susceptible of being revised” when performing design-related and construction supervision-related services. On the other hand, organizing for a project being delivered using the CMa method, the

A/E professional needs to consider an "extension-susceptible" length of involvement in the different performed services (i.e., design-related, bidding-related and construction supervision-related services), in view of the CM's underlying strategy for packaging. However, for the A/E professional to be engaged as a design subcontractor in a DB set-up, it needs to organize for a period of involvement in design-related services that (a) involves a split engagement between the duration of pre-proposal related services and post-proposal related services, (b) is determined based on the design-builder's schedule, and (c) possibly extends till the end of construction services duration (due to the potentially augmented scope of services stemming from rework). As for the length of involvement in construction supervision related services, it is determined and governed by the overall schedule set by the design-builder. Since the bidding-related services performed by the A/E in a CMAR or a DB set-up are limited to providing technical input that relates to subcontracting specialty design, the length of involvement in these services is considered to be running in parallel with the length of involvement in design-related services.

That said, the total length of involvement, being a key element of the basket of considerations that concern the A/E professionals when negotiating the agreement, is regarded (among other considerations) as a governing criterion, as shown in Figure 28. Accounting for the implications of all the identified circumstances underlying each delivery method, Figure 29 illustrates the basis of negotiation under each and, therefore, needs to be read in conjunction with Figure 28. In other words, Figure 28 and Figure 29, in complement of one another, present an overall set of considerations that the A/E needs to account for, if the same project is to be delivered using any of the alternative PDMs instead of being delivered through the traditional design-bid-build process.

If the owner intends to have the project in question delivered using the traditional DBB method, the A/E professional typically takes into account, as a common basis of negotiating the agreement, the following governing criteria: (a) the pre-determined total length of its involvement, (b) the pre-determined needed effort in design, bidding, and construction supervision services, (c) the theoretically minimal design effort at the construction phase, (d) the continuous involvement of the assigned staff, and (e) the considerable control over predetermined start/end milestones (top left part of Figure 28). After estimating the sub-total hours of design professionals, engineering managers and construction supervision professionals, the resulting total hours needed leads to the estimation of the total cost according to the different fee rates applicable to the assignment of the involved teams (top left part of Figure 29). As for the preferred schedule of payment, it becomes evident that payment may be phased in accordance with the hours expected to be invested up to the completion of a specific stage in a corresponding project phase.

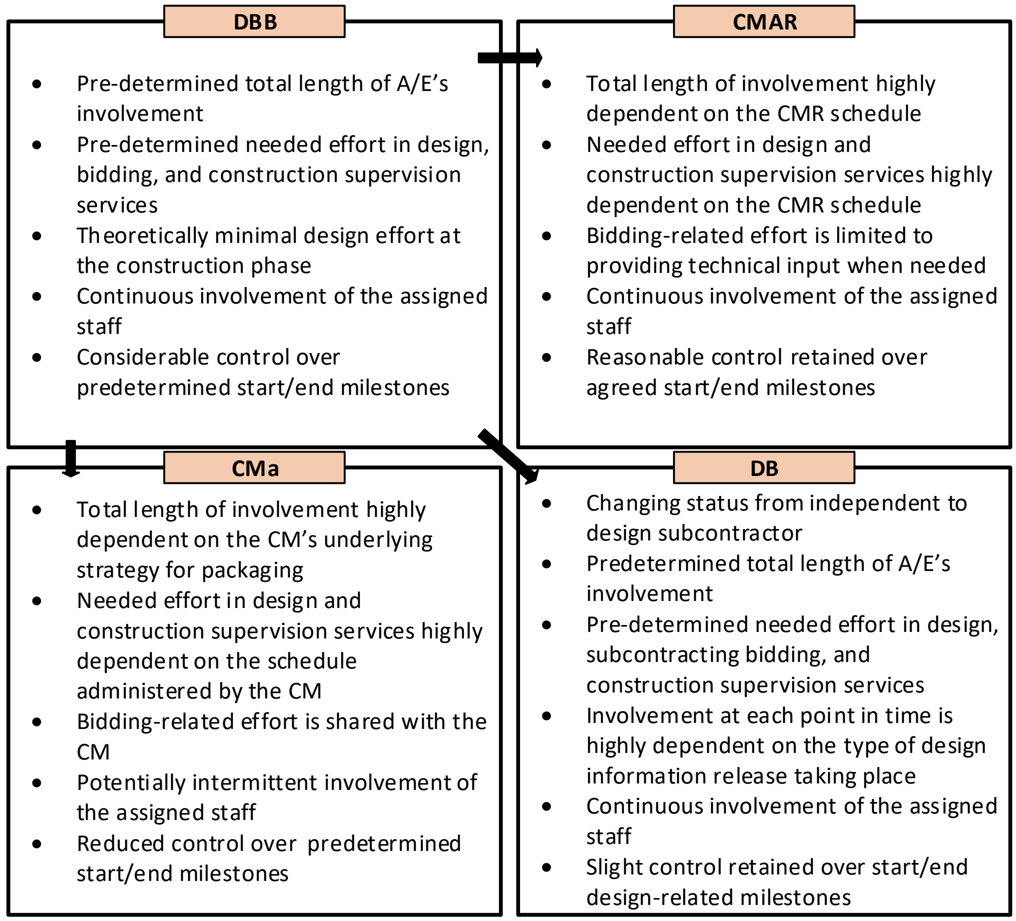


Figure 28. Criteria governing A/E's involvement under alternative PDMs

In the case where the A/E needs to organize for its involvement under a CMAR environment, the prevailing governing criteria are: (a) a total length of involvement that is highly dependent on the CMR schedule, (b) the needed effort in design and construction supervision services being highly dependent on the CMR schedule, (c) a bidding-related effort that is limited to providing technical input when needed, (d) continuous involvement of the assigned staff, and (e) reasonable control retained over agreed start/end milestones (top right of Figure 28). As such, the expected higher sub-total hours of design professional are the main cause for the higher cost associated with this method, as compared to the DBB one. As such, the total invested hours and, accordingly, the total fees increase (top right of Figure 29). For the preferred schedule of payment, two phases are identified. The first phase corresponds to the work accomplished before selecting the CMR, where it is envisioned that the fees for the total hours invested during this phase are paid in one lump sum (preferably in advance, but other than the generally known advanced payment normally practiced irrespective of the delivery method in place). During the second phase (i.e., the post-selection phase of the CMR), a progress-based mode of payment may be found to be more appropriate. For example, an advance payment is issued at the onset, followed by interim payments at an agreed fee percentage applied to the value of work accomplished by the CMR.

On the other hand, if the owner elects to have the project delivered using the CMa method, the A/E needs to plan for its involvement while accounting for: (a) a total length of involvement that is highly dependent on the CM's underlying strategy for packaging (b) the fact that the needed effort in design and construction supervision services are highly dependent on the schedule administered by the CM, (c) the bidding-related effort being shared with (and largely assumed by) the CM, (d) the potentially intermittent involvement of the assigned staff (due to the strategy of packaging as well), and (e) the reduced control over predetermined start/end milestones (bottom left of Figure 28). As such, the negotiation needs to be based on the increased hours invested by the design professionals' team, in contrast with the decrease in the hours needed for bidding-related (bottom left of Figure 29). As such, two phases for the preferred schedule of payment are contemplated. The first phase corresponds to the work accomplished before launching the first bid package, where it is suggested that the fees for the total hours invested at this phase be paid as an advanced payment. Thereon, post the launching of the first bid package, a package-based mode of payment may be better suited.

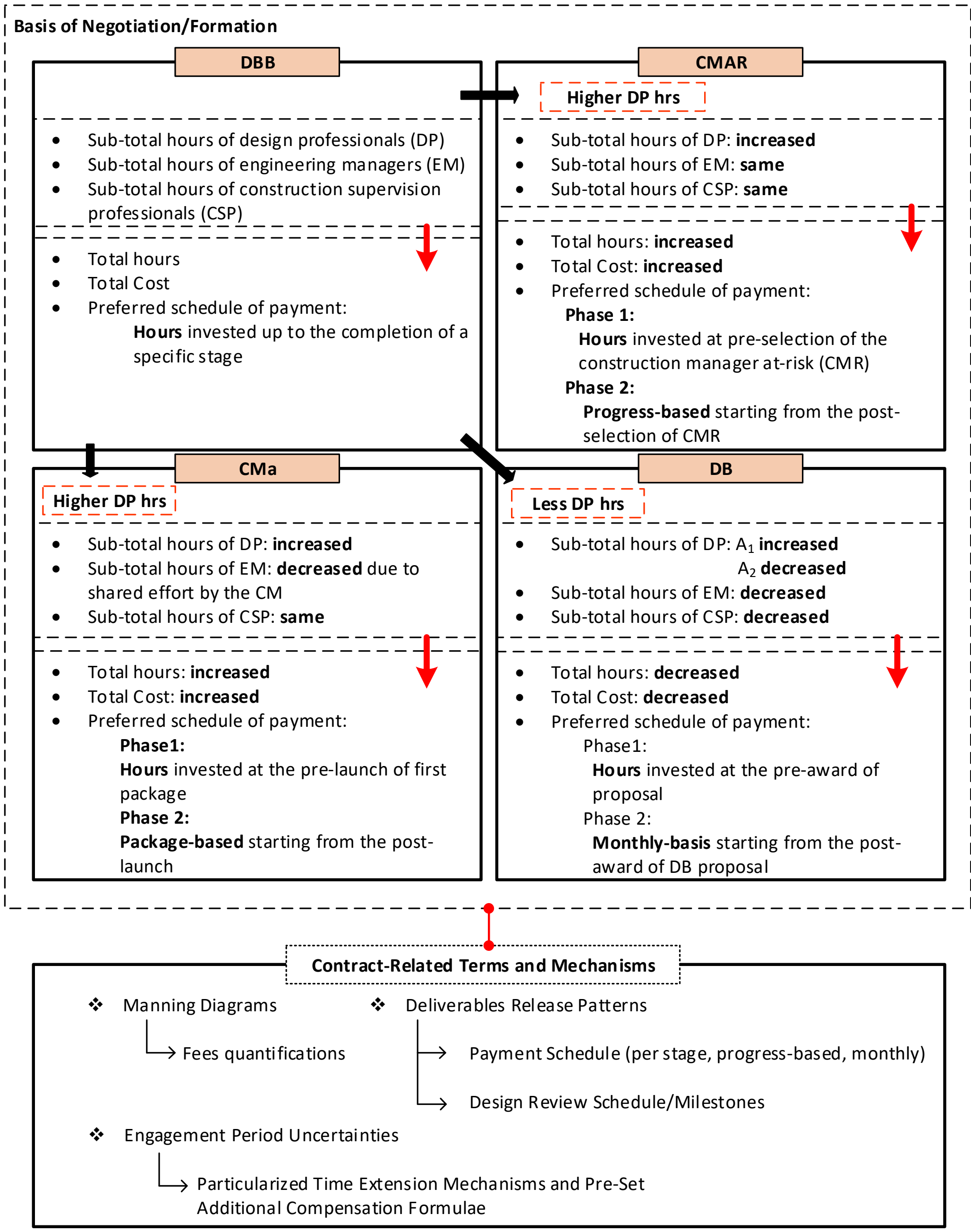


Figure 29. Bases of negotiation suiting alternative project delivery methods

Owners may rely on a single entity to provide them with design and construction services for a project in question. As such, A/E professionals may end up undertaking their role as design subcontractors to the builder under a contractor-led DB method. However, there are some major reported differences between the DBB and DB delivery methods. For instance, in DB owners are commonly willing to make progress payments in order to avoid having to indirectly pay for higher construction financing cost of design-builders. However, paying for design progress, where intellectual content is being developed, is far different than paying for a tangible construction progress (Koch *et al*. 2010b).

Another paradigm shift manifests by the basis of the contract itself. That is, in DB, design documents are deliverables of the contract, rather than forming the basis of the contract as in the DBB method (Koch *et al.*2010a). Moreover, owing to the need to ensure that the legal design liability remains on the shoulders of the design-build team, one major difference manifests itself by the design reviews methodology carried out by the owner. Such reviews become limited to a compliance-type review, with the technical side of it mainly being part of the design quality control process implemented by the design-builder's A/E (Koch *et al.* 2010a). Furthermore, while owners tend to base their selection of designers on their qualifications, design-builders do regard low fees as important, because their overall competitiveness is dependent in part on how much fees their design consultants are charging them (Ling 2004).

To this effect, the most important governing criteria underlying a design subcontractor's negotiations are (bottom right of Figure 28): (a) its status changing from being independent to becoming a design subcontractor to the design-builder, (b) the fact that its involvement at any point in time is highly dependent on the type of design information release taking place, and (c) the erosion of control over start/end design-related milestones that is now considerably retained by the design-builder. As such, less sub-total hours corresponding to design professionals, engineering managers and construction supervision professionals are accordingly expected and constitute the main cause for the decreased fees associated with this method, as compared to the case under the DBB. That is, the total invested hours and, accordingly, the total fees both decrease (bottom right of Figure 29). As for the preferred schedule of payment, two phases are identified for negotiation purposes. The first phase corresponds to the work accomplished at the pre-award of the design-build proposal, where it is suggested that the fees for the total hours invested at this phase be paid separately. During the second phase, corresponding to the post-award of the DB proposal, a monthly-based mode of payment is proposed.

The previously identified factors and criteria, to which the length of involvement of the A/E is sensitive, should be clearly spelled out and addressed in the contract terms and conditions (lower part in Figure 29). That is, particularized time extension mechanisms need to be negotiated with pre-set additional compensation formulae, to compensate for the uncertainties associated with the different periods of engagement. The proposed manning diagrams provide a clearer envisioning for the changes in the fees quantification under each of the considered alternative PDMs. Moreover, understanding the pattern of deliverables' releases aids in visualizing the distribution of the design hours required in order to set up a rationalized payment schedule. Furthermore, it helps in establishing a practical review schedule of the A/E's design work. This is viewed as being more critical under the CMa and CMAR delivery methods, as opposed to such owner's undertaken design reviews being done by proxy through the design-builder, as stipulated in the DB contract. Other relevant considerations that need to be carefully addressed include, among others, addressing changes and approvals by owners and by authorities and setting out the corresponding mechanisms that deal with possible work suspension and resumption.

CHAPTER 7

INVESTIGATING THE IMPLICATIONS OF ALTERNATIVE DIR DYNAMICS ON THE A/E'S LIABILITY EXPOSURE AND INDEMNITY

7.1 Preamble

A/E professionals are susceptible to different forms of professional liabilities, depending on the roles and responsibilities assumed by them in connection with the rendering of design and other related services. This chapter (covering module 3) is concerned with the types and extents of the professional liabilities inherent in the A/E assuming either of the two contrasting capacities, an independent consultant or a design subcontractor, for rendering the contracted deliverables. It also includes the different types of insurance policies that can be procured for indemnifying against professional liabilities in construction projects and the different possible options for risk mitigation.

7.2 Professional Liabilities Carried by Design and Construction Professionals

Professional liabilities arise from errors and omissions in providing professional services. However, when these actions or inactions occur, they do not always constitute negligence. Negligence is as such defined as the "failure, through a preventable error or omission, to practice within the prevailing standard of care" (ASCE Committee 2004). In other words, it is the failure to meet the level of skill and care ordinarily achieved by members of the same professions and in similar circumstances (ASCE Committee 2004). In the context of construction projects, A/E professionals, as well as contractors, can be exposed to risks in relation to the different services they provide, as shown in Figure 30. For instance, A/E professionals acting as independent consultants are traditionally in charge of (a) preparing drawings and specifications under their role as designers, (b) administrating the construction contract and providing technical supervision for the construction work under their role as the construction contract's "engineer" and (c) assessing claims and/or deciding on disputes when exercising such quasi-judicial roles.

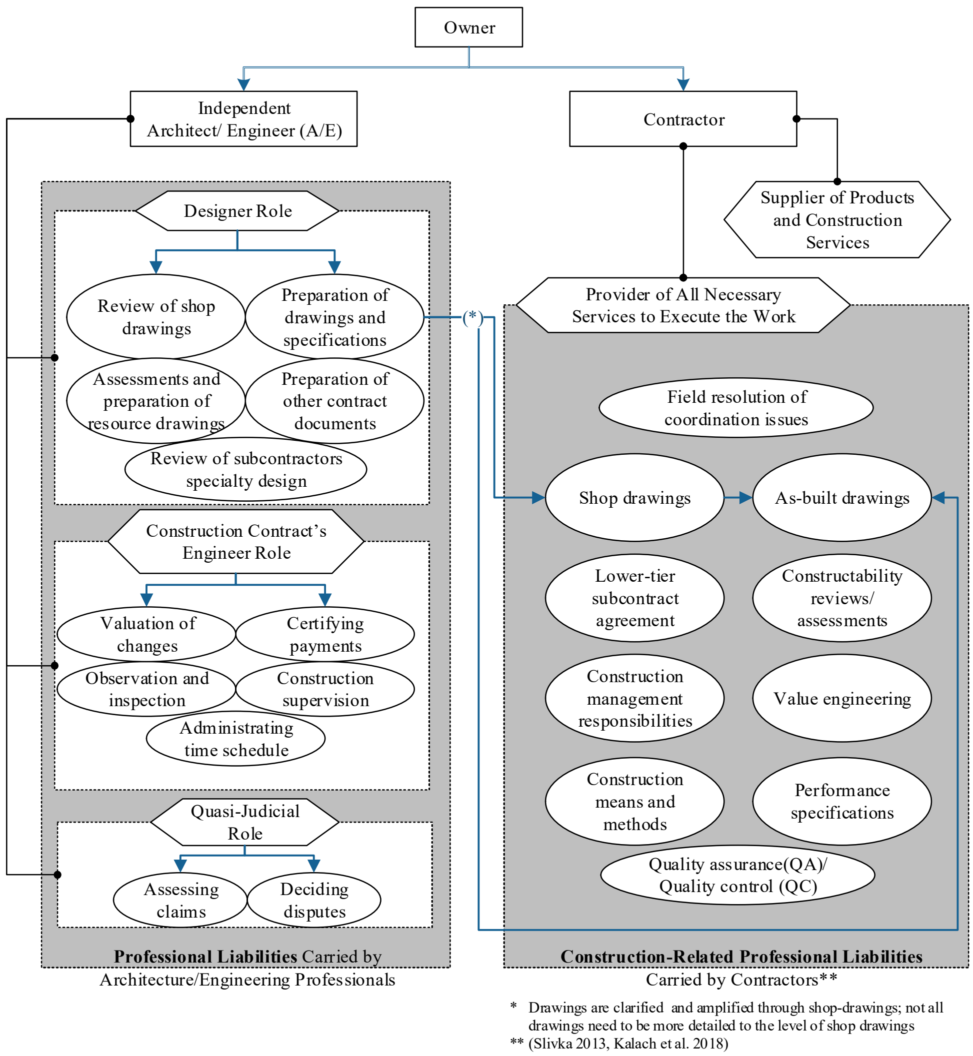


Figure 30. Professional liabilities carried by construction professionals in the DBB Setting

Alternatively, contractors are required to perform "all necessary" preparatory steps that may be required for the proper execution of the work (e.g., field resolution of coordination issues, construction means and methods (CMM), etc.), in addition to supplying products and construction services. Therefore, they are exposed to risks imminent from construction-related professional services (Slivka 2013). On the one hand, construction-related professional risks are overshadowed by the design risks although the former risks may extremely impact the project (Slivka 2013). On the other hand, it is argued that the degree of exposure to any of this combined collection of risks varies depending on the delivery approach used, which defines the scope of each party's services and the corresponding degree of liability exposure (Slivka 2013). Therefore, the following section discusses the implications on liabilities due to the changing role of the designer from being an independent consultant in the DBB approach to a design subcontractor in the DB delivery approach.

7.2.1 *Design Professional Status/Role: Implications on Liabilities*

The level of responsibility for carrying out design services, and the liability exposure associated with it, may differ depending on the project delivery method. For instance, when addressing construction safety concept in their design, A/E professionals may have an increased liability exposure to injured workers (Gambatese 1998, Behm 2005). Designers, under a DBB setting, are generally not responsible for construction safety, and as such construction contracts clearly place the burden of such responsibilities on the contractor (Gambatese 1998, Behm 2005). However, it is argued that, under the DB approach, this concept may gain momentum (Behm 2005). Moreover, Hatem (2006) discusses the dramatic impact on the nature and emphasis of the design professional's service effort resulting from the identity change of the client (contractor rather than owner) in a DB setting. That is, designers may have to (a) accept interaction from the contractor's side during the development of the design, (b) be involved in constructability reviews and analyses of CMM, and (c) eliminate "defensive detailing" due to pressure exercised by the design-builder in order to meet deadlines. That is, a design subcontractor in a DB setting could be assigned to carry out, or assist in carrying out, any of the aforesaid construction-related professional services on behalf of the lead design-builder, as illustrated in Figure 31. As design subcontractors, their duties to the builder are manifested through (a) their involvement in the DB proposals (Staak 2012), (b) the usual preparation of drawings and specifications and (c) the review of other subcontractors' design due to delegating design to specialty subcontractors (Hatem 2006). Designing for construction safety is shown as dotted in order to indicate that this service is not a typically undertaken one; however, it may well be required. That is, as design subcontractors, A/E professionals may have a greater – and sometimes different – scope of responsibilities compared to those on a traditional project, a situation that may lead to an increased liability exposure (Hatem 2006, Stipanowich 2015).

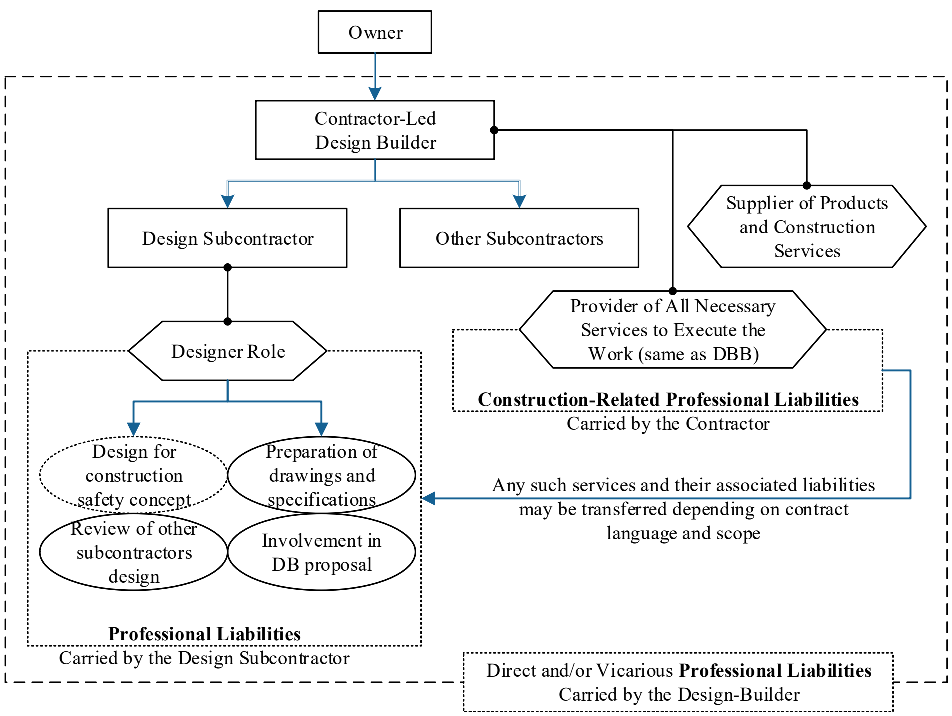


Figure 31. Professional liabilities carried by construction professionals in the DB Setting

Furthermore, the design-builder who is the ultimate carrier of risks through the prime design-build agreement carries direct and/or vicarious liability for the performed professional services (i.e. liability for professional services performed by or on behalf of the design-builder). To this end, limitations of liability as well as indemnification contract clauses are used by the project participants as part of a risk-allocation strategy (Ittmann *et al*. 2013, Aiken *et al*. 2018). Yet, Hutchens (1992) argues that such clauses are often not carefully constructed to meet the legal definition of "clear and unequivocal" and, therefore, professional malpractice risk reduction is not achieved. Moreover, where it is possible to draft limitation of liability clauses that apply to tort claims in addition to contract claims, such clauses do not apply to tort lawsuits brought by third parties. Therefore, the A/E's best defense against such lawsuits is to have a comprehensive insurance coverage. Here comes the role of the many forms of insurance coverage that are associated with the risks involved in a construction project.

7.3 Professional Liability Indemnity

Professional liability indemnity (PLI) is a means for providing protection against claims for errors and omissions (E&O) in providing professional services. By involving the insurance company early in the process, potential claims can be settled quickly at much less cost than defending a formal claim in courts (Horne 1990). These errors and omissions may result in third-party BI and/or PD as well as ED, such as costly time delays, budget overruns, and rework (Muse 2000, Taylor 2012). While claims for BI and/or PD may well be encountered, ED are reported to be the most common losses giving rise to professional liability claims against A/E professionals working on construction projects (Taylor 2012). An example is a coverage dealing with professional liability indemnity (PLI) focusing on the project's design and engineering risks (Saxe et al. 2011), while contractors are accustomed to carrying commercial general liability (CGL) coverage. Such CGL policies, however, only provide coverage for bodily injury (BI) or property damage (PD) as a result of an act not in connection with rendered professional-related services. In contrast, the PLI coverage provides protection for damages arising from negligent design errors and omissions and covers economic damages (ED) in addition to BI and PD coverages. The PLI-type coverage is claim made, whereas the CGL-type one is occurrence based.

7.3.1 ***Multi-Tiered Professional Liability Coverage***

This section presents the alternative measures available for each participant for insuring claims arising out of performing services of professional nature on construction projects and offers insight on the characteristics and the type of coverage provided by each insurance policy (Table 5). Annual basis policies refer to policies that need yearly renewal, whereas project-specific policies are dedicated to the specific project and procured for an overall duration as desired by the owner. The Designer’s Practice Professional Liability Indemnity (DPPLI) or the Contractor’s Professional Liability (CPrL) policy addresses the direct and/or vicarious liability of the insured for performed professional services (i.e. liability for professional services performed by or on behalf of the insured). Two types of coverage are provided by PLIs; these are first- and/or third-party coverages, depending on the policy procured. In a first-party type coverage, the policy indemnifies the insured for damages due to the negligent performance of its directly contracted design professionals. That is, on first-party claims brought by owner or design builder against the design team, the Owner's Protective Professional Indemnity (OPPI) or Contractor’s Protective Professional Indemnity (CPPI) first-party coverage indemnifies the owner or design builder for loss or damage in excess of the limits available from the underlying available DPPLI coverage (Willis 2014; Taylor 2012). The DPPLI/CPrL normally comes with an applicable deductible; that is, when the loss occurs, the insured party pays the specified deductible amount, and the concerned policy then covers the remaining amount of the claim. Moreover, the scope of coverage provided within OPPI/CPPI policies is often broader than that provided under DPPLI policies, providing difference in condition coverage (Aon 2013). However, if the available limit of the DPPLI is insufficient to recover this remaining amount, the OPPI/CPPI then settles the unrecovered costs. For third-party coverage, policies such as DPPLI, CPrL, or Project Specific Professional Liability (PSPL) ones cover the insured from third-party claims. As such, when a notice of claim from a third party is received, the carrier is accordingly notified, thereby triggering the third-party type coverage of the concerned policy (Willis 2014). The Mitigation of Loss/Mitigation of Damages (MOL/MOD) policy is another type of contractor's protective coverage, in that it provides the contractor with first-party coverage for damages it incurs as a result of a design defect discovered during construction and that, if not addressed, would result in a professional liability claim. As such, it allows for the construction to proceed with funding for the rectification costs coming from the insurer rather than from the contractor. The insurer may then subrogate back against the design professional for expenses incurred (Slivka 2011). However, to address the order in which liability insurance policies respond when more than one liability policy covers the same insured for the same claim, a policy written as providing primary coverage will respond first (Stanovich 2017). Figure 32 and Figure 33 present the type of insurances available to each participant, whether under the traditional design-bid-build setting (Figure 32) or under the design-build setting (Figure 33).

Table 5. Characteristics of the Different Forms of PLIs

PLI	Procured by	Insured	Coverage	Characteristics
DPPLI	Design firm	Design firm	Third-party	Annual basis; single aggregate limit; exclusion for projects insured by a PSPL; low and eroding limits; applicable deductible (Collings 2000 and Muse 2000).
CPrL	Contractor or design builder	Contractor or design builder	Third-party; could offer additional first-party coverage such as (CPPI) or (MOL/MOD)	Annual basis or project-specific basis; exclusion for projects insured by a PSPL; low and eroding limits; applicable deductible (Slivka 2014).
CPPI	Design builder	Design builder	First-party and third-party	Project-specific or group of projects built by a single design builder; excess and difference in conditions coverage over a subcontracted design professional's DPPLI; typically with applicable deductible if DPPLI has a reduced coverage (Taylor 2012).
MOL/MOD	Design builder	Design builder	First-party	Primary coverage; applicable deductible; allowing subrogation.
PSPL	Owner or A/E or design builder	All project's design team	First-party and third-party coverage for owner; only third-party coverage for A/E and design builder	Project-specific; dedicated limits to the project; replacing available DPPLI(s) and CPrL(s) for the specified project; significant cost; high limits; applicable deductible; any design services provider could be named insured; single source of responsibility for claims (Collings 2000 and Willis 2014).
OPPI	Owner	Owner	First-party and third-party	Project-specific; provides excess and difference in conditions coverages over a directly contracted design professional's DPPLI; typically with applicable deductible if DPPLI has a reduced coverage (Aon 2013 and Slivka 2008).

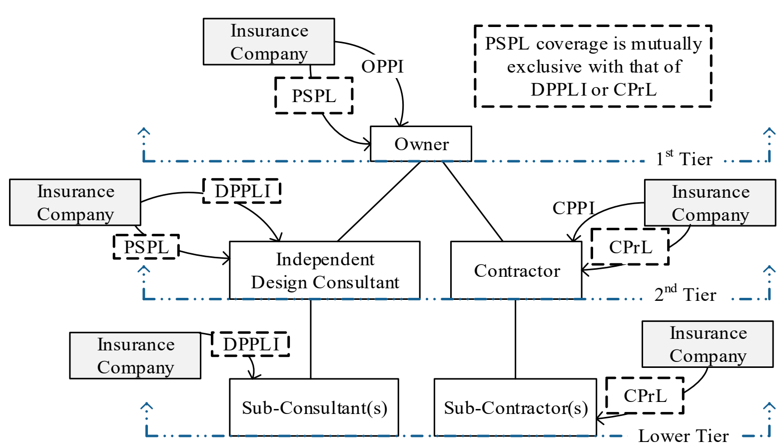


Figure 32. Multi-tiered professional liabilities in a DBB setting

These figures clarify the multi-tiered aspect of insurance procurement; that is, lower-tier insurances will be provided by designers' sub-consultants, by subcontractors, and their sub-subcontractors as well. To be noted is that since the PSPL replaces any available practice policy, the coverage of a PSPL policy is then mutually exclusive with any available DPPLI or CPrL policy. Visiting these figures in conjunction with Table 5 helps in understanding how these types of insurances could be combined to mitigate the risks associated with rendering professional services. The possible combination of these insurances and relevant comments as to the strengths and weaknesses of each risk mitigation option are further discussed in the following section

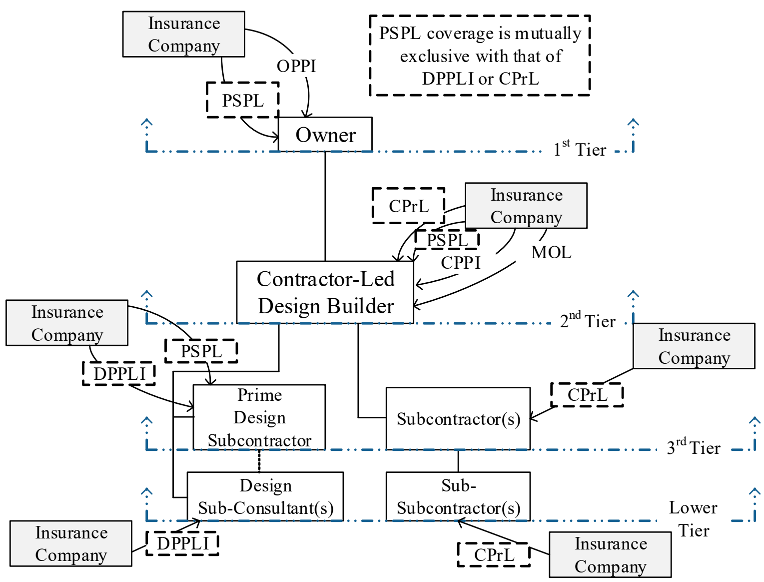


Figure 33. Multi-tiered professional liabilities in a DB setting

7.3.2 ***Risk Mitigation Options***

Four alternative options have been identified for insuring against professional liability claims associated with the design services of an independent design professional in a DBB project delivery method (see Table 6). The first option is to simply rely on the practice policy of the design firm, the DPPLI coverage. While this option is the lowest-cost option, it is the least effective one in providing complete protection for the owner.

This policy has low and single aggregate limits; that is, limits could be eroded by multiple projects triggering the use of the same policy. If the owner is concerned about the availability of the protection afforded by the DPPLI, he has the option to purchase an OPPI policy (Option 2). As mentioned in Table 5, this policy provides excess coverage over the underlying available DPPLI. A variation to these two options is when the design consultant is required to provide the specified professional liability coverage through a project-specific policy, thereby increasing or dedicating certain limits for a specific project. The cost of this type of insurance is much higher than where practice policies are utilized. A better approach can be to purchase such a project-specific policy that covers claims arising out of the work of all design firms providing services for the project. Such comprehensive coverage could be purchased either by the owner (Option 3) or by the design professional (Option 4).

Table 6. Risk Management Options under a DBB Approach

Project Participant	**Professional Liability Policy**	**Options**			
		1	**2**	**3**	**4**
Owner	Owner's Protective Professional Indemnity (OPPI)		√		
	Project Specific Professional Liability (PSPL)			√	
Independent Design Consultant	Project Specific Professional Liability (PSPL)				√
	Designer's Practice Professional Liability Indemnity (DPPLI)	√	√		

Under a DB approach, more options for layered coverage are available (see Table 7). However, procurement of an OPPI policy is underlined in order to note that its possible necessity depends on the availability of a design-criteria consultant before the engagement of the design builder. Accordingly, Options 1 to 4 could be with or without OPPI coverage. A design builder could rely on a design professional DPPLI policy

(Option 1), on its own CPrL policy (Option 2), or on both policies (Option 3); alternatively, he could procure an additional protective policy, CPPI (Option 4). Other options are when PSPL coverage is procured, either by the owner (Option 5), the design builder (Option 7), or the design consultant (Option 9). Because the “insured vs. insured” provision, provided in a PSPL policy, prevents the named insured to claim against another named insured, the design builder can procure MOL coverage (Options 6, 8, and 10) as an alternative to recoup the costs spent to correct design defects that would otherwise come out of its pocket or a professional liability coverage (Slivka 2011). Therefore, and in contrast to the DBB approach, where the designer could have a way of protection under a PSPL policy, under a DB approach, the DPPLI policy will always be exposed, and may well be triggered, if not directly, then by way of subrogation under an MOL policy

Table 7. Risk Management Options under a DB Approach

Project Participant	**Professional Liability Policy**	**Options**									
		1	**2***	**3**	**4**	**5**	**6**	**7**	**8**	**9****	**10****
Owner	OPPI	√	√	√	√						
	PSPL					√	√				
Contractor-Led Design Builder	PSPL							√	√		
	MOL/MOD						√		√		√
	CPPI				√						
	CPrL		√	√	√						
Prime Design Subcontractor	PSPL									√	√
	DPPLI	√		√	√						

* Suboptimal coverage
** Unlikely to be a desirable option

7.3.3 *Persistent Liability Exposure*

The framework presented in Figure 34 illustrates the possibilities of having any of the discussed policies triggered under these claim scenario paths. Each time the DPPLI coverage is triggered is highlighted in dark grey, to emphasize the liability burden persisting on the design professional. However, when the negligent act is caused by the DCC, the coverage process is similar to the one under a DBB approach, but the DCC is instead the independent design consultant.

As it is established in the previous sections, and emphasized throughout this flow chart, the design consultant can be held liable for issues adjudged to be pertaining to its rendered design services, regardless of his role as independent designer in the traditional approach or design subcontractor in a design-build setting. Whereas, under the DBB approach the design consultant could be protected under an owner's procured PSPL coverage, replacing his practice policy, a design builder's procured MOL coverage will prevent such protection under the DB approach, allowing for subrogation actions against the design consultant's DPPLI. As such, this persisting liability burden could impact the capability/willingness of the design consultant to give leeway to the design builder in imposing such unrealistic deadlines and constraints in releasing immature or not sufficiently coordinated design information bundles

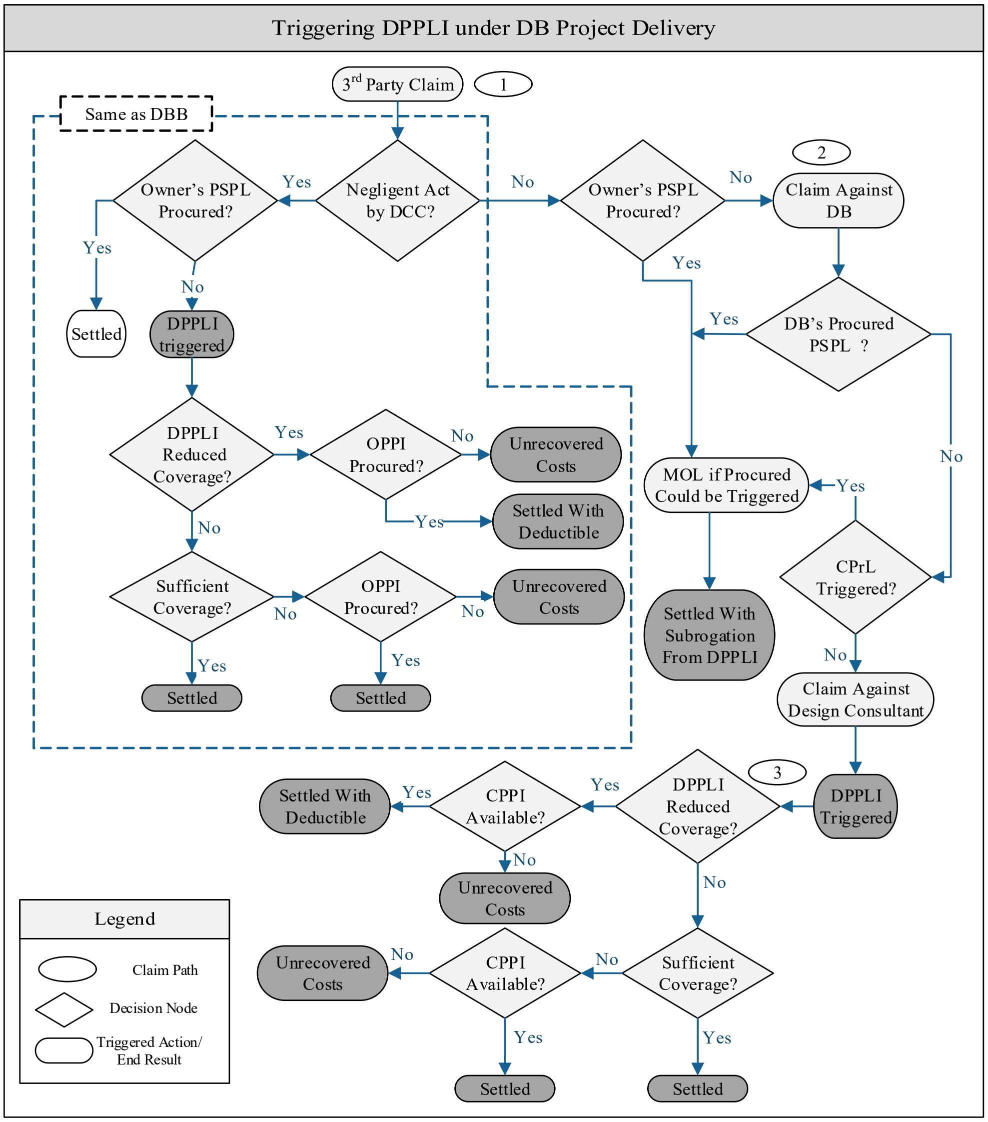


Figure 34. *Claim scenario paths*

7.4 Liability Exposure of A/E Professionals in Contract and in Tort

Through the terms of the contract, liabilities can be created, allocated, mitigated, or avoided (Schinnerer, not dated). Similarly, the parties use such terms to allocate their rights and responsibilities as well as their risks and rewards. Likewise, contracts help resolve claims/disputes if, and when, they occur. On the other hand, design professionals are also concerned with tort law issues that can be categorized into two types: (a) unintentional tort (i.e., negligence) and (b) intentional tort (i.e., intentional misrepresentation, defamation, and intentional interference with contractual or business relationships) (Schinnerer, not dated).

Moreover, where the parties to the contract are known and their duties agreed upon between them, in tort duties are then “imposed by law” (*Maudlin v. Sheffer* 1966). As such, design professionals can be held liable under tort law to “anyone to whom they owed a duty to act with reasonable professional skill and care” (Schinnerer, not dated). The latter duties are either “imposed by a valid statutory enactment of the legislature or . . . imposed by a recognized common law principle declared in the reported decisions of the appellate courts of the State or jurisdiction involved” (*Maudlin v. Sheffer* 1966). To have a viable negligence claim against the A/E, four elements must be proved: (a) the existence of a legal duty owed to the claimant, (b) the breach of that duty, (c) the proximate cause satisfied and (d) the availability of actual damages suffered (Caine and Thomas 2013). Alternatively, to assert a “breach of contract” claim, the plaintiff must (a) establish that it was in direct privity with the design professional who failed to perform according to the contract (without having a legal excuse for doing so) or (b) be a third-party beneficiary under the contract (Hale, not dated; Holub, not dated; Caplicki 2006). The latter is when one who is not a party to the contract proves that the contract was made for his/her sole benefit and therefore becomes entitled to sue for a breach of contract (Hale, not dated; Holub, not dated). For example, a project’s owner may require to be named as a third-party beneficiary in the A/E’s contracts with engineering sub-consultants in a DBB project or in a A/E’s contract with the design-builder on a DB project (Holub, not dated).

While parties to the contract have a legal venue to sue the A/E under a breach of contract claim, the A/E’s performance of the contract is generally dominated by the standard of care. However, the general rule to differentiate between actions in contract and actions in tort is as stated in *Maudlin v. Sheffer* (1966):

> "Generally, a mere breach of a valid contract amounting to no more than a failure to perform in accordance with its terms does not constitute a tort or authorize the aggrieved party to elect whether he will proceed [in contract or in tort]. . . . Accordingly, under the foregoing authorities, if there is no liability except that arising out of a breach of the express terms of the contract, the action must be in contract, and an action in tort cannot be maintained. . . . Thus, if a contract imposes a legal duty upon a party thereto, which duty exists apart from the specific obligation of the contract, the neglect of that duty is a tort founded upon a contract. . . . In such a case the liability arises out of the breach of duty incident to and created by the contract, but is only dependent upon the contract to the extent necessary to raise the duty. . . . So, it is well settled, under the foregoing authorities and others which could be cited, that in some cases the plaintiff may have an election to sue for a breach of contract or for damages in tort."

Moreover, a breach of duty can constitute both negligence and breach of contract; but, should a party sue for both tort and contract for the same set of facts, it is only entitled to recover on the basis of one theory (Ittmann *et al.* 2013). When seeking to recover damages resulting from a breach of a duty, either in contract or in tort, a plaintiff usually asks for monetary damages from the defendant (Singh and Sakamoto 2001). Compensatory or actual damages are as such awarded. These are intended to fully compensate the injured party for the actual sustained loss (Schinnerer, not dated) and to reinstate the plaintiff in the same financial position it had before the breach occurred

(Singh and Sakamoto 2001). But, in the case of intentional tort, i.e., where the defendant is liable for failing to act in good faith and/or impartially, punitive – on top of compensatory – damages may be awarded (Lunch 1990, Stein and Hiss 2003). To this end, Table 8 summarizes the main elements of tort law and contract law.

Table 8. Liabilities of A/E Professionals in Contract and in Tort

Elements	Contract Law	Tort Law
Type of Liability	Contractual Liability: Created or allocated by the terms of a valid contract	Unintentional Tort: Negligence Intentional Tort: Intentional/Fraudulent misrepresentation; Tortious interference with contract; and Defamation
Characteristics of the Duty	• Agreed upon explicitly or impliedly through contract terms • Owed to party or third party beneficiary in a contract	• Imposed by law • Owed to party and non-party to the contract
Type of Breach	Breach of a contractual duty	Breach of a duty of care
Recovery of Damages	Compensatory damages	Unintentional Tort: Compensatory damages Intentional Tort: Possibility for punitive damages, on top of compensatory damages

7.5 Negligent Tort Liability Exposure for Incurred Physical Damages

In general, tort liability is limited to situations where the negligent act causes physical harm to "some person or tangible thing other than the building itself that is under construction" (Singh and Sakamoto 2001). As such, one interpretation of the economic loss doctrine states that only personal injury and property damage are compensable in tort, and when economic damages are suffered, the contract will define the remedy, if any. For instance, the court in *Municipality of Anchorage v. Integrated Concepts and Research Corporation* (2016) held that:

> "Under Alaska law, tort-based claims that seek only a recovery for economic losses are generally precluded by the economic loss

> doctrine. But when the action seeks damages for personal injury or property damage, the economic loss doctrine does not apply and such damages may be recoverable. The line between property damage and economic loss is at times difficult to discern. Under Alaska law, damage to "other property" that is separate and distinct from the defective product is recoverable in tort. In addition, the Alaska Supreme Court has held that a party may recover for damage to the defective product itself when the loss occurs under dangerous circumstances that created a significant risk of personal injury or property damage."

Depending on the circumstances, when bodily/personal injury occurs as a result of an A/E's negligence, it can be sued by any party to whom it owes a duty of care. To this end, five cases related to BI are summarized in Table 9. These cases are selected to shed light on the viability of such claims. The case code assigned to each case is not intended to give any significance for the case, neither is it placed in order; rather it is a random number given by the author in order to keep a record (for the case in question) in the full database of the reviewed cases. For instance, an A/E owes a duty to (a) a third party in inspecting the contractor's work for compliance with the design drawings (Case C6) and (b) a third party injured worker in reviewing shop drawings and assuring that the design intent is met (Case C11).

Table 9. Summary of Cases Related to Liability Exposure for Incurred Physical Damages

Case Code	Plaintiff	Liability exposure in relation to	Court's Citation
C4	Third party, member of the public	Environmental conditions	***Sharon Reeser v. NGK North American, Inc.* (2011)** The court held that only if the engineer has expressly undertaken a duty to protect the public and performed it negligently, the court will find that the engineer owes a duty to the public.
C5	Third party, user of the facility	Construction administration services (failure to report construction defect)	***Black + Vernooy Architects v. Smith* (2011)** The court held that even though the plaintiff was a **foreseeable user** of the facility that likely would be injured from the defective work, there was **no independent duty of care owed**. The court reasoned that because the A/E's **contract did not give it control over the contractor who did the work,** there is no such duty owed.
C6	Third party, employee of the airport facility	Inspection of contractor's work for compliance with design drawings	***LeBlanc v. Logan Hilton* (2012)** The court held that the consultant owed an **independent duty of care,** to the electrician, to comply with its contractual obligations to the owner.
C11	Third party injured worker	Shop drawing reviews	***Jerome A. Jaeger v. Henningson, Durham & Richardson, Inc.* (1983)** The court held that the A/E was negligent and owed the plaintiff a **duty to exercise a standard of care in approving the shop drawings** to assure that the design intent was met. The plaintiff recovered damages for his injuries.
C12	Third party injured worker	Construction means and methods	***Glenn C. Waggoner v. W&W Steel Company* (1982)** The court held that "because the contractor, not the architect, was required under the contract to supervise the job and employ all reasonable safety precautions, the architects **cannot be held liable for injuries sustained as a result of an unsafe construction procedure.**"

In contrast, the A/E (a) has no duty to warn about dangerous environmental conditions unless it expressly undertakes such duty (Case C4) and (b) he cannot be held liable for unsafe construction procedures (Case C12). In Case C5, although the court first held that the A/E could be liable to the plaintiff who sustained permanent injuries due to defective construction work that the A/E failed to report during its construction administration services, it withdrew it on reconsideration, thus rendering judgement in favor of the A/E (Holland 2013). The court's reconsideration was based on the contract between the A/E and the owner (using the American Institute of Architects (AIA) standard form of agreement) having expressly provided that the A/E shall neither be involved in CMM nor safety precautions. Instead, the agreement explained that those obligations are solely those of the contractor. This case emphasizes the importance of using standard contract documents due to their appropriate language used for specifying the scope of services, the standard of care, and the various responsibilities of the parties involved. As such, for a physical damage to be recoverable in tort, it depends on whether or not the A/E contractually had a duty to prevent such losses. While the designer's duties to the public do not differ whether in a DBB project or in DB (Staak 2012), the DB approach creates the potential for the A/E in being involved in construction-related professional services. As such, the greater the involvement of the A/E in CMM- or safety-related services the greater the exposure will be to BI and PD professional liability claims (Hatem 2006).

7.6 Negligent Tort Liability Exposure for Incurred Economic Damages

Whether recovery of ED in tort is barred by the ELD or allowed based on a recognized exception to the rule, is an issue that is treated differently between states (jurisdictions) (Caplicki 2010, Terwilliger 2015, Scanlan and Hatfield 2018). For instance, courts enforcing the ELD to bar recovery in tort for ED aim to preserve the boundaries between contract law and tort law; this interpretation argues that claims for purely ED are matters of contract law and cannot be recovered in tort. For instance, as stated by the Washington Supreme Court in *Berschauer/Phillips Const. Co. v. Seattle School Dist. No. 1* (1994):

> "The economic loss rule marks the fundamental boundary between the law of contracts, which is designed to enforce expectations created by agreement, and the law of torts[,] which is designed to protect citizens and their property by imposing a duty of reasonable care on others."

Among the states applying this interpretation of the rule are, Nevada (Caplicki 2010, Scanlan and Hatfield 2018) and Wyoming as in the case of *Excel Constr., Inc. v. HKM Eng'g, Inc*. (2010), holding that:

> "The Court continues to believe that parties to a construction contract have the opportunity to allocate the economic risks associated with the work, and that they do not need the special protections of tort law to shield them from losses arising from risks, including negligence of a design professional, which are inherent in performance of the contract."

The rationale behind adopting such interpretation, as discussed by Terwilliger (2015), is that parties to a contract are better equipped to assess risks thereof and can agree on many ways as to how handle claims for economic losses. As such, a party to a contract should not be able to recover in tort what it was unable to bargain for in contract. Another observation of the rule, which totally contradicts with the previous one, is that recovery of ED in tort is allowed only if privity exists. However, this interpretation has been the most criticized for its weakness as it contradicts the reason for having a contract that defines and limits the liability if a breach occurs (Terwilliger 2015). Other jurisdictions recognized the unfairness and inequitable results of strictly applying the rule to innocent parties who suffer ED; as such, and as expressed in the case of *Mid-Western Electric Inc. v. DeWild Grant Reckert & Asc. Co.* (1993), the Supreme Court of South Dakota stated:

> "To deny a plaintiff his day in court would, in effect, be condoning a professional's right to do his or her job negligently with impunity as far as innocent parties who suffer economic loss. We agree

> the time has come to extend to plaintiff's recovery for economic damage due to professional negligence."

Accordingly, in such jurisdictions, courts have steadily abandoned the doctrine of privity and started to recognize exceptions to the ELD, the presence of which would imply a duty to protect third parties from ED. For instance, the "foreseeability" exception is characterized by the ability to foresee that a particular injury will result from the negligent actions of the A/E (Jensen and Land 1983, Caine and Thomas 2013, Scanlan and Hatfield 2018). However, as stated in *Ossining Sch. v. Anderson* (1989):

> "Courts have long struggled to define the ambit of duty or limits of liability for negligence, which in theory could be endless. While much of this struggle has been couched in the rhetoric of foreseeability of harm, under some circumstances foreseeability has appeared particularly inadequate for defining the scope of potential liability. In negligent misrepresentation cases especially, what is objectively foreseeable injury may be vast and unbounded, wholly disproportionate to a defendant's undertaking or wrongdoing . . ."

That is, parties became allowed to sue in tort even with the absence of a direct contractual relationship based on the "negligent misrepresentation" exception (Caine and Thomas 2013). This exception, which is characterized by the justifiable reliance on the professional judgement as stated in the § 552 Restatement of Torts (2D) (Jensen and Land 1983, Russell 2016, Scanlan and Hatfield 2018), provides that "[a professional who] supplies false information for the guidance of others in their business transactions is subject to liability for pecuniary loss caused to them by their justifiable reliance upon the information, if he fails to exercise reasonable care or competence in obtaining or communicating the information." Other exceptions are: (a) special relationship (Caine and Thomas 2013, Scanlan and Hatfield 2018); (b) fraudulent misrepresentation, which is characterized by the intent to mislead the plaintiff (Jensen and Land 1983, Scanlan and Hatfield 2018); (c) tortious interference with contract (Stein and Hiss 2003, Scanlan and Hatfield 2018); and (d) defamation (Stein and Hiss 2003). A variation in Washington law to the ELD applied in most states, the "independent duty doctrine", allows tort actions to proceed only when the tort duties arise independently of the terms of the contract (Rhodes 2014). States like Georgia, South Carolina and Virginia were found to be moving toward an independent tort analysis; that is, to prove negligence, a plaintiff must allege facts beyond and independent of a breach of contract that amounts to an independent tort (Scanlan and Hatfield 2018).

In construction projects, when delays or cost overruns occur, project participants may seek to recover their losses in tort by alleging defects in the design, interferences with the contract in performing construction contract administration work and the like whenever they lack remedy in contract. However, as previously discussed, liability exposure and the circumstances for the encountered liabilities of the A/E differ according to its role as an independent consultant or a design subcontractor. To this end, through emphasizing on the recognized exceptions to the application of the ELD (in the reviewed industry-reported cases), the following sections provide the constructs for the encountered liabilities of the A/E in the DBB and the DB project delivery approaches, respectively. These constructs are developed by mapping the several cases that were found to be touching on claims for ED and serving the purpose of either (a) shedding light on the liability exposure of the A/E in its independent role or in its role as a design subcontractor or (b) supporting a recognized exception to the application of the ELD.

7.6.1 *Liability Exposure for the Independent A/E Professional: Developing the construct for DBB*

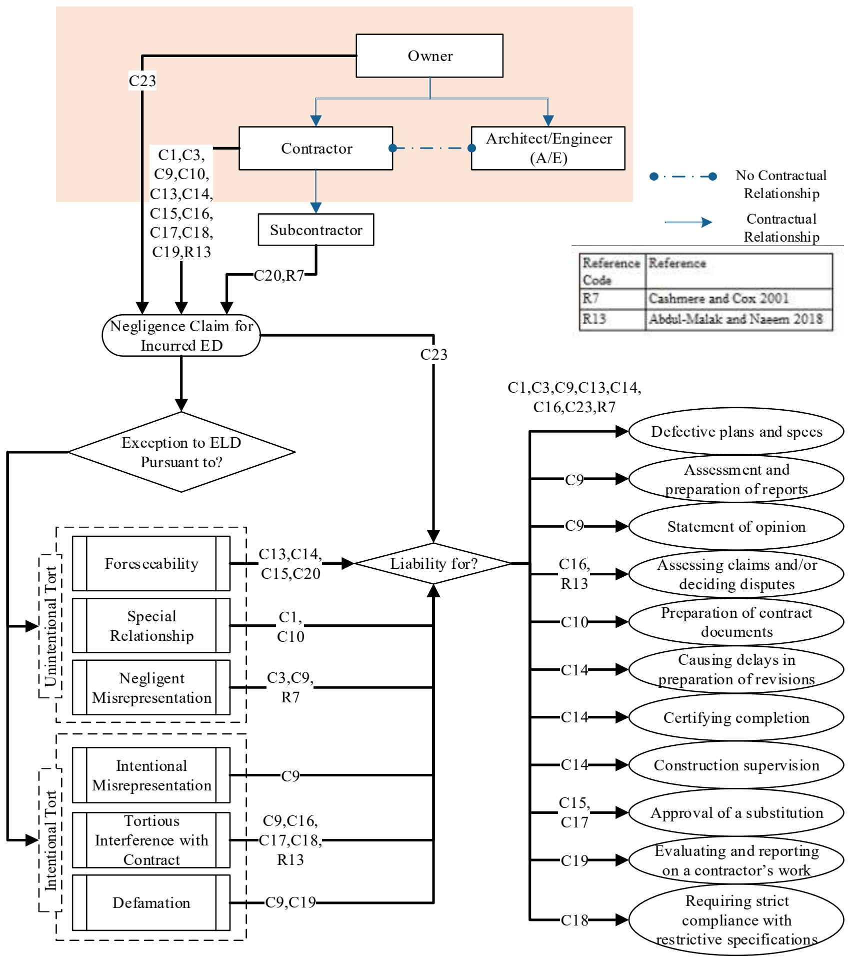
This section provides the construct developed for the encountered liabilities of the A/E in tort when acting as an independent consultant. As such, Figure 35 presents the main project participants in the DBB setting. The abbreviations (coding) used in the figure represent either a case denoted by "C" or a reference denoted by "R". Table 10 presents a summary for each case and is therefore to be read in conjunction with Figure 35. It includes for each case, the reference coding, the liability exposure of the A/E, the highlighted exception to the ELD and the court's citation. That is, negligence claims against A/E professionals could be asserted by the contractor, any subcontractor or even by the owner. However, it all depends on the circumstances of the case (i.e., availability of a recognized exception to the ELD) for a tort remedy to be available.

As for the unintentional tort, the foreseeability exception, as cited in Cases C13, C14 and C15, presented a liability exposure to the general contractor for (a) defective design (C13,C14), (b) causing delays in preparation of corrected plans and specifications (C14), (c) failing to award the general contractor the certificate upon the completion of the building (C14), (d) negligence in the supervision and control of the contractor (C14) and (e) approval of a substitution when dealing with the "or equal" clause (C15). While some courts continue to focus on the foreseeability analysis, others resort to: (a) the negligent misrepresentation theory (C3, C9), thereby focusing on the justifiable reliance of the general contractor on the defective design provided by the A/E and explicitly adopting § 552 Restatement of Torts (2D); or (b) finding some sort of a "special relationship" (C1, C10), otherwise called "intimate nexus", in order to prove the existence of a duty owed. That is, in Case C1, the court held that a design professional owes a duty of care to a contractor who relied upon the design prepared by the A/E due to the "special relationship" that exists between the two. However, in Case C10, the court held that in the absence of privity, no duty of care in tort runs from the A/E to the contractor for ED. In reaching its decision, the court argued that the "intimate nexus" test, used for establishing privity of contract under certain circumstances, does not apply to public construction contracts, and the ELD was therefore applied to bar the contractor's claim.

Alternatively, negligence claims could be asserted by third parties under an intentional tort liability. For instance, a claim for intentional misrepresentation "requires a showing of an intentional or malicious conduct", as cited in Case C9. In view of the foreseeable financial harm that may result from hindering the progression of the claim in accordance with the stipulated dispute resolution mechanism, coupled with an owed duty to provide a response to the claim in question, the "engineer's challenged authority" (i.e., allegedly coerced by the owner not to respond) would be regarded as a cause for justifying a lawsuit in tort against the A/E (R13), under a "tortious interference with contract" exception. Cases C9, C16, C17 and C18 can be visited to further clarify how to maintain a cause of action in tort under this exception. As for the defamation exception, it is clarified in Cases C9 and C19; These cases presented a liability exposure due to (a) a statement of opinion (C9) and (b) the A/E acting in bad faith when evaluating and reporting on the contractor's work (C19).

As for the legal duties owed to a subcontractor, it could be identical to those owed to general contractors (Staak 2012). For instance, despite the lack of privity, it was allowed for an excavation subcontractor to bring a negligent misrepresentation claim directly against the owner's engineering firm for defective design (R7). Moreover, Case

C20 provides that the same analysis concerning foreseeability is applied to allow a subcontractor's negligence claim against the A/E



Reference Code	Reference
R7	Cashmere and Cox 2001
R13	Abdul-Malak and Naeem 2018

Figure 35. Liability exposure for incurred economic damages in the DBB setting

Table 10. Summary of Cases Related to Economic Damages in DBB

Case Code	Liability exposure in relation to:	Exception to ELD	Court's Citation
C1	Negligence in preparation of plans and specs	Special relationship	**Eastern Steel Constructors, Inc. v. City of Salem** (2001): The court held that a design professional "**owes a duty of care to a contractor**, who has been employed by the same project owner as the design professional and who has **relied upon** the design professional's work product in carrying out his or her obligations to the owner, **notwithstanding the absence of privity of contract** between the contractor and the design professional, due to the **special relationship that exists between the two. . . .** Consequently, the contractor may, upon proper proof, **recover purely economic damages** in an action alleging professional negligence on the part of the design professional"
C3	False and misleading specifications	Negligent misrepresentation	**Bilt-Rite Constructors, Inc. v. Architectural Studio** (2005): "There is **no requirement of privity** in this state to maintain an action in tort. Rather, an action in negligence may be maintained upon the plaintiff's showing that the defendant **owed a duty** to him, that the duty was breached, and that the breach **proximately caused an injury** which resulted in **actual damages**." "(1) this Court should formally adopt **Section 552 of the Restatement (Second)**, which we have cited with approval in the past, as applied by those jurisdictions in the architect/contractor scenario; (2) there is no requirement of privity in order to recover under Section 552; and (3) the economic loss rule does not bar recovery in such a case."
C9	Defective design and negligence in reporting the soil conditions at the work site	Intentional misrepresentation; Tortious interference with contract; Negligent misrepresentation; and Defamation.	**Ric-Man Construction, Inc. v. Neyer, Tiseo & Hindo, Ltd.** (2017): A claim for intentional misrepresentation "requires a showing of an intentional or malicious conduct". "Ric-Man agreed that its **intentional misrepresentation claim failed as a matter of law**" "To maintain a cause of action for **tortious interference**, the plaintiff must establish that the defendant was a 'third party' to the contract rather than an agent of one of the parties acting within the scope of its authority as an agent. . . an agent who acts **solely for its own benefit** and not for the benefit of the principal may be liable for tortious interference with contract." "In a **negligent misrepresentation action,** the plaintiff must prove that a party **justifiably relied** to his detriment on **information provided without reasonable care** by one who owed the relying party a duty of care" "To further describe a claim for negligent misrepresentation, this Court has relied on the Restatement Torts, 2d, § 552" " A statement of opinion is not automatically shielded from an action for defamation . . . a statement of opinion that can be **proven to be false may be defamatory** because it may **harm the subject's reputation** or deter others from associating with the subject."
C10	Professional negligence and negligent misrepresentation in relation to supplying false information to prospective bidders and failing to establish a reasonable contract duration	Special relationship	**Balfour Beatty Infrastructure, Inc. v. Rummel Klepper & Kahl, LLP** (2017): "As a matter of law, in the absence of privity, death, personal injury, property damage, or the risk of death or serious personal injury, no duty of care in tort runs from an engineer or architect to a contractor for purely economic losses on a public construction project. In reaching this holding, we determine that Maryland does not expand the **"intimate nexus"** test to include extra-contractual concepts of duty for the recovery of solely economic losses in public construction cases"
C13	Plans and specs substantially in error	Foreseeability	**Donnelly Construction Co. v. Oberg/Hunt/Gilleland** (1984): "Design professionals are liable for **foreseeable injuries to foreseeable victims** which proximately result from their negligent performance of their professional services." "Design professionals have a duty to use ordinary skill, care, and diligence in rendering their professional services. . . . When they are called upon to provide plans and specifications for a particular job, they must use their skill and care to provide plans and specifications which are sufficient and adequate. . . . This duty extends to those with whom the design professional is in privity . . . and to those with whom he or she is not."
C14	Preparation of plans and specifications; Causing delays in preparation of corrected plans and specifications; Failing to award the general contractor the certificate upon the completion of the building; Negligence in the supervision and control over the contractor.	Foreseeability	**A. R. Moyer, Inc. v. Graham** (1973): The court held that a "third party general contractor, who may **foreseeably be injured or sustained an economic loss proximately** caused by the **negligent performance of a contractual duty** of an architect, has a cause of action against the alleged negligent architect, notwithstanding absence of privity" and that "each of the conditions would present a cause of action: (a) supervising architect or engineer is negligent in preparation of plans and specifications; (b) the supervising architect or engineer negligently causes delays in preparation of corrected plans and specifications; (c) the supervising architect or engineer negligently prepared and negligently supervised corrected plans and specifications; (d) the supervising architect or engineer negligently failed to award an architect's certificate upon completion of the project; (e) the architect or engineer was negligent in exercise of supervision and control of contractor . . . "

Table 10. **Continued**

Case Code	Liability exposure in relation to:	Exception to ELD	Court's Citation
C15	Approval of a substitution	Foreseeability	**Waldor Pump v. Orr et al.** (1986): The court held that: "Courts in other jurisdictions have recognized a **tort duty** between design professionals and contractors when the harm to the particular plaintiff was **foreseeable**. We find it foreseeable that Waldor Pump and other subcontractors, who were **bound to follow the specifications** prepared by [the engineering firm], could be harmed by [the engineering firm's] **negligent drafting or interpretation of the specifications.** Therefore, [the engineering firm] owed a duty to Waldor Pump to reasonably draft and interpret the project's specifications."
C16	Errors in plans and specs; Assessing claims and deciding on disputes	Tortious interference with contract	**Lundgren v. Freeman** (1962): The court based its decision on **whether the architect acted in bad faith and with bias toward the owner** when deciding to terminate the contractor from the job. Therefore the contractor's claim against the architect for **interference with the contract** was not dismissed.
C17	Bad faith in inducing the owner to terminate the construction contract due to the substitution of "an equal" product	Tortious interference with contract	**Dehnert v. Arrow Sprinklers**, Inc.(1985): The elements of **tort of intentional interference with contractual relations** as identified by the court are: "(1) the existence of a valid contractual relationship;(2) knowledge of the contractual relationship on the part of the interferor;(3) intentional and improper interference inducing or otherwise causing a breach or termination of the relationship; and (4) resultant damage to the party whose relationship has been disrupted."
C18	Bad faith in asking for a strict compliance with allegedly unnecessarily restrictive specifications	Tortious interference with contract	**Waldinger Corp. v. CRS Group Engineers,** Inc. (1985): The court held that "if an architect induces a breach of contract not to further its principal's best interests but with the intent to harm the other party to its principal's contract or to further its personal goals, the architect is liable for tortious interference with the contract." The court held that if the mechanical contractor could produce evidence that the A/E insisted on strict compliance with the specifications in order to harm the subcontractor or to further his/her own personal goals the A/E would be liable for the costs incurred by the mechanical contractor to procure substitute performance.
C19	Bad faith in evaluating and reporting on a contractor's work	Defamation	**Quality Granite Construction Co., Inc. v. Hurst-Rosche Engineers, Inc**.(1994): As per the court,"[w]ords are **considered defamatory** *per se* if they:(1) impute commission of a criminal offense; (2) impute infection with a loathsome communicable disease; (3) impute inability to perform or want of integrity in the discharge of duties of office or employment; or (4) prejudice a party, or impute lack of ability, in his trade, profession or business." The court held that "numbers three and four of the defamation *per se* categories are implicated...[W]e do not believe that the letter could reasonably be construed as a simple attempt to resolve a contract dispute. It clearly accused the plaintiffs of professional incompetence." The court ruled against the engineering company for defamation and awarded the general contractor **punitive damages**.
C20	Performance of his contract with the owner	Foreseeability	**Davidson and Jones, Inc. v. New Hanover County** (1979): "an architect in the absence of privity of contract may be sued by a general contractor or the subcontractors working on a construction project for economic loss foreseeably resulting from breach of an architect's common law duty of due care in the performance of his contract with the owner"
C23	Design deficiencies	Implied warranty	**Skidmore, Owings, & Merrill v. Intrawest I Limited Partnership** (1997): (the case is CM at risk and not DBB) The court held that "where a person holds himself out as qualified to furnish, and does furnish, specifications for a construction project, he thereby impliedly warrants their sufficiency for the purpose in view."

Owners may have a claim against the A/E for negligent design documents, using a breach of contract claims, negligence, or a hybrid of the two (Hale, no date). For instance, if the owner could satisfy the definition of justifiable reliance (Holub, no date), it may have a claim for negligent misrepresentation under either inadequate plans or improper preparation of reports (e.g. soil reports). Moreover, courts have found that payment certifications are for the benefit of the owner, and it is foreseeable (Hale, no date) for the A/E that negligently certified payments would harm the owner. This is also supported by Fletcher (2014) stating that A/E is liable to the employer in case of an overvaluation of the work and to the contractor for an undervaluation. As for Case C23, the A/E provided drawings to the owner as being 90 percent complete allowing the "at risk" construction manager (CM) to provide the guaranteed maximum price (GMP) accordingly. During construction, substantial changes due to major drawing defects were encountered increasing project cost and delaying completion. Evidence showed that the drawings used for the purpose of establishing the GMP were way below a 90-percent completion, thus allowing recovery of damages by the owner under a breach of an implied warranty claim (Terrill 1998).

7.6.2 *Liability Exposure for the A/E Design Subcontractor: Developing the construct for DB*

This section provides the construct developed for the encountered liabilities of the A/E in tort when acting as a design subcontractor (Figure 36). While it provides instances where the A/E is exposed to tort liabilities to the design-builder and other subcontractors, the main purpose is also to highlight the liability exposure of the A/E in pertinence to the duties that are expected to be instead owed to owners. Table 11 presents a summary for each of the relevant encountered cases and is therefore to be read in conjunction with Figure 36. The design criteria consultant (DCC) is appointed by the owner to provide the criteria and requirements upon which the design-builder submits its proposal. Furthermore, the role of such a design professional is normally extended to include overseeing the conformity by the design-builder thereto.

The main difference between this construct and that of DBB is that the two ELD exceptions of "tortious interference with contract" and "defamation" are not included, as they were not supported by any of the encountered case law or reviewed references. In addition, informed by the previous cases touching on these matters, but in the DBB setting, it was inferred by analogy that these are not reasonable to be viable under the DB setting. The rationale behind such an exclusion is that the third element of "intentional interference with contract", as listed previously in Case C17 (Table 10), is not sustainable since in DB the A/E is not in a position to bring the contractor to terminate the contract with the owner. Moreover, a design subcontractor to the design-builder will not logically attempt to harm the reputation of the owner or deter others from associating with him as in Cases C9 or C19 (Table 10). Another difference between this construct and that of DBB is the addition of the "agency theory". This theory, appearing under Case C24, essentially treats the designer and the builder "as one cohesive group, with each [therefore being] liable under the contract". This was explained by Terrill (1998), and further extended by Staak (2012) to view the designer and the builder as partners.

As for the unintentional tort category in the DB context, A/E professionals have a duty of care to owners based on "special relationship" factors (Castro 2009) or if "the bond between them [is] so close as to be the functional equivalent of contractual privity" (Gumaer 2017). For instance, in Case C2, the owner was allowed to claim against the design subcontractor of its directly contracted designer because of negligence in the structural assessment of an existing facility. Therefore, although the case applied to a DBB setting, it can be by analogy applicable to the DB setting, thereby allowing an owner to claim against the design subcontractor of the design-builder, instead.

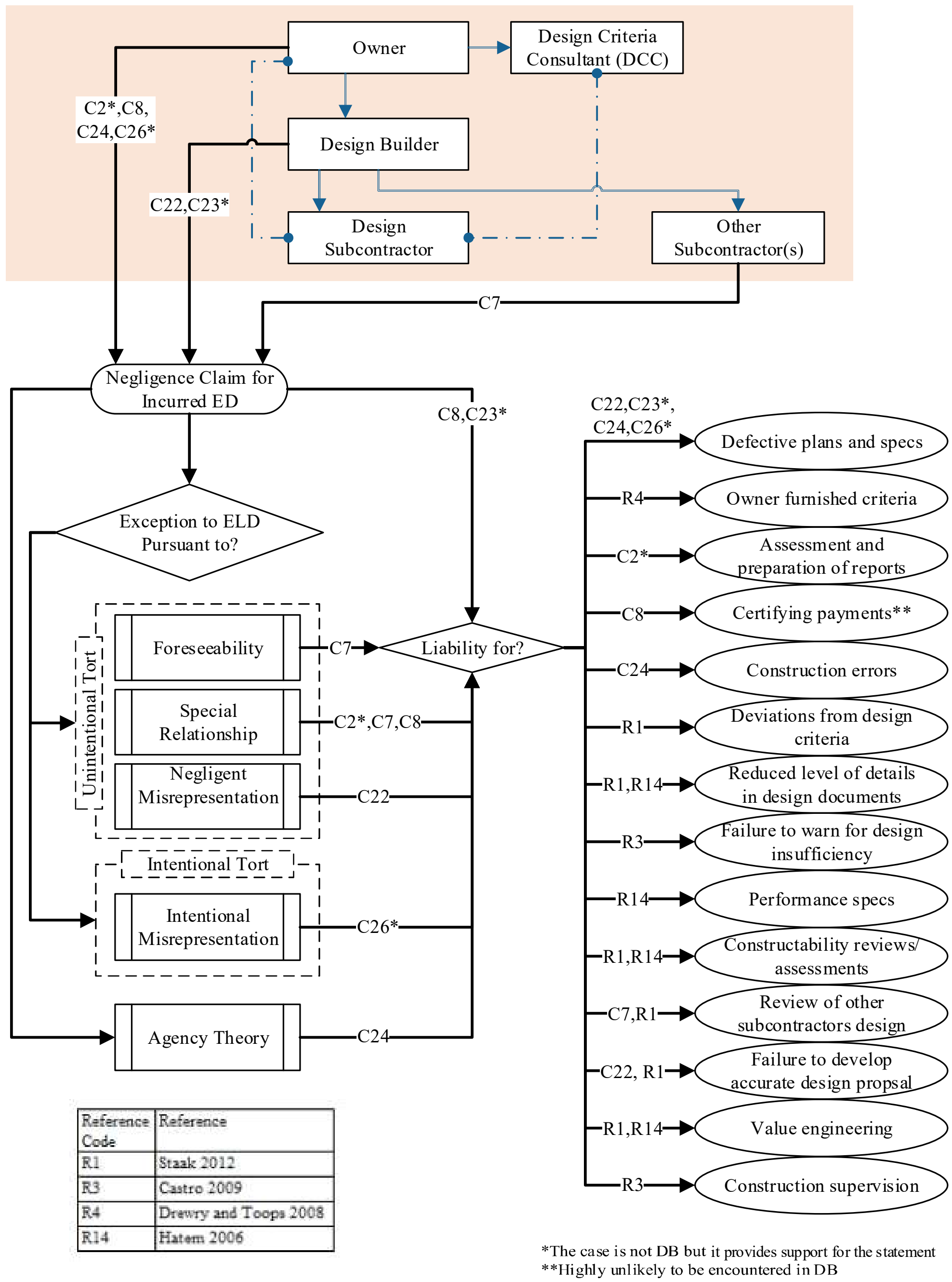


Figure 36. Liability exposure for incurred economic damages in the DB setting

Cases C7 and C8 were also found to support the “special relationship” exception; however, certifying payments for the design-builder is highly unlikely to be the design subcontractor’s duty in DB (C8), and Case C7 involved liability exposure to another subcontractor (rather than to the owner). Furthermore, the “foreseeability of harm” exception is considered as one of the factors used by courts to assess whether there is a duty owed to owners based on the special relationship factors (Castro 2009). These factors could be visited in Case C7 (Table 11).

Table 11. Summary of Cases Related to Economic Damages in DB

Case Code	Plaintiff	Liability exposure in relation to:	Theory of Liability	Court's Citation
C2	Owner claims against the designer subconsultant of its contracted designer	Negligence in structural assessment of existing facility	Special relationship	**OSSINING SCH. v. Anderson** (1989) (the project is DBB): The court held that, "in negligent misrepresentation cases, which produce only **economic injury**, [a plaintiff not in privity of contract with the defendant, to state a cause of action, it] requires that the underlying relationship between the parties **be one of contract** or the **bond between them so close as to be the functional equivalent of contractual privity**".
C7	Subcontractor	Negligence in properly inspecting the subcontractor's design prior to approvals	Special relationship; and Foreseeability	**U.S., Penn Air Control, Inc. v. Bilbro Constr. Co., Inc.** (2016): "In this case, there is **no contractual privity** or applicable statute, therefore Alpha must allege facts which **establish the existence of a "special relationship" giving rise to a legal duty of care."** "To assess whether there is a special relationship in the absence of privity of contract, California courts balance six factors: (1) the extent to which the transaction was intended to affect the plaintiff, (2) **the foreseeability of harm to the plaintiff**, (3) the degree of certainty that the plaintiff suffered injury, (4) the closeness of the connection between the defendant's conduct and the injury suffered, (5) the moral blame attached to the defendant's conduct, and (6) the policy of preventing future harm."
C8	Owner	Negligence in reviewing and certifying payment applications	Independent duty; and Special relationship	**Auburn Hills Tax Increment Finance Authority v. Haussman Construction Co**. (2018): "Determining whether a duty arises **separately and distinctly from the contractual agreement** . . . generally does not necessarily involve reading the contract, noting the obligations required by it, and determining whether the plaintiff's injury was contemplated by the contract . . . rather, the test is to determine whether a defendant owes a noncontracting, third-party plaintiff a legal duty apart from the defendant's contractual obligations to another. . . Therefore, whether a particular defendant owes any duty at all to a particular plaintiff in tort is generally determined without regard to the obligations contained within the contract . . . Michigan courts recognize that a **separate and distinct duty** to support a **cause of action in tort** can arise by statute, or by a number of preexisting tort principles, **including duties imposed because of a special relationship between the parties**, and the generally recognized common-law duty to use due care in undertakings"
C22	Design-builder	Failure to develop accurate design-build proposal; Deficiencies in the final design	Negligent misrepresentation	**C.L. Maddox, Inc. v. Benham Group** (1996): (As summarized in Terrill 1998 and Staak 2012) The designer was found liable for breaching an implied warranty regarding the sufficiency of its design to enable the contractor to adequately price the project in its design-build proposal to the owner. The court noted that the designer understood that the design builder would be **relying** on its preliminary design and quantity information to price the work and that this reliance is **justified**.
C24	Owner	Design and construction errors	Agency theory	**Kishwaukee Community Health Services Center v. Hospital Building & Equipment Company** (1986): The court held that the contractor and the designer were hired "as one cohesive group, with each liable under the contract" allowing the owner's suit under an agency theory, equating the designer and the design-builder to partners (much like a joint venture arrangement). Therefore, the A/E was held liable not only for design errors but also for construction errors.
C26	Owner claims against the specialty subcontractor	Fraudulent misrepresentations (convinced the owner to install a different type of system known to have a poor success record)	Fraudulent misrepresentation	**Aiken County v. B.S.P. Div. of Envirotech Corp**. (1989): "In order to recover in an action for **fraud and deceit, based upon misrepresentation,** the following elements must be shown by clear, cogent and convincing evidence: (1) a representation; (2) its falsity; (3) its materialty; (4) either knowledge of its falsity or a reckless disregard of its truth or falsity; (5) intent that the representation be acted upon; (6) the hearer's ignorance of its falsity; (7) the hearer's reliance on its truth; (8) the hearer's right to rely thereon; (9) the hearer's consequent and proximate injury. Failure to prove any one of the foregoing elements is fatal to recovery."

Moreover, the “negligent misrepresentation” exception manifests through the owner’s justifiable reliance on the designer’s recommendations, “[t]o the extent [that] the owner relies on these recommendations in defining its [p]roject [c]riteria and thereafter [contracts] with the design-builder” (Staak 2012). This is supported by

Gumaer (2017), arguing that a design professional is well aware that the owner will be relying on the adequacy of its professional services. As such, this should establish a sufficient relationship between the owner and the designer to allow a potential liability under negligent misrepresentation and/or special relationship exceptions. For instance, a failure to develop an accurate DB proposal and deficiencies in the final design (Case C22) exposed the design subcontractor to liability to the design-builder under a breach of an implied warranty; however, it is included under the "negligent misrepresentation" exception due the justifiable reliance recognized by the court.

As for the "intentional misrepresentation" theory, the elements that must be proven to recover damages using such an exception are cited in Case C26. The case involved an owner claiming against the specialty subcontractor for fraudulently convincing him to install a system with poor success record. Moreover, and by reference to Figure 36, it is shown that a design subcontractor is found to be exposed to liability in tort to the owner resulting from: (a) performance specifications (R14), (b) owner furnished criteria (R4), (c) the failure to warn or disclose design insufficiency or design deficiency (R3), (d) negligent supervision whenever assuming supervision duties (R3), (e) deviating from the project criteria (R1), (f) negligent review of other subcontractors designs (R1), and (g) the involvement in negotiations leading to the award of the design-build contract (R1). The involvement in pre-award activities (e.g., input, advice, or recommendation) can expose the A/E to liabilities to both the design-builder and the owner. For instance, any advice or recommendation given by the designer to the design-builder or, sometimes, to the owner is well understood to be justifiably relied upon by them. Therefore, should any problem occur if this advice proves to be incorrect, it would be the ground for a negligence claim (Staak 2012). To the extent the owner asserts claims for negligent design, this most likely implies a passthrough claim against the design subcontractor (Staak 2012). Moreover, in their capacities as design subcontractors, A/E professionals should be cautious of the inherent conflict of interest. For instance, time pressure by the builder could prevent the A/E from devoting sufficient time for the design that would otherwise be afforded in the DBB setting. Consequently, owners may allege inferior quality of the design (Stipanowich 2015).

Typical DB contracts place responsibility for the accuracy of the initial design on the design-builder, and builders will therefore have little recourse against the owner for deficient design. A lack of recourse could be translated by a higher risk of claims by the design-builder against its A/E subcontractor (Hatem 2006, Stipanowich 2015). As such, the frequency of claims asserted by design builders against their designers for negligent design is an indication of the increased risks designers accept when designing directly for the builder (Staak 2012). For instance, the builder's CMM, constructability review/assessment, and value engineering services are activities that often drive design solutions in a DB setting (Hatem 2006, Staak 2012). Of paramount importance is the issue of potentially eliminating defensive detailing when producing design drawings, particularly if coupled with the probable increased reliance on informal communication; both of which are practices observed by Hatem (2006) in DB. On the one hand, reducing details in the design documents is likely to have undesirable effects when things go wrong; these are translated by a higher risk of encountering claims if field mistakes are made (Staak 2012). On the other hand, design drawings are an important source of evidence in courts (Hipel *et al.* 2010, Philips-Ryder *et al.* 2013, Zillante *et al.* 2014). Therefore, reducing unnecessary details in the plans may only be exercised with caution and without drastically compromising on the design documentation quality.

7.7 Framework Underlying Negligence Claims in Tort

Based on a synopsis of the circumstances of the encountered liabilities, along with the varying practices for the application of the ELD in the various states (jurisdictions), a general framework underlying negligence claims against the A/E is presented in Figure 37 (to be read in conjunction with Table 12). Depending on the type of damages suffered, and the possible identity of the claimant (in the case of ED) which varies according to the project delivery method in place (i.e., DBB or DB), the framework encompasses the different deduced constructs reflecting the different paths/possibilities for a negligence claim against the A/E to prevail or fail. For instance, if physical damages occur as a result of a breach of a duty owed, courts readily find liability, the ELD is not applied, and the A/E is therefore sued for negligence.

On the other hand, if purely ED occurs, recovery of damages will be subject to either of the four deduced constructs. For instance, under Construct 1, if damages are solely economic, the ELD is strictly applied to bar recovery in tort. As such, ED are only recovered in contract by the parties or a third-party beneficiary, if any. Under the second construct, ED is recovered in contract and in tort whenever privity exists (direct privity or a third-party beneficiary); however, recovery for third-parties is denied. As for the jurisdictions that apply an independent duty analysis, presented under Construct 3, if the duty owed is beyond and independent of a breach of contract and amounts to an independent tort, ED could be recovered in tort. Under Construct 4, which has been thoroughly discussed throughout the previous section, a case by case analysis is conducted. As such, the concerned jurisdiction should at least recognize any of the exceptions to the rule; should the claimant prove that his claim satisfies at least one recognized exception, a duty would be owed. It should be highlighted that a third-party beneficiary clause for the benefit of the owner, properly drafted in the design agreement between the contractor and the designer in a DB setting, will give the owner a direct right of action against the designer (McGreevy *et al*. 2005). As for contractors, it is highly unlikely for them to be named as beneficiaries. Engineers should make sure to have their contracts with owners in the DBB approach clear from third-party beneficiaries (Caplicki 2006). Finally, since courts treat the recovery for ED and the application of the ELD differently in different states, it is therefore of paramount importance for the different project participants to understand how construction law principles (e.g., ELD application) operate in the states where they conduct their businesses.

Table 12. Parties Identification Depending on the Delivery Approach

Project Delivery Approach	Design Agreement	First Party	Third Party	Third Party Beneficiary
DBB	Owner − A/E	Owner	Contractor	Contractor*
DB	Design-builder − A/E	Design-builder	Owner	Owner**

* Highly unlikely to be named as beneficiary in the design agreement

** Likely to be either named or implied to be as beneficiary in the design agreement

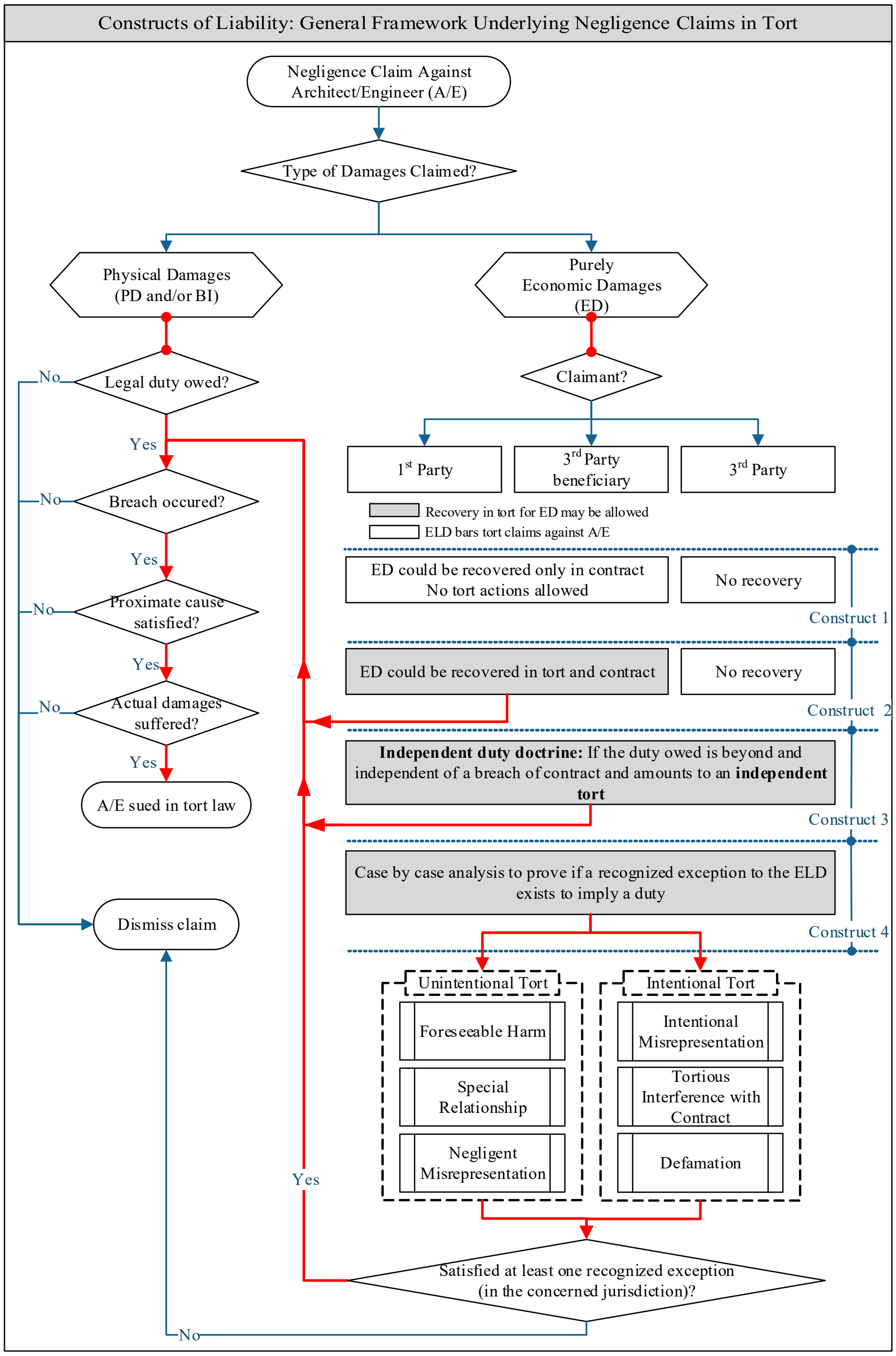


Figure 37. General framework underlying negligence claims in tort

7.8 Implication of DB Operational Variations on Liability Exposure

Although the design-builder is responsible for the design in a DB setting, the owner will inevitability be required to provide some design input. Operational variation refers to the proportion of this design input provided by owners before engaging the design-builder. On the one hand, "the extent of design information to be provided is an unsettled debate, which involves consideration of design liability" (Chan and Yu 2005), particularly that there is no such bright line separating the design performed by the owner from the more detailed design performed by the design-builder (Hatem 2006). On the other hand, many contract documents are not clear as to "whether the owner's preliminary design is a limitation placed upon the design-builder" (Castro 2009). Therefore, in DB, the risks of the A/E to be sued in tort law may be of different magnitudes and may have varying likelihoods of being encountered owing to the various DB operational variations related to initial design input by owners. For instance, due to the multiplicity of terms and concepts used, a systematic classification framework for DB variants based on their operational attributes was established by Xia *et al.* (2012). Among four classification rules adopted, the proportion of design completed by the owner was considered the most fundamental one. For the purpose of emphasizing on the magnitude of shared liability resulting from this splitting of design effort between the owner's A/E and the contractor's A/E, three classes of operational variations are adopted. For instance, class A refers to "design criteria design-build" where the owner only provides design criteria (DC) for the project. Class B refers to the "enhanced design-build" where the owner's A/E develops the design to a point where significant facility programming is determined, usually through schematic design (SD). Class C refers to the develop-and-construct or the "bridging" variation, where the design performed by the owner's A/E usually extends through design development (DD).

As such, based on the presented definition of each class of the DB variants, the conceptualization proposed in Figure 38 classifies these variants according to the magnitude of shared liability, expected to be encountered according to the increased/decreased proportion of design undertaken by each party (i.e., owner or design-builder). Moreover, the "novation design-build" is also a DB operational variation and corresponds to instances where the owner's A/E agreement is novated to the design-builder after completing a certain percentage of the design (Xia *et al.* 2012); sharing of liability would not therefore be expected to prevail under such a variation.

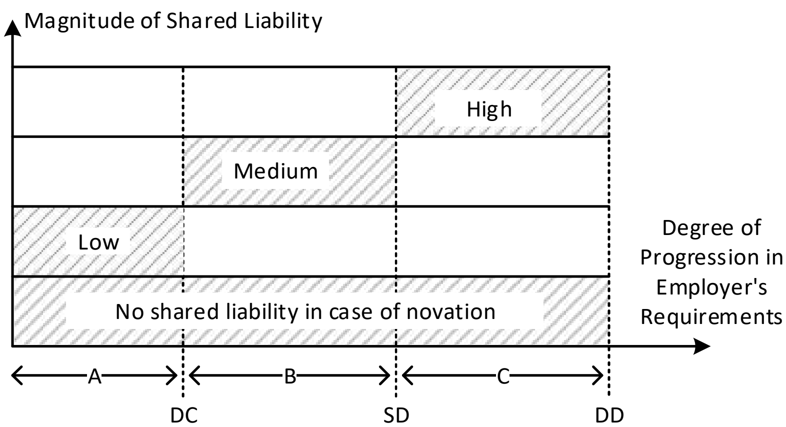


Figure 38. Magnitudes of shared liability according to the DB operational variations

CHAPTER 8

EXAMINING BIM APPLICABILITY TO DESIGN-BUILD PROJECTS

8.1 Preamble

Project delivery describes the system used by the project owner to plan, design, construct, operate, and maintain facilities by entering into legal agreements with one or more entities or parties. Building Information Modeling (BIM), on the other hand, is a process involving the generation and management of digital representations of physical and functional characteristics of places. While BIM and its associated tools are argued to be applicable to all types of project delivery, their successful implementation by engineering firms on projects is still not being achieved consistently. The application of BIM to support an optimal cross-disciplinary and cross-phase collaboration creates a new vision for the roles and relationships among all project participants. In particular, the Architect/Engineer (A/E) who is accustomed to playing an independent role under the traditional delivery approach is now a design subcontractor under the design-build (DB) delivery approach or a project team member under the integrated project delivery (IPD) approach. Through focusing on the DB delivery system, this chapter investigates the applicability, in terms of the usefulness and the degree of relevance, of BIM to DB projects. This is achieved by modeling and comparing the design-construct phase in traditional design-bid-build (DBB) projects and in DB projects, both under a BIM environment. The main contribution of this analysis is to offer a better understanding of the use of BIM on DB projects, thereby covering the first objective of the last module, i.e., module 4.

8.2 BIM-Based Design in DBB Projects

The production of design deliverables under the traditional DBB system evolves sequentially from schematic design (SD), through design development (DD), to the production of construction documentation (CD). Figure 39 shows the legend associated with the mapping of this sequential process in a BIM environment, as depicted in Figure 40. The conceptual design is not explicitly included in this figure as it is assumed to be the starting point in the process. The three main disciplines in a typical building project, structural, architectural and mechanical/electrical/plumbing (MEP), are presented to indicate the development of separate BIM models. Within the same stage (i.e., SD, DD or CD), and in real time, the three main cross-functional teams develop their models simultaneously. At the end of each stage, the three individual models are merged into one federated model, the central BIM model. After running clash detection, the model undergoes a review by the owner. Feedback loops end when the owner's requirements are met. The design review is therefore represented in a decision box to indicate that acceptance by the owner triggers the official start of the following stage.

The concept of model element author (MEA) is adapted from AIA (2013) and refers to the party responsible for the actual modeling of any element. Therefore, under the DBB system, it is assumed that the MEAs are the A/Es developing the BIM models. As for the management of the different BIM models presented in this process, as well as the management of the central model, one or more model managers are assigned.

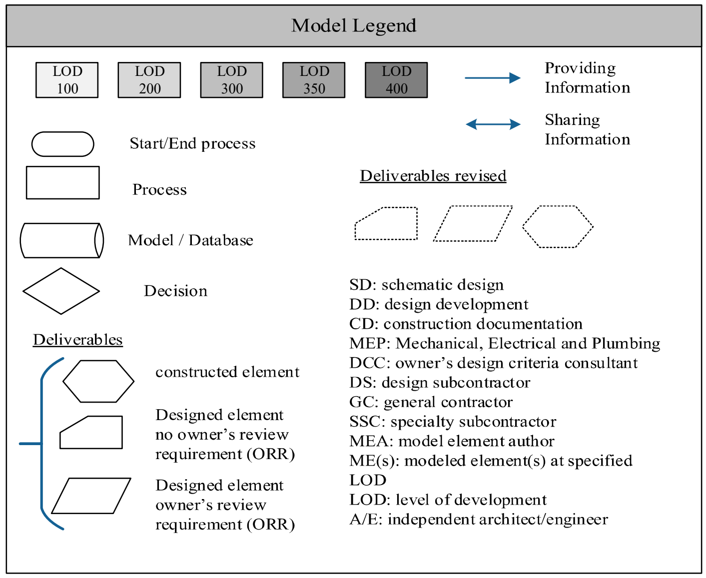


Figure 39. Components of the BIM-based design progression frameworks

Model managers are responsible for the assembly, control, and integrity of the models (AIA 2008). The majority of the modeled elements are presented at LOD 200 at the end of SD, LOD 300 at the end of DD, and LOD 350 at the end of CD. The existence of some elements at LOD 400, which is considered to be the shop-drawings level, is attributed to the possibility of such details becoming available for subcontracted systems or long-lead items. When the final BIM model is ready at the end of the design phase, bidding is carried out followed by the selection of the successful contractor. Typically, under a BIM contractual requirement, the builder is asked to provide a BIM model as well, mainly developed to an LOD-400 level. The BIM model is then continuously updated as construction evolves to reflect the site-verified elements, better known as the as-built elements.

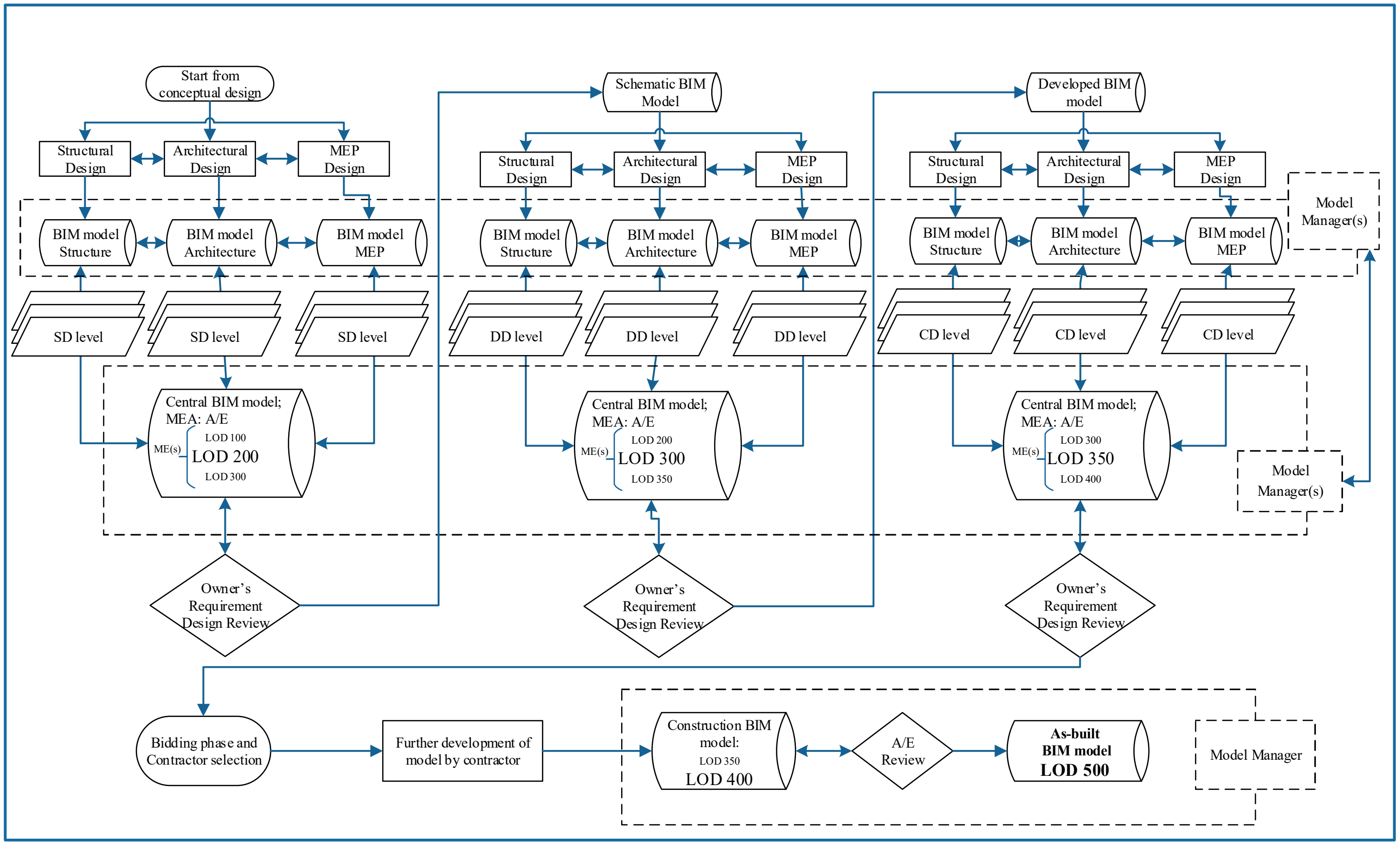


Figure 40. BIM-based sequential design progression under DBB

8.3 BIM-Based Design in DB Projects

A main advantage of the DB system is that it allows for fast-tracking, whereby construction is allowed to proceed concurrently with design. Figure 41 illustrates the evolution of design deliverables for DB projects executed in a BIM environment. Acknowledging the existence of many different variations of DB, depending on whether or not the owner has appointed a design criteria consultant (DCC) before engaging the design builder, or how much design is completed before its engagement, the presented model is not intended to show all the variations. Rather, the purpose is to show one case only, as an example for illustrating the difference with the DBB system. The adopted example considers that the design starts by engaging a DCC and developing the design up to 20 percent of SD. Then, the DB proposal is prepared, reflecting an SD that is 30 percent complete. After the contract award, the design builder's A/E, referred to as design subcontractor (DS), starts with an SD-level model manifested by a majority of elements at LOD 200.

The deliverables illustrated in Figure 41 are given two different shapes to differentiate between those with versus without owner's review requirements (see legend in Figure 39). A more detailed presentation of the types of deliverables, which are referred to as releases that are suiting either the purpose of design progression or that of construction, is provided in Table 13. These releases are in the form of either submittals, which are contractually required, or bundles of design information released directly for construction. Figure 41 maps the rework scenarios caused by the gradual releases of these deliverables on DB projects. For example, the first deliverable in discipline A, $R_{1,A}$ developed to LOD 350, is released for construction after coordination with an associated element ($R_{1,B}$) from discipline B, which may still be at LOD 200. When time comes for $R_{1,B}$ to be developed to LOD 300, thus allowing more accurate coordination, $R_{1,A}$ is then given new information; this may induce rework for this element ($R_{1,A}$) as it may have already been constructed.

Rework is envisioned to happen as a result of one of two possibilities: (1) a release for an element in question, which is detailed enough, but its coordination with an associated element is not fully attained due to the incompatible levels of LOD for each element, or (2) a specific release is not mature (detailed) enough for the purpose of construction. The latter case is mainly due to a lack of an owner's review requirement preceding construction, combined with the non-independent role of the A/E, being a design subcontractor under the DB approach and, as such, possibly afforded less control over the required level detail for each design information release to be made.

As illustrated in Figure 41, the central BIM model is shown to have a wider range of LODs in contrast with the model built for DBB projects (Figure 40) and a variety of MEA(s) due to the integrated nature of the DB system. Figure 41 also highlights the evolution of releases and an example of rework.

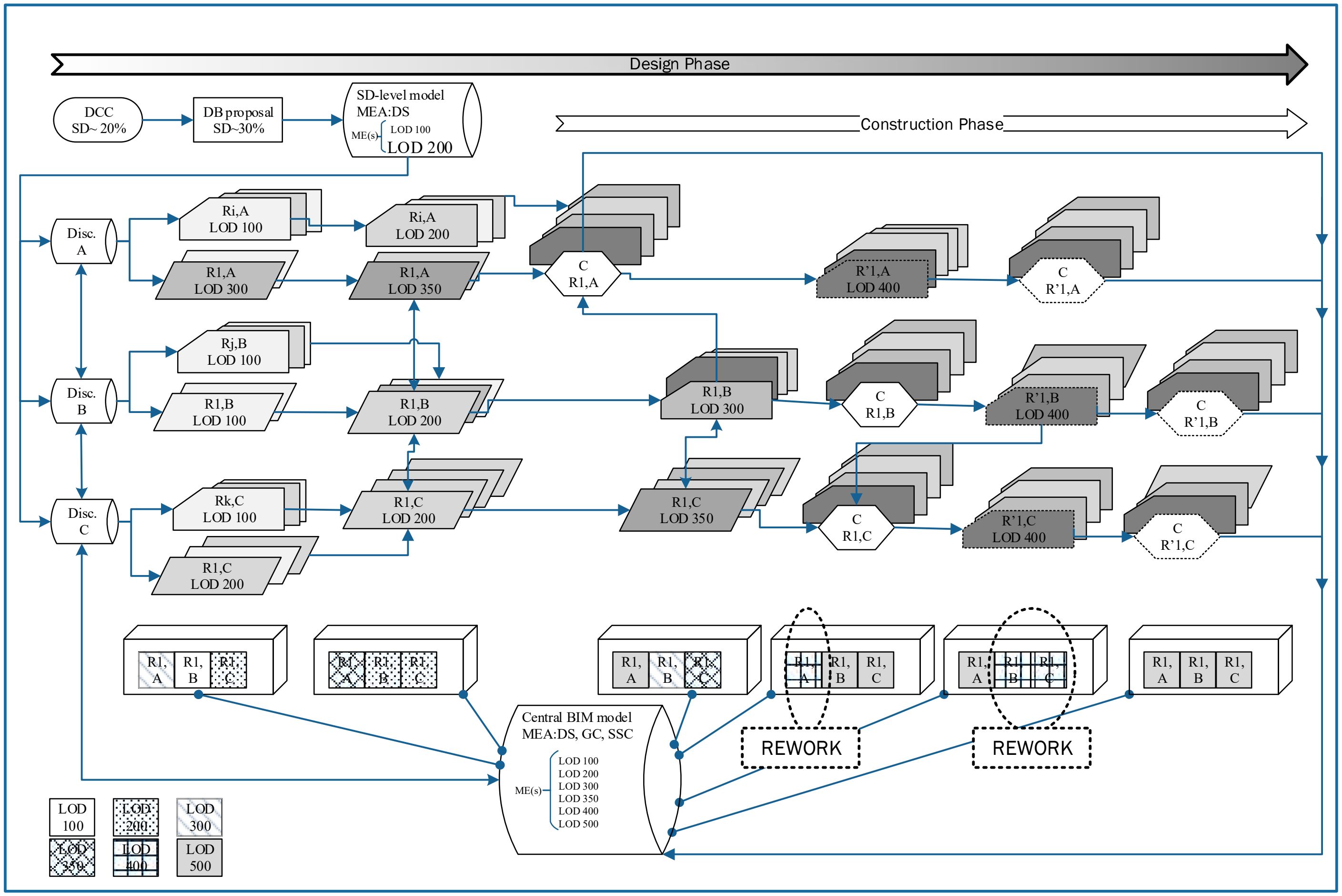


Figure 41. BIM-based fast-track design progression under DB

Table 13. Form of Releases in DB BIM-Based Design

Suiting the Purpose of	Form of Releases	Purpose	Level of Detail Required by Design Builder's A/E
Design progression	Submittals	Review	Design level: LOD 100-200-300-350
		Review and approval/consent/clearance	Design level: LOD 100-200-300-350
Construction	Submittals	Review prior to construction	Execution level: LOD 350
			Shop drawings level: LOD 400
		Review and approval/consent/clearance prior to construction	Execution level: LOD 350 Shop drawings level: LOD 400
	Bundles	Construction directly	Execution level: LOD 300-350
			Shop drawings level: LOD 400

8.4 Coordination-Related Implications

BIM enables the integration of information obtained from various design disciplines and construction input into a coherent model for easier and faster access and visualization of this information. Therefore, DB projects are good candidates for implementing BIM concepts. Using BIM, the proposed design and engineering solutions can be measured against the client's requirements, thereby inducing better coordination strategies.

Clearly, two coordination aspects are highlighted: the systematic and consistent coordination under DBB, manifested by (a) the compatibility of the development of the modeled elements at any point in time, and (b) the incompatible coordination under DB, manifested by the wide range of LODs. Moreover, under DBB, timely coordination is the norm, and the review by the owner takes place following a discrete approach, in line with the milestones for review specified at the completion of each design stage. Whereas under DB, coordination may be deferred while the review process takes place dynamically due to the fast-track nature of this approach. In DB projects, the fact that at any point in time the BIM model embeds a wider range of LODs for various elements, any clearance given at any such stage of review has to be reconfirmed when conducting another review cycle. This is due to the fact that some of these elements, which may have reached LOD 500, may have to go back to LOD 200 by reason of rework; the model then no longer shows LOD 500 for this element.

It is concluded that, in a DB environment, the BIM model offers the advantage of keeping the client informed about the basket of elements that make up the model at any point in time and giving him warnings as to when certain elements have been revisited for one reason or another. Inherent with the DB system is the risk of cut and patch. Yet, if one is to argue that construction should wait for a bigger basket of elements to reach LOD 400 before proceeding to construction, this will actually defeat the purpose of fast-tracking. By visualizing the evolution of elements at different LODs on DB projects, BIM allows for better documentation of design and construction processes. To counter the likelihood of rework, which is associated with the fast-track nature of DB projects, BIM plays an important role in allowing the client to track potential changes, so that "premature clearances" that have been issued are revisited during subsequent review cycles. This helps clients set and incorporate requirements for certain elements to be subjected to a more stringent coordination protocol

CHAPTER 9

DEVELOPMENT OF A BIM-ENABLED CHANGE TRACKING SYSTEM FOR DB PROJECTS

9.1 Preamble

While it becomes clear that in fast-track DB projects emergent changes are almost inevitable, the impact of such changes in a DB setting − where the performance of the design is under the responsibility of the design-builder – should not be overlooked. That is, under construction project organizational structures where owners maintain direct contract for design services (e.g., DBB), the burden of design changes (whether those that are client-driven or designer-driven) and any possible impact on the contractor and any potential propagation of the impact of such changes to lower-tier subcontractors' work remain the owner's liability. In contrast, in DB the design-builder holds the ultimate liability for the timely completion of design and construction services towards the owner, and, therefore, any emergent design change may propagate to lower-tier subcontractors' work and bring about detrimental impacts on project performance, the burden of which is carried by the design-builder. To this end, this chapter (which is the second chapter of module 4) includes the work performed in fulfilling the last objective of this research work, which is to demystify BIM potentials in tracking and monitoring changes. Namely, this chapter includes the development of a change tracking system and a Revit plugin extension to track the inevitably encountered emergent changes on fast-track DB projects and ultimately serve the control of their impact.

9.2 BIM-Based Fast-Track Design Progression in DB Project Delivery

9.2.1 *Definitions*

The design phase is a continuous whirling process that starts with defining and interpreting the design problems of the different project elements/components, generating feasible design solutions, comparing these solutions, and then making the appropriate decision/selection (Gray and Hughes 2001). This process can also be perceived as the progressive elimination of uncertainties through selecting and then continuously refining the chosen design solution (Mitchell et al. 2011). In this context, an element represents a "construction entity part which, in itself or in combination with other parts, fulfills a predominating function of the construction entity" (ISO12006-2 2015), irrespective of the material or the specific technical solution selection (OMNICLASS 2012). On the other hand, a designed element (DE) is an "element for which the work result(s) have been defined" (ISO12006-2 2015). That said, for each element, several technical solutions (i.e., the designed elements) may accomplish its elemental function and more than one solution may be selected within the scope of a particular project (OMNICLASS 2012). For instance, a vertical structure may contain several slab elements; for each slab, one design solution (e.g., solid slab) is adopted among the many design solutions that might have been entertained (e.g., solid slab, waffle slab) in accomplishing the slab's elemental function, and more than one solution (i.e., at different levels) can be selected within the whole building structure. The power of a BIM-based design resides in its parametric and data-rich MEs. Namely, MEs are classified according to a certain hierarchy in discipline-specific templates. For instance, within the construction template in Revit, elements are classified in a three-step hierarchy starting from the *Category* (e.g., doors) to the corresponding *Family* (e.g., single passage steel flush door) then to the specific *Type* (e.g., a single passage steel flush door with a specific dimension). While such a template facilitates the modeling process, it allows designers to insert (from the library) an element with a high level of details at early design stages where certainty about the specific design of such elements may be very low. To this end, the industry has adopted a formal language that describes the design progression or the level of completeness of an ME at a given point in time. Namely, the level of development (LOD) describes the design progression of an ME at six different stages (LOD100, 200, 300, 350, 400 and 500) and, therefore, allows users to specify and articulate with a high degree of clarity and consistency the content and reliability of MEs at various stages in the design and construction process (BIMForum 2019). Based on the definitions of each LOD, the LODs for MEs progressively increase in conjunction with the design naturally progressing from the schematic design (SD) stage to the more detailed design development (DD) stage, and finally to the construction documentation (CD) stage. That said, it could be safely deduced that the LOD metric embeds two combined aspects: a level of details and a level of certainty. Figure 42 illustrates the full progression of an ME from a generic representation at LOD100 to a field-verified element at LOD500. For instance, an LOD300 designates the end of DD of an ME, whereby the respective level of information (corresponding arrow “b” in Figure 1) reflects *developed* detailing and *defined* certainty of such information. Such an LOD metric facilitates the communication among the various involved stakeholders about the advancement of the design (regarding the MEs of concern). However, being disconnected from the model makes this metric of limited usefulness for the sharing of information between the A/E subcontractor and the design-builder. As such, its incorporation within the modeling process itself, as illustrated later, is well justified.

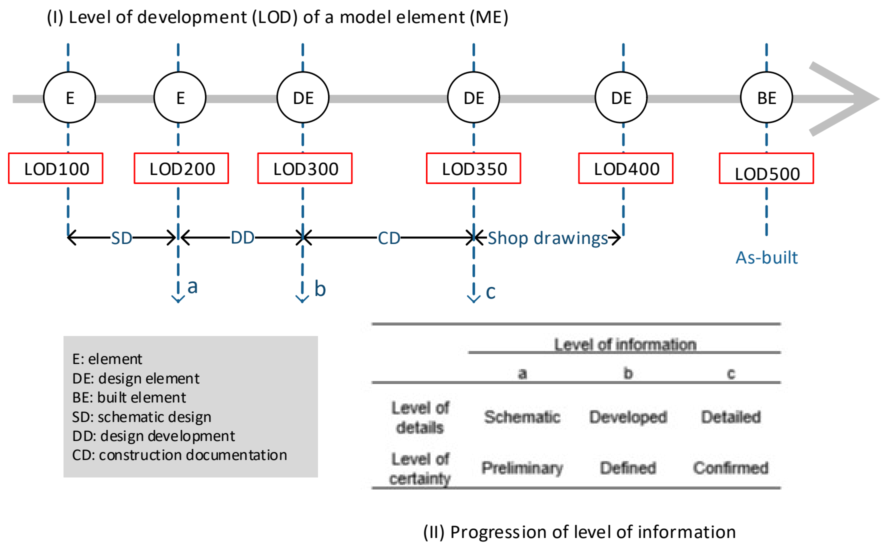


Figure 42. BIM-based design progression of a model element

9.2.2 *Types of Association Between Model Elements*

Different types of association (e.g., dependency, connectivity, etc.) may exist between two MEs, and one element may be associated with several other MEs through different types of association. However, BIM tools are still of a limited capacity in identifying many of the types of inherent associations between MEs (Moayeri et al. 2017; Pilehchian et al. 2015). To this end, this section examines the association types that are easily identifiable in BIM and those other types that rather need to be defined by the user in order to track the impact of a certain design change. For instance, Pilehchian et al. (2015) classify dependencies between MEs into spatial and analytical dependencies; the former type arises due to the geometry (e.g., shape) or position/location of components in 3D space, and the latter refers to the relationships between MEs that allow them to perform a specific function or operation. Similarly, Moayeri et al. (2017) refer to physical and logical connectivity existing between the BIM components, whereby logical connections between the components can be established by defining constraints in BIM during the model development stage. In this study, we differentiate between three types of association between MEs (Figure 43): (a) the built-in (referring to the BIM automatically recognizable association) spatial association, (b) the user defined spatial association, and (c) the user defined analytical association. The built-in spatial association includes the definition of hosting/hosted elements or connected boundaries, which are defined through easy modeling methods. On the other hand, adjacent elements, intersections of elements, or penetrations are spatial associations that can be defined through specific rules that need to be coded over specific BIM platforms (e.g., Revit, BIM 360). Similarly, designers can facilitate the coordination of changes within their own discipline by defining their own discipline-specific design rules (intra-discipline design rules), as well as the coordination of changes across disciplines by integrating inter-discipline design rules within the modeling process.

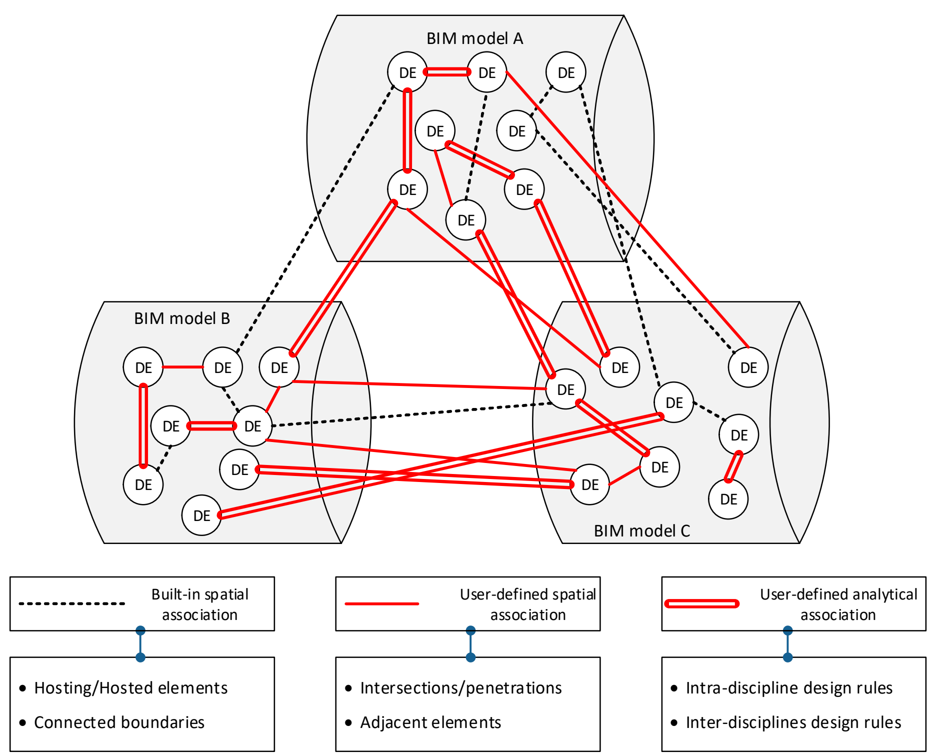


Figure 43. Hypothetical representation of the different types of association between model elements

9.2.3 *Design Information Release*

Design solutions are ultimately translated by means of drawings and specifications (i.e., design deliverables) that are released by the A/E subcontractor in different forms and various levels of details depending on the purpose released for, i.e., either suiting the purpose of design progression or that of construction (Kalach et al. 2018). Namely, the releases may be in the form of submittals for review or for review and approval/consent/clearance, bundles of design information released directly for construction (or to initiate one or more post-design activity, i.e., procurement/fabrication/construction activity), or tender packages for subcontracting prior to construction.

A hypothetical representation of the design progression in a BIM-based DB delivery method after the award of the DB proposal is illustrated in Figure 44. Starting from the initial BIM model (i.e., the DB proposal), three separate discipline-specific BIM models are illustrated. These indicative models represent the design work performed by each discipline, whereby a set of design problems is identified and interpreted. Design decisions are made first at the element or system level (MEs are expected to be at LOD 100 or 200), then at the level of a DE (the LOD increases to 300, 350 or even 400), and ultimately ending with a built element BE. A release may include one DE or a group of DEs that are combined to form a released design deliverable. Given the simultaneous progression of design and construction phases, when a release R_i is released for the design-builder (at time t_i), the associated elements (AE)s for each of the components of this release can be at any LOD. In this context, in order to track the impact of a certain change, there is a need to identify the matrix of associations for each release reflecting the current LOD of each AE, which can only happen if proper coordination processes are in place. To this end, the following section elaborates on the inferred coordination processes that need to take place in a DB delivery method.

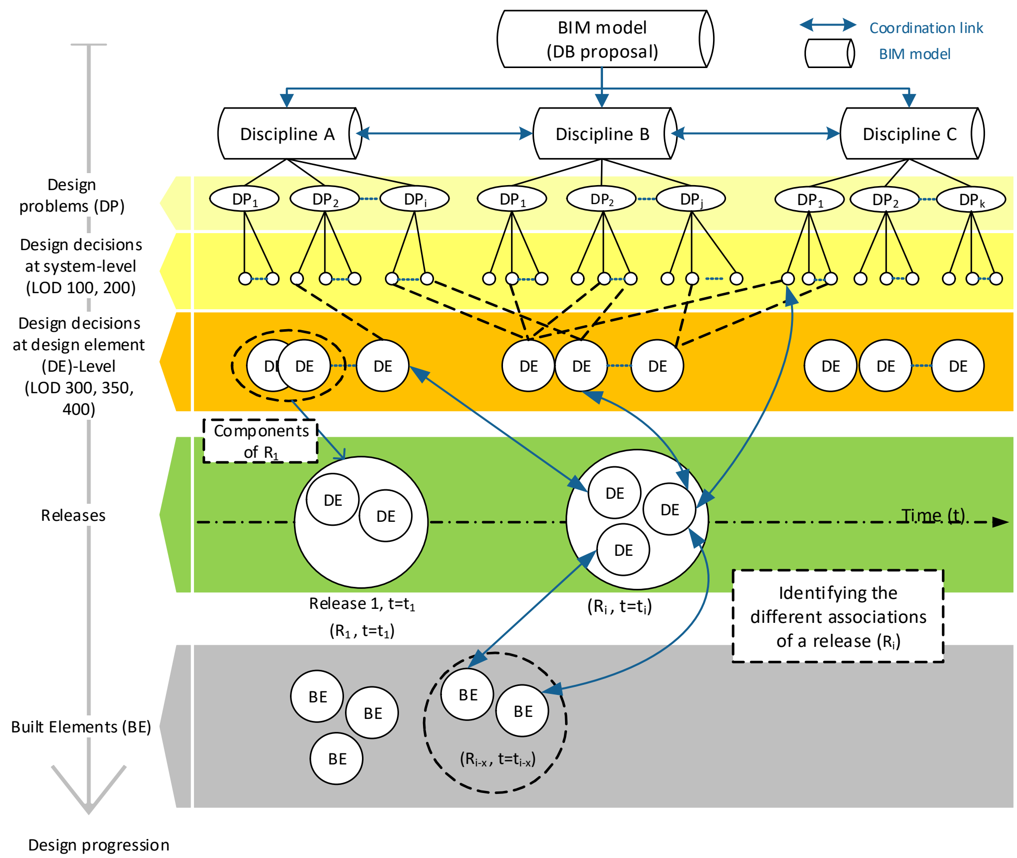


Figure 44. Design progression in BIM-based DB delivery method

9.3 Inferred Coordination Processes

Design coordination is essential to achieving design integrity, minimizing design discrepancies, reducing errors and omissions, and ensuring that the design quality criteria are being met. In fast-track construction projects, given the overlap between the design and construction phases, coordination processes become more critical since the design coordination tasks become constrained with what has already been executed on-site (Mehrbod et al. 2019b). On the one hand, the rates of design progression for the various

MEs normally follow the planned schedule of release needed by the design-builder, in satisfaction of the construction schedule and priorities. That said, when design deliverables are released by a certain discipline, the various associated MEs, whether those are from the same discipline or from other associated ones, can be at any LOD. It goes without saying that at each time design information is being prepared to be released for construction, this triggers some form of coordination to take place. Namely, a release-imposed coordination is needed (Figure 45) in order to check the viability, correctness, or – even – sustainability of previously coordinated information. On the other hand, although there is a dire need for design outputs to be released to the builder at the soonest possible, one cannot deny that whatever is integral to maintaining a coherent design is to remain satisfied in order to preserve design integrity. As such, this mandates that, every now and then, coordination is needed irrespective of whether a certain release is to take place. This second coordination process is described as a design progression-mandated coordination, as illustrated in Figure 46.

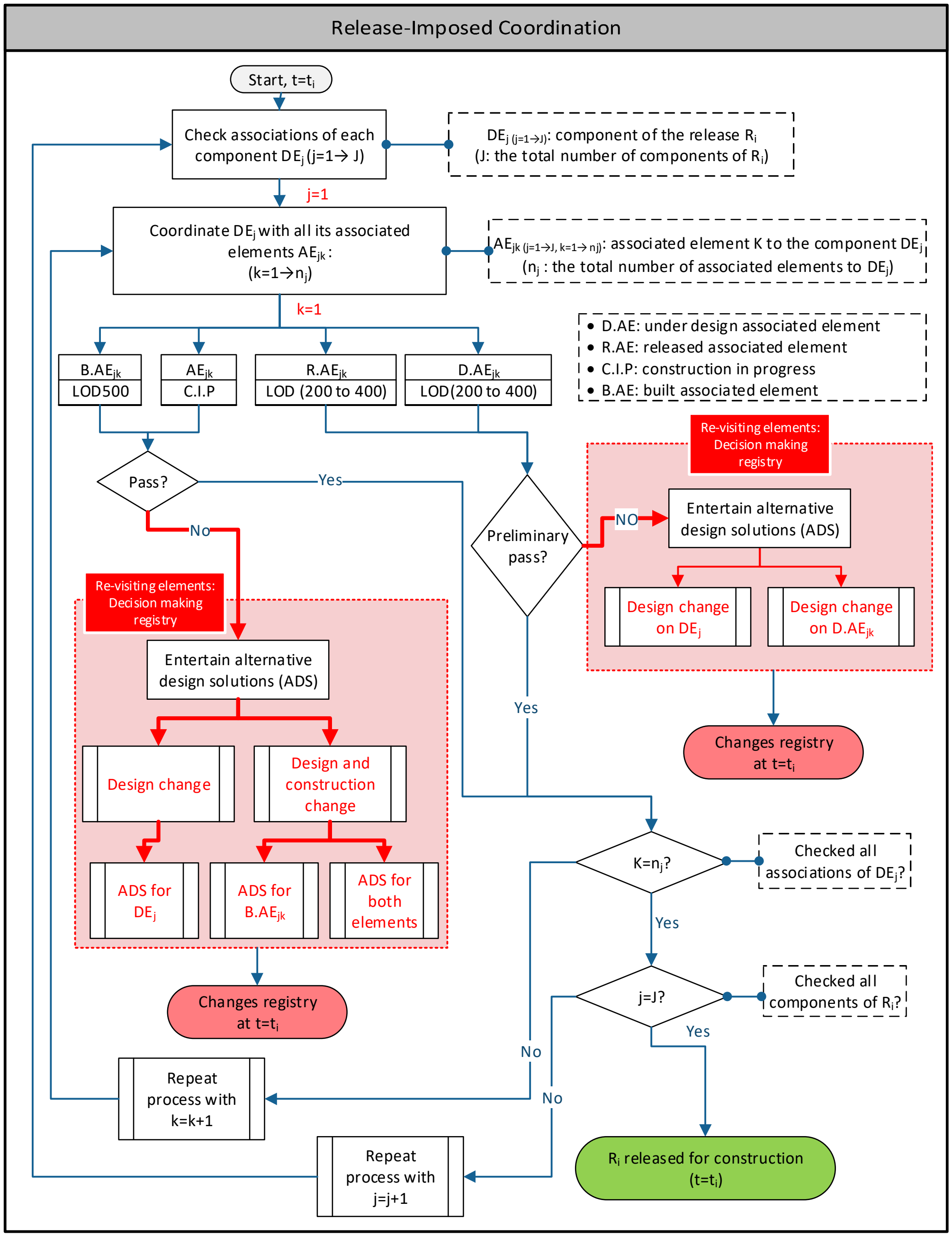


Figure 45. Flowchart illustrating the release-imposed coordination process

Figure 45 maps the release-imposed coordination process that needs to accompany the release of design deliverables. If, at time $t=t_i$, a release R_i is being prepared to be released, each component DE_j of R_i needs to be coordinated with all its associated elements AE_{jk}, which can be at any LOD, as previously discussed. Namely, an AE_{jk} may (a) be under any design stage (i.e., D.AE), (b) have already been released (i.e., R.AE), (c) be under construction (i.e., construction-in-progress (C.I.P) element), or (d) be an already built element (i.e., B.AE). When the coordination with an AE that is either under construction (i.e., C.I.P) or built (i.e., B.AE) reveals inconsistencies or other element-to-element compatibility issues, a revisit of elements is to take place. This can result in a design change and/or a construction change. In all cases, the change is reflected through the release of a revised design deliverable showing the alternative design solution (ADS). This process ends with the registry of the changes that took place at $t=t_i$. Similarly, if coordination problems were encountered with an AE that is either under design or has been released for the builder, the designer needs to entertain ADS either for the element that is the subject of the release and/or for the AE, and the process ends with the registry of such a change or changes. On the other hand, if the coordination with all the associations of all the components of R_i pass without any problems being detected, the A/E can proceed with releasing R_i at $t=t_i$.

As for the design progression-mandated coordination (Figure 46), it is triggered by the need to either share and coordinate design updates or else communicate design changes. As such, it ends with either a registry of the changes encountered or – otherwise – with a documentation of the design updates. The documentation approach of the coordination outcomes is described in the following section.

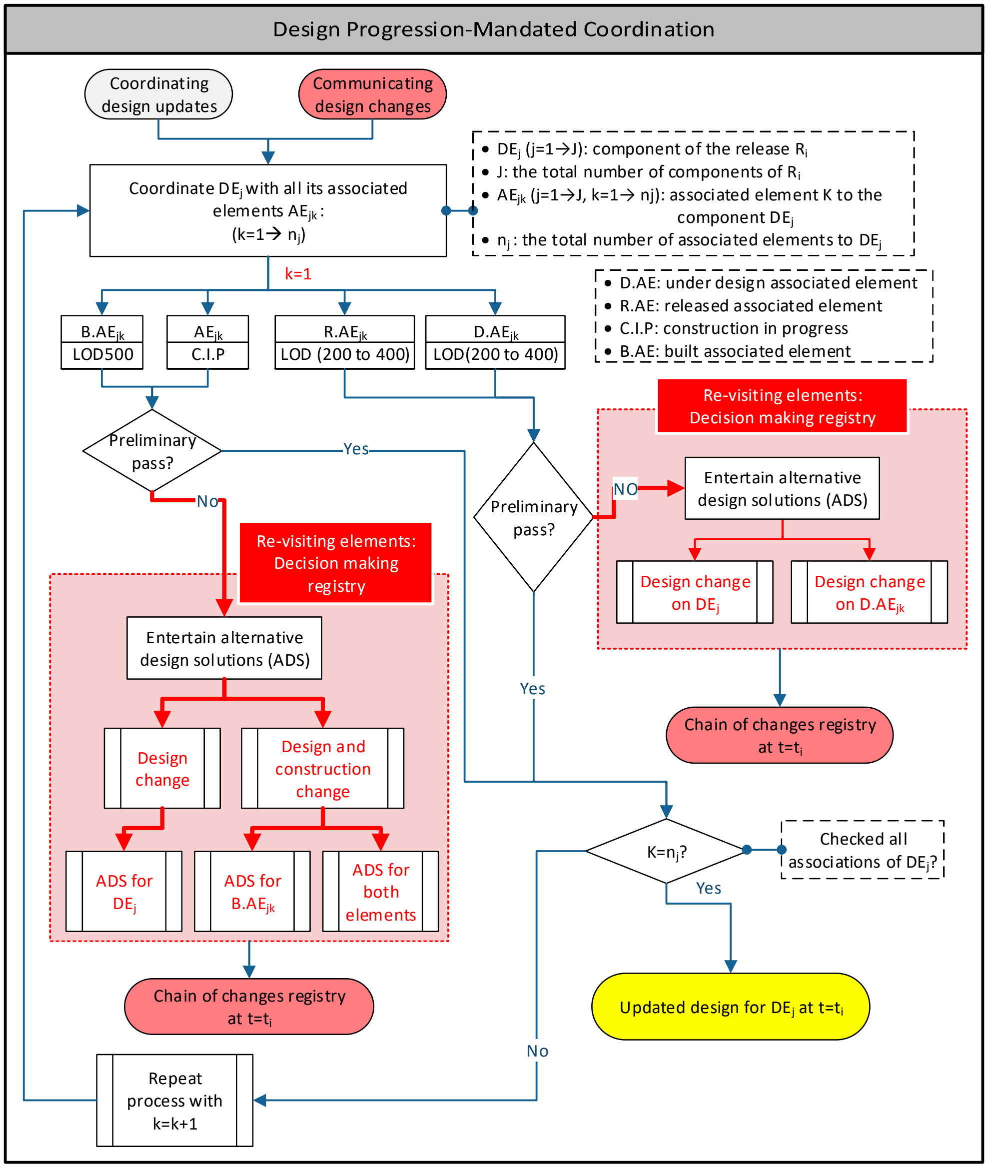


Figure 46. Flowchart illustrating the design progression-mandated coordination process

9.4 BIM-Enabled Dynamic Dashboard Development

The previously illustrated coordination processes may result in identifying the changes (or the chain of changes), updating the status of MEs, or authorizing the release of design deliverables. This section elaborates on the development of an information display tool that visually documents the time-based coordination outcomes. First, the ME parameters that are needed for a proper documentation of the changes are defined in Table 14. These parameters are stored in the BIM model and can be extracted at any time for further analysis. Two types of parameters are included: (a) the built-in parameters which correspond to the geometry, position, and specifications of each ME and (b) the user-defined parameters. The latter type includes the LOD, the design model element author (DMEA) and the construction model element author (CMEA). As for the LOD parameter, and in addition to the six levels (i.e., LOD100, 200, 300, 350, 400 and 500) that are typically adopted, the A/E subcontractor can agree with the design-builder on specific additional LOD levels for further designating any needed progression stage(s). For instance, an LOD 450 can be agreed on as reflecting a C.I.P status. The DMEA and CMEA refer to the design and construction responsibilities, respectively. Namely, a specific ME can be within the design responsibilities of the lead A/E subcontractor and the construction responsibilities of any of the design-builder's specialty subcontractors.

That said, when the A/E proceeds with the release of design deliverables, Figure 47 illustrates the BIM-enabled registry of the status of DEs and of their associations. The process starts with the release of R_i at t_i. Given the maintained database of ME attributes (Table 14), it is possible to extract the current LOD of each component DE_j of the release R_i as well as the LOD of each AE_{jk}. After checking all the components DE_j of the release R_i, and registering their corresponding LOD status, the dashboard can be updated accordingly, as illustrated in Figure 48. The dashboard is used as an information display tool for the design-builder, allowing him to simultaneously track the design and construction progress with respect to the status of different releases and of their associations. Six indicative different circular shapes are used to signal six different types/statuses of MEs: design element, associated element, released element, changed element, construction-in-progress element, or built element. Note that in a real-world application the corresponding LOD for each ME will be used; and, therefore the dashboard looks more like a matrix of the design and construction status updates. For instance, at time t_0 all MEs appear as DEs. When the first DE is released at t_1, the release-imposed coordination inherent to this release allows for updating and registering the statuses of the various AEs. While at any time t_i the release R_i can include one or more DE_j, it is considered – for simplicity purposes – that only one DE is released at a time, as depicted in this indicative representation of the dashboard.

Table 14. Model element parameters stored in a BIM database

Type	Parameter	Attribute/Example
Built-in parameter	Geometry	Shape
		Dimension
	Position	Coordinates
		Orientation
	Specifications	Material
		Properties
User-defined parameter	Level of Development (LOD)	LOD100
		LOD200
		LOD300
		LOD350
		LOD400
		LODxxx
		LOD450 (e.g., construction in progress)
		LOD500
	Design Model Element Author (DMEA)	Lead Architect/Engineer (A/E) subcontractor
		A/E's 1st tier subconsultant(s)
		A/E's 2nd tier subconsultant(s)
		—
		A/E's nth tier subconsultant(s)
	Construction Model Element Author (CMEA)	Design-builder
		Design-builder's 1st tier subcontractor(s)
		Design-builder's 2nd tier subcontractor(s)
		—
		Design-builder's nth tier subcontractor(s)

On the same row across from a specific time t_i, the dashboard displays the updated status of all MEs at that time. Each column in the dashboard allows the dynamic registry of the updated status of a specific ME at every time t_i. Moreover, several scenarios for the tracking of changes is displayed. For instance, a closer look at the row of the corresponding time t_{11} reveals the identity of the element subject of the change (DE_y), along with the elements impacted by that change. On the other hand, the dashboard at time t_{13} informs the builder that the element released at t_{13} caused changes to other elements, three of which were still under design and one was under construction. While the designed dashboard visually displays the emergence and the propagation of changes, it needs to be integrated within a comprehensive framework to control their impacts. The development of this monitoring and control tool is discussed in greater detail in the following section.

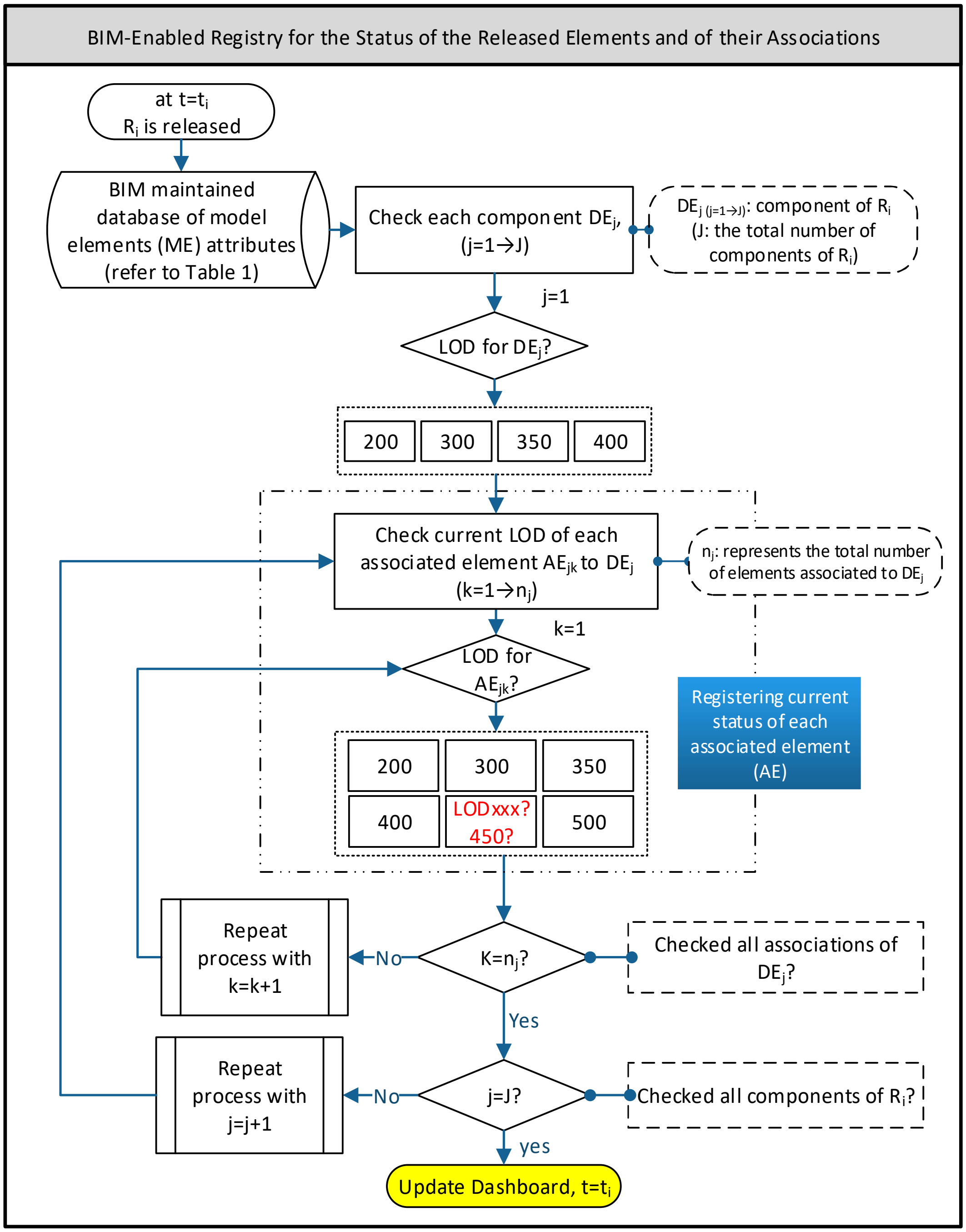


Figure 47. BIM-enabled process for registering the association matrix of each release

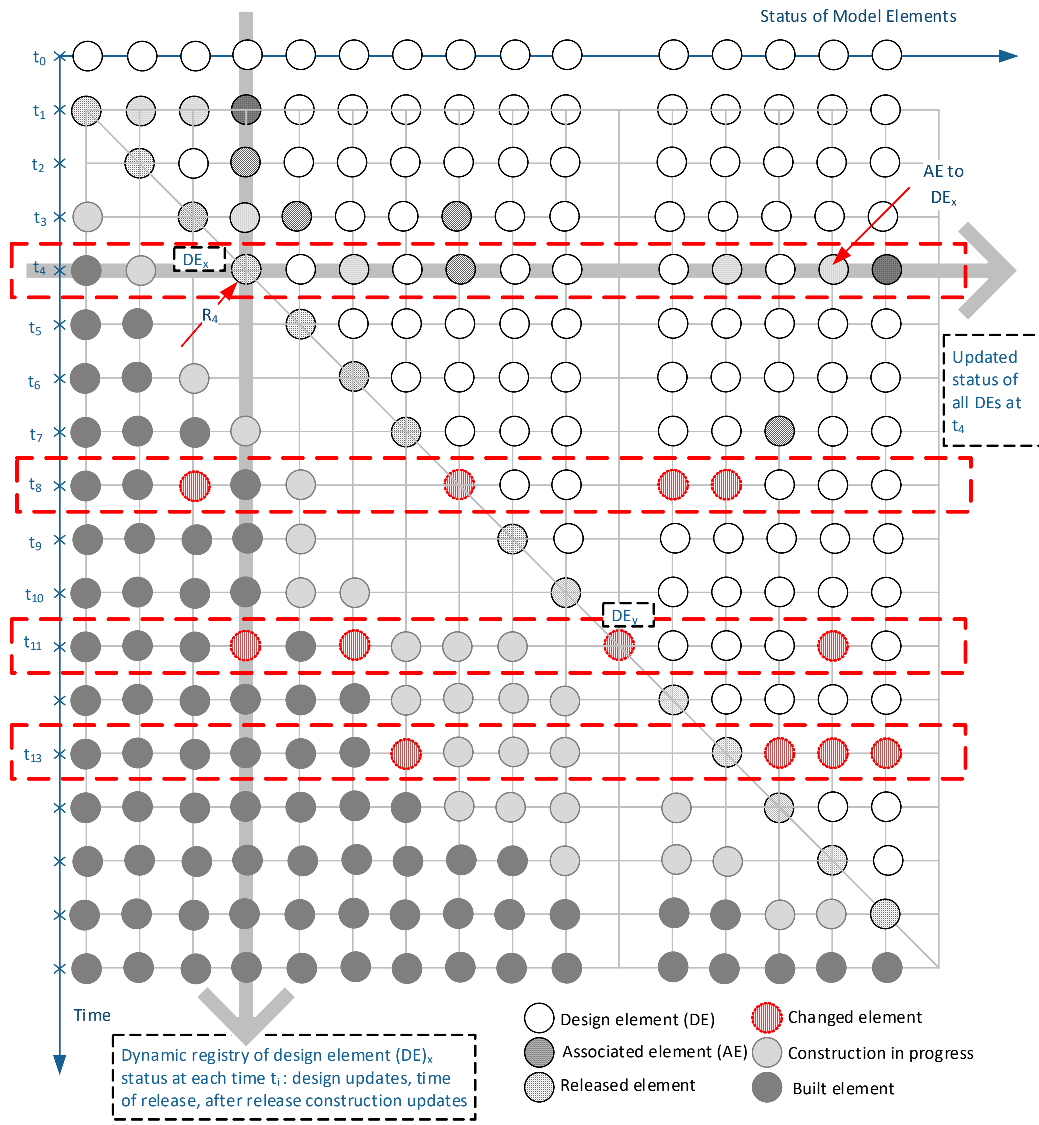


Figure 48. Dashboard representation

9.5 BIM-Enabled Streaming of Changes and Potential Claims

This section introduces a BIM-enabled framework that has been devised for allowing the timely identification of changes and their potential emergence into claims. The framework is a synthesis of the previously discussed steps and is divided into two parts that are illustrated in Figure 49 and Figure 50. At a high level, the framework presents a BIM-enabled workflow that starts with integrating the coordination processes within BIM through a Revit Plugin or Add-on and then documents the coordination outcomes on the designed dashboard (Figure 49). Besides, when design changes surface, the framework in Figure 50 aids design-builders proactively track their potentially induced claims through identifying the responsibility matrix of the chain of impacted elements. Finally, the framework serves the documentation of the changes and of the respective impacts in a BIM-maintained database of changes.

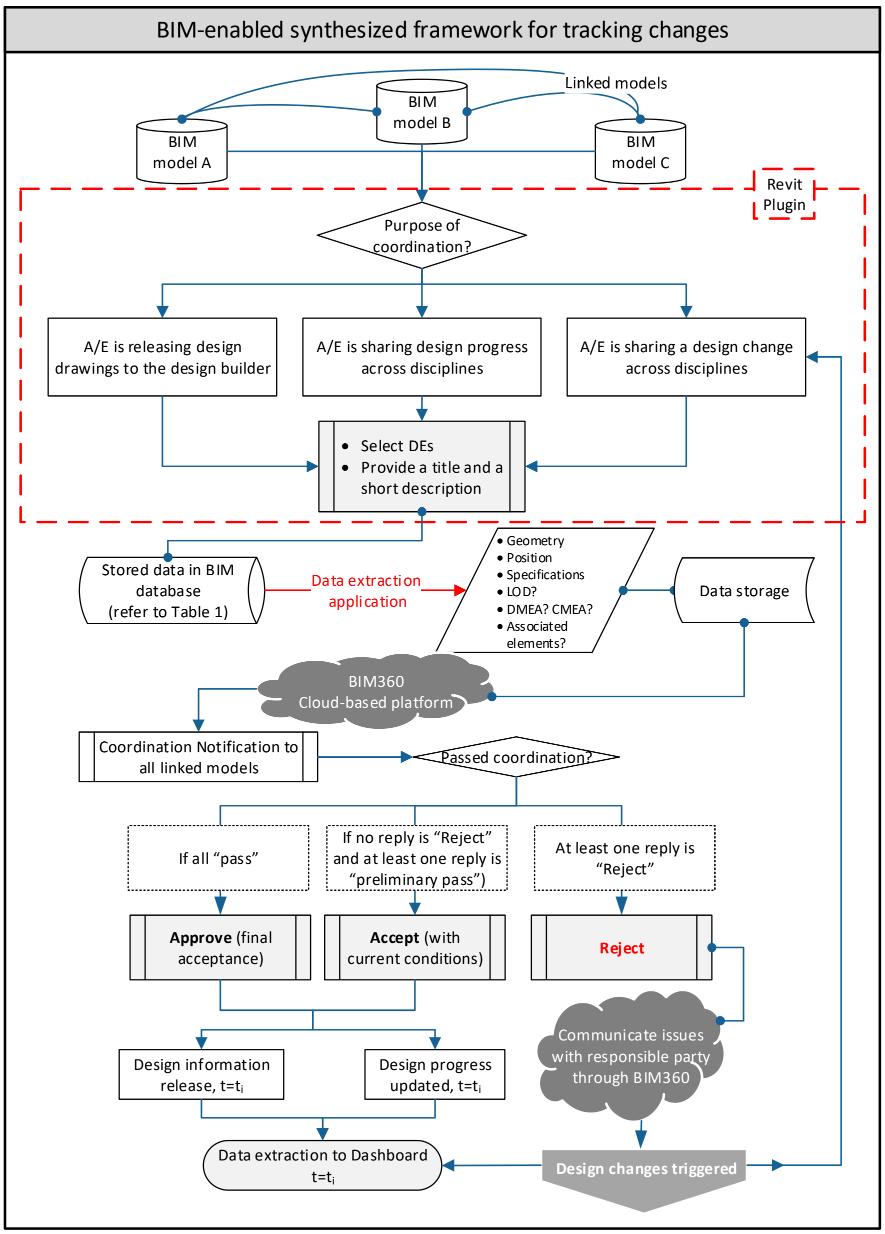


Figure 49. BIM-enabled framework for tracking design changes

Starting with the framework for tracking changes (Figure 49), three indicative BIM models A, B, and C − referring to three different disciplines − are displayed. Each discipline may initiate the coordination process whether for the purpose of releasing design deliverables to the design-builder, sharing design progress, or sharing a design revision across the concerned disciplines. Owing to the BIM-maintained database of ME parameters in Table 14, a data extraction application allows the extraction of these parameters into a specific data storage file (e.g., an excel file) for further analysis. Then, through the BIM360 Software, which is a cloud-based workspace, a coordination notification is sent to all linked models. If all notified models agree on the DEs subject of coordination, an "Approve" or "Accept" is issued and the dashboard is updated accordingly.

Alternatively, when at least one linked model rejects the ME updates, the subject of coordination, design changes are generated. This prompts the reader to the second part of the framework, illustrated in Figure 50, which should be read in conjunction with the database of changes illustrated in Table 15. Namely, the framework starts with the emergence of design changes, whereby for each changed DE, the attributes of the initial design solution (IDS) of the original DE along with the alternative design solution (ADS) reflecting the change made with respect to that element are displayed. These attributes correspond to the list of ME parameters previously defined in Table 14 along with the type of change (see Table 15). The same data attributes need to be extracted for the associated elements impacted by the change. The affected associations may result in one or more affected elements from the direct 1st-tier associations (referred to as 1st-tier transversal propagation of changes) and/or from longitudinal chains of impacted elements. The ADS is then evaluated by assessing the direct and indirect impacts that it may have on the affected party(ies). Namely, the direct impact of the change may include abortive and/or additional design and/or construction work. As for the indirect impact, it consists of a list of design quality attributes in order to document if any compromise is being made vis-à-vis the design quality inherent to the adopted ADS (as compared to that of the initial design solution) and also registers the workmanship quality of the constructed changed element (Table 15). Finally, when a change takes place, the action taken by the affected entity is also registered.

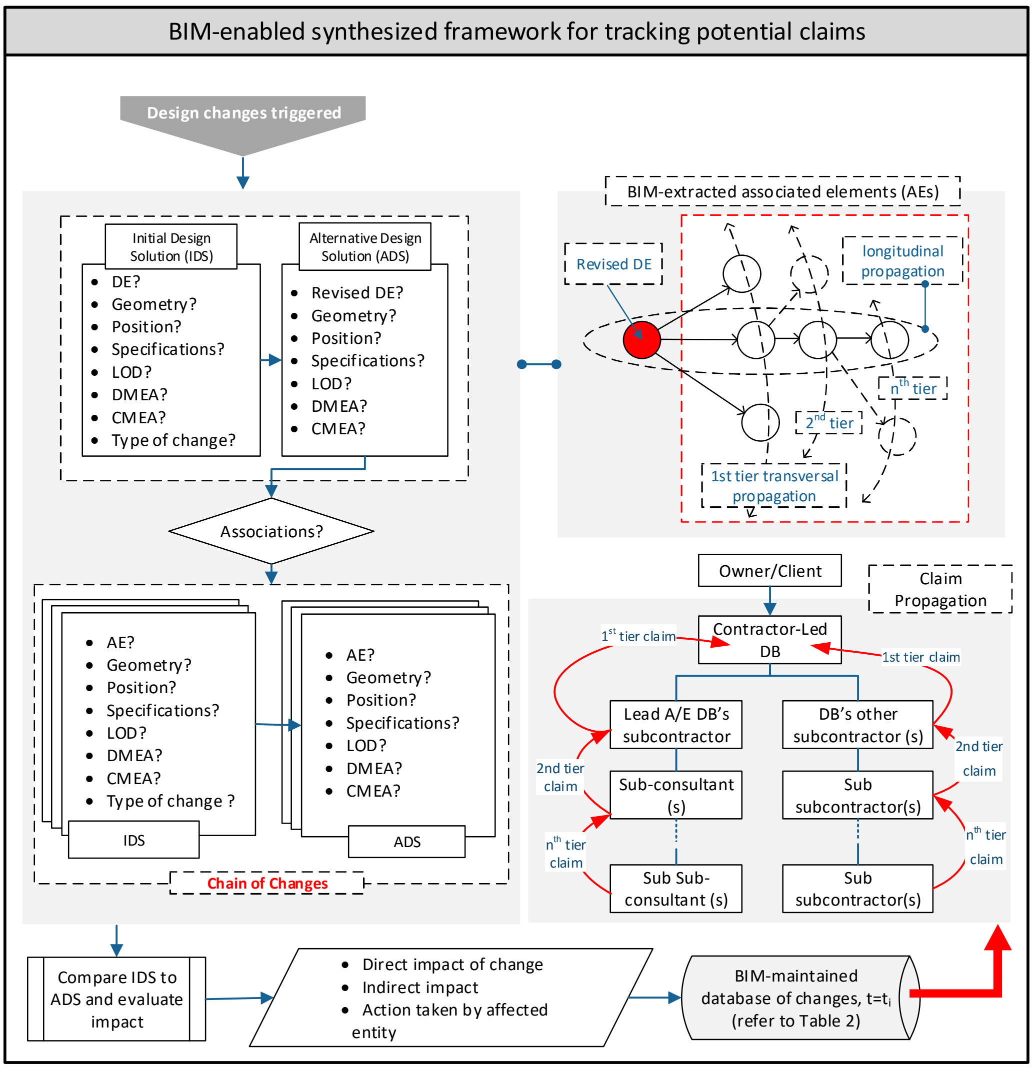


Figure 50. BIM-enabled framework for monitoring and controlling the impact of design changes

While the act of absorbing a change or otherwise claiming its impact is well contingent on the resiliency of the party concerned with the change implementation, the worthiness of the proposed tool resides in allowing the design-builder to proactively assess and plan for the potentiality of claims to emerge from the streamed changes. Namely, this BIM-enabled changes streaming tool lays down the foundation for better understanding or mapping how changes may eventually propagate into claims.

On the one hand, knowing the tier level(s) of the affected entity(ies), within the multi-tiered network of subcontractors and sub-subcontractors, allows the assessment of the likelihood of an upward propagation of an expected claim to ultimately reach the design-builder entity. On the other hand, the farther the tier of the affected participant is from that of the design-builder, the higher the aggregate value (reflecting the inherent compounding of incurred indirect expenses or losses) of a claim can be expected to be. This is assuming weak resiliencies for absorbing the impacts of the streamed changes on the part of the implicated lower-tier participants. Moreover, the systematic registry of such subcontractors' pursuits of claims can be of value to the design-builder when making subcontractors' selection decisions on future projects.

Table 15. Database of Changes

Data	Attribute
Type of change	Addition (Creating a new element)
	Deletion (Deleting an existing element)
	Modification (Modification in geometry, position, or specification of an existing element)
Affected associated elements	1st tier elements (direct associations)
	2nd tier elements
	—
	nth tier elements
Direct impact of change	Abortive design work
	Additional design work
	Abortive construction work
	Additional construction work
Indirect impact with respect to design quality of alternative design solution (ADS)*	Life-cycle cost: ADS *considers whole life-cycle cost issues*
	Material efficiency: ADS ensures an *efficient use of materials*
	Economy: ADS is *cost effective*
	Relevancy/ Client's objectives: *ADS meets project requirements*
	Constructability: ADS *considers constructability and safety aspects*
	Innovation: ADS *incorporates innovation*
	Expressiveness: ADS *provides symbolic expression and feeling*
	Aesthetics: ADS *reflects a visually pleasing finished product*
	Sustainability: ADS *considers the ecological sustainability*
	Site compatibility: ADS *effectively uses and makes due allowance for site conditions*
	Material selection: ADS *considers the availability, suitability and compatibility of materials*
	Functionality: ADS *effectively serves the purpose for which it was intended*
Indirect impact with respect to construction quality of ADS	Workmanship of constructed element
Action taken by affected entity	Absorb impact
	Claim impact

* Design quality attributes are adapted from (Andi and Minato 2003)

9.6 Practical Viability of the Proposed Framework:

Current BIM tools offer a limited support in automatically detecting design and/or construction changes and coordinating those changes across the concerned disciplines. Therefore, besides the other steps followed as part of the research design, the author sought guidance from BIM coordinators with respect to the BIM-based workflow employed in four of the top engineering and construction firms in the MENA region. Such guidance aimed at assessing the current BIM capabilities, on the one hand, and the viability of practically imparting further custom-made capabilities into the BIM platform, on the other hand. The received input was instrumental along several fronts, particularly in clearing the matter of effectively incorporating the mechanics of the proposed changes streaming tool into the BIM platform. Namely, the built-in types of associations were highlighted along with the types of associations that rather need to be defined by the user through the incorporation of appropriate design rules. Moreover, the ME parameters that are needed for a proper documentation of the changes were defined. Consequently, the two flowchart diagrams illustrating the inferred BIM-compatible coordination processes that need to be implemented in fast-track DB projects were then formulated. The visualization of these coordination processes was instrumental in articulating the concept underlying the development of a Revit plugin or add-on that aims at validating the implementation of the proposed framework. The detailed description of the developed plugin is presented in the following sections.

9.6.1 *Plugin overall description*

The developed plugin is named DB-CTS (DB change tracking system) and includes three modules: *Label ME, Tracker, and Extractor* (Figure 51). The *Tracker* module allows the registry of design and construction updates through the *Update* command, thereby allowing the automatic registry of the previously defined ME parameters in Table 14 (it should be emphasized here that these parameters consist of design-related data, e.g., LOD, and management-related data, e.g., the corresponding DMEA or CMEA) and maintaining it in the BIM model. As for the *Respond* command, it allows the tracking of changes and/or chain of changes by registering the previously defined data in Table 15 and maintaining it in an external database of changes that can be later extracted for further analysis from the *Extractor* module. Namely, the *Extractor* module allows the automatic extraction of the database of change through the *Database* command, and the automatic display of the previously offered dashboard through the *Dashboard* command. The detailed description of these modules follows.

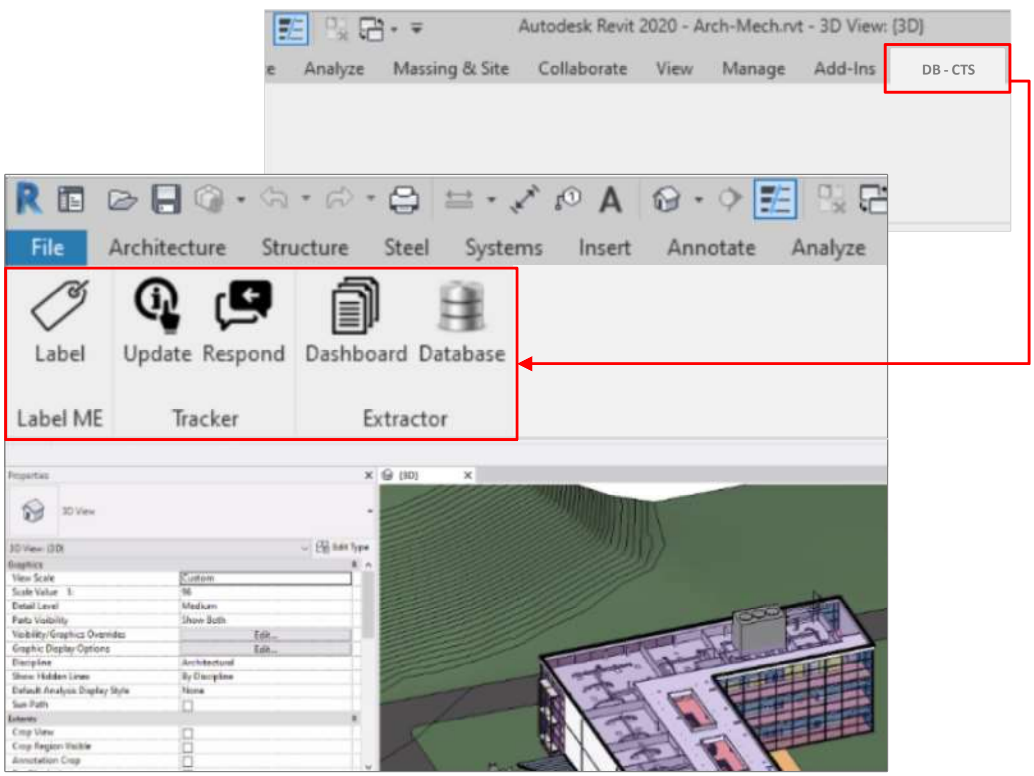


Figure 51. User interface screen for the "DB-CTS" plugin

9.6.2 ***Definition of packages***

In this developed change tracking system, elements are defined at the smallest feasible scope level. This is due to the previously established possibility of a reduced scope level for the DIR under DC Mode 4 (i.e., in the findings of module 1). Namely, the "Label ME" module of the plugin categorizes all model elements in a given project in the following hierarchy: starting from the (1) Floor Level and zooming into the (2) Room Level (within the same floor, different spaces or rooms are identified) to the (3) System Level (i.e., discipline-specific systems within each room); and finally to the specific (4) Package Level (which shall include the detailed building objects, such as walls, doors, windows, beams, columns, air terminals, ducts, etc.). The proposed building project hierarchy, as such, provides a unique description for each component in a building project as shown in Figure 52. This step, i.e., automatically providing each package with a unique code, is essential to allow the tracking of changes at the package level, with all the respective design-related and management-related data. This way, the concept is to create active components that store the time-based updates or changes that happen to their defined parameters so that the record of changes is effectively stored, as it is further explained in the following sections through a hypothetical scenario of a change.

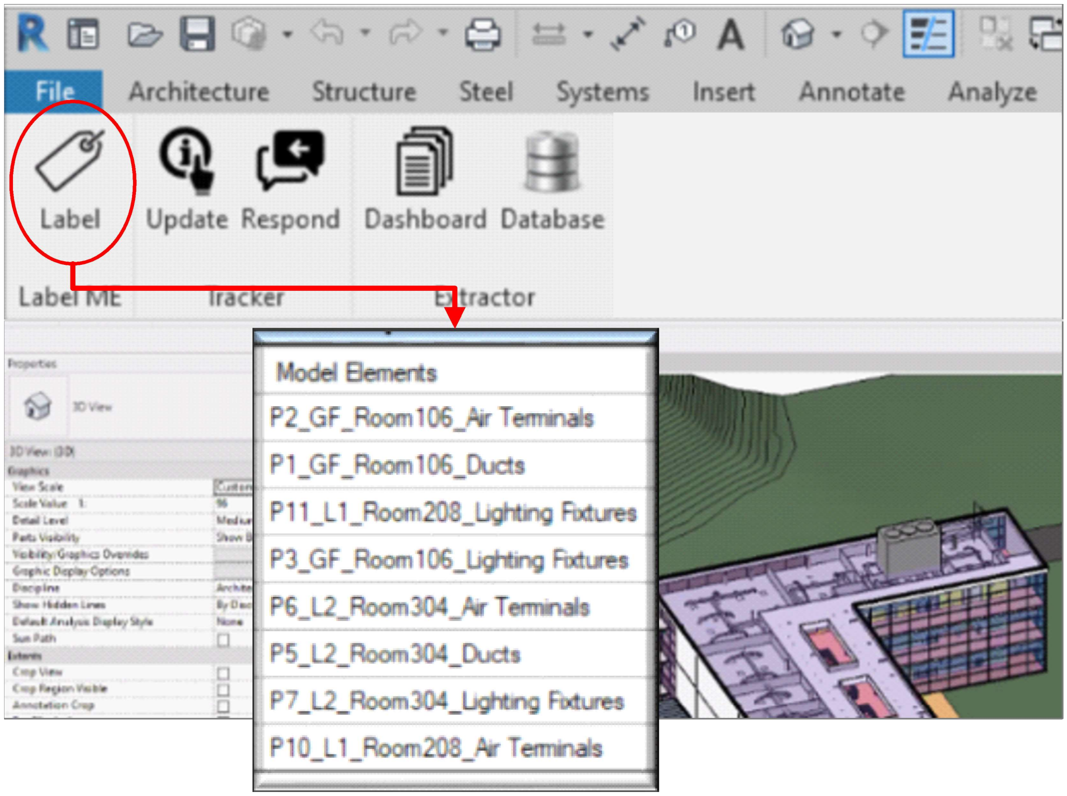


Figure 52. The "Label ME" module

As for the associations of ME, associations are defined as well at the package level. These associations include the built-in types as well as the user defined associations through specific design rules as previously discussed. Having all the associations defined, an association matrix of these packages is created. Such association matrix is fed into the model through the BIM manager, in order to build the communication paths across the concerned parties of each of the defined packages.

9.6.3 ***Hypothetical scenario***

The hypothetical scenario in Figure 53 shows the propagation of a change in package P3. This example shows that a change in P3 caused a change in P5 and P7. Then, the change in P7 caused a change in P11 and P10, which by itself caused a change to P2 (as tracked though the solid line arrow). Moreover, given the defined DMEA and CMEA of each package, the dotted arrow indicates a potential claim propagation with respect to the suffered change. Following are the steps that need to be followed in order to track such a change propagation scenario through the developed plugin.

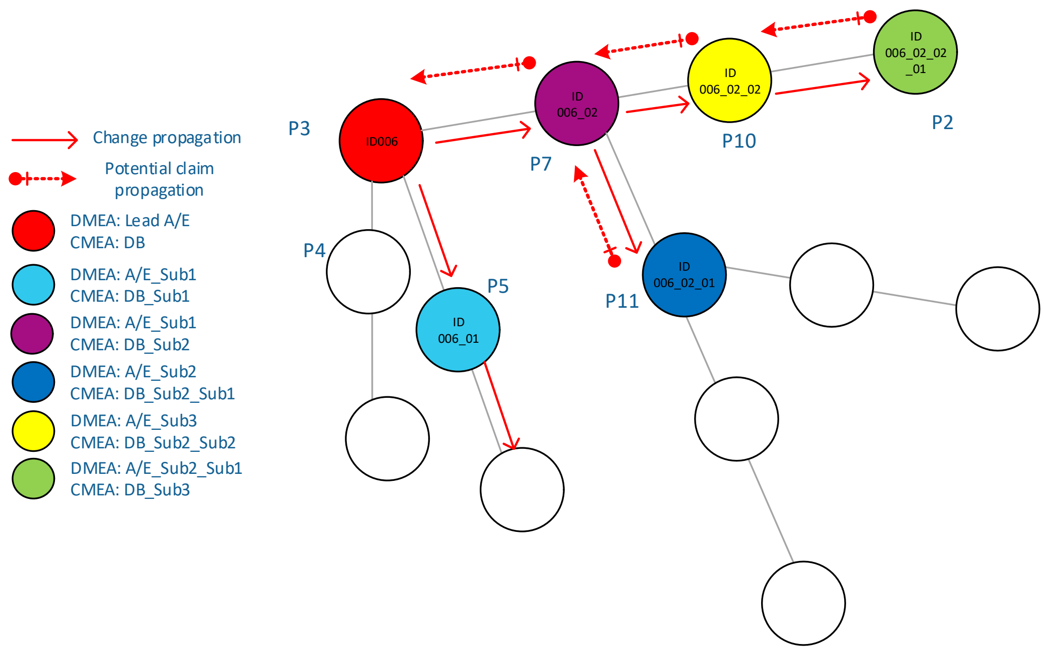


Figure 53. Proposed scenario for the tracked chain of changes

9.6.4 ***Data feeding technique through the "Tracker" module of the developed plugin***

The change happening to package P3 is first recorded through the *Update* command of the *Tracker* module as shown in Figure 54. When clicking on this command, the user interface displays a corresponding Ticket ID for this specific update made (e.g., ID006). Through this interface the design manager selects the package in question and indicates that the updated status is "changed". Note that, the previously defined parameters (which are fed in a similar data feeding technique through this command) appear in their latest updated data.

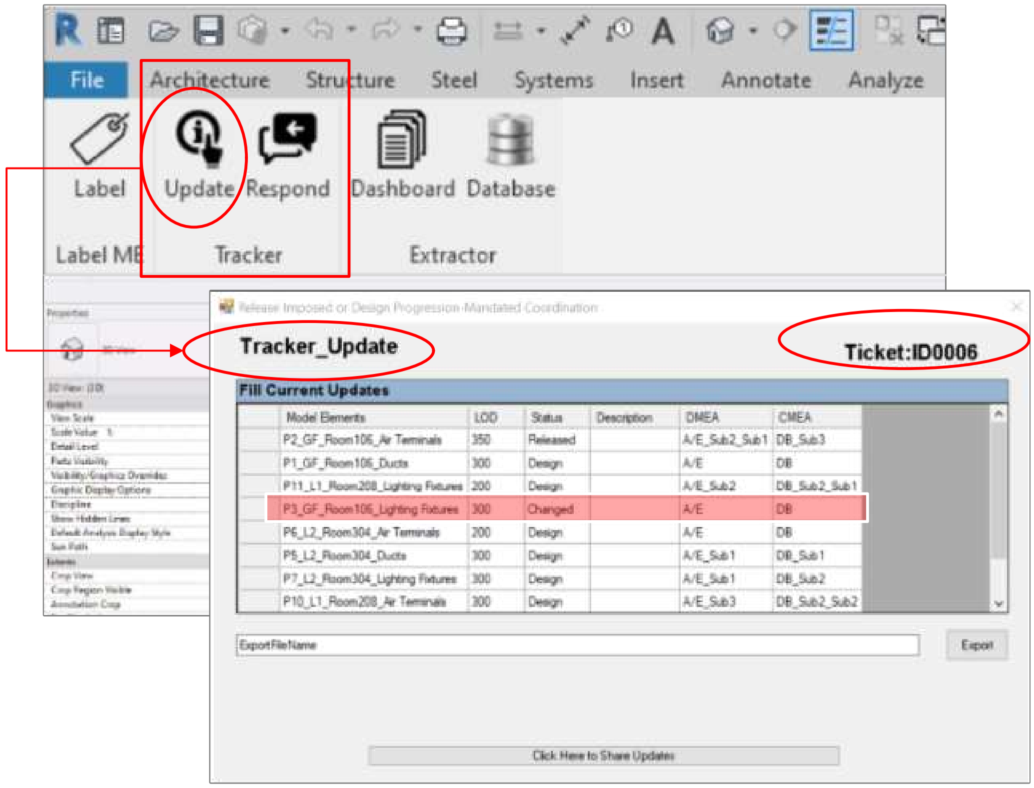


Figure 54. User interface screen for the "Update" command of the "Tracker" module

Now, a change impacted by the change in P3, needs to record the suffered design and/or construction change through the *Respond* command. This command prompts the user to answer several questions before feeding the specific change impact. Namely, the user is asked first to identify the Ticket ID he/she is responding to, and whether the data entry is with respect to a design or a construction change (see Figure 55). As shown in this example, the user selects ID006, and specifies that the change in question is a design change.

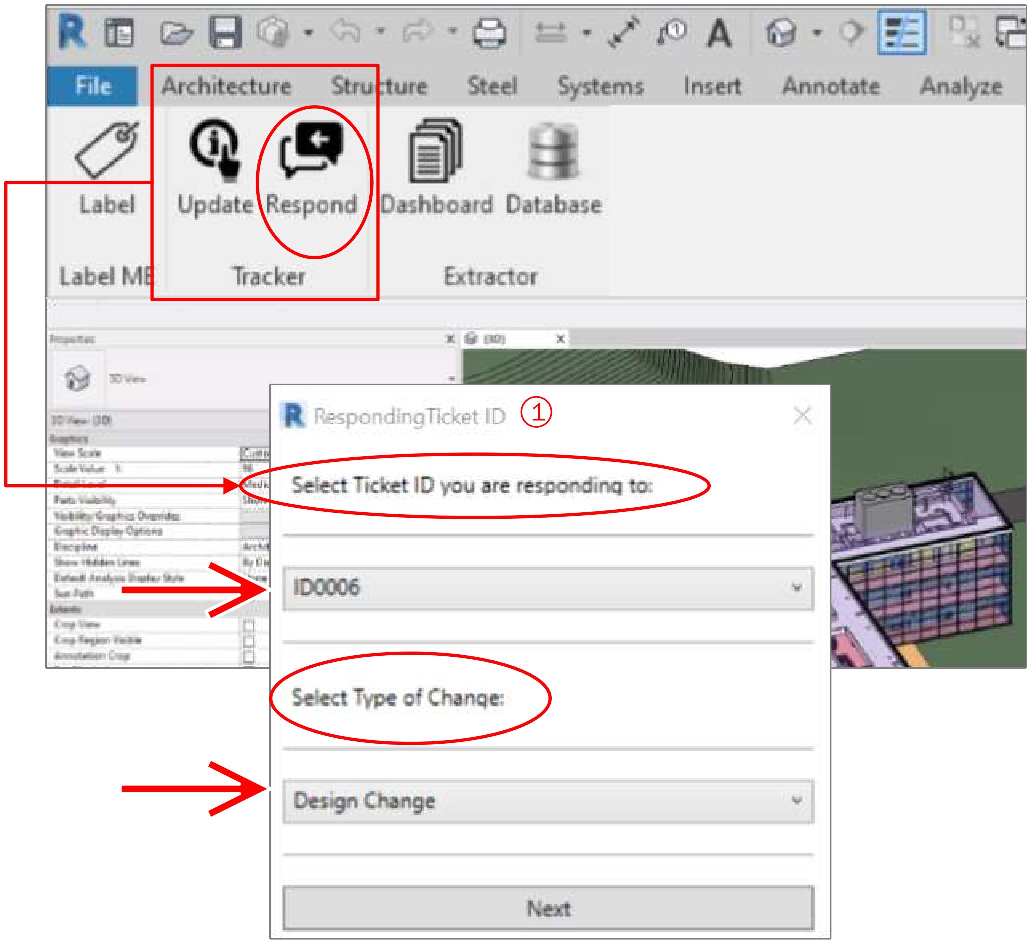


Figure 55. User interface screen for the "Respond" command of the "Tracker" module (step 1)

Then, the user is prompted to select the affected package subject of the suffered change. As shown in Figure 56, the user selects package P5. Then, the 3rd step is to fill the corresponding data in the user interface as it appears in Figure 57. Note that the automatically generated Ticket ID is a sub-ID of the originally selected ID006. The rationale underlying the creation of this ID and sub-ID ticket numbering concept is the need for a reliable record of the chain of changes. The rest of the changes illustrated in the hypothetical scenario of Figure 53 are fed into the model following a similar approach.

For instance, Figure 58 and Figure 59 show the data entry corresponding to a construction change in P2 located at a lower tier in the change of changes.

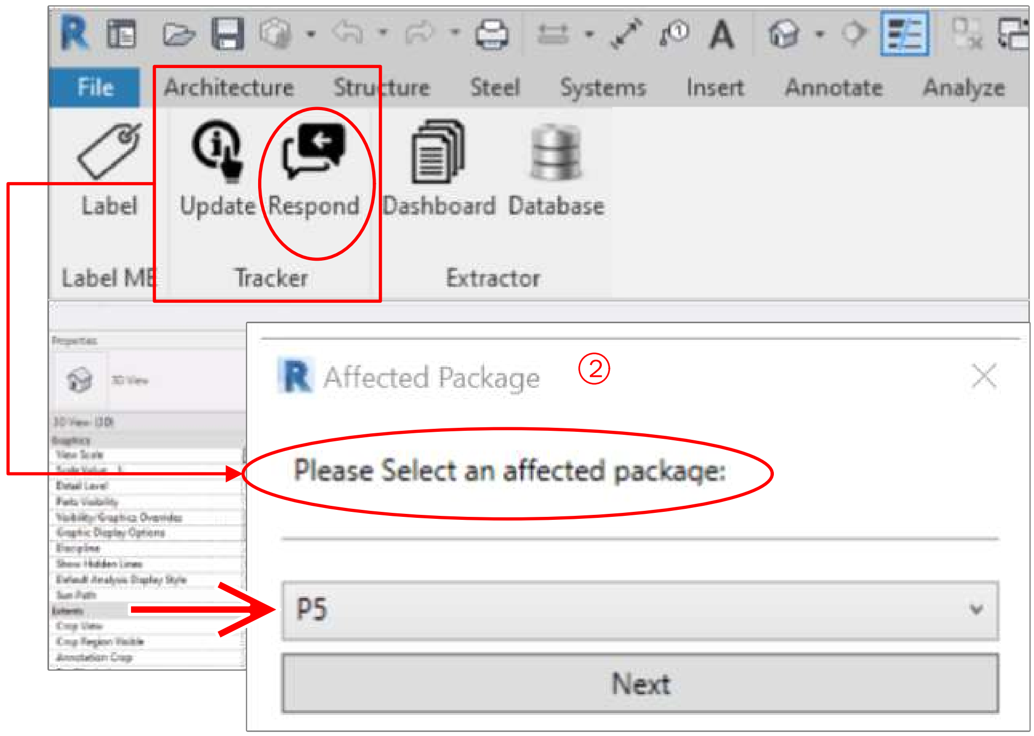


Figure 56. User interface screen for the "Respond" command of the "Tracker" module (step 2)

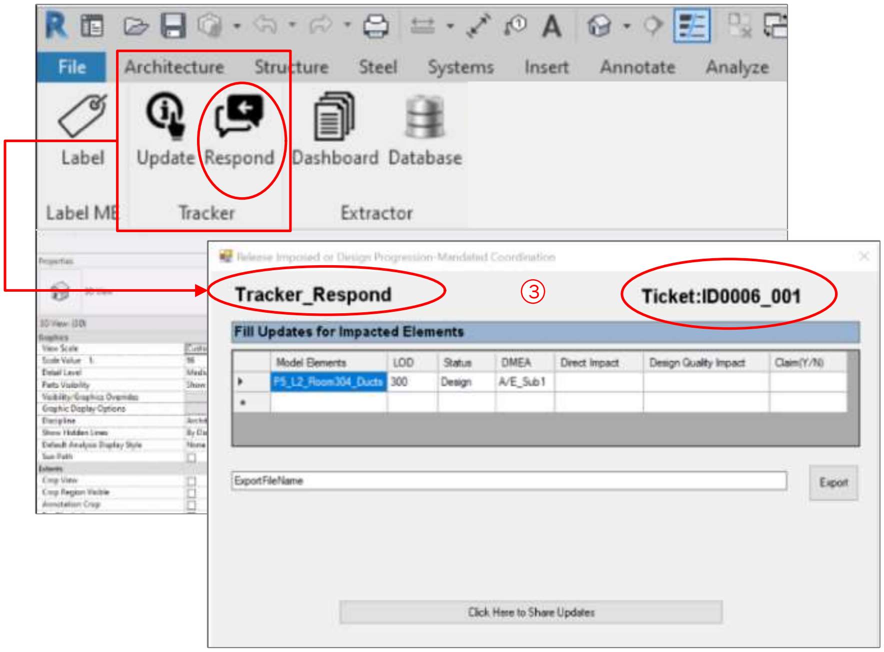


Figure 57. User interface screen for the "Respond" command of the "Tracker" module (step 3)

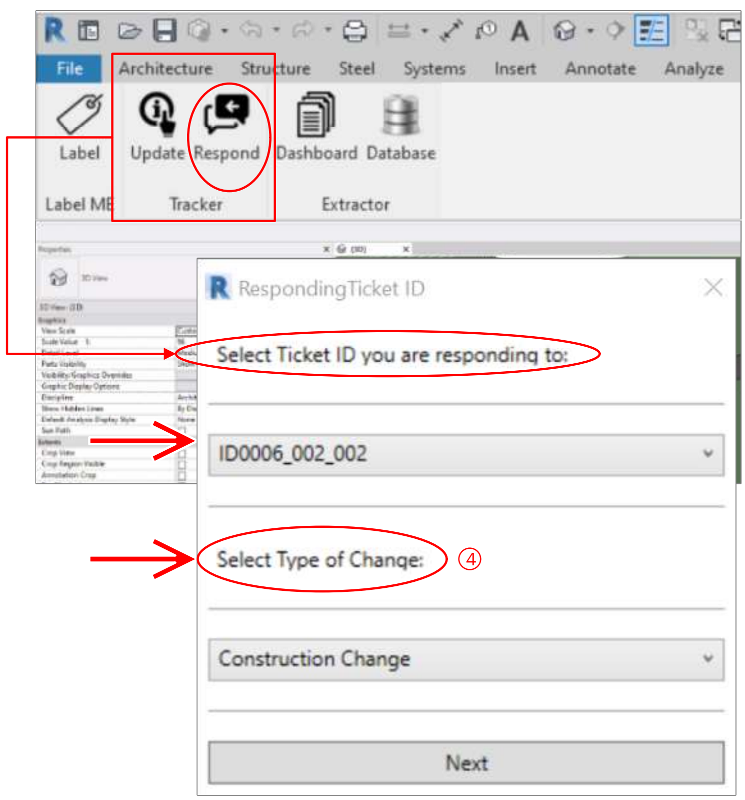


Figure 58. User interface screen for the "Respond" command of the "Tracker" module (step 4)

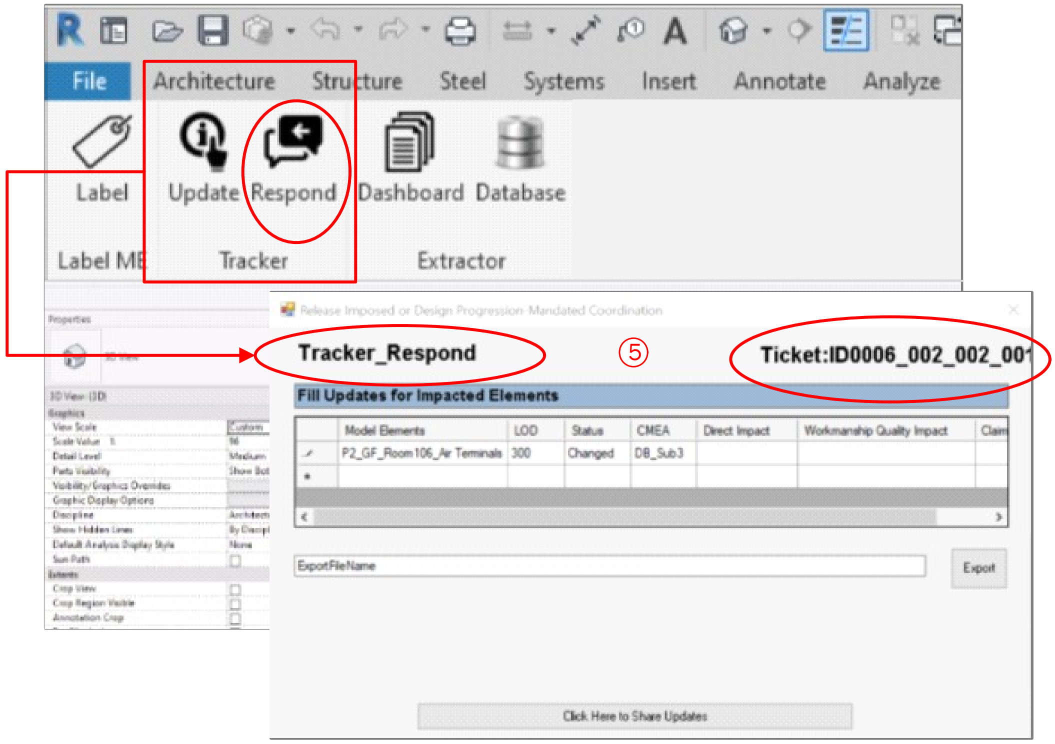
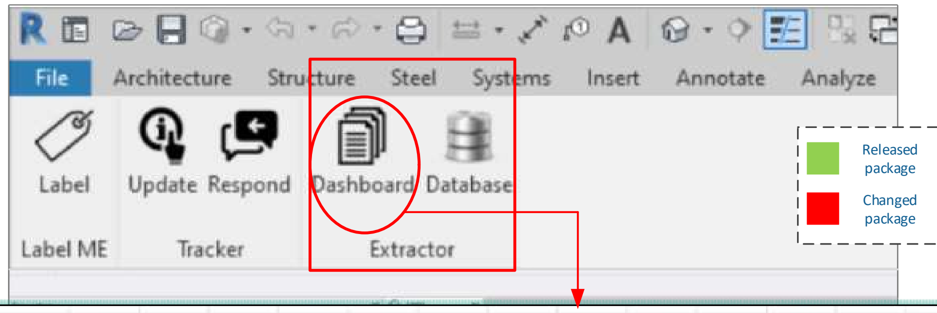


Figure 59. User interface screen for the "Respond" command of the "Tracker" module (step 5)

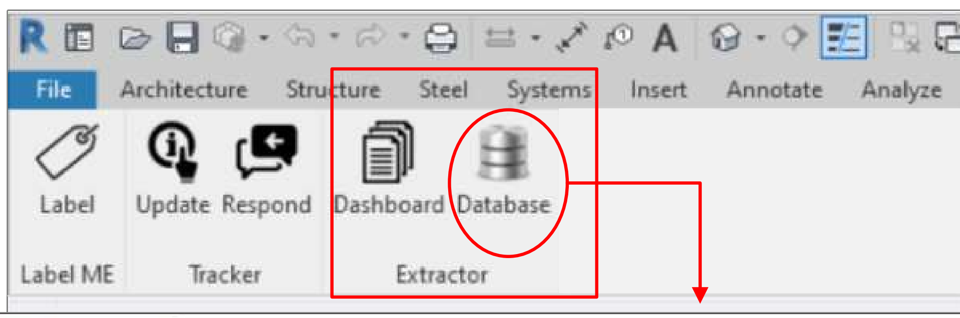
9.6.5 ***Data retrieval through the "Extractor" module of the developed plugin***

When it comes to the retrieval of data, the *Extractor* module allows the automatic display of the offered dashboard through the *Dashboard* command (Figure 60) and the automatic extraction of the database of change through the *Database* command (Figure 61).



	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
	200	200	200	200	200	200	200	200	200	200	200	200	200
ID001	300	200	200	200	200	300	200	200	200	200	200	200	200
ID002	350	300	200	200	200	450	200	200	200	200	200	200	300
ID003	350	300	200	200	200	450	200	300	200	200	200	200	300
ID004	400	350	200	450	200	450	300	350	200	300	200	200	350
ID005	450	350	200	450	300	500	300	350	200	300	200	200	400
ID006	450	350	300	500	300	500	300	350	300	300	200	200	450
ID006_01	450	350	300	500	300	500	300	350	300	300	200	200	450
ID006_02	500	350	300	500	300	500	300	350	300	300	200	200	450
ID006_02_01	500	350	300	500	300	500	300	350	300	300	200	200	450
ID006_02_02	500	350	300	500	300	500	300	350	300	300	200	200	450
ID006_02_02_01	500	300	300	500	300	500	300	350	300	200	200	200	450

Figure 60. The extracted dashboard from the "Extractor" module



Initiating Changes	Chain of changes										
Ticket ID	Sub Tickets IDs	Date	Package	Pre-change state		DMEA	CMEA	Description	Direct Impact	Claim (Y/N)	Indirect Impact
				LOD	Status						
ID006			P3	200	design	A/E	DB				
	ID006_01		P5	300	design	A/E_sub1					
	ID006_02		P7	300	design		DB_sub2				
	ID006_02_01		P11	200	design		DB_sub2_sub1				
	ID006_02_02		P10	300	design		DB_sub2_sub2				
	ID006_02_02_01		P2	350	released		DB_sub3				

Figure 61. Template of the database extracted from the "Extractor" module

CHAPTER 10

CONCLUSIONS, CONTRIBUTIONS, AND FUTURE WORKS

10.1 Preamble

This chapter summarizes the main objectives and key findings of this dissertation in addition to the research limitations and the prospective future works.

10.2 Summary and Conclusions

This research work investigates the impact of alternative DC modes under APDMs on the release of design deliverables and the respective implications on the Architect/Engineer's role and liabilities on the one hand, and the design-builder's time and budget performance on the other hand. This is mainly achieved by conceptualizing the possible alternative design information release (DIR) dynamics under alternative design-construction (DC) modes, and then benchmarking these dynamics against the well-established release of design deliverables under the sequential DC mode of the DBB method, which is covered in the first module. Then, this study examines the implications of these alternative dynamics on the A/E's needed resources staffing and liability exposure and indemnity, which are covered in module 2 and 3, respectively. Finally, given the increased uncertainties and challenges associated with the undertaking of the design phase in fast-track contractor-led DB projects and the inevitable emergence of changes that may bring about detrimental impacts on project performance, the last objective of this research work is to devise a tool that helps design-builders tracking those changes to serve the control of their impacts, which is covered in module 4.

To summarize, this study starts with the argument that various DC modes may exist depending on the characteristics of each delivery method, with each entailing different design phase properties and, respectively, different DIR dynamics. To this end, three alternative DC modes corresponding to the CMa, the CMAR, and the DB method were identified, and the possible alternative DIR dynamics were conceptualized under each. It was inferred that delivering construction projects using the sequential DC Mode 1 of the DBB delivery method can be said to afford a compatible coordination for the various design elements due to the one-time packaging of design deliverables, thereby allowing a full coordination at the project level to be performed. By benchmarking against DC Mode 1, alternative DC modes were found to potentially lead to less certainty as to the scope, timing, frequency, and coordination quality of their associated releases of design deliverables. This uncertainty mainly emanates from starting construction activities with partially completed design and having design activities potentially driven by the builder's schedule and related priorities. Moreover, it is concluded that more uncertainty may prevail when the A/E ends up rendering the contracted deliverables as a design subcontractor, in DC Mode 4. As such, it was possible to infer that the potential advantages of schedule compression – when opting for alternative DC modes − may contribute to causing a compromise in respect of the quality of released design documentation, thereby increasing the likelihood of such deliverables to be prone to being in error. Namely, the risk emanates from the uncertainty associated with the release of deliverables at any of the displayed levels of incompatible coordination, as illustrated in the conceptualized DIR constructs. However, the several possible alternative dynamics of the DIR under alternative DC modes, influence the possible number of design packages that may be released at each of the identified levels.

Then, the second module focuses on examining the implications of alternative DIR dynamics on the design agreement negotiation and formation process. This is mainly achieved by (a) conceptualizing the models pertaining to the A/E's staging of services under each of the considered PDMs, (b) identifying the parameters/factors that the A/E needs to deal with in order to realistically strategize and organize for its involvement/engagement throughout the project, (c) inferring the expected changes in the staffing requirements, and then (d) establishing the foundation for negotiating the agreement for design and construction supervision services. Namely, in negotiating the design agreement, A/E professionals aim at ensuring themselves with what is good enough to self-finance the job. The DBB method affords A/E professionals with a high degree of control over the relevant pre-set milestones. Therefore, this method leads to an increased certainty as to the predetermined lengths of the A/E's involvement, to such extent that these periods can be regarded as being relatively fixed. Negotiating the agreement for design and construction supervision services under such circumstances is well established in practice. As such, contract clauses addressing the scope of services, fees and payment methods, and review periods, along with corresponding mechanisms for requesting extensions of time and additional compensation have been already standardized in many standard forms of agreements. This study, through shedding light on the several potential sources of uncertainties associated with the alternative delivery methods, established for the important implications pertaining to the staffing requirements and the corresponding basis of negotiation. These uncertainties are shown to be mainly stemming from the relatively indeterminate duration figures and the reduced level of the A/E's control over the numerous involved milestones. The offered analysis concludes with a means for facilitating the negotiation process, in light of the several unveiled parameters.

The third module focuses on examining the implications of alternative DIR dynamics on the A/E's liability exposure and indemnity. Namely, under the different PDMs design professionals may end up undertaking their design and other related services either as independent consultants appointed by owners or as subcontractors acting under design-builders. To this end, the third module of this study investigates the types and extents of the professional liabilities inherent in assuming either of these two contrasting capacities for rendering the contracted deliverables. This is mainly achieved by: (a) investigating the various types of professional liabilities and their associated indemnity coverages that can be procured by designers or contractors, (b) reviewing industry-reported cases involving designers being sued under tort law, and (c) developing the construct under which the involved liabilities may be encountered. It is concluded that the risks of the designer being sued under tort law, which have for long been realized to otherwise exist whenever contractors can prove the foreseeable harm resulting out of the negligence of owner-appointed designers, seem to continue to prevail when these designers act as design subcontractors under a design-build (DB) environment. This is also in relation to designers' negligence but now with pertinence to the duties that they are expected to instead owe to owners. The findings also revealed that such risks may be of different magnitudes and may have varying likelihoods of being encountered owing to the various DB operational variations. Namely, when negligence claims are asserted against A/E professionals due to incurred physical damages, the economic loss doctrine (ELD) does not apply, and courts therefore readily find liability. However, being a design subcontractor presents some implications on the liability exposure. For instance, with fast-track construction, the design-builder may significantly control the design process owing to the demands and priorities of the construction schedule. In addition, the DB approach creates the potential for the A/E to be involved in construction-related professional services. The greater the involvement of the A/E in construction means and methods - or safety-related designs the greater the exposure will be to bodily injury (BI) and property damage (PD) professional liability claims. Alternatively, when economic damage (ED) occurs, recovery in tort is subject to the applicability of the ELD. As such, and depending on what jurisdiction governs the case, tort remedies may well be available to third parties. However, liability exposure of the A/E professionals will differ depending on the assumed capacity (i.e., independent or design subcontractor) on a specific project. For instance, in the construct developed for the encountered liabilities in design-bid-build (DBB), it clearly appears that A/E professionals are exposed to tort liabilities in relation to their role as designers. Moreover, meddling with the engineer's contract administration role, or failing to act in good faith and with impartiality in their quasi-judicial role, seems to expose them to intentional tort liabilities. Moreover, the selected project delivery system (e.g., DB instead of DBB) has a direct impact on the type of professional liability insurance that may be needed by the various project members. As such, this study also investigated the available options to procure and administer PLI coverage under a multi-tiered DB approach. Regardless of the selected option, the design consultant can be held liable for issues adjudged to be pertaining to its rendered design services. To this end, the study concludes with a conceptualization on the impact of this persisting liability burden on the capability and willingness of the design consultant to deal with (or accept to abide by) a certain pattern or extent of design information release that is in satisfaction with the construction priorities or preferences imposed by a DB contractor.

Finally, the last module is dedicated to tracking the emergence of changes in DB projects. Design changes are commonly encountered in construction projects. However, in fast-track DB projects the design-construction overlap and the respective incompatibility of coordination between the released deliverables and their associated elements cause changes to become inevitable. To this end, this module is concerned with the tracking of such inevitably encountered changes on fast-track DB projects, whose impacts may affect the design-builder's own work and/or propagate to the work of lower-tier design and/or construction subcontractors, and the potential claims that may be induced by such impacts. Given that DB projects combine the design and construction phases under a single point of responsibility, the need for integrating design and construction information into a comprehensive pool of data becomes crucial. As such, this module starts with investigating the applicability, in terms of the usefulness and the degree of relevance, of BIM to DB projects. Then, a BIM-enabled change tracking system is developed for tracking changes and ultimately serving the control of their impact. This is achieved by first, modeling and comparing the design-construct phase in traditional design-bid-build (DBB) projects and in DB projects, both under a BIM environment. Then, this study offers a BIM-enabled workflow for tracking changes and potential claims induced by fast tracking DB projects, in order to guide design-builders manage those changes. Namely, two constructs mapping the coordination processes that need to be implemented for a timely identification of the changes and/or of the chain of changes have been conceptualized. The visualization of these coordination processes was instrumental in articulating the concept underlying the development of a Revit plugin or add-on that helps tracking those changes and to serve the purpose of controlling their impact. Namely, the plugin, developed with hands-on support from one of the consulted

BIM professionals, includes three modules: *Label ME, Tracker, and Extractor*. The *Tracker* module allows the registry of design and construction updates through the *Update* command, thereby allowing the automatic registry of the previously defined ME parameters that are defined and maintained in the BIM model. As for the *Respond* command, it allows the tracking of changes and/or chain of changes by registering the data previously defined and maintaining it in an external database of changes that can be later extracted for further analysis from the *Extractor* module. Namely, the *Extractor* module allows the automatic extraction of the database of change through the *Database* command, and the automatic display of the previously discussed dashboard through the *Dashboard* command. The offered dashboard allows the visual tracking of changes and of the design and construction schedule performance, (i.e., the as-planned versus actual progress).

10.3 Contributions and Recommendations

The contribution of this work lies in offering a novel study that starts with theorizing the impact of time-reduction related factors, under alternative design and construction modes, on the release of design deliverables, then examines the implications of such a hypothesized alternative dynamics. As such, by shedding light on the relevant criteria underlying the various uncertainties at the time of the agreement signature, this study examined the implications of the A/E's spectrum of engagement under APDMs on the respective design agreement negotiation and formation process. The offered analysis is viewed as a means for facilitating the negotiation process, in light of the several unveiled parameters. It also serves as an eye-opener for the A/E when planning and organizing for the assignment of resources required under each project delivery method and formulating the services' professional fees proposal. In other words, the work's contribution lies in offering a better understanding of these underlying uncertainties and helps in approaching the negotiation and formation of the A/E's services agreement in a more informed way under any of the discussed APDMs. Sensibly addressing the reasons that cause these uncertainties to emanate and the different periods of involvement to get extended and/or revised, through adopting appropriate mechanisms reflecting new paradigms, is therefore argued as critical to shielding A/E professionals from potentially detrimental implications.

Moreover, with the increasing complexity in construction projects and the amplified need for a higher level of integration between designers and contractors, whether under the DB approach or IPD, professional liability risks are considered to be among the most difficult to insure for. Given the limited capacity of the designer's practice policy and the increasing level of professional activities carried out by builders, early planning to manage those risks is therefore of paramount importance. While it could be argued that design services are protected by way of a combination of insurance coverages, a design professional working in a subordinate position is not likely to accept to blindly abide by the builder's imposed requirements given the potential negative impact on its reputation. The increasing popularity of opting for alternative project delivery methods makes it crucial for the different project participants to understand their roles and the interplay among their direct or inherent different relationships. While active participation in contract negotiations is critical to risk mitigation, favorable terms in the design agreement with the design-build contractor seem not to be effective in limiting owners' claims. The work also inferred that such risks may be of different magnitudes and may have varying likelihoods of being encountered, owing to the various DB operational variations.

While the deduced constructs mapping the A/E's liability exposure help in providing some insights as to the recovery of damages in tort pursuant to the different interpretations/observations of the exceptions to the ELD, construction professionals are advised to educate themselves on the law in the locality of the project. Understanding if the concerned jurisdiction (at the project locality) strictly applies the ELD and, as such, bars tort claims against A/E professionals for ED, or recognizes any exception to the rule, thus allowing such claims, is key to understanding and weighing the risks undertaken on any project. Failure to account for the different exceptions to the ELD will result in a failure to weigh the potential risks on a project. To conclude, in order to minimize the potential liability exposure, A/E professionals are advised not to compromise on design documentation quality, which is argued to be one important evidence in courts.

Moreover, given that in fast-track DB projects emergent changes are almost inevitable, the impact of such changes in a DB setting − where the performance of the design is under the responsibility of the design-builder – should not be overlooked. That is, under construction project organizational structures where owners maintain direct contract for design services (e.g., DBB), the burden of design changes (whether those that are client-driven or designer-driven) and any possible impact on the contractor and any potential propagation of the impact of such changes to lower-tier subcontractors' work remain the owner's liability. In contrast, in DB the design-builder holds the ultimate liability for the timely completion of design and construction services towards the owner, and, therefore, any emergent design change may propagate to lower-tier subcontractors' work and bring about detrimental impacts on project performance (e.g., propagation of claims, schedule delays, and cost overruns), the burden of which is carried by the design-builder. To this end, another main contribution of this analysis is that it offers a better understanding of the use of BIM on DB projects, and a system for tracking the propagation of changes - and the potentially induced claims - that are bound to emerge due to the fast-track nature of DB projects. That is, the developed DB-CTS allows the automated and flawless tracking and documentation of the coordination outcomes on the designed dashboard which continuously and simultaneously monitors design and construction progress and keeps track of design changes propagation. Besides, when design changes surface, the offered BIM-enabled synthesized framework aids design-builders proactively plan and control their work in expectation of such potentially emanating claims through identifying the responsibility matrix of the chain of impacted elements. Finally, the framework serves the documentation of the changes and of the respective impacts in a BIM-maintained database of changes. As for the synthesized framework, it can be used by the design-builder for contract administration purposes, including: (1) assessing the likelihood of claims being raised by its subcontractors; (2) tracking any payment setting-off being effected by the owner, as regards workmanship quality that is deemed inferior to that stated or implied by the owner's requirements; (3) objectively addressing time-extension entitlements for subcontractors; and (4) evaluating the justifiability of requested extra fees or additional payment in respect of design or construction rework, respectively.

Finally, the findings of this study shall assist A/E professionals and design-builders in controlling risk-related matters brought about by APDMs. For instance, it informs design managers about the need for a design team's re-structuring to accommodate for alternative DIR dynamics. Moreover, it alerts designers about a potentially increased liability exposure emanating from the reduced certainty on the DIR's coordination quality. Accounting for the quality of design documentation, while keeping in mind the persisting liability burden, is expected to impact the capability and willingness of the A/E to deal with (or accept to abide by) a certain pattern or extent of design information release that is in satisfaction with the construction priorities or preferences imposed by a DB contractor. From a design-builder's perspective, monitoring time and budget performance in view of potential claims induced by emergent changes leads to a better assessment and planning for potential risks.

10.4 Study Limitations and Future works

The following statements summarize the main limitations encountered in this research work, along with some suggestions on prospective areas for future research works.

- The offered constructs illustrating the pattern and packaging the of the DIR under APDM are a conceptualization of the possible alternative dynamics. Although this conceptualization was validated through interviews with industry practitioners, the lack of empirical data that supports the study findings can be considered as a limitation of this study. However, the conceptualization made provide the theoretical baseline for further extending this research into simulating these dynamics by using actual data from similar project types but delivered under different project delivery methods.
- Another limitation of this study is the lack of empirical data to support the conceptualization made with respect to the A/E's spectrum of engagement under APDMs. Unfortunately, researchers are not usually privileged for such data, which is very confidential and more importantly remains planned as compared to the actual data. Unfortunately, no firm will be willing to disclose such information of actual hours spent on a given

project. However, adding case studies to validate the model developed that include actual hours worked in various PDMs would be a great prospective area for future research, as it would help visualize how these designers' roles and hours spent vary from one PDM to the other.

- The developed plugin is instrumental in serving the purpose of controlling the impact of emergent changes by allowing the builder to proactively act in response to potentially emanating claims. Given that the time and cost impact of changes have been already addressed in previous literature work, linking such available methodologies to the developed plugin would be an interesting complementary work to the developed change tracking system.

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