INTEGRATED PROJECT DELIVERY APPLIED TO SHIPBUILDING

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MASTER THESIS

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Preface

Taking up a master's degree in Norway was a very bold step for my personal growth and and development. The decision to come to Norway represented one of the few moments I choose to do something for myself.

At first, it appears to be a beautiful idea, moving into a new country, the excitement of meeting new people and studying at NTNU, with the hope of a new leap in the development, made me very excited to come here. Those excitement was almost extinguished by the lack of finances I experienced as a self-financed master's student. Keeping an eye on my books, meeting-up with assignment deadlines, and at the same time in combinations with odd jobs just to pay bills made life a bit difficult. But, in all, I must admit that it was never a wrong choice, the master's program improved my knowledge in the maritime world significantly and I feel more confident to pursue my future endeavours.

My appreciation goes out to my thesis supervisor, Hajnalka Vaagan, and other staff members at the university.

To my family back in Nigeria, I sincere do appreciate every bit of support, effort, support and encouragement.

Ålesund, 2018-12-18

Masi Lucky Chukwuladi

Abstract

Using a classical or system-based design approach, the naval architect in consultation with a ship-owner, develops a concept for a vessel and a contract is entered into between the design team and the ship-owner. The design team progresses to concept design and basic design and then, a tender is opened for shipyards to bid for the building contract. The nominated shipyard then in consultation with the design consortium, develops a contract design, detailed and subsequently production design.

These sequencing where the yard is not part of the concept development and design, generates fragmentation in the flow of the design information. Also, the process of design and production follows a concurrent engineering approach where overlapping of activities are visible. Such Overlap and design fragmentation creates to a large extent project uncertainty which is triggered by the design and planning/production separation, engineering concurrency and often a third factor originating from the continuous dialogue between the ship-owner and the design team and the gross effect is a shipbuilding project with time and cost overruns.

To solve the problem, the master's thesis embarked on a mixed research method, exploring to determine the prerequisite measures needed to apply Integrate Project Delivery to Shipbuilding and through its features of collaboration, project uncertainty could be controlled. Combining multiple literature survey to generate broad opinion which would provide a foundation for a semi-structured interview. The interview were conducted within More og Romsdal region of Norway and provided the author with industry related account on how IPD could be used to achieve stakeholders integration, information sharing and retrieval.

The findings as presented in the result section, suggest that applying IPD to a shipbuilding project would require re-organizing the design process workflow, allowing yard participation at the point of project conceptualization, approach the concept development of the vessel through a collaborative means, adopting a communication protocol that spells out responsibility to parties and to project and approaching design either through a collaborative approach or a pull-

back formation.

On the problem of uncertainty, a design delay period was introduced in-between major milestones to test phase accomplishments and design outcomes in accordance to a defined Level of Detail (LoD) in the protocol, integrated the stakeholders and adopting a multi-disciplinary approach to qualifying design change requests from ship-owner before implementation.

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Chapter 1

Introduction

This is a master's degree thesis work that discusses the prerequisite for the application of Integrated Project Delivery (IPD) in shipbuilding within the context of digital transformation and Building Information Modelling (BIM). The aim is to develop understanding from ship design perspective on how to connect stakeholders within a shipbuilding project scope, enabling information sharing and retrieval across the project timeline (throughout the design, engineering, procurement and planning activities) to improve project performance with an end objective of reducing waste and risk. A demo case (design-change scenario mock-up) is developed to illustrate in theory the IPD concept within the framework of design change implementation, management and the meaning of collaborative decision approach in shipbuilding.

The focus of the study is on eliminating design information fragmentation which stem from the present practice design and planning separation and engineering concurrency within both design and production timeline of ships. The overlapping of design activities from concurrent practice limits the availability of useful and important pieces of design information which is needed to support decisions that have least possible disturbance and risk factors. While concurrency is a good practice, it is carried out in an environment where design and planning are treated as two distinctive domain within a project lifecycle. The consequences is that it leaves planners and controllers with an assumptive decision support process that could be very-well prone to error.

With concurrency, design separation and discrete information from the ship-owner, there are always the potentials for a design change or variation in order, and the possibility of errors becomes high and such errors amounts to re-work, cost and a possible change in the project master plan. Re-work on both the design and production, could be advantageous in terms of business and profits, but the implementation of such if not well-managed and implemented could adversely impact on the project performance.

Hence, the thesis intends to employ the principles of Integrated Project Delivery (IPD) to enable shipbuilding project stakeholder's collaboration, information sharing, and reducing the impact of design changes *(particularly external variation-order)* to obtain a better performing project with high good project deliverables. Figure 1.2 shows most basic design approaches

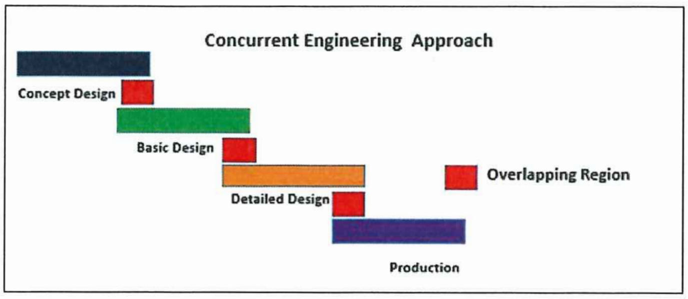


Figure 1.1: Concurrent Engineering (Adapted from Google 2018)

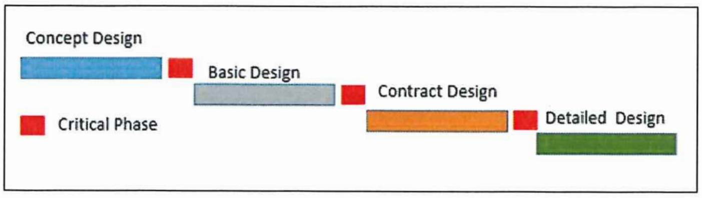


Figure 1.2: Classical Design Timeline (Adapted from Google 2018)

used used in ship production, as seen from the design perspective. These process has almost been over-taken by the principle of concurrency, and future activities no longer needs to wait until previous finishes rather they overlap. Concurrent engineering represents a common-sense approach to products development in which, elements of the product's lifecycle from concept phase to disposal are integrated into a continuous feedback-design driven process Mistree et al. (1990). The approach is to cause developers, from the beginning, to consider all elements of the product lifecycle from conception through disposal, including quality, cost, schedules, and user requirements (Winner R.I 1988).This cyclic approach or so-called feedback in reality, those information needed to make the required consideration regarding cost, quality etc are never sufficiently available because of coupled activities.

With Concurrency placing emphases on achieving high-quality preliminary designs, to allow early transfer of information between manufacturing, marketing, design engineering, and others, engineering concurrency is therefore very challenging when design is uncertain Eckert and Clarkson (2003). The mainstay of this master's thesis is to demonstrate, through the concept of integrated project delivery, how "high performing" project can be achieved by limiting the risk caused by the non-availability of design or technical information or footprints from design perspective.

Figure 1.3 depicts a design process timeline, the gross idea behind the conceptualisation of

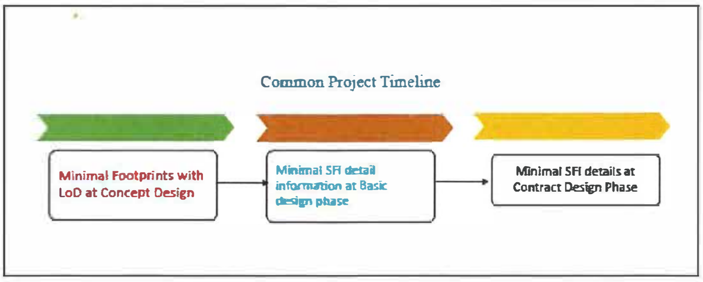


Figure 1.3: Footprints enabled design timeline

the thesis problem area is that at the completion of each specific design task, there should be design information that is rich enough in technical details and supports further task execution, planning and procurement through the use of relational contracting-Integrated Project delivery (IPD), to bring stakeholders to a common project delivery timeline, enable information exchange at any time or point within the project scope.

The outcome of the thesis, perhaps can leverage on leverage on previous work conducted by team of researchers within "lean project delivery, design uncertainties and complexity in planning" headed by Hajnalka Vaagan at the Norwegian university of Science and Technology (NTNU) Aalesund, to demonstrate how IPD can be implemented for a ship-based design and construction project.

1.1 Research Background

In the shipbuilding industry, the acquisition of a new vessel would require the convergence of different stakeholders and parties i.e. the naval architectural firm saddled with design responsibilities, the nominated shipyard where the keel laying will be performed and subsequently built and outfitted, classification society, product and solution suppliers etc. These stakeholders apart from the their distinctive roles, have their individual roles, often have their respective business or policy interest embedded within the project scope, and therefore attention and priority is set on satisfying individual goals rather than collectively working to actualise the project which is the connecting factor.

In practice, ship design is an Engineering-to-Order construction process. The ship-owner is always locked in a dialogue with the design team and the shipyard where production is to be executed. Most times, the outcome of theses back-and-fort communication are requests for design, specification changes or say change in ship systems.

Since design team and production team has contractual obligation to deliver vessel according to specifications, the pressure to meet set-out project timeline and plans then resides with project planning and procurement teams whose build strategy and developed timeline has to be constantly updated to incorporate the disturbance created by the design change request. The impact such request creates within the planning domain is a set-of uncertainties created by design changes, perhaps coupled with the fact that design is treated distinctively, and the required pieces of information are incomplete.

Even to this effect, planning and procurement decisions are still being made under this very uncertain conditions, the implication thereof is are often erroneous and poor judgement with substantial probabilities of re-work which attracts more cost and delayed delivery, re-planning etc. With these, there are chances of compromising the project deliverables and that could put stakeholders in a conflicting position. As estimated by Vaagen et al. (2017), the penalty could be almost twice the originally estimated time and cost.

With the forgoing, the thesis likens a ship design and production project to a classical construction project of complex buildings. The theory and principles of Integrated Project Delivery (IPD) as outlined by the American Council of Architects AIA (2007) as an innovative approach approach to relational contracting in combination with BIM technology with the aim of improving project performance has gained remarkable adoptions for both private and public sector projects. It is therefore of the interest of the master's thesis to centre its framework within the bounds of using IPD to improve performances of a shipbuilding project.

1.2 Problem Statement

At the beginning of the chapter and section 1.1 of this document, the thesis tried to explain and give insight to the downsides of concurrent engineering which has been visibly present within project execution strategies of many Norwegian shipbuilding projects. In the same manner, the separation of design and planning was seen as a major contributor to planning complexity and grossly responsible for lack of adequate pieces of information to support decision making at critical phases along the common project timeline. However, even in these very dynamic and complex situations decisions are being made.

As underscored by the study "Impact of Design Uncertainty in an Engineering-to-Order Project Planning" conducted by Vaagen et al. (2017), the penalty of making decisions within such complex, dynamic conditions caharacterized by a discrete arrival of information from the ship-owner or client, is a poor performing project with almost twice the initial cost and scheduling time. The problem therefore, is a problem of uncertainty created or initiated by engineering concurrency, separation of design from planning and discretized information arrival due to the continuous dialogue between the ship-owner, the shipyard, design team and other stakeholders alike.

While the subject of "project uncertainty" may have received significant attention within Operational Research and project management, this sort of uncertainty being highlighted in this document is not the same as those resulting from task execution, rather, stems from design itself, external factors (variation-orders) and the down-sides of engineering concurrency and could as well be one of the key sources of uncertainties in task execution. The focus herein is removed from uncertainty in task completion.

NB: *For a shipbuilding project, external variation-orders are considered profitable, since the ship-owner will certainly pay more for additional features or re-work, the challenge is how the design teams and yards will adequately manage the implementation without exceeding their benchmark and incurring overruns. The study is therefor not concerned with eliminating variation-orders but how to handle its effects within an already complex design environment.*

Attempts to improve project performance through the use of relational contracting like the Design Build (DB) method have received significant adoption within the shipbuilding sector with focus on collaboration and more stakeholders involvement within the project scope. With DBB and DB having their pros and cons, coupled with fact that the ship-owner decides on which contractual model is suited for the project, the issue of planning complexity have not been effectively addressed neither has the the problems of design changes and engineering concurrency.

Through scheduling approaches (buffering, CPM, moving baseline, simulations etc) are more focused on handling project uncertainties relating to task completion. From the perspective of this document, there are two-level of project uncertainties; uncertainties in the design process of the project, caused by external factors, separation of design and planning, and engineering concurrency, regulation-related changes, changes in ship specification or functions and the other level of project uncertainty emanating from either linear scheduling or similar factors.

This problems the master's thesis work intends to proffer solutions to is therefore an exploratory study, to assess best possible approach on how Integrated Project Delivery (IPD) can be applied to a shipbuilding project, with focus and attention on how shipbuilding and engineering project uncertainty and its impact on project performance man be controlled through a prescriptive order for organizing a shipbuilding design process that bridges the communication gap between project stakeholders by integrating design and planning into one common project timeline, enabling information exchange across the common project timeline, providing planners, procurement teams and others alike assess to the right design information that guarantees project decision making process with least possible disturbance, and ultimately reducing project waste and maximising project performance.

1.3 Thesis Objective

The objective of this master's thesis work is to generate an approach that will aid the process of integrating design and planning within the framework of shipbuilding and enable project participants across the common timeline sharing the needed information that is critical to good performing projects.

Enabling project stakeholders ability to share and exchange the right information at the right time, committing all stakeholders to a more collaborative form of relational contracting, and by using IPD which advocates for shared risk and reward AIA (2007), the thesis work can shed some light on how to achieve a better performing project where both the shipbuilder, designer, other retained partners can collectively achieve some degrees of satisfaction. This could be very beneficial for shipyards particularly in Norway where project cost is one of their downsides compared to say their Asian counterparts.

Amongst others, the leverage the Norwegian shipbuilding sector has over its foreign counterparts are their ability of the shipyard to deliver high quality, technologically complex vessels on the edge of known-technology (with frequent changes in design, and other technical specifications) within short lead time. Equally, the shipbuilders in Norway offers to ship-owners the possibility of to postpone outfitting, detailing, and adapt specification changes at both engineering and production phases. Since the industry functions in somewhat dynamic market conditions, with prospects rapid changes in demands on both vessel and its technical features, the fact that the shipbuilders would need to adapt and deliver to the ship-owner the additional requirements could is challenging as decision making process under such conditions can lead to twice project cost and time overruns.

Hence, if a robust model could be developed using IPD to prescribe a collaborative approach to design process management, that can effectively help in hedging against project uncertainty, then the issues of waste (time and cost) resulting from poor decision making process and disintegrated design process, then interested Norwegian shipbuilding projects can profit business wise from the outcome of the thesis.

Then on a research-base, the overall goal of the Master's thesis is to explore the prerequisites of IPD for a ship-based design and construction project. This includes but not limited to information sharing and retrieval from design-planning perspective. The thesis shall rely on established theories within the subject area of lean construct on, project management and design to outline procedures with the intent of prescribing certain lean-based design management procedures, methods and approach needed for using IPD to enhance project performance in shipbuilding.

1.4 Research Question

1. How can the thesis draw-up existing knowledge from Integrated Project Delivery in general construction to propose a model for shipbuilding projects?

2. Can the such models be used to describe from clear perspective the meaning of IPD for a shipbuilding project, absorb, handle and manage the complexity in planning due to design changes and limit its impact on project performance?

3. Using research question 1 and 2, can a mock-up case be built to demonstrate in clear

terms how IPD can be used to manage design changes and process implementation?

1.5 Research Scope

The research will apply theories from IPD, Project Management, Design and digitisation see figure 1.4.

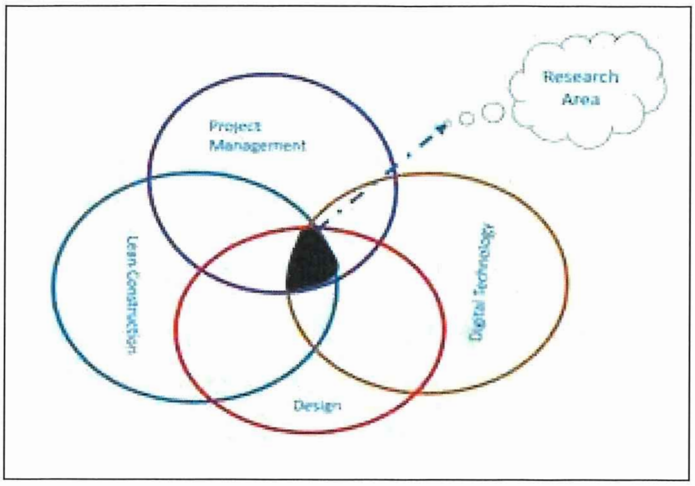


Figure 1.4: Research Scope

1.6 Limitation of the Study

The research is conducted within a complex theoretical basis. The impact of the accomplishment on project delivery and the design process planning will require studying different projects where the outcome of the theories prescribed by the study was applied and sampling the performance of those projects in comparison to other project delivery techniques used in shipbuilding project execution.

Therefore, the thesis represents a conceptual theory building process which can be applied to develop further standardised approach for IPD in shipbuilding the same way the AIA have successfully standardised IPD for building construction. Hence, it's appropriate to state that the issue of how waste can be eradicated using the prescribed principles are hypothetical, it requires further validation.

The mock-up example does not represent wholly, the entire design process planning and execution, as well as ship production process, to this end, it serves the function of mere explanatory purpose.

1.7 Chapter Summary

This chapter con stains the introductory aspect of the thesis and the problem the study intends to solve and form the foundation upon which further chapters, section and subsection shall be based.

The research is intended to develop a a prerequisite for applying IPD to a shipbuilding project with the anticipation that IPD processes in shipbuilding can limit the negative impact of project uncertainty created by concurrent engineering, design-planning separation and discretized information arrival.

A research question *(see 1.4)* has been developed as a guide on how to approach the problem *see (1.2)* with an intent to accomplish the objective *(see 1.3)* set out by the study.

1.8 Structure of the Study

The report has been organised to include nine chapters, a reference and an attached appendix.

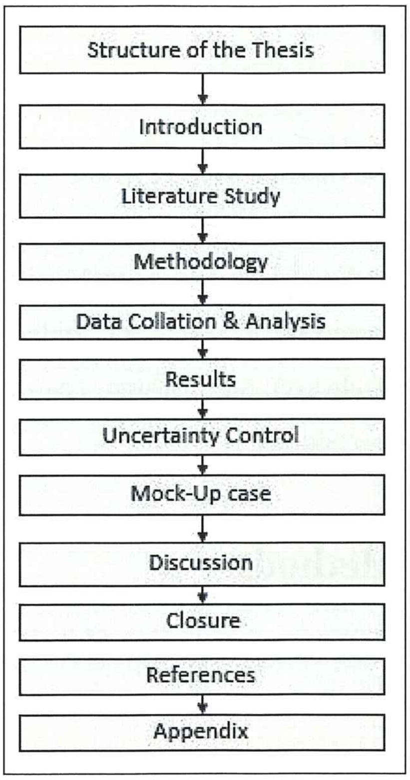


Figure 1.5: Structure of the Thesis

Chapter 2

Literature Study

This chapter contains the review of relevant articles within the scope of the master's thesis see figure 1.4. The literature study focuses on learning and drawing-up understanding from relevant credible sources in other to shape the way and manner the research will be organised and designed. Following the scope, the review is carried out for: Project Management (Project Delivery methods and Integrated Project Delivery), Ship Design, Lean Construction Building Information Model (BIM) and Design Uncertainties.

2.1 Project Delivery Methods

To begin, it will be imperative to understand what a project actually means, perhaps within the confines of construction.

According to Webster and Knutson, Projects are unique undertaken that results in a single unit of output. Projects consist of activities and consistent with the definition of a project, activities have beginning and an end. Activities are interrelated in one of three possible ways. In some situation, one activity must complete before the other begin. They went further to state that a project is a temporary endeavour, undertaken to create a unique product, service and or result Webster and Knutson (2004).

Project Management in the view of Olsen, is the application of a collection of tools and techniques (such as the CPM and matrix organisation) to direct the use of diverse resources towards the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of these tools and techniques, structured to fit the task environment and lifecycle (from conception to completion) of the task Olsen (1971).

To deliver a project of choice, the project owner enter into a contractual agreement with either a single entity or multiple entities. Construction contracts are written agreements signed by the contracting parties (mainly an owner and a contractor), which bind them, defining relationship and obligations O'Reilly (1999). There are different types of contractual models used for project execution whose choice of appropriation depends on the decision of the project owner Al Khalil (2002) and the success of projects as well depends largely on the project delivery style or execution strategy.

This literature study shall consider a review of the Design, Bid & Build, Design Build, Construction Manager (CM) (which are visible within construction including shipbuilding) Multi-Party Agreement and the so-called innovative approach-Integrated Project Delivery (IPD).

Design Bid & Build (DBB) is the traditional project delivery method where the project owner contracts separately with a designer and a constructor to design and construct the facility respectively Ling et al. (2004). The design prepares a design package, including contract documents. The owner submits the package for bidding and selects the best bidder to undertake the construction of the project, requires the owner to monitor the contractor to ensure adherence to the project and often end in adversarial relationship amongst the parties involved in the project Al Khalil (2002).

The design, bid and build offered client's a sequential approach of design, bid and then build. Due to the specialisation of services, design and construction entities fir a DBB-styled project shared information only at the end of design and at end of construction. Interaction within design phase is extremely low. The result thereof is an inefficient design, increased error, higher cost and increased scheduling period Konchar and Sanvido.

Design-Build (DB) is a project delivery approach where the owner contracts with a single entity for both design and construction of the facility under a single DB contractual models Molenaar et al. (1999), while Janssens described it as a contracting condition where the owner enters a contract with a single entity to perform both design and construction under a single DB contract Janssens (1991).

The Design -Bid approach thus hold hold the potential to eliminate the adversarial relationship often associated with DBB Al Khalil (2002). Ling et al. studied how to predict the delivery speed of DBB and DB projects and concluded that DBB project performance can be predicted using two parameters: gross flow area and the contractor's design parameters while for DB, gross flow area, level of project scope completion when bids are invented, extents to which contract periods are allowed to vary during bid evaluation, and level of design completion when the budget is fixed. Ling et al. (2004).

The Construction Manager (otherwise called Construction Manager at Risk) is an integrated team approach to planning, design and construction of a project, to control schedule, and budget to and to assure quality for the project owner. The team consist of the owner, the designer who–who might be an in-house engineer or a design consultant- and the risk construction manager Shane and Gransberg (2010).

Collaborative construction project arrangements have been the subject of many development efforts owing to the frustrations felt towards the opportunism created by traditional contracting Lahdenperä (2012). Beyond opportunism, are problems of construction process fragmentation. Fragmentation of construction processes and the resulting adversarial relationships between parties involved have been a constant topic of critical writing for decades and still burdens the current process in most cases. Increasingly, collaborative forms of project delivery have been and are being developed under various parts of the world Lahdenperä (2012).

Researches within this field of practice while attempting to offer innovative approach to contracting, came-up with different relational contracting models. These models are targeted at building a collaborative working procedures to contracting and contractual processes. Some of these models follows a multi-party contracting model Lahdenperä (2012).

A multi-party contractual agreement can be seen as one where primary project participants execute a single contract, specifying their respective roles, rights, obligations and liabilities. In effect, the multi-party agreement creates a temporary virtue and in some formal instances. A multi-party agreement requires trust as compensation is tied to overall project success and individual success depends on contributions of all team members AIA (2007).

2.2 Integrated Project Delivery

The AIA defined Integrated Project Delivery (IPD) as a project delivery method that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all project participant to optimize project results, increase value to the owner, reduce waste and maximise efficiency through all the phases design, fabrication and construction AIA (2007).

Integrated Project Delivery (IPD) is an emerging construction project delivery methodology that involves key participants and stakeholders very early in the project timeline often right from the conceptual phase of the project to final delivery. It's differentiated from a multi-party agreement due to its ability to evenly distribute risk and reward across boards El Asmar et al. (2013). The concept of shared risk and reward is also essential to IPD processes. It provides for a more collaborative effort between the contracting parties because everyone has a stake in the outcome AIA (2007).

IPD on like other project delivery approaches, seeks to improve project outcomes through a collaborative of aligning the incentives and goals of the project tea through shared risk and reward, early involvements of all parties, and can equally be considered s a multi-party agreement AIA (2007). The coupling of Building Information Modelling (BIM) with IPD enables a level of collaboration that not only improves efficiency and reduces errors but also enables exploration of alternative approaches and expansion of market opportunities. With this, several professional organisation supporting the advancement of IPD, the number of projects using IPD still remains relatively small Kent and Becerik-Gerber (2010).

Integrated Project Delivery is a new approach to to agreements processes for design and construction conceived to accommodate the intense intellectual collaboration that twenty first century buildings require. The inspiring vision of IPD is that of a seamless project team, not portioned by economic self-interest or contractual silos of responsibility, but a collection of companies with mutual responsibility to help one another meet the goal of the project owner AIA (2007).

IPD was proposed to overcome problems caused by fragmentation within the construction organizations by improving project procurement and product delivery process to achieve team integration Nofera et al. (2011).

Such integration can be considered as the merging of different discipline, or organization with different goals, needs, and cultures into a cohesive and mutually supporting unit Nofera et al. (2011). Although, several professional organization are supporting the advancement of IPD AIA (2007), Becerik-Gerber and Kent stated that some projects are demonstrating its benefits, but, the amount of projects using IPD remains relatively small. This Becerik-Gerber and Kent thinks is due to the lack of significant research investigating the current adoption status and causes of slow adoption of IPD in the industry Becerik-Gerber and Kent (2010).

There are several reasons for the slow adoption of IPD amongst industry professionals. Among these are high degree of concern regarding risk in relation to IPD, the close partnership it necessitates, and need for new legal frameworks to match new IPD approaches. Moreover, many industry stakeholders feel there is a need for those within the industry to assimilate new competence and skills relating to collaboration and information management to support IPD Autodesk (2008).

Efforts to standardize IPD came from the release of the CONSENSUS DOC, Perlberg described IPD in the released white paper as a contract execution style involving mulit-party agreements. In affirmation, AIA stated that for a project to be considered an Integrated Project Delivery system, it must contain; a multi-party contract, shared risk and reward between contracting parties, early Involvement of key participants, liability waivers among key participants, collaborative decision making, and control, jointly developed and validated project goals AIA (2007).

Integrated Project Delivery IPD is a relational contracting approach that aligns project objectives with the interest of key participants. It creates an organization able to apply the principles and practices of lean project delivery systems Matthews and Howell (2005).

2.3 Lean Construction

The concept of 'lean' was first introduced by Womack et al. in order to describe the working philosophy and practice of the Japanese vehicle manufacturers and in particular the the Toyota Production System (TPS). More specifically, it was observed that the overall philosophy provides a focused approach for continuous process improvements and targeting of a variety of tools and methods to bring about such improvements Womack et al. (1990). Effectively, the philosophy involves eliminating waste and unnecessary action linking all the steps that creates value Hicks (2007).

The application of the "new philosophy" to construction was first discussed by Koskela, Koskela (1992) and subsequently works within the field became known as lean construction Jorgensen and Emmitt (2009). The initial concept of lean was more effectively defined and described by five key principles. Lean involves the ongoing elimination of unnecessary, non-value-added steps within a process which contributes to bottom-line results, increased competitiveness, and improved level of customer service. Lean thinking offers a way to make work more satisfying and challenging by providing regular feedback on efforts to convert waste into value. Differing noticeable from the recent emphasis on process organizational re-engineering, lean provides a way to create a new methodology and design for work rather than just destroying jobs for the sake of achieving efficiency Womack and Jones (1997).

Lean as a project delivery system emerged within 2000, from theoretical and practical investigations, and is in the process of on-going development through experimentation in many parts of projects, applying concepts and methods drawn from the Toyota Product Development System Ballard (2008).

In Lean Project Delivery System, project definition starts with business planning, proceeds business plan validation if the initial plan appears to be feasible, and ends with a decision by the client to fund or not fund a project. If the project is not funded, the companies participating in the business plan validation are paid for their service is killed. If the project is goes forward, target values and constraint are set, then design is launched and steered towards those those targets. The first step in the design Lean Project Delivery System is the target setting, the second and third steps are design development and detailed engineering steered towards those targets Ballard (2008).

Lean is usually associated with the 'operations' of a manufacturing enterprise; however, there is a growing awareness that these principles may be transferred to other functions and sectors. the application to knowledge-based activities such as engineering design. Lean can be applied basically away from the factory; with the understanding and definition of value is key to success; that a set-based approach to design is favoured together with the strong leadership of a chief engineer and that the successful implementation requires organization-wide changes to systems, practices and behaviours Baines et al. (2007).

The meaning and definition of Lean has drifted. In the 1980s, lean was associated with a reduction in waste in the factory, then on quality, cost, and delivery down to the 90s before the focus shifted to customer value after 2000. Today, the popular emphasis is on 'value' and how it can be maximized. These shift from waste elimination to vale enhancement is exemplified by Browning and Sanders (2012) who argued that that during the PD, process maximizing value can be achieved by doing more, not less.

Lean thinking can be applied to information management; where information management can be considered to involve adding value to to information by virtue of how it's organized, visualized, and represented; and enabling information (value) to flow to the end-user (customer) through the processes of exchange, sharing and collaboration Hicks (2007).

Similarly Haque and James-Moore argued that engineers needed to move from a production focus to, in which the primary aim is waste reduction to, to one of identifying and enhancing value, activities that creates useful additional information and, or reduce risk Haque and James-Moore (2004).

The lean project management concept is taken from lean manufacturing to construction industry. Standardization is one of the leanest approach in large scale projects. Lean project management is comprehensive outcome of other lean principles and has many ideas in common. Still, the main definition of lean project management is delivering more value with less waste in project context Nekoufar and Karim (2011). The lean project management system is subdivided into; Project definition, Lean Design, Lean supply and Lean assemble Ballard (2008).

2.3.1 Last Planner System of Production

The last planner system was developed in the early 90s Ballard with a focus on improving the quality of assignments in weekly work plans, and eventually was extended from construction to design. During the development attention shifted from improving productivity to improving the reliability of the work flow and resulted in a change in the conceptual framework Ballard (2000).

According to Ballard, the Last Planner System is especially appropriate for design production control because of the value generating nature of design, which renders inneffective traditional techniques such as detailed front-end planning and control through through after-the-fact detection of variance Ballard (2000).

Hamzeh et al., detailed adjustments applied to the Last Planner System to suit design process using a small health-care project in North America as a case study. A novel standardized planning practice was developed and subsequently analysed based on performance at the look-ahead planning and weekly work planning stages where planning takes into account changes in the environment the uncertainty affecting inputs, processes and outputs of design activities Hamzeh et al. (2009).

2.4 Project Uncertainties

Uncertainty is a state where; a current state of knowledge is such that; (1)-the nature or order of things are unknown, (2)-the consequences, extent or magnitude of circumstance, conditions, or event is unpredictable and (3) credible probabilities to possible outcomes cannot be assigned A. (2013).The type of uncertainty described by the third option refers to the particular level of project uncertainty the study targets to eliminate in the design and production process of vessels. This type of uncertainty where meaningful statistics and probabilistic distribution can not be assigned and studied have received little academic attention. Most focus has been on centred on modelling uncertainty using statistical and probabilistic distribution Vaagen et al. (2017).

Design uncertainties stem from the continuous dialogue between the customer/client and the design team. This sort of communication goes goes on into the project lifecycle and often leads to specification changes after the design phase of the project has started, sometimes even far into the engineering and production phase. While such communication flexibility is good for the customer, it does lead to continuous adjustments in procurement, engineering, and execution process Vaagen et al. (2017).

Project uncertainty also emanate from design changes and design changes may be due to revised requirements, or approval comments, by an owner, classification societies and other regulatory bodies, a revised build strategy, or insufficient design department study and development work. as outlined by Storch et al. (1988)

The engineering design process connects the phases of basic design with detailed design with project planning and scheduling Vaagen et al. (2017). However, most times design and planning are treated separately Emblemsvåg (2014). This is a result of traditional project management and planning, where the project where the project phases are separated and carried out sequentially. This implies that when design is ready, it is thrown over the walls of the planners, who would rely on design information to generate project plans. In this regards, a sequential process is not able to able to properly handle changes and disturbances that do not naturally belong to that phase Eckert and Clarkson (2003).

Design uncertainty is therefor a major driving of planning complexity in an Engineering-to-Order project where design and engineering is separated and taking place concurrently Vaagen et al. (2017). This separation have led to generation of project plans that have failed to take into account the uncertainties created by design in the project scheduling Eckert and Clarkson (2003).

2.5 Ship Design

Ship design is a complex endeavour requiring the successful coordination of many discipline, of both technical and non-technical nature, and of individual experts to arrive at valuable design solutions Papanikolaou (2010).The ship design process is one that has very vague information content at early stages of design. The design process essentially applies iteration to satisfy the relevant requirements, such as stability, power, weight, and strength Yang et al. (2007).

According to Storch et al. the ship design stage can be sub-divided into four stages:

- Basic Design
- Functional Design

- Transitional Design and
- Work Instruction Design Storch et al. (1988).

Significant contribution to the science of shipbuilding was made in 1959 with the visualization of the design process, and the general design diagram known as the "Design Spiral" which captured the basic tenets of a widely accepted approach to ship design Evans (1959).The most common way to describe the ship design process has been the spiral model, capturing the sequential and iterative nature of the process. The task structure requires "select-dimensions, evaluate capacity, and performance re-design". With that, the model locks the naval architect to his first assumption and focus in the design process will be to patch and repair this single design concept rather than generate and evaluate alternative designs, therefore an approach that supports innovation and creativity is needed Erikstad and Levander (2012). A major characteristic of the design spiral approach was the sequencing of design and iterative processes rather than concurrency, laborious and expensive. While some changes have been made over the years, some of these features remains unchanged Mistree et al. (1990).

Buxton introduced economic issues into the spiral Buxton (1972). The Evans design spiral is a conceptual model of a process to for effecting ship design. The major units of the spiral (conceptual design, preliminary design, detailed design etc) are central to implementing any ship design process and there are numerous ways of implementing these units. However, most formal algorithm and mathematical approaches that have been reported in the open literature are for preliminary design Mistree et al. (1990)

The system-based design however shows deviation from the design spiral model, and was first presented at the IMDC in Kobe in 1992. Since that, it has been successfully applied to the development of a large number of ship design solutions. The SBD adaption towards OSV's includes the development of appropriate breakdown structures for vessel's main function, weights, areas, and volumes Erikstad and Levander (2012). With the SBD the functional design of the vessel can be developed to a high detail without premature commitment to specific specific overall dimensions, layout and arrangement. SBD can also provide a foundation for modular foundation for modular design. Combined with 3D visual sketching tools, this method can support the generation of several alternative vessel configuration fast and with much reduced design effort Erikstad and Levander (2012).

Storch et al. gave description of the different activities for the various activities that follows the design phases described in (2.5) with the under-listed details:

As part of the basic design phase, naval architectural calculations are performed. Among these are weight estimate, longitudinal strength, hydro statics, tank capacity, Bonjean curves, intact trim and stability data and evaluation, wake survey, resistance, and self-propelled test, electric load analysis, piping system and analysis, HVAC analysis, propeller analysis and shafting arrangements and represents the phase where the contract document are produced, the design provides an overview of he ship to be built and consequently represents a total ship system orientation. Amongst the plans developed at the basic design phase are-the general arrangement (GA), lines, midship section, machinery arrangement, cabin plans, diagrammatic of major outfitting systems and contract specification Storch et al. (1988).

The second stage (functional design) displays the ship function on a system diagrammatic and plans, definition of all outfitting materials required by the system, including raw materials (such as pipe, structural angle iron and electric cable), budget control lists, which addresses all concerned updated material quantities and weights prepare purchase specifications not prepared by basic designer, prepare manufacturing drawing for long-lead-time items identified during functional design, obtain owner and regulatory approval and obtain vendor's drawing Storch et al. (1988).

Storch et al. described the third phase as the process of transferring system oriented information (functional design) into zone oriented information whose end products are yard plans. Yard plans in this context represents the way information are grouped to suit the production process Storch et al. (1988).

2.6 Building Information Modelling

According to EUBIM, Building Information Modelling (BIM) is a digital form of construction and asset operation. It brings together technology, process improvements and digital information to radically improve the client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle EUBIM (2018).

A BIM model is a digital representation of an actual building project for project communication over the whole building-project lifecycle. A physical, tangible appearance of a building from a time standpoint can be represented by three categories: 'as-it-was', 'as-it-is', or 'as-to-be', Cerovsek (2011).

AIA view of BIM, is that of a data, 3D model, linked to a data base of project information. Among other things, it contains the design information, fabrication information, erection instruction, project management and logistics information in one data base system AIA (2007).

For the public sector, BIM can be thought as 'digital' construction. It is similar to the technology and digital process revolution that entered the manufacturing sector in 1980s to improve productivity rates and output quality. It combines the use of 3D computer modelling with the whole life asset and project information to improve collaboration, coordination, and decision-making when delivering and operating public asset EUBIM (2018). The concept of Building Information Modelling (BIM) emerged to address the seamless exchange of information throughout the life of a facility following early modelling efforts focused on providing providing solution to data exchange problems between CAD analysis systems Isikdag and Underwood (2010).

Building Information Modelling is the largest generation of Object-Oriented Computer Aided Design (OOCAD) system in which all of the intelligent building object that combine to make up a building design can coexist in a single project data base or virtual building that captures everything known about the building. In theory, a building information model provides a single logical, consistent source for all information associated with the building Howell and Batcheler (2005).

Building Information Modelling (BIM) is a set of interacting policies, processes and technologies generating a methodology to manage the essential building design nd project data in digital format throughout the building's lifecycle Succar (2009) BIM is considered both modelling technology and associated set of processes to produce, communicate, and analyse building models Eastman and Sacks (2008). The benefit of these models are better data for real-time decision making, improved design quality, shorter delivery times, and the reduction or elimination of rework after assemble has begun. In order to achieve most of these benefits, closed collaboration between the primary stakeholders including the owner, architect, engineer, general contractor, trade contractor, manufacturer, etc is required which fundamentally impacts the role and responsibility of the participants and how information is share Ku et al. (2008).

BIM is neither a virtual representative of a real project nor a static encapsulation for project information. It provides dynamic decision-making information throughout a project lifecycle, meanwhile, its encapsulated information sychronizes with construction practices ranging from design, execution, operation, maintenance, through to renovation Lu and Li (2011).

BIM allows the visualisation and understanding of construction project to take place in 3D dimensions. BIM is suitable for supporting the simulation of a construction project in a virtual environment. Virtual models can be surface or solid models. Surface models are only for the visualisation purpose and the components of a surface models contain information concerning only size, shape, location, etc which facilitates the study of the visible parameter Kymmell (2007).

Today, Building Information Modelling (BIM) are promising to be the facilitators of integration, interoperability, and collaboration for the future of the construction industry. Recent definitions of Building Information Modelling highlights the roles of BIMs as enabler of collaborative working process. In parallel, collaborative teamwork can be in form capable of supporting (synchronous and asynchronous) collaboration between various stakeholders by acting as an information backbone through the entire building lifecycle Isikdag and Underwood (2010).

In other to achieve successful implantation of BIM, and make use of its potentials, there is need to understand how the how the implementation of BIM is dependent upon conducting the necessary changes in the organization Succar (2009).

BIM applications are rapidly being embraced by the construction industry to reduce cost, time and enhance quality as well as environmental sustainability . BIIM holds the potential to bring significant benefits to the transfer, storage and access of construction project information Eastman and Sacks (2008). To take advantage of the integrative potential of BIM and model-based collaboration, architects need to embrace radically new practice model which begs for a business approach that integrates design leadership and business plans Ku et al. (2008).

2.6.1 BIM/Software Interoperability

The on-line economy and society is expected to undergo another wave of transformation and growth over the next decade and beyond. New economic activities will arise with new classes of networked applications and services, new forms of enterprise collaboration, new business models, and new value propositions. It is generally accepted that Information and Communication Technology (ICT) is an enabler for innovation. What is less clear and controversial, however, is the changing nature of innovation and the mechanisms for catalyzing it. Still, it is generally accepted that in order to take full advantage of ICT, companies must increase their level of interoperability Grilo and Jardim-Goncalves (2010).

As in many other industrial sectors, a major difficulty that Architecture, Engineering, and Construction (AEC) companies are currently facing with ICT is the lack of interoperability of software applications to manage and progress in their business. AEC organizations are being pressured by new business relationships (i.e. - driven by new contractual challenges such as the contractual typology of the project finance initiative (PFI)), and the exchange of information and documents with new partners, which often cannot be executed automatically and in electronic format. This is principally due to problems of incompatibility with the reference models adopted by the software applications they are working with. This problem arises not only during the project phase, but also across the whole lifecycle that includes operation and maintenance stages Grilo and Jardim-Goncalves (2010).

Collaboration between the participants in construction projects is pivotal to the efficient delivery of facilities. Organizations are constantly working in new collaborative environments in other to achieve higher standards of quality and re-use of existing knowledge and experience. A major constituent of these collaborative environment is the ability to communicate, share data or pieces of information efficiently without loss, contradiction or misinterpretation BSI (2016).

In a collaborative work environment, system interoperability is important for exchanging contents within a given project lifecycle. Interoperability can be defined as "The ability of two or more systems or components to exchange information and to use the information that has been exchanged IEEE (1990). Interoperability is achieved by mapping parts of each participating application's internal data structure to a universal data model and vice versa if the universal data model employed is open (i.e. not proprietary), any application can participate in the mapping process and thus become interoperable with any other application that also participated in the mapping Grilo and Jardim-Goncalves (2010).

In an effort to provide an answer to these requirements, within the AEC context, the TC184/SC4 (industrial automation systems and integration — product data representation and exchange: industrial data) of the International Organization for Standardization (ISO) was launched, within its WG3 (product modelling), the T22: building construction group. Under the umbrella of T22, for ISO10303-STEP, part 225 titled: "Application Protocol (AP): Building Elements Using Explicit Shape Representation" was developed. The outcome of this effort is now an International Standard (IS) and specifies the requirements for the exchange of building element shape, property, and spatial configuration information between application systems with explicit shape representations, specifically the physical parts of which a building is composed, such as structural elements, enclosing and separating elements, service elements, fixtures and equipment, and spacesvon Haartman et al. (1970).

Previous efforts to provide a common means of exchange of graphical information and data was the joint "Integrated Computer-Aided Manufacturing Program". funded by NASA, the US army, navy army and the US air force and other cooperation within the AEC industry. The outcome of the project, gave rise to Initial Graphics Exchange Specification (IGES). The IGES format is in the public domain and is designed to be independent of all CAD/CAM systems. The benefit of this common format is that a user does not have to develop special translators for each different piece of equipment. The only requirement is translators to and from the IGES format. These translators called pre- and post-processors, are generally available from the equipment vendor. Another benefit is that an IGES file can be stored on magnetic tape or disk memory for future use and can be transmitted between systems via telecommunications Smith (1983).

Interoperability has become recognized as a problem in the AEC sector due to the many heterogeneous applications and systems typically in use by the different players, together with the dynamics and adaptability needed to operate in this sector. In spite of the availability of many proposals to represent standardized data models and services for the main business and AEC activities, the goal of seamless global interoperability is far from being realized Adamus (2013).

2.7 Chapter Summary

This chapter presented a review of scholarly articles within the interest areas of the Master's thesis work. By carefully studying different literature within the scope (see figure 1.4) of the thesis, ah extensive understanding and knowledge from different authors have been collated and will be instrumental in directing the path of the study and guiding the author in setting-up the design for the exploratory studies.

The literature study suggests that the problem defined in chapter 1, remains of interest as the different sources points to the fact, establishing the need why the problems has to be addresses.

Chapter 3

Methods

The research method presents the approach, and techniques in combination with tools employed by the thesis to answering the research questions. After thoroughly studying the research questions, a mixed research method- i.e., "Theoretical and Qualitative (Exploratory) Research Design" techniques in combination with a multi-level literature study was used design the method.

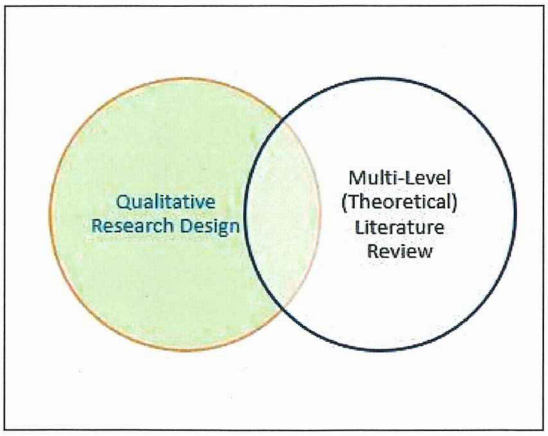


Figure 3.1: Research Method

According to Maxwell, Qualitative research design presents research as a flexible process rather than fixed, inductive, rather than following a strict sequence or derived from an initial decision. In this manner, qualitative "Research Design" is presented as a reflexive process operating through every stage of the project. The activities of collecting data, analyzing, developing and modifying theory, elaborating and refocusing the research questions, identifying and addressing validity threats are all going on more or less simultaneously Maxwell (2012). However, the master's thesis doesn't rely wholly on just Qualitative Research Design but combines QRD and a Theoretical Review of literature within the subject area of the master's work. Hence, the adopted method shall reflect both the theoretical approach and the qualitative research method.

Thus; to develop a qualitative study, you can't just develop (or borrow) a logical strategy in advance and then implement it faithfully. You need to a substantial extent to construct and reconstruct your research and this is a major rationale in any design model. Qualitative research design to a much greater extent to Quantitative research is a "do it yourself" rather than an "off the shelf" one that involves "tacking" back and forth, between the different components of the design assessing their implication for one another Maxwell (2012).

3.1 Design of Exploratory Study

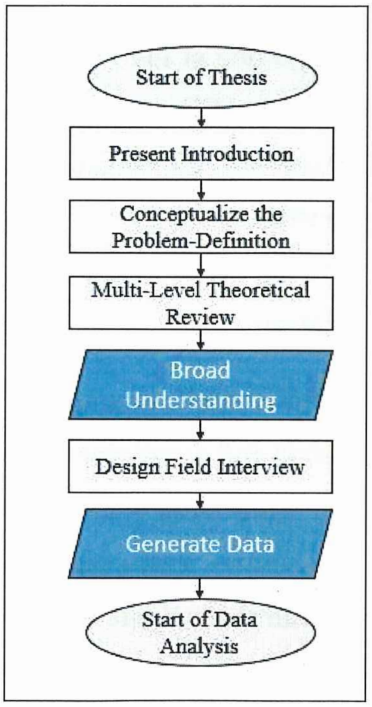


Figure 3.2: Research Design Process

From the forgoing, it is therefore imperative to present the order in which the thesis shall follow through in developing or generating data, knowledge or creating an enhanced understanding that will be relied upon to address the goals of the research see 3.2.

To accomplish the task, the thesis shall apply exploratory and experimental process of research technique. The experiments conducted shall be social experiments involving semi-structured interviews. The interview shall seek to generate understanding and knowledge that could be relied upon to postulate or prescribe the "prerequisite" needed for the application of "Integrated Project Delivery" to ship construction and how that could aid to mitigate against the impact of changes on project performance. To further this, the research shall identify geographical area, individuals and develop questions that will be asked during the interviews.

With the aid of figure 3.2 and table 3.1 the author prepares to conduct the interviews, first by identifying the More og Romsdal region of Norway as the target environment. More og Romsdal is one of the eighteen counties of Norway. The region has been carefully selected due to its strategic location and its role in the Norwegian maritime industrial cluster, housing many shipyards, naval architectural firms, product suppliers, fishing companies and strong maritime education.Aalesund, which is one of the towns in the region is a host to both the Norwegian university of science and technology and the Norsk Maritime Competence Center (NMK) amongst other key players. With that, it does provide the right environment for the exploratory/experimental research to strive.

3.1.1 Semi-Structured Interview

The interview represents one of the most sensitive aspects of the master's thesis as it provides one of the key sources of data and shall and serves one of the foundation upon which the research shall base its argument on the application of Integrated Project Delivery to the process of shipbuilding. Interviews are conversations with a purpose, namely, to sit with another and learn what that particular individual can share about a topic, to discover and record what that person has experienced and what he or she thinks and feels about it Mears (2009). The interview process shall involve different range of individuals identified in table as resources. Multiple interviews allow for maximizing the opportunity to build rapport and learn from reflections of the

Table 3.1: Order of Field Interviews

Event	Objective	Output
Geo Identification	To set out the specific geographical location where the semi-structured interview shall be conducted.	Interview shall be conducted within More og Romsdal Region of Norway
Resource Identification	Identifying prospective individuals that shall participate in the interviewed.	Interviews shall cut across both the academia and professionals working in both maritime and construction sector
Interview	Hold discussions, ask questions, derive knowledge and extract the experience of the interviewee using the interview guide developed from literature study.	Requisite understanding that shall be combined with the outcome of the literature study.
Data Collated	The Data gathered shall be analyzed and based on the outcome of the analysis, the thesis can be the outcome of the study.	Recorded transcript (Audio and Hand written)
Results	The results shall is intended to present answers to the research question in the leading chapters	IPD applied to Shipbuilding
Mock-Up	Relying on the Findings to make demonstration	Conclude based on findings.

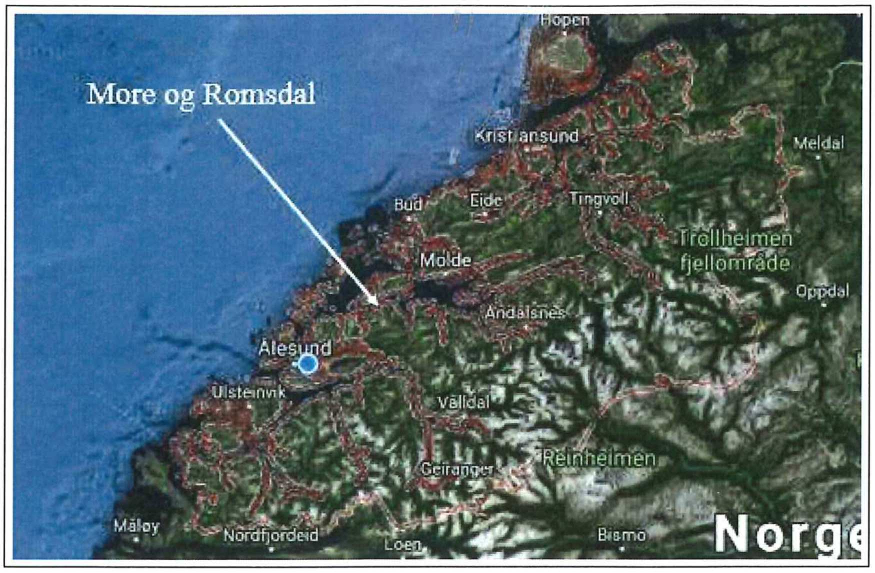


Figure 3.3: More og Romsdal (Source: Google Map, 2018)

"informed" individuals who agrees to participate in your study Mears (2009)

1. The Interviewer (Author)
2. Participants (i.e. Interviews, identified as resources in table 3.1)
3. Area (Society, community, location etc- In this regards, More og Romsdal)
4. Interview Guide (Developed from literature study, see Appendix A2)
5. Data Storage Device (Data will be recorded via hand-written and audio recording transcript)
6. Formally booking appointment on when and where to meet.

Following the enumerated list above, the author of this document shall have the sole responsibility of conducting the interview, there would be need to expand on what classes of people shall participate, the area where the interview shall take place already has been identified see figure 3.3, interview guide has been design relying on the extensive literature study (see Appendix A2), data storage shall be stored as transcript, recorded and hand-written and booking of appointment shall be done using convenient means of communication (short message services-sms, electronic mails, phone calls etc).

Table 3.2 gives an overview into the classification process of of resources (Participants) needed to aid the process of data extraction from participants.

Table 3.2: Classification of Interview Participants

Classes	Expertise	Experience Level (yrs)
A	Design and Procurement Managers	5 and above
B	Design and Project Engineers	1 and above
C	Academics	2 and above
D	Team leaders and Controllers	5 and above

NB: *Ranging of the experience by years for the participants area of "expertise" (please see table 3.1) was done to add some degrees of credibility to the expected outcome of the interview. By associating years of experience as criteria for qualification to participate, it opens up the process to assess the individuals knowledge within the concept being explored, and will help the author attach relevant level of consistency and importance to the accounts that shall emanate from such source.*

Interview Proceedings:

In order to proceed with the interview, request for meeting and appointments were sent through electronic means, notifying the interviews of the subject to be discussed and seeking their participation in the process. A total of twenty-five emails/request was dispatched covering the various classes of individual identified in table 3.2 covering companies such as VARD, ULSTEIN Shipyard, Havyard, NTNU Alesund, Skipsteknisk, Brodren, and Kleven.

The interview is conducted using inductive approach. Inductive process to interview begins with an empty mind, using the research question and guide, attempt is made to draw-up a hypothesis based on the research question and the interview guide. The gross aim of this is to develop an unbiased experienced-based opinion from those participating in the process and use the outcome as a foundation for drawing-up results and conclusions.

The recorded data (transcript) is classified and shall not be made public because the author did not receive permission either from participants or agencies they represent to publicise it. Also, the issues of business confidentiality and privacy rights are among the factors considered to making the outcome classified.

From the design of the research, a method was developed, to combine exploratory studies with a multi-level literature review. While this section have dealt extensively on the design of the exploratory research design (semi-structured interview), one can say that executing another round of literature study in this chapter amounts to an unnecessary redundancy. An extensive literature study has already been carried out during the multi-level review in chapter 2 with a view to generate extensive understanding in form of data that will shape this present phase and equally learn how the industry have responded to the subject of Integrated Project Delivery (IPD).

At the end of the interview and literature study, it is expected that substantial amount of information are generate. Pieces of information that could either or not support the objectives of the study. If the combinatory outcome of both method yields data that are in affirmation to the research question, a data analysis shall be executed, upon which the thesis shall base the findings.

3.2 Demonstration of Concept

The demonstration of the concept shall be based on the findings. The findings shall provide underpinnings for the concept which is intended to provide direct response to Research Question 3 in chapter 1 of this report.

The target of the concept will focus on how IPD shall handle the problem of design change and, project uncertainty and engineering concurrency. This should not be confused for a validation, rather, should be seen from the perspective of presenting a more concretize insight into what the how IPD responds to the key problem areas identified as being a driver of planning complexity.

3.3 Chapter Summary

This chapter explains the systemic approach the thesis intends to follow in order to arrive at the research goal. During the design of the method, exploratory research techniques in combination with a multi-level literature study was identified as most appropriate method for solving the problem. To proceed with the exploratory research, the thesis relied on semi-structured interview approach using a guide developed from the literature study (see Appendix A2).

The interviews were conducted within the More og Romsdal region of Norway. Interviews were identified and classified as "resources", rated and grouped according to level of experience and expertise in order to associate some degrees of importance and credibility to the expected data.

The region was chosen due to its strategic importance, history and role in the development of the Norwegian maritime cluster. The level of participation, names and position of those who participated in the process were deliberately left out of the report to protect their rights and the organization they worked.

The interviews where conducted between the month of February to June of 2018, with nine participants, and a subsequent post interview discussion within the month of October-November 2018 with two other participants within the field of design to specifically discuss the concept of collaborative design, collaborative environment and the reality of such beyond conceptualisation. This discussion was initiated to corroborate the idea with the current industrial practice while reviewing a bunch of tools used within the ship design process.

Chapter 4

Data Collation and Coding

Through the use of Research Design method established in chapter 3, varying degrees of opinions were extracted through the use of a semi-structured interview. In the same order, multiple literatures were reviewed, with different authors positing varying opinions in the subject of Integrated Project Delivery. This section, presents the data collated through use of these mixed research method, and forms the basis upon which the findings will be established.

4.1 Research Output Data

The data generated can be classified into two separate sources. One represents data collated through interviews and the other data collated through carefully analyzing multiple journals and articles. These two separate source of data extracted from the research reflects the design of the methodology of to the problem solving approach of the Master's thesis.

In order to adequately appropriate the right concept to the study, an in depth analysis of the collated data is required. The data as seen in figure are both knowledge, experienced-based and extracts from scholarly articles. These knowledge came from active participants in the interview who voluntarily gave their opinions based on the different shipbuilding projects they had participated during their professional careers.These experience as narrated are one of the primary sources of data because it relates directly to the maritime sector and shipbuilding.

Recorded through transcript (written and audio), the research will rely hugely on the out-

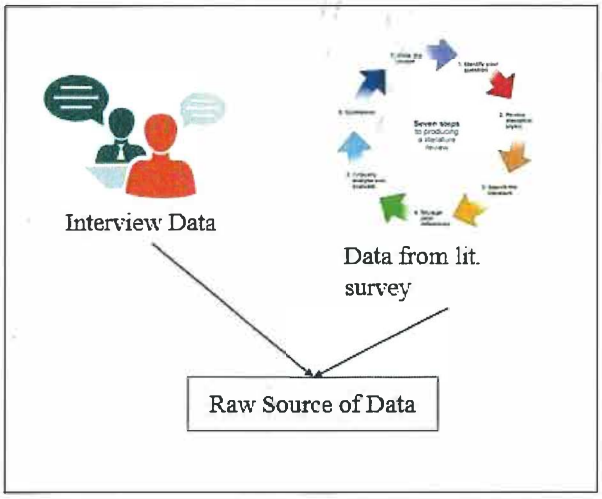


Figure 4.1: Sources of Research Data

come of the mining process to formulate the results. The next phase will require data analysis or coding to carefully separate the varying pieces of information extracted from the raw source of data see figure 4.1.

4.2 Data Coding Method

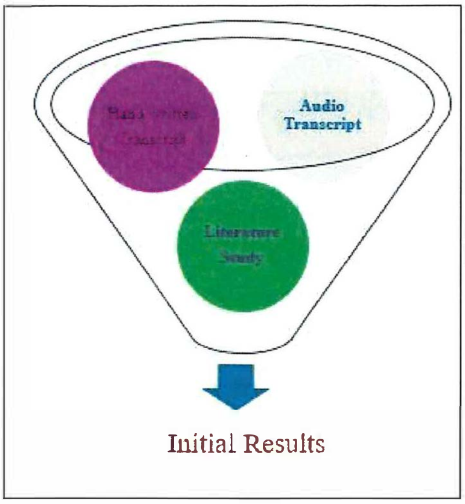


Figure 4.2: Data Analysis Process

Data coding or otherwise called data analysis represents the stage in the data collation process were the outcome of the research is analyzed to give a lead on the findings of the study.The approach used for the analysis of the raw data is General Inductive Coding process. According to Thomas, the purposes for using an Inductive Approach are to (a) condense raw textual data into a brief, summary format; (b) establish clear links between the evaluation or research objectives and the summary findings derived from the raw data; and (c) develop a framework of the underlying structure of experiences or processes that are evident in the raw data Thomas (2006).

Thomas outlined the processes of the Inductive coding process as one carried with the following sequence of activities:

- To condense extensive and varied raw text data into a brief, summary format;
- To establish clear links between the research objectives and the summary findings derived from the raw data and to ensure that these links are both transparent (able to be demonstrated to others) and defensible (justifiable given the objectives of the research); and
- To develop a model or theory about the underlying structure of experiences or processes that are evident in the text data Thomas (2006).

4.2.1 Data Analysis and Strategy

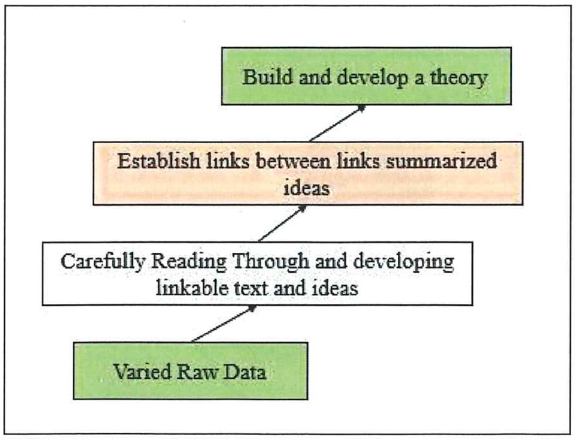


Figure 4.3: Coding Strategy

This sub-section details the strategy (see figure 4.3) adopted by the author in the analysis analysis of the raw data. This is crucial because, it's important to state the overriding philosophy and reasons for arriving at the results. The process shall hugely rely on the method outline by Thomas in the article "A general Inductive Approach for Analyzing Qualitative Data"

Thomas (2006) due to its straight-forward approach, which could be helpful for individuals or researchers with less experience from social science and qualitative research and figure 4.3 has been developed from the description given in Thomas (2006).

As highlighted earlier, the process uses Inductive Coding. Inductive coding begins with close readings of text and consideration of the multiple meanings that are inherent in the text. The evaluator then identifies text segments that contain meaningful units and creates a label for a new category to which the text segment is assigned. Additional text segments are added to the categories to which they are relevant. At some stage, the evaluator may develop an initial description of the meaning of a category and write a memo about the category Thomas (2006).If the researcher has chosen to use inductive content analysis, the next step is to organize the qualitative data. This process includes open coding, creating categories and abstraction. Open coding means that notes and headings are written in the text while reading it. The written material is read through again, and as many headings as necessary are written down in the margins to describe all aspects of the content Burnard (1996); Hsieh and Shannon (2005); Elo and Kyngäs (2008).

Figure 4.4: Domains of extracted Data

Content analysis is the intellectual process of categorizing qualitative textual data into clusters of similar entities, or conceptual categories, to identify consistent patterns and relationships between variables or themes. Qualitative content analysis is sometimes referred to as latent content analysis. This analytic method is a way of reducing data and making sense of them-of deriving meaning. It is a commonly used method of analyzing a wide range of textual data, including interview transcripts, recorded observations, narratives, responses to open-ended questionnaire items, speeches, postings to listservs, and media such as drawings, photographs, and video Julien (2008). Data analysis is guided by the evaluation objectives, which identify *domains and topics* to be investigated Thomas (2006).

When analyzing qualitative data such as interview transcripts, analyses across the whole set of data typically produce clusters or codes that translate into "themesJulien (2008) such domain was constructed (see figure 4.4) to help the author organize the extracted raw pieces of information into sub-areas of strategic importance. By critically separating the ideas into sub-units, it became easier to link and connect the sorted opinions into a coherent piece of information upon which a conceptual theory will be built to provide response to the problem statement.

4.3 Initial Results

Early results after the data analysis process suggest that Integrated Project Delivery (IPD), just like other contractual model can be applied to the processes of design and constructions of ships and other similar offshore structures alike. Though many of the articles reviewed, contains pieces of information about IPD within general engineering construction with no particular mention of the shipping industry, however, the idea behind this exploratory study is to learn from this industry and apply same knowledge to ship construction process.

In the same order, industry knowledge gained through the semi-structured interview and data analysis did not explicitly spell how a shipbuilding project must be organized to suit the definition of Integrated Project Delivery (IPD) and its implication with respect to the general organization of the shipbuilding process. But generally, interviews expressed positive opinions on working more collaboratively, with the hopes it could cut waste and unite every stakeholder within a common goal of delivering according to agreements and specification.

The process of design interaction with planning, early involvement even before the commencement of design and opening up design process, creating the opportunity for non-naval-architects to have opinions and be part of a determining process of design progression which is in itself an attribute of Integrated Project Delivery (IPD) received mixed-feelings with varying opinions for and against. The questions of how Non-design engineers can understand the design process and design process challenges, design thinking and decision making, and the engineers ability to think freely, exercising his creative ability are amongst other issues areas of concern for such packed collaborative process.

Beyond average, the results obtained are reliable enough to prescribe what Integrated Project Delivery should imply for shipbuilding and how it could be organized to yield expect project goals. The next chapter contains the findings structured into two primary areas; Integrated Project Delivery before commencement of design and Integrated Project Delivery at Design phase with a discussion on how ship production could organized within the IPD's conceptual framework of collaboration uniform participatory approach across the common project timeline.

Subsequently, with the findings, a mock-up case is conceptualised to demonstrate in theory the meaning of IPD, and its reaction to design process change and uncertainty. Just as the findings relied on the method in chapter three, such demo case shall equally utilize the results (see subsection 3.2 of chapter 3).

4.4 Chapter Summary

This chapter contains details of the approach adopted for analyzing the raw pieces of information (data) extracted from interviews and journals. The data coding method used for the a general inductive coding approach which required that the author establish a domain of of topics bounding the semi-structured interview, and carefully read through multiple tarn scripts and listen to to audio records and draw-up different pieces of ideas which is subsequently connected to generate a coherent concept which then is used to formulate a theoretical concept on the subject under investigation.

Chapter 5

Results

The results presented in this chapter emerged from the combination of the the research method 3 and the data analysis techniques described in chapter 4. From the objective of the thesis, the cardinal focus of the research was to apply integrated project delivery to ship construction, perhaps, using such innovative approach to project delivery and contract execution, the challenges posed by "design changes" which affected project deliverables could be addressed. First through multiple sources, it is somewhat consistent to state that; Integrated Project Delivery is neither a tool nor technology, but a strategy which could employ some level of technology to the process of project execution where parties seek mutual cooperation and understanding with a common objective to maximize project performance with minimum disturbance.

Using such description, the results presented shall detail how the author's interpretation of the data extracted from the research on how shipbuilding projects could be structured and organized if IPD becomes the the project and contractual execution model of choice. For clarity, the results have been sub-classed into the following:

- Pre-Project Planning
- IPD during Design Phase
- IPD & ship Production
- Fragmentation Control

5.1 Pre-Project Planning

Integrated Project Delivery (IPD) at early stages of project otherwise called IPD at Pre-Design phase discusses the relevant & prerequisite processes, structures and organizational measures that parties to a given IPD-driven shipbuilding project must establish before the commencement of design process should parties seek IPD as the contractual model for the project execution.

The qualification measures for a shipbuilding project to be termed "Integrated" will require that at least, the ship-owner, the design consortium and the building consortium enters into one single entry agreement. The number of parties to the agreement can be more, and should be determine by the scale of the project and "perceived" construction complexity. The idea behind such recommendations is to have all participating partners on a common level, before commencement of different activities. However, the practicality of penning a contractual agreement without a definition of the scope and valuing different phase of the project seems far from reality. Therefore, the shipbuilding process could be re-approached as thus;

5.1.1 Collaborative Concept Development

Concept Development is the first phase in the ship design process and is the lowest level along the common project timeline where significant improvement on the design can be made with very little or no cost effects. Therefore, concept development needs to take broader perspective to approach it. One very profound response received from one of the respondents was the scope of the process of concept development for a new vessels. Developing a new concept as he recounted was reduced to a mere meeting of ship-owner's representatives and the design team. As the studies learnt latter, this narrowed scope of conceptualization had significant impact on how naval architects would subsequently approach the design task. Corroborated by another interviewee, with this presents designers with less ability to develop designs that were less costly to engineer because there was no cross-stakeholders involvement whee views as to other design dependent variables were sampled.

Collaborative Concept development demands for an expanded approach, establishing critical understanding of what the overall project seeks to accomplish in terms of time and cost. Different concepts of vessels are to be developed, at this stage, notifications could be sent to prospective shipyards to be part of the concept review & concept development process process, with that, the ship-owner, yard and the design team begins an early process of relationship that will be subsequently expanded into the project life. The outcome would be a varied concepts, with inputs from yards, then selection of concept is done and the yard whose contribution to this early phase is most profound and outstanding notified as and denoted as the "secondary" builder of the vessel, while the rest are kept as "tertiary". The point is that at this phase, a building contract is yet to be signed, and the yard can not be classified or addresses as the primary builder.

With yard notification, contacts are made with varieties of product suppliers, particularly those with very high lead-time if any, choice of suppliers could be guided by a lot of factors such as: Product Platform and Complexity, care/support after sale, financial strength and the total cycle time of the products. With that, in combination with the experiences from the design team, and the secondary yard, the ship owner is presented with a clear and reliable options on how different choice combination will affect the overall project goal and most importantly, time and money, and what the implication could mean for his operation.

The next round of activities shall involve open establishment of goals for at least the primary stakeholders (*primary stakeholders in this regards could mean the ship-owner, the secondary yard and the design firm*) and these goals are to be communicated explicitly and then parties are obliged to relate same to retained entities. Since IPD advocates for shared risk and reward AIA (2007), risk avoidance in itself is more rewarding than risk shared. In attempt to minimze the risk, retained entities such as suppliers are to be selected not on pre-conceived notion or prior relationship but on the basis that they are technically capable to deliver products according to specifications, financially healthy and share seemingly the same goal as the rest of the project team.

5.1.2 Team Assembling

Assembling the project team represents the second step in building a collaborative team in the use of Integrated Project Delivery contractual model to shipbuilding. Using different qualifying measures, a yard is selected and key product suppliers enlisted. These qualifying measures could range from ability to embrace open communication- desire or willingness to share different pieces of technical information (*possibly sensitive*) regarding either a product backed up by a verifiable, and documented work or build strategy. The goal of extracting these high-level commitment is that; the key to a successful Integrated Project Delivery is assembling a team that is committed to collaborative process and is capable of working together effectively AIA (2007).

Just like the approach adopted within the public sector projects in the Britain BSI (2016) where compliance to COBie or IFC file format or mode of organizing information became amongst other factors, criteria for winning of project bids, the shipping industry can impose the same measures with regards to how design and other information are transmitted. As the data suggested, poor communication within project scope was not only inherent within design but equally across the common timeline. Therefore, it is of interest, that at such phase of assembling team members, party's willingness to adopt such measures that enhances collaboration becomes very important in influencing the choice of potential members.

There are multiple academic works dedicated to the study of features and characteristics of an IPD team which carefully would provide the requisite knowledge on different team election criteria. Amongst these features are cross-functionality of the assembled team. IPD teams should always be interdisciplinary and should generally be cross-functional. Interdisciplinary teams are composed of members with differing training and experience. Cross-functional teams are composed of members with differing responsibilities Ashcraft (2011).

Hence, the advantages of a good project team can not be over-emphasised and since the IPD team shall contain members with varying responsibilities and task definition, familiarization and team acquaintances are necessary. This could be achieved using the normal project kick-off meeting if parties so wish. In addition, the outcome of this phase shall include consensus on:

- Qualified project team members
- Understanding of the goal of the ship-owner
- Identification Machinery with high lead time with with possibility of causing project delays
- Possible classification Society involved.
- Task to be outsourced beyond the spheres of the assembled team
- Possible Constraints and map task dependencies
- A common directory for secondary retained entities, contacts and scope

5.1.3 Project Information Management System (PIMS)

If any key-point could be used to describe IPD, and how it differs from other contractual model that would be "Collaboration." Collaboration in this regards will deal with how the information flow is organised across the common timeline. In accordance with the AIA standard, one way to achieve an efficient information management system will be the use of a Common Communication Protocol, and deciding on a Common Data Environment to enhance information sharing and retrieval.

Shipbuilding projects generates tonnes of data (graphical and non-graphical), data interaction is therefore one very key forms of enhancing communication. The protocol for enabling such free-flow of information exchange shall spell out *explicitly, information responsibility to both project and other stakeholders alike, define responsibilities, project's progress decision board (joint trustees), agree on modes/formats for transmitting meta-data, define the level of detail that is expected of different classes of the model and its attributes, etc.*

This protocol should be in the form of both technical, technological and a legal document and possibly should represent the first legal document to be entered into before the actual contract document itself. The framework should be designed not to create a punitive measure but to extract commitment and ensure that parties are on the same platform or level of understanding regarding what has to achieved and the different roles parties owe to the shipbuilding project.

The next on the scope of the PIMS is the Common Data Environment. In general term, a Common Data Environment (CDE) is defined as a common digital project space which provide well-defined access area to project stakeholders, combined with clear status definition, and a robust work-flow definition for sharing and approval process Turk and Scherer (2002) The Common Data Environment used to be deployed for a shipbuilding project shall rely on the established protocol for communication to be structured, providing an unrestrained access to project stakeholders so as to deliver the required project goal already established.

As the study understood, the issues of task separation, outsourcing of responsibility (e.g. company A performs hull design and development with dynamic load assessments, company B performs structural design, local and global load assessment and company C is responsible for steal cutting and block production) if not well-managed creates an environment of non-synchronous pieces of information. These amongst other factors affects project performance, the different rounds of follow-ups (emails, phone calls, and other types back-and-fort exchange) may be very insufficient tools for communication and this could be perhaps, often frustrating and defeats the goal of project integration.

On the overall, a Common Data Environment should house or contain as a sub-set (different design and non-design software (see figure 5.1)) that are able to link-up and communicate, making sharing of different project information possible while providing unhindered assess to all parties within "Common Protocol Specified" limit. The goal is to have a central virtual space, in the form of a cluster, where active and complex engineering is being undertaken, possibly portioned within sub-units (design, production, planning, purchase and procurement). Building a Common Data Environment is really not a simply endeavour and it requires services of

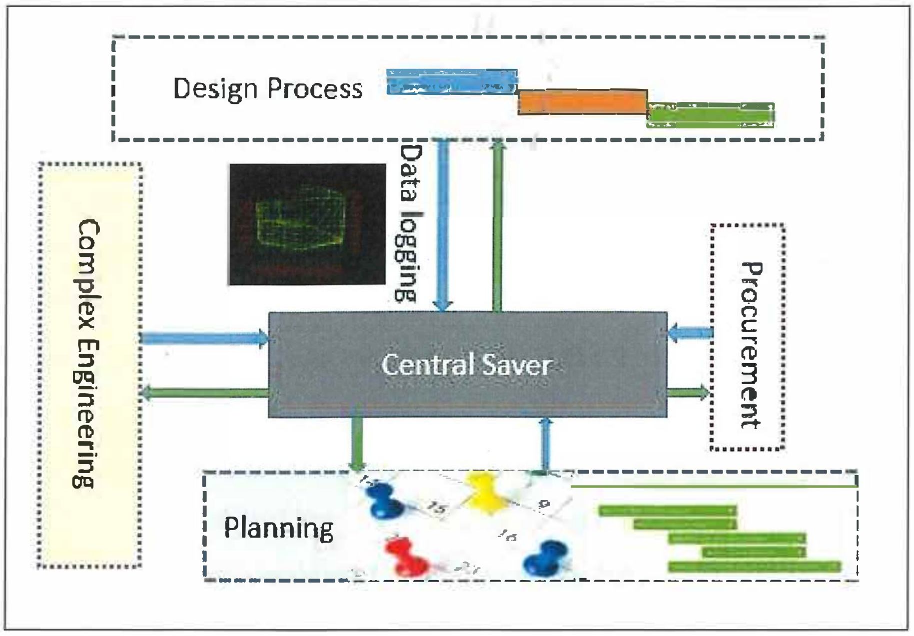


Figure 5.1: Mock-Up Sample of a CDE

Software Engineers or Data Scientist(s) and comes in different format. Upon a general consensus within the stakeholders, project complexity, available technology and cost for building a CDE, the team will therefore agree on the right form; extranet, intranet, or cloud based CDE. The lifecycle of the environment could stretch longer than the project itself and could provide a platform for data repository which could be subject to mining over periods and used for research on IPD project performance.

Figure 5.1 depicts the concept a Common Data Environment housing different units of a shipbuilding project. The idea of creating a CDE for Integrated Project Delivery in Ship Building, takes the shipbuilding process into a phase where Building Information Model (BIM) possibly level 3, becomes the driver of the entire information flow beginning from design to closure of the project. Though, this study was not conduct to determine BIM industry standards for shipbuilding process, it's now to a large degree evident that IPD in shipbuilding will require some levels of Building Information Modelling if the goals of people and process integration is to be achieved.

Though, IPD can be implemented without a BIM process however, the full potential of IPD cannot be achieved without the use of a BIM process AIA (2007). Therefore, for the full benefits of IPD (shared risk and reward, reduced project waste, collaboration and stakeholders integration- including design and planning etc) to be realized in a Ship Construction Project, the incorporation of either a BIM process or similar digital technology would be very essential.

The subject of CDE is a very broad one, including the managerial process, data migration and retrieval, structuring the different pieces of information itself to serve the right purpose are areas that possibly need more exploration. Because, with such central information repository, there are high tendency to create a store house of information mess, this will not only create problems for those who wish to "know what", "when" and from 'where" but ultimately serves as a defeat to the idea of providing information throughout the project lifecycle. As estimated by Payne there could be as much as 20-25% extra cost added to the overall project cost for the built environment resulting from poorly unstructured information logged into the CDE. If this becomes the case, there could be chances of compromising the project goal. To counter this, expert knowledge would be needed before, sorting of what goes and some qualification or approval measures undertaken to limit the prospect of waste creation from the central system Payne (2018).

Project Information Trustees

Some of the Key problem with complex construction projects like that of shipbuilding is the how the flow and exchange of information are managed. Open unstructured, and unregulated communication can be as well be as ineffective as a process with no communication links. The trustees in this regards, shall manage and coordinate the activities of the CDE and could be a retained partner with the ship-owner or a cross-party assembled individuals or individual or individuals hired for the task of managing the environment.

5.1.4 The Contractual Model

Design Information sharing, data exchange, and the transfer of sensitive pieces of information on the basis of just achieving project success sounds logical, but there could be issues of possible potential conflicts regarding questions of property rights and privacy within and after the closure of the project. How does one guarantee that information shared under mutual trust particular within a highly competitive business environment like shipbuilding is not stolen and replicate without adequate approval?

To protect parties from this business risk, the result suggest that parties to a ship-based IPD would need to enter into a non-disclosure agreement. NDAs remains amongst other business protective mechanism for integrated project delivery, one which emphasizes punishment(s) for theft of business strategy, technology, violation of commercial rights, reverse engineering AIA (2007), and wilful character that may be displayed by a party or parties with intent to criminally acquire someone's idea. A non-disclosure agreement can be signed in part, or drafted into the global contractual model. The next mode of contractual document could be in the form of a Multi-Party agreement, a Joint Liability or Joint Venture. The goal is to draw-up different participants within the project scope to pen-down one single contractual documents that may vary in terms, with respect to organizational role, scope of activities, degree of participation, sensitivity of assignment and how the risk is distributed, not evenly as widely perceived or suggested or speculated by multiple sources[1] but *equitably* across board.

Also studying the different contract signing guiding documents (the Norwegian Contract 2000, the SAJ form) it is yet unknown to this document how those traditional documents will respond to the IPD contractual model. The fundamentally clear understanding derived is that an IPD contractual document is that of a single, unifying and binding document entered between a potential ship-owner, a design consortium and a building consortium (shipyard). These are the primary actors or principal stakeholders. For the sake of structured work organization, these primary stakeholders can retain secondary stakeholders (product suppliers, steel suppliers etc, however, the principle of open communication requires that all retained secondary contractors shall be fully disclosed and the scope of contract and responsibility made public within the

[1]Different sources (Articles, including AIA (2007)) have suggested that risk within an IPD project should be evenly distributed. If that applies to other industry, it may not hold in the shipbuilding industry. Risk must be equated according to roles, scope of assignment, and "worth" in terms of money. He who receives more should be pay more.

framework of the global contract.

5.2 Ship Design Phase

Much has been document by some authorities and authors on the innovation that IPD brings to the table and what that implies to the design process. The concept of early involvement of key stakeholders have been vaguely described and lacking to some degrees in content. This section is dedicated to discussing the ship-design process within a conceptual framework of Integrated Project Delivery. Ship design remains one of the most complex design task in human evolution and the stories of catastrophes originating from maritime accidents are evident of the fact that the impact of erroneous designs or misuse of design information can be very consequential through the lifecycle of the the asset. The next attempt is to prescribe on a conceptual basis how the design processes would be organize to provide the opportunity for stakeholders' integration and collaboration .

5.2.1 Model Acceptable Level of Detail

To begin the ship design process within an IPD-driven project model environment, there is need to impose a certain level of detail that is required for either a local or global model. The concept of "Level of Detail" for the model in any of its dimension, refers to providing minimum or maximum acceptable pieces of information for a 3D model or a 5D model either in whole or part, that is technically clear, understandable,readable with specification as *required* that is considered important and needed in making decisions within the common project timeline without creating "uncertainties", confusion and errors that could cause a re-work, unnecessary waiting, waste of time and money.

The concept was adopted from the "BIM Industry Protocol" EUBIM (2018). Creating a standardized "level of detail[2]" for the ship model will not only serve as a standardize way for model

[2]Level of Detail can as well be said to mean technical footprints- i.e properties of the model that is required, considered relevant and important to give a detailed explanation of the model to a so-called lame or a novice in the field of engineering design/naval architect or project management. The essence is to ensure that there is understanding across board.

presentation and representation but can ultimately make the process of information exchange less rigorous and confusing with some potentials of creating internal variation order.

Design fragmentation was was not just a mere problem originating from concurrency or separation of design from planning. Issues of lack in detailed pieces of information also created fragmentation and are more of an internal variation-order and affects internal firm efficiency and could as well affect profit through the accumulation of more working hours as a result. The shipping industry do have the SFI coding systems which could be described as a very low level of building information model.This i.e the SFI codding system can be combined with the LoD standard to create a more elaborate understanding of any of the ship systems or functional requirement. A level of detail has to be defined and agreed upon by all parties at the point of creating a Common Protocol for the project, the model should be engaging and interactive, provide assess to other parties-accessibility point, model has to show originating source, model should have restriction on who can utter its features, goals and purpose the model serves in the global project domain should be explained and other ship global properties that interacts with the model should be listed, and consequences of possible data misuse provided as a precautionary measure.

Figure 5.2 and 5.3 shows a demonstrative concept of Level of Detail for am LNG fuel tank for vessel under construction. Figure 5.2 purports to show the model (3D and draft) with different level of information on the right while for figure 5.3 it shows the 3D model in a dynamic environment similar to a CAD design environment but with ad-ins that makes it possible for other stakeholders (planners, procurement, classification etc)to interact with the model, extract relevant pieces of design information, enabling communication with the originating source and give suggestion if there are clashes.

5.2.2 Design Delay Period

Integrated Project Delivery requires a cross-platform and domain participation. Theoretically speaking it could be easier to just describe without really substantiating what that actually entails and how such cross-platform participation can be made possible.

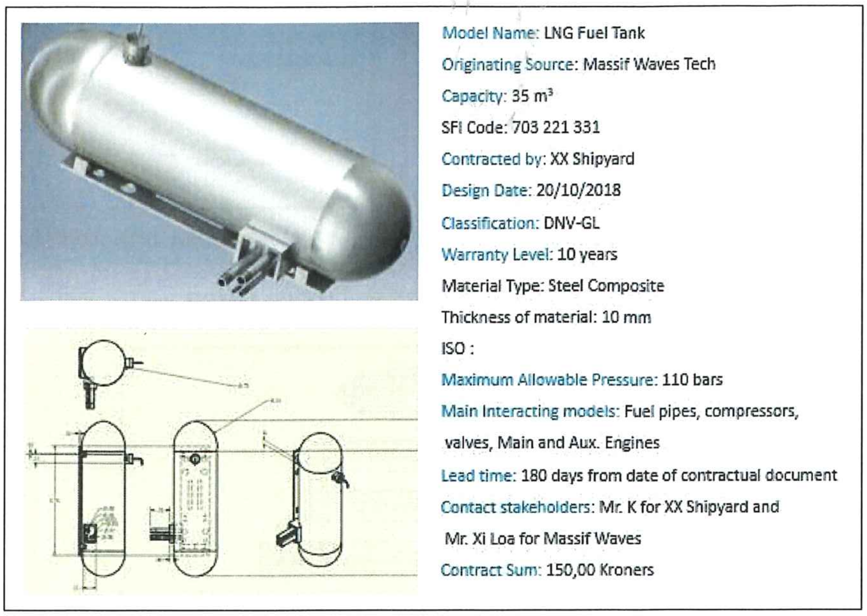


Figure 5.2: Mock-Up Sample of Level of Detail (LoD)

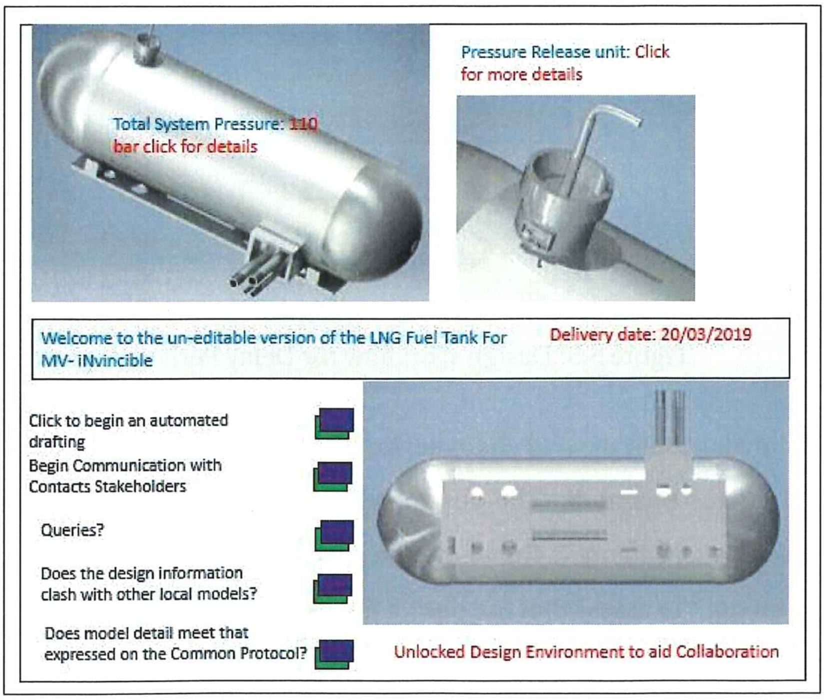
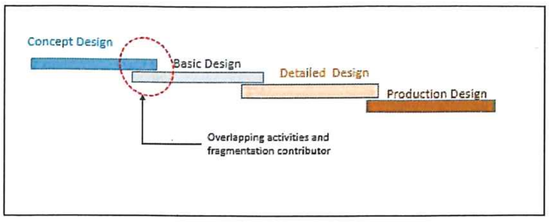
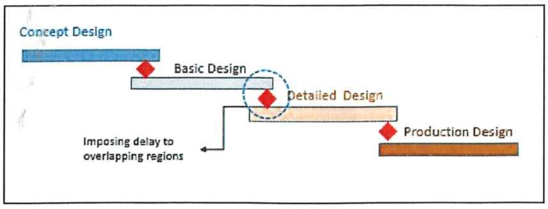


Figure 5.3: LoD-Interactive-Dynamic and Engaging

To propose a response to that, one can say that the so-called participation, collaboration



(a) Design Timeline with no Delay



(b) Delay Imposed Timeline

Figure 5.4: Demonstrating Design Delay

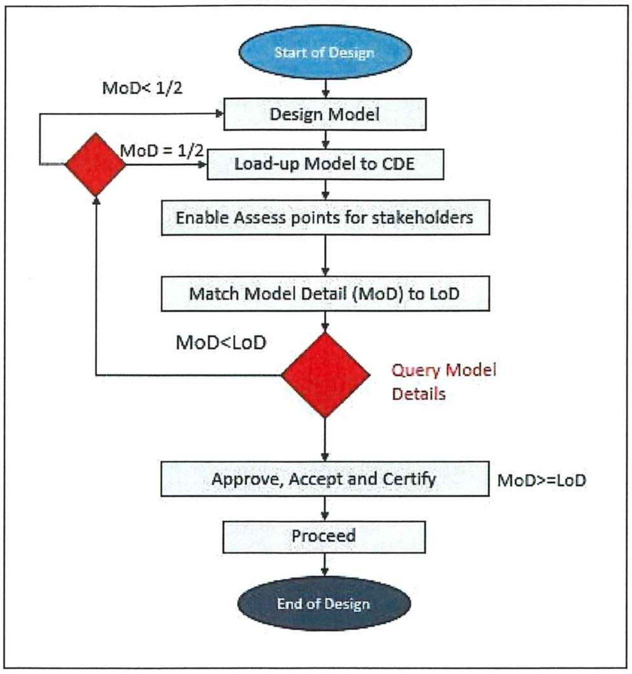


Figure 5.5: Design Workflow for Delay Period

and stakeholders involvement used to characterize IPD has to be enabled structurally in terms of organizational modus-operandi. The design delay period is therefore a measure imposed in-between milestones (see figure 5.4b) where the stakeholders carryout a comprehensive assessments of the model [3] to assess that the design details contained in the model is satisfactory and reliable in terms of supporting decision-making within the common project timeline without creating or causing any form of complexity or waste.

This proposal attempts to address the complexity created by engineering concurrency. This

[3]The model could be a local model e.g. piping systems for ventilation or part of the global/federated model e.g. bridge deck and accessories

implies that, at those overlapping regions, the design footprints are tested using any qualifying measure developed by the project team to ensure that the model conforms with the pre-existing protocol and meets the level of detail required to support decision making and the overall actualization of project goal.

The essence of some of these constraints on design is to guide against unilateral decision making ability of the design team, create the right environment that enables participation and adopt collectivism that helps to maximize the best of everyone through participation. Carefully examining figure 5.5, it shows the workflow for implementing delay in the ship design process, the red diamond shapes denotes decision points, if Mod < 0.5, the implications is that the design footprint contains less than required, and may possibly cause a problem in the future, therefore there is need to comprehensively develop the model to meet the specification of Common Protocol and the the Acceptable Level of Detail (LoD). If the MoD = 0.5, the implication is that a mean level of detail has been provided, then the algorithm routes to requesting that the complete detail be loaded up or provided, and finally if MoD >= LoD, then design outcome/footprint is deem satisfactory and can aid decision-making without causing fragmentation of design information, constituting and creating some degrees of planning complexity and will give rise to no waste that could affect project deliverables.

To this end, even if further results suggest otherwise, that a more jointly approved to have met the requirement specified in the Protocol is found defective, then the IPD principle of shared risk can then apply since originating decision was jointly taken.

5.2.3 Collaborative Ship Design

Collaborative ship design requires that the design process integrates other key stakeholders or its accredited representative into the design workflow, provide the assess point and enabler for active participation, answers to questions and supplying every necessary detail with regards to design footprints that parties require to successfully deliver their respective duties that are linked to the design process with an end objective of achieving overall project success.

Collaborative Design seems somewhat suitable within the contextual framework of Integrated Project Delivery (IPD). Collaborative design, will require a collaborative environment either in space, or any other form deemed fit by project participants to strive. According to Kleinsmann, collaborative design entails three key building blocks:- knowledge creation and - integration between actors from different disciplines - communication between the actors about both the design content and the design process - the creation of shared understanding about the subjects communicated Kleinsmann (2006).

With that, it's is of the opinion of the findings of this thesis that Collaborative Design approach, if adopted as the guiding process to the ship design process and other "child model[4]" alike, could discourage the act of design/planning separation.

The view that collaborative design holds the key to bridging the gap between designs and planning stem's from the works of Kalthoff et al. Which states that collaborative design is a technique, and the technique includes defining a stored data set maintained by a first entity to include a locked and an unlocked data set, and providing a second entity with access to the stored data set. The second entity has "permission" to view the locked data set and to change only the unlocked data set Kalthoff et al. (2013). Adopting Kalthoff et al. argument to the process of ship design will entail classifying the "design" consortium as the first "entity" and other partners as the second within a common shared design environment where project planners can have access to certain footprints, make alterations, suggestions, within allowable limits.

With such collaborative system across the common project timeline, a design process that is powered by a form of digital technology in terms of communication, that whose progression is determined by a "Pull" factor from stakeholders regarding the quality of the present, and "how" by agreed standard, the details of now can help the navigation and execution of activities of the future without disturbance, the combinatory effects of these, are a re-organized design process workflow, with some inherent lean-based approach and that which heavily influenced by a net-

[4]The term "child model" has been used to describe other products that is housed within the vessel e.g. Deck cranes, with the vessel as the parent model.

work of stakeholders.

5.2.4 Collaborative Design-Pull

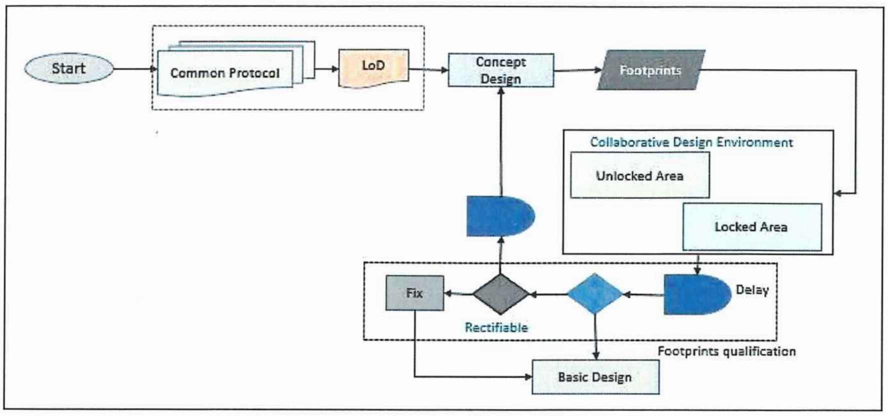


Figure 5.6: Lean-based design

The concept of pull-back design is coherent with lean construction principles particularly the Last Planner System. Pull-back design is an approach to design that advocates and discourages the straight-line thinking and direct approach to design. This method, places the design activity as central with it's outcome having either a positively or negatively impact throughout the lifecycle of the model.

The process requires that design progress should be determined by how much is known at the present that can support the future decisions or progress into next design phase without creating a rework that will consume time and money. Pulling-Back requires that progress is delayed, data analyzed and certified by project trustees and stakeholders who needs adequate communication, including those that could support error and hitch free design fully notified and allowed to present opinions and views (see figure 5.6).

Collaborative design-Pull is therefore coined to suit the context of the research in question, using the principles of Collaborative Design, the Common Protocol, Level of detail and a digital design environment in form of that described by Kalthoff et al. (2013) and incorporating a sort of decision support that guarantees that the quality of the "model as designed" is supportive of project goals and objectives.

The question of how much should be known early enough before commencement of design is underlined during the protocol establishment, though, it should be noted that complex design and engineering construction are very dynamic in nature, so the Common Protocol and Level of Detail (LoD) for the model should always be review and upgraded if possible as the project becomes more complex. Also, learning from previous experience on similar project can play a significant role in helping stakeholders respond to the changing environment.

5.3 IPD & Ship Production

From the varying degrees of concept suggested for the design phase for a shipbuilding project, it is important to explore how these concepts responds to the engineering otherwise called the production phase. Though, the study itself has been centred around the design phase, the driving goal was to use the IPD approach to limit the impacts of design change in the actual engineering phase so, that explains why more of the discussion has been tailored to the design phase. Equally, the production process is in itself a very elaborate engineering process hat may not fit into the scope of a single master's thesis. Therefore, the discussion here on what IPD implies for ship production will be though conceptual, and projecting based on available knowledge.

To effectively implement IPD during the production phase, more than just design and planning integration is required. Assembling an integral team without visualization of how such team will handle different activities, learn and improve, how the re-organized design process workflow could affect yard operation station by station, teams by teams and the general work attitude may not be very helpful.

The contraction industry which has been very fundational to this study, have successfully moved to a point where production simulation is used to demonstrate in a virtual space a building construction in order to minimize both risk and errors. By doing this, the design information already integrated are harnessed and put to use. As rightly noted by AIA, using BIM and other tools to construct a building virtually in advance of actual construction substantially diminshes the risk of design errors and omissions AIA (2007). This could actual be the future of ship production where relying on 3D, 2D CAD models, and aesthetic simulations are considered less sufficient to help detect clashes, accurately estimate cost of decisions either taken or not and may be somewhat insufficient to use as a decision support model to accurately deliver a very robust, dynamic engineering endeavour. The objective of such concept is the computerization of the whole process of ship production, at present, research on simulation-based ship production process is incomplete Kim et al. (2005).

So the gross effect is a shipbuilding process where stakeholders are integrated and Incorporated into the both design process timeline and the common project timeline using what was described by Kalthoff et al. (2013) as collaborative design design environment, enabling parties access to the ship "model as designed", with the prospects of either suggesting changes within an "unlocked[5]" design environment/area which shall then be subjected to qualification, and if that is approved by the project trustees, instead of implementation, an actual construction simulation is executed to see and learn through virtual space how such implementation will respond to the actual production in terms of man-hour, conflicting interfaces, performance, and what that could mean for the end user. This is what Integrated project entails.

5.4 Chapter Summary

Chapter 5 discussed the findings in relation to the research questions 1.4. From the nature of the question, a method was design that gave rise to the results. The results are a mere conceptual proposal for the application of Integrated Project Delivery in Shipbuilding or other offshore constructions of same kind.

The opinion of the results is that IPD is applicable to the processes of shipbuilding if measures that provides the entry point for cross-stakeholders participation is provided. These measures the thesis have itemized and discussed herein. The next process, will require the use of

[5]see figure 5.3 it's a simple concept of an unlocked design environment as inspired by Kalthoff et al. (2013).

these conceptual frameworks to handle design changes, fragmentation and control of uncertainty. Hence it is right to say that the research questions at this point has been answered in part.

Chapter 6

Uncertainty Control

The identifiable causes of Project uncertainty in this study as understood from the multi-level literature study and the field interviews does not in any way differ. Uncertainty is largely a primary effect of design and planning separation, incompatibly project goals, unstructured communication, and lack of collaboration across the common project timeline.

Through the use of Integrated Project Delivery contractual model, there could be huge potentials for eliminating these causes and it's effect on the project deliverables. Though, on the preliminary basis, this is not something magical but a product of a well-thought, organized, structured and goal-driven project decision making. The following sub-sections of this chapter shall discuss on a conceptual framework proposal to handle project uncertainty emerging within an Integrated Project Delivery environment.

6.1 Controlling Through Integration

Integration of key Stakeholders into the common project timeline is one of the upsides/advantages of IPD and appears to be one key process to handling project uncertainty. Such integration in a dynamic collaborative measure that allows active participation of stakeholders, tracking of activities as they change, notification of changes to either a model or decision and a joint decision-making process with respect to any form of implementation or alteration keeps a level-playing field for all, everyone and progress driven not by one single party based on the stake they control

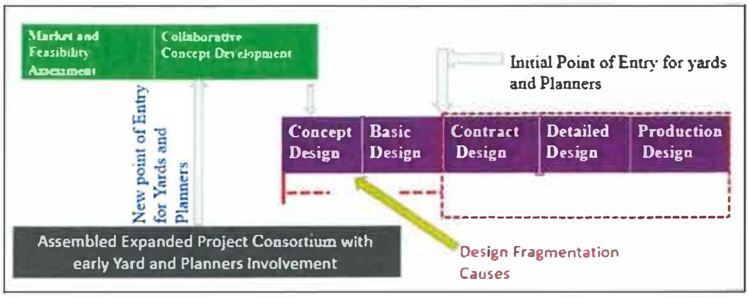


Figure 6.1: Design Timeline with Early Involvement

in the project but by the sense of a "common good" of the project.

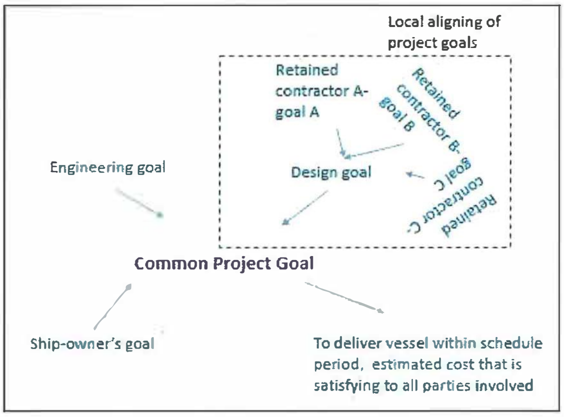


Figure 6.2: Aligning Project Goals

Figure 6.1 depicts the idea of early involvement of stakeholders, right at the concept development phase, then, the concept and basic design phase are shown to be one of the key sources of design information fragmentation, with shipyards and other project teams entering the common project timeline at the end of the basic design phase. The new approach where integration of stakeholders is key to uncertainty control should therefore discourage the practice of contracting design separately, completion of concept and basic design which is then used for bidding from shipyards. As outlined earlier, such practice is inordinate with the tenets of IPD.

For integration of stakeholders to effectively handle design project uncertainty, individual project goals needs to be aligned as shown in figure 6.2 and contained within the central project goal. Through the project pre-planning phase, such goal definition has to be defined, mapped, understood and contained. The idea is to create a harmonious working environment that maximizes the best potentials of participants, encourage innovation and amicable resolution of conflicting project goals and objectives.

6.2 Controlling Through Qualification

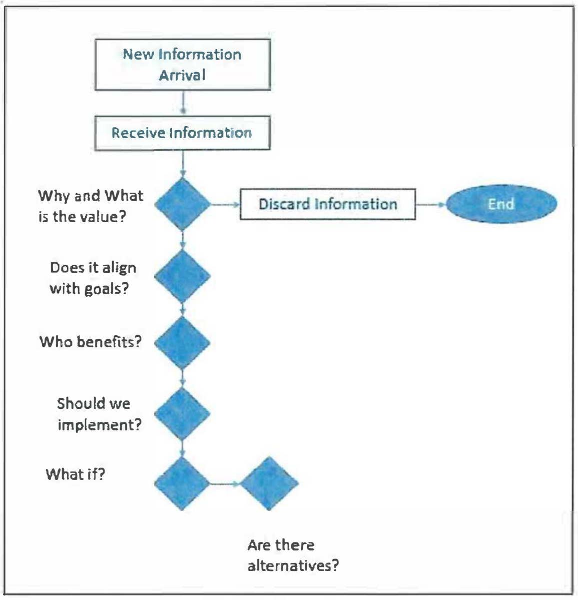


Figure 6.3: Decision Qualifying measures

Imposing, incorporating or perhaps adopting a qualifying measures as shown on figure 6.3 not only on the design information produced from design activities, but on all other facets of the shipbuilding project is important to ensure quality of decision that is goal-oriented.

Fragmentation, which created uncertainty were not only visible because design and planning was separated. Incoherent decision-making that is out of touch with the reality on ground and using anticipation, speculation or "guess-timate" as the foundation upon which actions are taken should be discouraged if project uncertainty has to be curtailed.

Such qualification process should utilize the "5-Why" approach, always seeking to know why and comprehensively outline if decisions such as those leading to design changes are actually good for the ship-owner from a long-term business perspective, if it serves the interest of the project, if it meets the standard agreement and the gross implication for not just the stockholders but the whole value chain.

Project uncertainty is therefore seen from the perspective of this study as one created as a result of design practice, the structure of the workflow, how project goals are aligned, how information and communication across project timeline are structured. More often they are not very visible and difficult to even approach using statistical and probabilistic measures because the originating sources are latent and not very well-understood. But by using a very elaborate lean-based techniques such as those discussed in this chapter with key emphasis on figure 6.3 rather than spending time developing mathematical models which require lots of hours to simulate and trying to communicate the out of such simulation, by just sticking to very lower-level decision-support measures and collaborative work ethics and process, design project uncertainties could be largely controlled.

Chapter 7

Mock-Up Case

Chapter 5 & 6 presented the findings in relation to of "if" and "how" the concept of Integrated Project Delivery could be applied to shipbuilding. This chapter deals with research question number 3, on how through the ideas presented in chapter 5 & 6 the thesis can demonstrate how the challenges originating from design changes, its implementation, enabling footprint retrieval and the concept of collaboration can be shown to help digest the concept present which in general terms may appear to be very abstract for some categories of people or perhaps conceptual and very theoretical.

7.1 Fixed Constraints

To begin with building the mock-up case, it's important to describe to some degrees of details how the case will be centred, what is needed, conditions are parameters that are either static or subject to change. The first assumption is that of a client 'A', with a request for the design of a platform supply vessel by design company 'B' and subsequently, to be built by shipyard 'C.'

By the definition of IPD, it implies that stakeholder A, B & C at least shall enter into a single point agreement either in the form of a Multi-Party Contract, Shared Liability or something in that form. Also, it implies that design is iterative and collaborative with project participants admitted to the design timeline, project goals aligned, protocol established and the model level of details set to the acceptable standard.

Design is organized in a collaborative environment and software system interoperability is enabled across board and both graphic and non-graphic data are able to interact, link-up and communicate. At this point, BIM technology has been initiated and design information management process is fully automated.

So we assume that somewhere into the detailed contract design phase, a request for specification and functional requirement of the supply vessel is requested by part A, which will prompt part B and C to implement. So let's model this classical case using a design process workflow to have a clearer perspective of what is being conceptualised.

7.2 Case Chronology

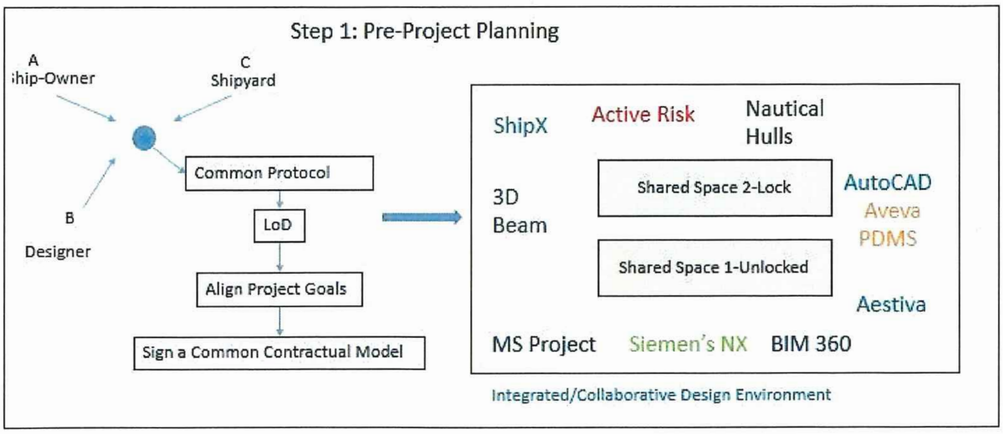


Figure 7.1: Pre-Planning Phase

Figure 7.1 depicts the structural set-up for the pre-planning phase of the offshore vessel. Following the results, these are typically procedural process that should be followed before the commencement of design. The integrated/Collaborative environment provides the platform for integration of stakeholders[1], enabling cross-platform participation and follow-up even re-

[1]For the sake of clarity, stakeholders integration does not literally mean just different individuals working together but working in such a way that the various tools, software, technology used are able to dynamically interact to solve common problems and yield the desired results. For example, modifying ship hull lines and automatically, new hydrodynamic data such as sea-keeping, manoeuvring etc are fetched and its implications on choice of propulsors and purchase and procurement

motely.

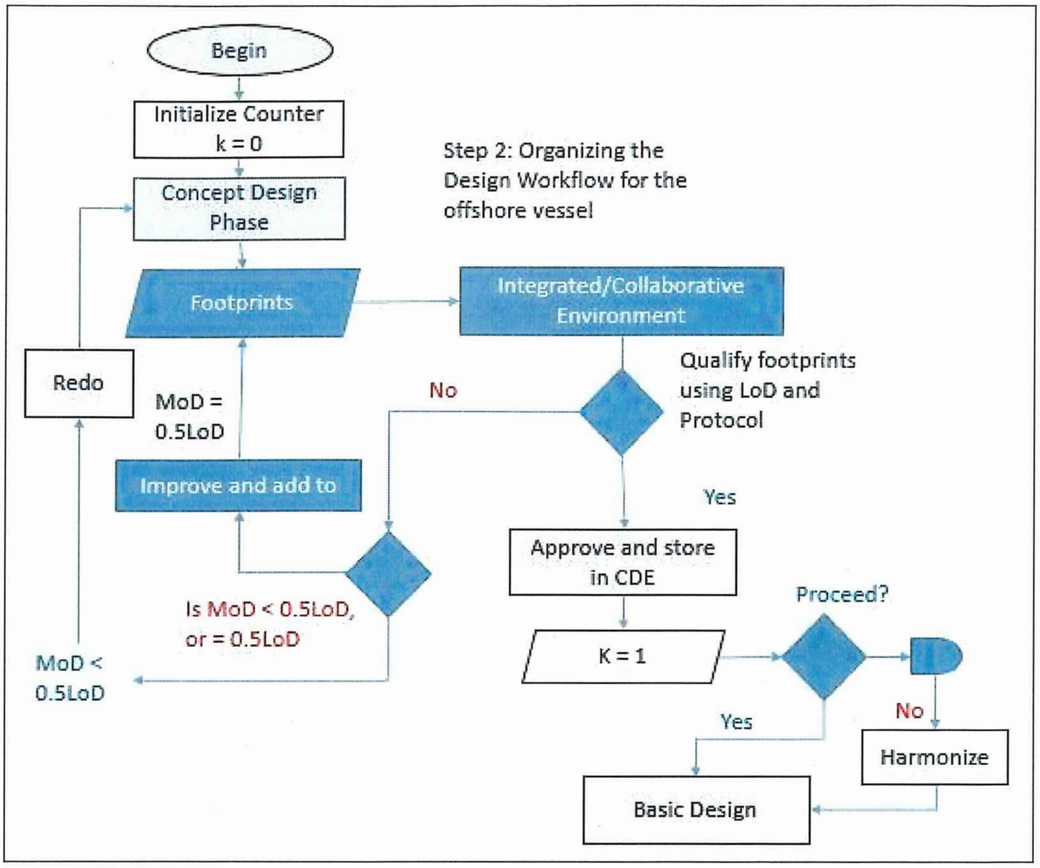


Figure 7.2: Design Phase Workflow

With figure 7.2, a pull-design process is assumed to have commence. As shown in the figure, the process tends to incorporate key elements of what have been in discussed in 5.What follows are sets of outcomes, i.e. design parameter; geometric definition, weight and space groups, GA and every detail that is consistent with Basic design phase.

To adequately communicate the design outcome, the case shall utilize the SFI[2] coding system s a means of representing either the functional or system classification of the vessel. Let's say somewhere in to the end of basic design phase to the commencement of contract/detailed phase, the ship-owner, in this context party 'A' approaches the integrated team for a design change request regarding crew size increase and the overall DWT of the vessel.

[2]please see Appendix A3 for the description of the SFI coding system

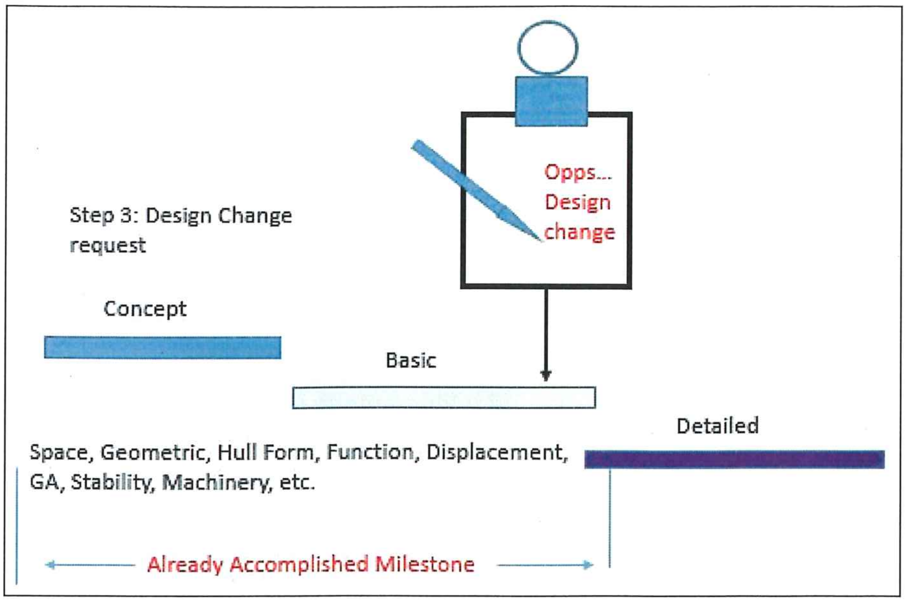


Figure 7.3: Design Variation Order

In a non-Integrated project, with such request as show in figure 7.3, the ship design team, estimates how much re-work is needed often with very sketchy communication or sometimes a lengthy back-and-fort e-mails, design reviews meetings are held between different stakeholders and particularly the yard whose "build strategy" may have been compromised by the new request. These are the common sources of design fragmentation. While such changes are good for business, the process of executing them are much more complex. As sources from the field interview suggest, if the cost of re-work emanating from the design change request exceeds 10% of the contractual sum, the contracts get re-negotiated and this affects the Master Schedule, and may as well attract more cost than initially estimated.

7.3 Response Model to Design Change

As earlier discussed, IPD is not driven by singularity, self-interest, or personal gains rather advocates for collectivism over individualistic approach. The process of responding to the request from the ship-owner will not be limited to a scenario where the design team unilaterally execute the changes as requested but will require cross-stakeholders approach who should begin by performing different degrees of assessment to objectively understand; *what is required, how* *to achieve it, and whats will be affected.* The main goal of such multi-stakeholders approach reflects the proposal of using integration to manage design fragmentation (see chapter 6).

According to Storch et al. there are two possible ways to responding to design change request; one is through the use of a preventive approach-where the design unit and the yard actively engage the ship owner through series of discussion to ensure that such changes are accommodated within the limits of what the yard can deliver based on the contractual document and the is to develop what Storch et al. called a counter measures, requiring the development of strategies to down-grade the effects of such changes on the overall project performance.

In the view of this document, responding to design change request should incorporate both preventive and counter measure approach. The goal is to limit project uncertainty as a result of the design change request within the best possible limits. Through team integration as discussed earlier, it is assumed that the communication and exchange of information are more or less structured, eliminating the sets of uncertainty that resulted from information fragmentation, but how such team members/stakeholders integration plays out in this regards are down to how the powers and upsides of such integration are utilzed.

With reference to figure 7.4, the design process begins, the request is registered and asses of what the ship-owner wants is clearly understood from all perspective. This requires a proper knowledge of why the need for design change in the first place? what is the driving motive? was it the change conceptualized based on poor market decisions? Does he want more or less? Is such change internally triggered? etc. Such broader scope of understanding should be rooted in a knowledge-based assessment and the parties should be open in communicating the findings to the central project team.

When the above rhetorical questions have been dully answered, the design team, in partnership with those whose task could be adversely affected carryout an in-dept study of possible list of systems, sub-systems equipment, functional requirements that are possibly going to be affected by the implementation of such request, ranking them from Most-Critically Affected

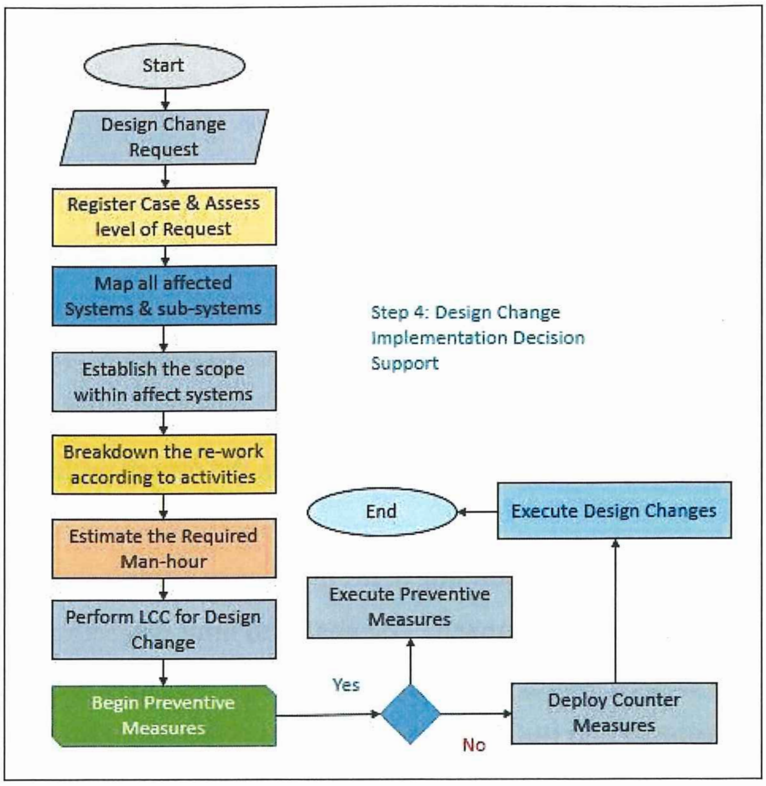
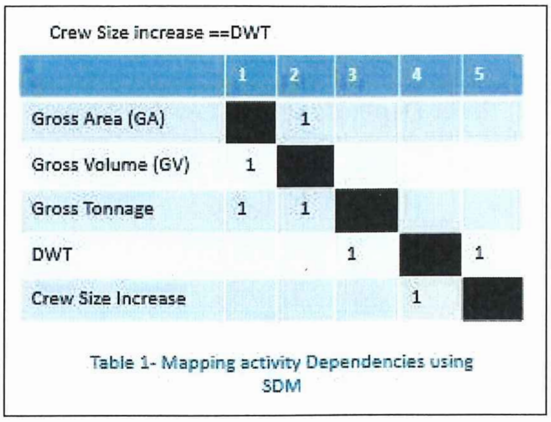


Figure 7.4: Design Change Implementation Decision Support

(MCA) > Critically Affected (CA) > Less-critically affected (LCA).

Such ranking and mapping can be done using some very basic methods such as performing a simple giga-mapping[3] based on relational constraints, breaking down of the activities required and using Design-Structural Matrix to visualize how the activities and events are coupled. At least, the knowledge of the complexity associated with the implementation of such request could be well-established. This is could help create a balanced understanding of what needs to be done and how much is affected. As the field research would suggest, sometimes when request for design changes arrive, lack of comprehensive understanding of the boundary or scope of activities that such request often commands are not well-understood. This of course leads to poor estimation of man-hour in terms of re-work and cost estimation. It's either it's over billed or under billed. Then what follows could be scenarios where parties are less happy because of possible claims of in-balance.

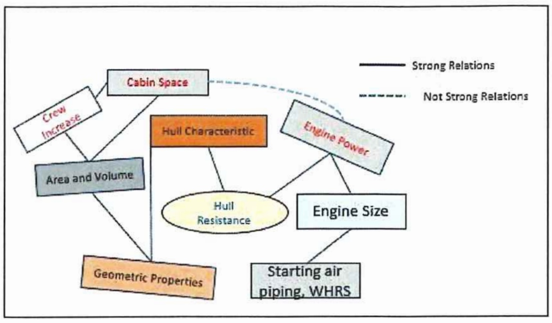
[3]www.systemsorienteddesign.net/index.php/giga-mapping


Crew Size increase ==DWT

	1	2	3	4	5
Gross Area (GA)		1			
Gross Volume (GV)	1				
Gross Tonnage	1	1			
DWT			1		1
Crew Size Increase				1	

Table 1- Mapping activity Dependencies using SDM

(a) DSM Sample



(b) Giga Mapping System Relations

Figure 7.5: Establishing System Relations

What the proposal in this mock-up case is advocating is simply a comprehensive understanding, then proper communication and before either deciding to apply the preventive or counter measures measures as suggested by Storch et al.. From figure 7.5a & 7.5b, table 7.2 & 7.1 such comprehensive assessment was performed just to present an overview of what the concept of "comprehensive assessment" seeks to accomplish. With emphasis on *table 7.1*, the level of impact on ship system using bot the DSM, and the Giga map, criticality level is assigned and at this stage, "open communication" of IPD requires that elaborate notification and communication is carried out and as a deviation from the normal, this has to be done within the integrated/collaborative design environment. The essence is to avoid the lengthy meetings and unnecessary waiting.

Using figure 7.4 as a support tool, a lifecycle cost model is perform not just for the implementation of the requested change but should include and accommodate different conditions such as:

- Lifecycle Costing of Implementation of Design Change for both the ship-owner and the rest of the project team
- Lifecycle costing for a possible alternative to the requested Design change

Table 7.1: System Dependencies and Criticality Level

Type of Variation	Primary point of Impact (SFI)	Inter Dependencies	Level of Impact
Crew Size Increase	2, 20-204001-201006	20	Very Critical
		201006	
		202	
		203	
		401	
		401001	
		401002	
		401003	
		6	Critical
		601	
		601001	
		601002	
		601002002	
		602003002	
		7	Less Critical
		70	
		701	
		702	
		8	Less Likely
		80	

Table 7.2: Mock-Up of Activity Breakdown for Crew Size Increase

Activity	Description	Imm. Predecessor	Duration
Crew size Increase A	Increase from 20-38	None	5 Weeks
Space and Weight Balance B	Re-calculating geometric	A	0.125 Weeks
Hull Performance Cal. C	Stability and Resistance Sim.	A,B	0.25 Weeks
Machinery Re-assessment D	Prop, Power Balance and Piping	C	0.25 Weeks
Assessment E	Gross simulation	A,B,C,D	0.25 Weeks
Communication F	Team Communication	E	0.125 Weeks
Implementation D	Implementation of Request	E,F	1 Week

- Lifecycle costing for a "no" Design Change scenario i.e. not implementing any of the the first two alternatives

Now, taking a look at the last options itemized above, options such as a shipbuilder and the design department deciding to say no may not be a very good option in a business environment. Such options should only be considered when the ship-owner is requiring a certain level of change in the design that was not captured in either the Common Protocol, the Level of Detail (LoD), and the contractual model and not wanting to take financial responsibility and cost of such implementation. The other scenarios could mean that such changes runs contrary to rules and classification regulations, or goes beyond the expertise of the project team. At such conditions, a preventive measure for design change could be triggered.

Preventive Design Change approach in the context of this thesis document will require amicable resolution of ship-owner's request and to accommodate such change within the scope of what has been agreed in the original contractual document on the basis that the lifecycle cost model and other decision support tools suggest a possible cost overruns and major delays that are possibly obstructive to the master schedule and therefore considered to constitute a somewhat negative impact on the overall project performance. Implementing a no-design-change alternative could also be an option when the request is out of touch with market conditions and not at the best interest of the ship-owner, then the investors has to be well-convinced that such request does may not necessarily produce the best possible expectations and performance.

The second option of implementing an alternative cost model to aid the decision-making process of executing an alternative design change instead of the original specification requested by the ship-owner is what is considered as *preventive-counter* measures. There is a prevention i.e. the project team having to do a way with the request to completely engineer something new, different or an alternative arrived after exhaustive iteration and trade-off. The counter measures then requires that the re-engineered option to a large extent satisfies the collective interest of the parties.

With specific reference to the case being described in this mock-up case (Increasing an offshore vessel crew size from 20-38), let's assume that after series of iterations and analysis, the design and production team realizes that fully implementing such increment from 20-38 could require series of coupled activities whose cot of implementation could be way higher than what the ship-owner's budget is able to accommodate, a workable alternative that serves as a counter measure is developed and there is a prevention or ditching of the initial request.

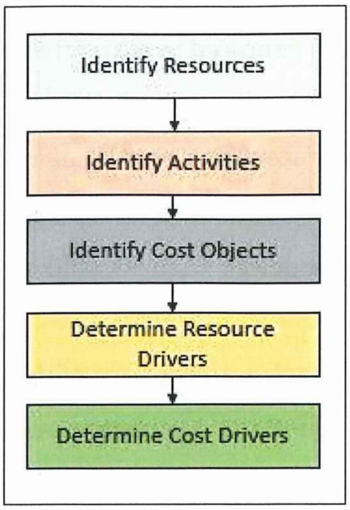


Figure 7.6: Activity-Based Costing Model adapted from (Emblemsvag, 2003)

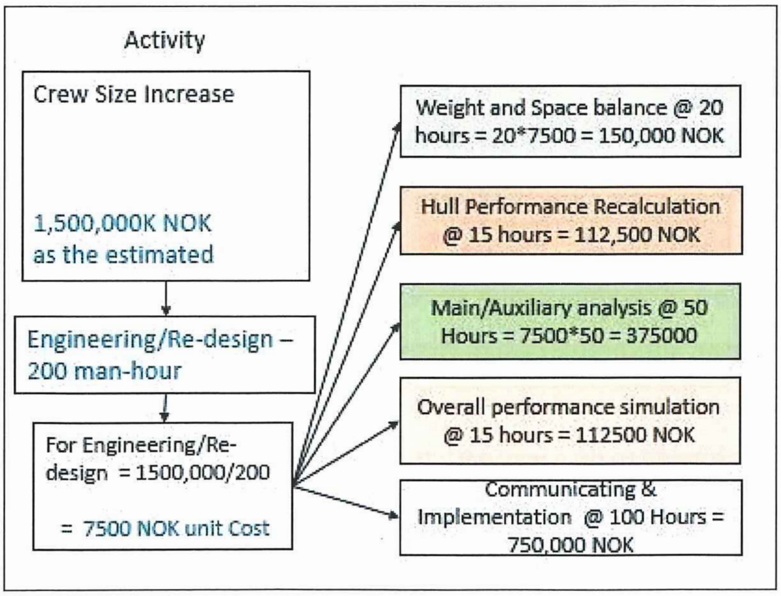


Figure 7.7: Mock-up Cost Model for Engineering service

Using figure 7.6 as a guide to develop a lifecycle cost model, summarized using the activities (table 7.2) and demonstrated as shown in figure 7.7 the various cost drivers are seen from a more detailed perspective, this then makes it easy to communicate to the ship-owner and other project stakeholders on which of the key activities/cost elements and drivers. At this level, the challenges of poor design change process communication can be handled robustly with cost elements tagged directly with the drivers it provides the project team with the ability to make decisions on whether or not such changes should be implemented or if some activities could be controlled depending on the cost performance.

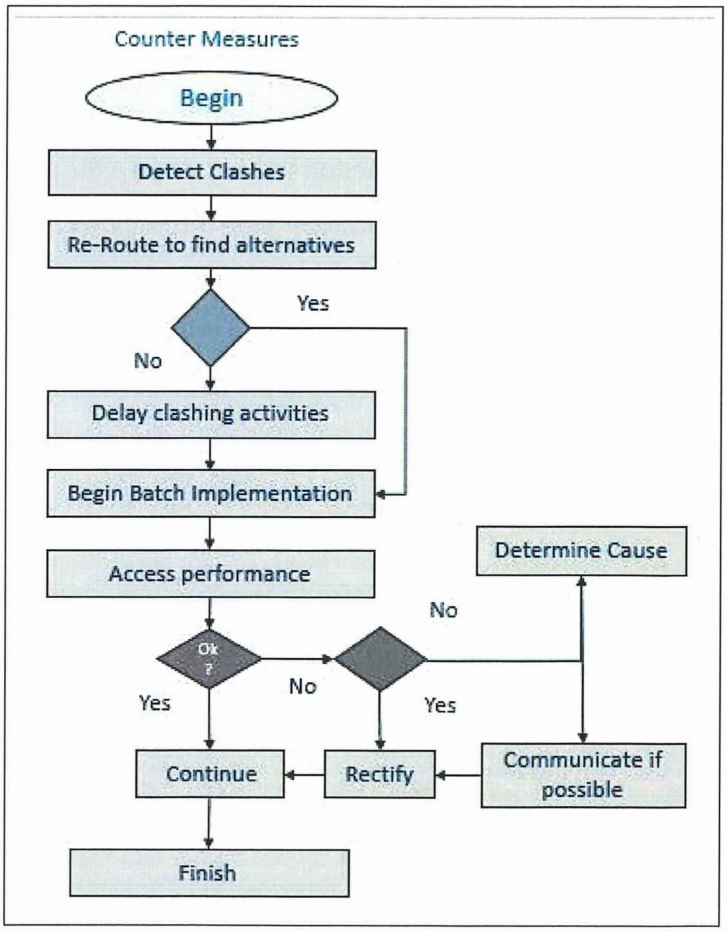


Figure 7.8: Design Change Implementation Algorithm using a counter measure approach

This form of analysis using cost drivers should be completed for all the sub-activities triggered by the design change process including materials to be purchased, ship system components, cost of classification, etc until an exhaustive system analysis has been completely implemented.

Figure 6.3 shows a possible counter measure approach, beginning with clash detection, then re-routing for possible activity sequence that optimally downgrades such clashes and when that is no found, the next action will be impose a delay period on the those clashing activities so that a very dynamically complex scenario is not created, followed by batch implementation and assessment of the system performance, depending on the prevailing system, response, the project team after due cross-domain communication, would either proceed or render possible rectification before executing/finishing the design change activity.

The role of IPD in this interdisciplinary approach to handling design change is that different set's of conditions are imposed on the plan of action to limit or stop the ability of either design or production team to proceed with implementation plan without a broader overview of the cross-platform relationships and activities and cost drivers are connected. With the combinatory effects all the processes listed here, designers will be very unable to just carryout design changes and through it over the walls for planners and production to deliver.

Chapter 8

Discussion

This study was designed to create a conceptual understanding for the use of Integrated Project Delivery in a shipbuilding project, the essence of which was the reduction of the impact of design changes on project performance and ease the complexity in the project planning process.

To proceed with the research, a research question (section 1.4) was developed to present the pathway to the problem statement 1.2 which resulted from design and planning separation, poor collaboration among other factors within the project execution timeline of vessels. With both the research question and problem statements defined, a research method was developed in chapter 3 to provide leads on the questions and the problem areas discussed in chapter 1 of this document.

The results show a general trend suggesting that Integrated Project Delivery could be applicable to the shipbuilding projects if the right environment is provided using technologies and methods that guarantees collaborations and team integration. The results presented in chapter of this document had been segmented into:

1. Pre-Design i.e. Pre-Project Planning Phase

2. IPD at Design Phase

3. The Concept of IPD in Ship Production

The findings enumerated from 1-3 provided direct response to the first and second research questions (1.4) during the introductory chapter of the thesis. A proposed "conceptual" model for handling and controlling project uncertainty through the process of either integrated the project stakeholders into a single team with a structured communication approach and that of qualifying design footprints and using a joint vetting method to approve progress if the models met the standard established with in the Level of Detail LoD was proposed in chapter six.

A mock-up example relying on both chapter 5 & 6 presented in chapter 7, purported to show how the process of implementing a design change could be either prevented, perhaps implemented through preventive-counter measures or just using a counter measure approach.

8.1 Review of IPD at Pre-Project Planning

The success of adopting IPD for a shipbuilding project might depend hugely on the structuring of the framework at the early stages before signing the contractual model. The implication thereof is that the Pre-Planning Phase, utilizes a semi-front end planning approach, where series of modes of operation are agreed upon by all parties and those agreements form part of the general contractual document making it binding on all parties.

The concept of IPD as outlined by AIA could be seen to be largely built on collaboration and integration of members, the meaning of which has been vaguely provided by most academic papers reviewed in the period of this thesis work. IPD at Pre-Project planning phase describes the structural organization of activities that if well-orchestrated can provided the enabling environment for the actualization of early involvements of parties before the commencement of design, integration of stakeholders and achieving the required degree of collaboration which is distinctive of IPD.

These measures as outlined in the results 5, figure 6.1,6.2, 5.2 differ significantly, structurally in formation, organization and managerial forms from the other contractual models (DB & DBB) that is largely visible in construction projects with no exception to shipbuilding. The ideas-(i.e.IPD at Pre-Planning) on a theoretical formulation seems workable but the reality is that as at the time of filling this reports, there are no standardized approach to how theses measures are to be undertaken or structured. The AIA that has pioneered a lot of standardization task of IPD in building constructions admits that more research and joint efforts is required from stakeholders within the construction industry to clearly work-out and develop a comprehensive framework in terms of contract structuring, risk and reward distribution amongst other key elements of project process.

Therefore, the measures conceptualized to provide the enabling environment and best practices, gives meaning to the concept of early involvements and collaborations, project stakeholders integration with the assumption that under the "right framework", as suggested by Becerik-Gerber and Kent, early collaboration, under the right conditions, can directly address the problem of fragmentation between design and construction professionals that results in inefficient work practices and costly changes late in the construction phase Becerik-Gerber and Kent (2010) and that is what the Pre-Design IPD for a shipbuilding project seeks to accomplish.

8.2 Feasibility of Collaborative/Integrated Design

The concept of collaborative design in shipbuilding as described in this thesis document shows a certain shift in the art of ship design where data and people integration is central to the design process. such processes are typical of a Building Information Modelling approach in design process management.

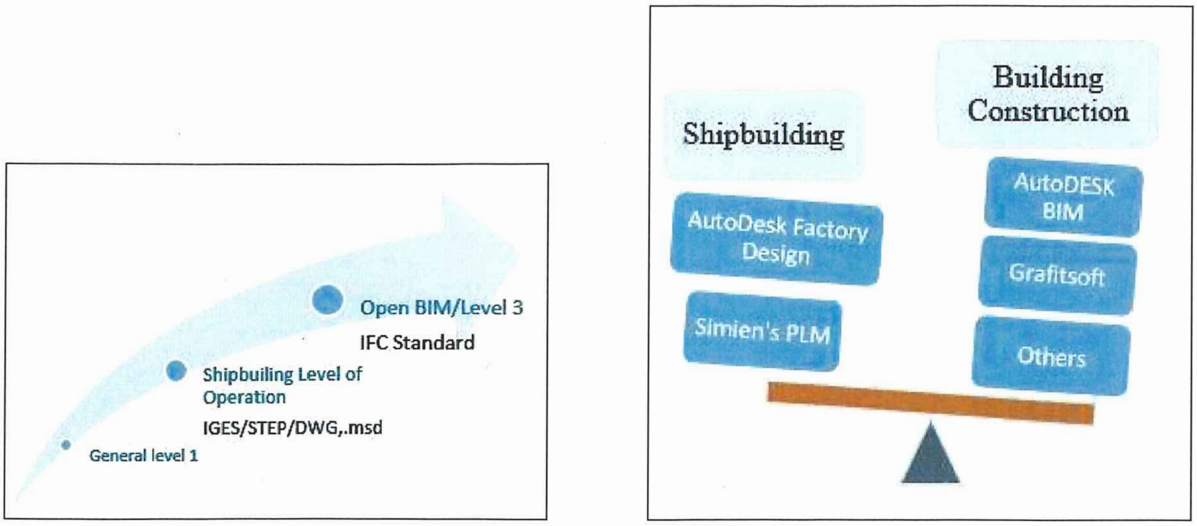
With BIM-driven processes such as that of Collaborative/Integrated design, the Kalthoff et al. proposed collaborative design environment, model qualification according to Level of Detail, the proposed approach for managing uncertainty and the mock-up case presented appears to describe a level of technological drive in the design processes of ship that the industry is either navigating towards or have been left out by industries such as that of building and construction. The present file formats used in exchange of meta data for most ship design processes are good enough to transmit 3D CAD or CAM files that are not intelligent, and often when exchanges of models are done, model properties distortions are visible and therefore healing are often required. This thus present collaborative design that may not be totally realizable in the ship design process because of the level of maturity of the CAD systems and the incompatibility of the CAD software.

Therefore the challenges posed by design fragmentation which emanates from poor communication may not be evaporating so soon. The term "communication" as understood by the author does not mean literally, but poor communication in terms of both the various project domain interacted, design and technical information sharing and retrieval processes and the total efficiency that associated with the process. Such communication has to be fluid and fitting to all parties involved. A BIM level 3 IF class offers such fluidity and holds the key to effective design phase collaboration.

8.3 BIM in Shipbuilding

Building information modelling has been part of shipbuilding process starting from when the use of computers and electronic means of communication was introduced. The proposals on this document suggests that for the level of collaboration that IPD seeks to accomplish, an open standard of BIM could be the key driving element of its success. The role and importance of BIM in construction have been documented by different authors and there is no alternative view as to the pivotal role BIM could play, particularly with respect to detection of clashes, prediction of cost and dynamically presenting the model in such a form that eases interaction and communication across the value chain.

The significant shift BIM brings thereof is that the design process is opened up, making it possible for cross-platform participation with the aid of a BIM saver. These technology is available but is rarely utilized in the entire value chain of the shipbuilding process. This could be attributed to the maritime industrial culture of tending to stick to old domain tradition, initial investment cost, researches, and expertise. While most shipbuilding projects have relied on the use of 3D CAD file and AutoCAD 2D, the building industry have successfully grown the BIM maturity level to the Industry Foundation Class standard where open communication, robust in-



(a) BIM Adoption Progression (b) The BIM Scale

Figure 8.1: Measuring BIM Adoption Progress

teroperability leads the way, giving room to the use of 5D simulations for construction projects.

Figure 8.1 is presented to give a pictorial overview of how the shipbuilding industry measures as compared to the general building industry and reiterates the need for either re-rapprochement of BIM if there has been non or a fresh approach on how BIM can aid the successful transition of dealing with a 3D CAD model to a state where 5D can play significant role in predicting time and cost as well as undertaken production simulation.

Haven stated the prospect BIM offers, it's also important to state that the road to BIM has some rocks on it. There could be legal issues as to ownership and how BIM generated information are used, security of the virtual environment/BIM Saver and its integrity, data breach, and the technical ability of parties deploying a BIM solution to effectively leverage on its upsides without creating a stress house of information mess are just but a few of the challenges that could arise, some of which can be addressed with probably contracting the management of such system to an experience and knowledgeable third party.

Chapter 9

Closure

In this final chapter you should sum up what you have done and which results you have got. You should also discuss your findings, and give recommendations for further work.

This section encloses the closing argument of the thesis with respect to the findings, conclusion, recommendation and critique. The critique serves as a reflective overview of the entire research, mostly the downsides and possibly short-comings in either exploratory research design, the data analysis, and the result interpretation.

9.1 Conclusion

The findings from the thesis work suggest that there are already existing knowledge and understanding on the subject of Integrated Project Delivery (IPD). This sources of IPD-based knowledge are from the well-referenced articles and journals with the attempted standardization from AIA (2007) as a key source of fundamental understanding of what an IPD-based contractual process entails.

To adequately apply such process (IPD) to a shipbuilding project, there would be need to re-organize the ship design and construction processes beginning from conceptual design to the point of closure. The result have organized "Integrated Project Delivery (IPD) Applied to Shipbuilding" into the following distinct phase namely:

1. Integrated Project Delivery at Pre-Design Phase
2. Integrated Project Delivery during Design Phase
3. Discussion on the concept of IPD and ship production simulation
4. Using 1,2 & 3, a theoretical concept for handling project uncertainty was proposed
5. With 1,2,3 & 4 a mock-up model was proposed on how the challenge of design change could be managed

IPD at Pre-Design phase discusses different Pre-Project Planning, documentation and definition of goals for both the project and the key stakeholders that will be entering into the common contractual pact otherwise called the Multi-Party Agreement. Amongst other objectives of the Pre-Project planning phase, is the creation of the Common Communication Protocol, the protocol, shall utilize a BIM-based approach to direct how design information shall flow with the end objective of ensuring that both the design and non-design stakeholders can be connected to the common project timeline. With such linkage With such linkage every party involved must have been on the same pedestal.

The problem resulting from design information fragmentation and its effect (uncertainty and complexity in planning) was created because yards and other key stakeholders entered the project timeline after basic design phase. If this practice continues, the issue of design fragmentation will continue, therefore, in-line with the principles of IPD (early involvements of stakeholders), design process must not begin, until, the project team has been assembled and then, design follows a common timeline with input from all parties. To achieve this measure, the thesis recommended the use of collaborative-Integrated Design through the aid of the Integrated Design Environment.

The challenges created by engineering concurrency can be addressed using the Last Planner System inspired "Pull-Back", perhaps "Hold-on" approach, where instead of allowing overlapping of activities, critical assessment and qualification measure imposed to the overlapping region to assess how much the already completed activities conform with the Pre-Project planning measures established to give level of details to what is expected of either a 3D or 5D ship model or property.

As for the discrete arrival of information from the ship-owner on design changes, it is important that the ship-owner retains the power to make changes in the design as dictated by market forces or condition. This option though, sometimes requires contract re-negotiation, should be approached collaboratively with the project as a central point of reference. The efforts should be made on how to address issues with extra cost and time without necessarily re-negotiating the contract since this can cause delays, with series of meetings and paper work. By doing this, most Norwegian shipbuilding companies can continue to retain and maintain advantage over foreign counterparts.

Keeping the project central and using it as a reference points simply requires that no party should be allowed under the signed protocol to rip each other off, project timeline respected, defined responsibility to the project, self and other stakeholders alike respected and honoured before putting anything of self-interest forward. The management of the design changing period requires experience-based approach to understanding the scope of design change, other ship system and functions affected, the estimated duration for the implementation of the desired change and the cost of implementation. After this analysis, it will be imperative to fully notify all stakeholders, with detail information of what the implication is for task and activities ahead, activities completed, and the overall project deliverables.

Conclusively, applying Integrated Project Delivery (IPD) to shipbuilding is very likely possible, it will require the re-organization of the design breakdown structure, the use of Interoperable software systems (BIM-Driven design approach) to achieve Collaborative-Integrated Design where fragmentation which is one of the key sources of project uncertainty can be eliminated through synchronised meta-data, open communication, Pull-Back to engineering concurrency and an expanded and robust analysis of design process change management and implementation.

9.2 Recommendation & Future Work

The boundary, scope and standardization for Integrated Project Delivery (IPD) in shipbuilding needs to be established. To this effect, it's imperative to have a joint industry and academic response to to such research. The Norwegian shipbuilding sector can lead this project, just like they did prior to the development of the SFI code.

The concept of Building Information Modelling (BIM) in general construction has attained the BIM level-3 state where open communication is the driver of the entire value-chain from project conception to completion, unfortunately, the shipbuilding industry is lagging behind. To meet both the technological gap between the general construction industry and shipbuilding, there is need for software vendors within the shipbuilding sector to begin the process software tool integration (e.g ShipX-Nautical Halls) with some degrees of automation.

9.3 Critique

This thesis was conducted on a more theoretical basis, though efforts were made to demonstrate how design changes could be managed and implemented, it is worthy to note that emphasis has been largely placed on project conception (Pre-Planning-IPD at Pre-Design phase) and Design phase with less attention to the production phase or process which is where complex engineering is performed. Hence, the thesis outcome does not completely cover the entire stretch of a shipbuilding project

Appendix A

Acronyms

3D Three Dimensional

AIM Asset Information Management

AEC Asset, Engineering Construction

BIM Building Information Modelling

CAD Computer Aided Design

DB Design Build

COBie Construction Operation Building Information Exchange

DBB Design, Bid and Build

DWT Dead-weight Tonne

ETO Engineering-to-Order

GA General Arrangement

IGES Initial Graphical Exchange Specification

IPD Integrated Project Delivery

NTNU Norwegian University of Science and Technology

OOCAD Object-Oriented Computer-Aided Design

OSV Offshore Supply Vessel

PWBS Product Breakdown Structure

RC Relational Contracting

STEP Standard for Exchange of Product Data

SBD System-Based Design

WBS Work Breakdown Structure

LoD Level of Detail

MoD Model Detail

PIMS Project Information Management System

DSM Design Structural Matrix

LCC Life Cycle Costing

ABC Activity-Based Costing

CAM Computer-Aided Manufacturing

CDE Common Data Environment

DE Design Environment

WBS Work Breakdown Structure

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Appendixes A2

Interview Questionnaire

Exploratory Research Conducted by Masi Lucky Chukwuladi on the Application of Integrated Project Delivery to the Shipbuilding Process.

Name of Interviewer	Masi Lucky Chukwuladi
Purpose of Interview	Master's Thesis
Name of Interview	
Firm/Company	
Confidentiality Level	
Mode of Data Extract	Recording and handwritten
Duration of Interview	
Interview Location	

Field Questions

S/N	Topic	Questions	Notes
1	Familiarization	Can I meet you? What is your background? Have you been involved in any shipbuilding project? What was your level of participation? How familiar are you with the current design practice? How often can you say design specification changes within a given	

		shipbuilding project in your period of active employment? Have you experienced any poorly performed projects?	
2	Rating the current design practice	In your capacity, can you say there are needs to improve or perhaps change the way design task are being conducted? Do you think there are problems with the contractual models upon which vessel delivery processes are based? What do you think are the major causes of specification/design changes? In a Scenario where design changes, what impact does it creates on the project? Does the contractual model specify how to handle such changes? How would you say the projects you have been involved in performed with arrival of changes in terms of cost and time? Are you of the opinion that since the naval architect is more knowledgeable in design compared to other counterparts, he/she should be responsible to making design decisions?	

		What would you normally classify as a well-performing or performed project? How best can you measure it? How would you rate collaboration level within the projects you have been involved in? How can you rate the collaboration level within a project in relation to the project performance and stakeholder's satisfaction?	
3	Introducing IPD	How would you rate your knowledge on the concept of Integrated Project Delivery? Are you aware of the level of application of IPD in other sectors say the building Industry? Do you think IPD and shipbuilding projects are compactible? What key difference can you say such measures (IPD) have in relation to say Design Build and Design, Bid and Build contractual models? In your view is IPD applicable in shipbuilding?	
4	Exploring Interviewees	What do you make of the BIM processes in building construction?	

	knowledge on BIM, IPD and digital transformation.	Are you aware of such level of digital integration in shipbuilding? Have you experienced software inability to accurate link model properties when graphical data are exchanged? How would you rate the software smartness particularly those used in ship design and building projects? What can you say are the downsides with IGES and STEP formats for data exchange? Do you think the same open approach to communication, the so-called BIM level 3 with similar IFC standard could be helpful in managing design projects information? Do you think the collaborative measures introduced by IPD are good, helpful or would you say it reduces design creativity? Do you think the present information classification systems for ships used in ship construction are rich enough and could be adequately relied upon for a Building Information Modelling approach in the shipbuilding Industry?	
		Do you think collaborative/Integrated Design concept used in general	

		construction IPD projects can be applied to the ship design process? In such scenario how can the design information and activities be well managed?	
5	Exploring Design Fragmentation	Design fragmentation over the years have been seen to affect project performance negatively. What's your opinion on how to manage such fragmentation problem? This opinion of yours, is it consistent with the current industrial practice? What's your view if a BIM process would be introduced to design, enabling information retrieval and other form of exchange in the ship design timeline? In a suggestive manner, do you think having an integral approach to design will aid in eliminating design uncertainties?	
6	Exploring collaboration in production	How best would the ship production process fare under such collaborative environment with enormous data integration?	
7	Closure	Generically, what's you closing argument for or against the use of IPD for ship design projects?	

		Do you think there would be need for more research on standardization of IPD and BIM as seen in the Building Industry?	

Appendix A3

Footprint nomenclature explains how the technical data or features of design are named. The master thesis utilizes the SFI coding system to organize and name ship parts and product.

The SFI coding and classification system is a means of organizing, naming and classifying ship and maritime products on technical and cost basis. The classification covers from concept development, concept design, basic, detailed, construction and operation (McConnell, 1977). The

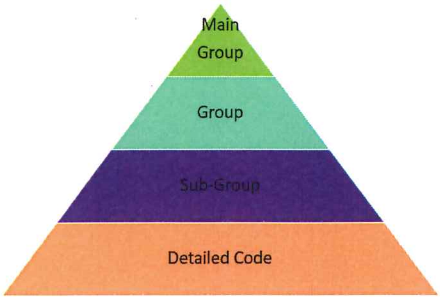

Fig 1-Layout of the SFI Coding system

system was primarily developed by a collaborative efforts of different Norwegian ship yards through a government support. One of the reasons for this, was that the Norwegian ship yards were contracting to amongst themselves and needed a non-ambiguous means of generally accepted code of communication. The SFI coding and classification system can otherwise be called "The SFI Group System" (McConnell, 1977).

The SFI Group System is built up as a three-digit decimal classification system with *ten main groups* at the highest level. Each of the main groups (one digit number) consist of ten groups (two digit number) and each group is further subdivided into ten subgroups (three digit numbers). Hence the system is organized as thus:

The digit "0" (zero) is reserved for a special purpose as well as the digit "9" (nine). The reservation is to enable users define special equipment, features other related attributes for ships and maritime structures since the industry is an ever-evolving sector. The other factor is that some ships are built on specialized request or order. This could involve conceptualizing and development of a new product.

With the SFI Group System, communication, classification, repairs, sub-contracting are done harmoniously using this format. Design and testing criteria for each system can be readily located. Cost and progress reporting does not need to be translated from one format to the other. The SFI Group System have gained international repute and remains one of the most functional oriented,

Well-structured and organized means of technical and cost information related to ship building.

The thesis shall use the SFI Group System for communicating and transmitting technical, cost and other relevant information at different stages of the project's lifecycle.

Table 1-1 SFI Group System

Digit	Purpose
0	Reserved for Special Purpose
1	For Ship General, including cost which cannot be charged to any general function onboard, such as launching, sea trails, guarantee work etc.
2	For ship Hull, Superstructures, Hull Cleaning, Painting and hull related activities
3	Cargo Equipment, including task related equipment and system, cargo winches etc.
4	Ship Equipment-Comprising equipment and system which are peculiar to ships, such as navigation equipment, anchoring equipment. It also includes weapons systems and fishing equipment and other working equipment for specialized ship types.
5	Equipment for Crew and Passenger-This includes comfort equipment that serves the passengers such as furniture, elevator, hotel facilitates etc.
6	Machinery Main Component-Comprising the main component in the engine room. This includes, main engines, boilers, compressors, pumps etc.
7	Systems for Machinery Main Components-This is for main propulsion system such as fuel, lube oil systems, starting air systems, exhaust system etc.
8	Ship System-Comprising Auxiliary systems such as bilge and ballast, firefighting, electrical distribution, and wash down systems.
9	Reserved for special purpose.

The master's thesis shall in course of presenting the mock-up concept use the SFI coding system to represent, either ship systems, functional requirements or attributes.

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Integrated Project Delivery (IPD) Applied to **Ship design** Process☆

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Abstract

Shipbuilding projects remains one of the most complex engineering endeavours of modern civilisation, bringing together different parties from many different sectors. Largely, success of such complex projects does not only depend on the ability of the contractors but how the entire value chain is organized. These study focused on investigating how IPD could be applied to a shipbuilding project with the goal of maximizing project performance, eradicating design fragmentation and integrated project stakeholders. Through a mixed research method, the findings suggest that IPD could be applicable to shipbuilding, but requires more standardization and the adoption of BIM processes to actaulize effective, robust and dynamic design information sharing and people integration.

Keywords: Ship design, Ship building, Project Management, IPD, BIM, Lean Construction, Design Fragmentation, Collaborative & Integrated Design & Construction Simulation

1. Introduction

The focus of the study is on eliminating design information fragmentation which stem from the present practice design and planning separation and engineering concurrency within both design and production timeline of ships. The overlapping of design activities from concurrent practice limits the availability of useful and important pieces of design information which is needed to decisions that have least possible disturbance and risk factors. While concurrency is a good practice, it is carried out in an environment where design and planning are treated as two distinctive domain within a project lifecycle. The consequences is that it leaves planners and controllers with an assumptive decision support process that could be very-well prone to error.

With concurrency, design separation and discrete information from the ship-owner, there are always the potentials for a design change or variation in order, and the possibility of

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errors becomes high and such errors amounts to re-work, cost and a possible change in the project master plan. Re-work on both the design and production, could be advantageous in terms of business and profits, but the implementation of such if not well-managed and implemented could adversely impact on the project performance.

1.1. Problem Statement

Design fragmentation resulting from separation of design and planning and its impact on planning and the gross project performance are visibly a challenge for most complex engineering, design and construction projects.

The effect of such sequence have resulted in creating a dynamically complex project execution environment, making it difficult for stakeholders to cooperate and collaborate to deliver shipbuilding projects within estimated time and cost. Also, with the separation, coupled with the effects emanating from the continuous dialogue between the ship owner, the design consortium and the nominated yard, which often leads to design changes[1] creates a very high level of uncertainty.

While project uncertainty may have received significant attention within the field of operational research, this form of uncertainty deviates greatly from that which could be modelled with statistical and probabilistic approach. As demonstrated by Vaagen et al., the resulting effect of either executing a task or activities with such level of uncertainty present could be as high as twice the initial cost & time.

To solve these problems, this research embarks on a theoretical/exploratory study to prescribe how Integrated Project Delivery (IPD) can be applied to a shipbuilding project with the anticipation that the study can leverage on its collaborative nature to solve the problem of design information fragmentation, design project uncertainty and enhance project performance through improved deliverables.

1.2. Research Questions

1. How can the thesis draw-up existing knowledge from Integrated Project Delivery in general construction to propose a model for shipbuilding projects?
2. Can the such models be used to describe from clear perspective the meaning and implication of adopting IPD for a ship design/building process?
3. With Research Question 1 & 2, can a model be proposed on how design fragmentation/project uncertainty can be controlled using the features of IPD?

1.3. Scope of the Research

The research is conducted within the framework of ship design, Project Management, Digitization and Ship Production.

[1]Design change could be change in specification of one pr multiply components, ship systems or ship function from that initially specified in the actual contractual document.

2. Literature Study

The literature study focuses on learning and drawing-up understanding from relevant credible sources in other to shape the way and manner the research will be organised and designed. Following the scope, the review is carried out for: Project Management (Project Delivery methods and Integrated Project Delivery), Ship Design, Lean Construction Building Information Model (BIM) and Design Uncertainties.

2.1. Project Management

According to Webster and Knutson, Projects are unique undertaken that results in a single unit of output. Projects consist of activities and consistent with the definition of a project, activities have beginning and an end. Activities are interrelated in one of three possible ways. In some situation, one activity must complete before the other begin. They went further to state that a project is a temporary endeavour, undertaken to create a unique product, service and or result [2].

Project Management in the view of Olsen, is the application of a collection of tools and techniques (such as the CPM and matrix organisation) to direct the use of diverse resources towards the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of these tools and techniques, structured to fit the task environment and lifecycle (from conception to completion) of the task [3].

To deliver a project of choice, the project owner enter into a contractual agreement with either a single entity or multiple entities. Construction contracts are written agreements signed by the contracting parties (mainly an owner and a contractor), which bind them, defining relationship and obligations [4]. There are different types of contractual models used for project execution whose choice of appropriation depends on the decision of the project owner [5] and the success of projects as well depends largely on the project delivery style or execution strategy.

This literature study shall consider a review of the Design, Bid & Build, Design Build, Construction Manager (CM) (which are visible within construction including shipbuilding) Multi-Party Agreement and the so-called innovative approach-Integrated Project Delivery (IPD).

Design Bid & Build (DBB) is the traditional project delivery method where the project owner contracts separately with a designer and a constructor to design and construct the facility respectively [6]. The design prepares a design package, including contract documents. The owner submits the package for bidding and selects the best bidder to undertake the construction of the project, requires the owner to monitor the contractor to ensure adherence to the project and often end in adversarial relationship amongst the parties involved in the project [5].

The design, bid and build offered client's a sequential approach of design, bid and then build. Due to the specialisation of services, design and construction entities fir a DBB-styled project shared information only at the end of design and at end of construction. Interaction within design phase is extremely low. The result thereof is an inefficient design, increased error, higher cost and increased scheduling period Konchar and Sanvido.

Design-Build (DB) is a project delivery approach where the owner contracts with a single entity for both design and construction of the facility under a single DB contractual models [8], while Janssens described it as a contracting condition where the owner enters a contract with a single entity to perform both design and construction under a single DB contract [9].

The Design -Bid approach thus hold hold the potential to eliminate the adversarial relationship often associated with DBB [5]. Ling et al. studied how to predict the delivery speed of DBB and DB projects and concluded that DBB project performance can be predicted using two parameters: gross flow area and the contractor's design parameters while for DB, gross flow area, level of project scope completion when bids are invented, extents to which contract periods are allowed to vary during bid evaluation, and level of design completion when the budget is fixed. [6].

2.2. Integrated Project Delivery

The AIA defined Integrated Project Delivery (IPD) as a project delivery method that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all project participant to optimize project results, increase value to the owner, reduce waste and maximise efficiency through all the phases design, fabrication and construction [10].

Integrated Project Delivery (IPD) is an emerging construction project delivery methodology that involves key participants and stakeholders very early in the project timeline often right from the conceptual phase of the project to final delivery. It's differentiated from a multi-party agreement due to its ability to evenly distribute risk and reward across boards [11]. The concept of shared risk and reward is also essential to IPD processes. It provides for a more collaborative effort between the contracting parties because everyone has a stake in the outcome [10].

IPD on like other project delivery approaches, seeks to improve project outcomes through a collaborative of aligning the incentives and goals of the project tea through shared risk and reward, early involvements of all parties, and can equally be considered s a multi-party agreement [10]. The coupling of Building Information Modelling (BIM) with IPD enables a level of collaboration that not only improves efficiency and reduces errors but also enables exploration of alternative approaches and expansion of market opportunities. With this, several professional organisation supporting the advancement of IPD, the number of projects using IPD still remains relatively small [12].

Integrated Project Delivery is a new approach to to agreements processes for design and construction conceived to accommodate the intense intellectual collaboration that twenty first century buildings require. The inspiring vision of IPD is that of a seamless project team, not portioned by economic self-interest or contractual silos of responsibility, but a collection of companies with mutual responsibility to help one another meet the goal of the project owner [10].

IPD was proposed to overcome problems caused by fragmentation within the construction organizations by improving project procurement and product delivery process to achieve team integration [13].

Such integration can be considered as the merging of different discipline, or organization with different goals, needs, and cultures into a cohesive and mutually supporting unit [13]. Although, several professional organization are supporting the advancement of IPD [10], Becerik-Gerber and Kent stated that some projects are demonstrating its benefits, but, the amount of projects using IPD remains relatively small. This Becerik-Gerber and Kent thinks is due to the lack of significant research investigating the current adoption status and causes of slow adoption of IPD in the industry [14].

There are several reasons for the slow adoption of IPD amongst industry professionals. Among these are high degree of concern regarding risk in relation to IPD, the close partnership it necessitates, and need for new legal frameworks to match new IPD approaches. Moreover, many industry stakeholders feel there is a need for those within the industry to assimilate new competence and skills relating to collaboration and information management to support IPD [15].

Efforts to standardize IPD came from the release of the CONSENSUS DOC, Perlberg described IPD in the released white paper as a contract execution style involving mulit-party agreements. In affirmation, AIA stated that for a project to be considered an Integrated Project Delivery system, it must contain; a multi-party contract, shared risk and reward between contracting parties, early Involvement of key participants, liability waivers among key participants, collaborative decision making, and control, jointly developed and validated project goals [10].

Integrated Project Delivery IPD is a relational contracting approach that aligns project objectives with the interest of key participants. It creates an organization able to apply the principles and practices of lean project delivery systems [17]

2.3. Lean Construction

The concept of 'lean' was first introduced by Womack et al. in order to describe the working philosophy and practice of the Japanese vehicle manufacturers and in particular the the Toyota Production System (TPS). More specifically, it was observed that the overall philosophy provides a focused approach for continuous process improvements and targeting of a variety of tools and methods to bring about such improvements [18]. Effectively, the philosophy involves eliminating waste and unnecessary action linking all the steps that creates value [19].

The application of the "new philosophy" to construction was first discussed by Koskela, [20] and subsequently works within the field became known as lean construction [21]. The initial concept of lean was more effectively defined and described by five key principles. Lean involves the ongoing elimination of unnecessary, non-value-added steps within a process which contributes to bottom-line results, increased competitiveness, and improved level of customer service. Lean thinking offers a way to make work more satisfying and challenging by providing regular feedback on efforts to convert waste into value. Differing noticeable from the recent emphasis on process organizational re-engineering, lean provides a way to create a new methodology and design for work rather than just destroying jobs for the sake of achieving efficiency [22].

Lean as a project delivery system emerged within 2000, from theoretical and practical investigations, and is in the process of on-going development through experimentation in many parts of projects, applying concepts and methods drawn from the Toyota Product Development System [23].

In Lean Project Delivery System, project definition starts with business planning, proceeds business plan validation if the initial plan appears to be feasible, and ends with a decision by the client to fund or not fund a project. If the project is not funded, the companies participating in the business plan validation are paid for their service is killed. If the project is goes forward, target values and constraint are set, then design is launched and steered towards those those targets. The first step in the design Lean Project Delivery System is the target setting, the second and third steps are design development and detailed engineering steered towards those targets [23].

Lean is usually associated with the 'operations' of a manufacturing enterprise; however, there is a growing awareness that these principles may be transferred to other functions and sectors. the application to knowledge-based activities such as engineering design. Lean can be applied basically away from the factory; with the understanding and definition of value is key to success; that a set-based approach to design is favoured together with the strong leadership of a chief engineer and that the successful implementation requires organization-wide changes to systems, practices and behaviours [24].

2.4. Project Uncertainty

Uncertainty is a state where; a current state of knowledge is such that; (1)-the nature or order of things are unknown, (2)-the consequences, extent or magnitude of circumstance, conditions, or event is unpredictable and (3) credible probabilities to possible outcomes cannot be assigned [25].The type of uncertainty described by the third option refers to the particular level of project uncertainty the study targets to eliminate in the design and production process of vessels. This type of uncertainty where meaningful statistics and probabilistic distribution can not be assigned and studied have received little academic attention. Most focus has been on centred on modelling uncertainty using statistical and probabilistic distribution [1].

Design uncertainties stem from the continuous dialogue between the customer/client and the design team. This sort of communication goes goes on into the project lifecycle and often leads to specification changes after the design phase of the project has started, sometimes even far into the engineering and production phase. While such communication flexibility is good for the customer, it does lead to continuous adjustments in procurement, engineering, and execution process [1].

Project uncertainty also emanate from design changes and design changes may be due to revised requirements, or approval comments, by an owner, classification societies and other regulatory bodies, a revised build strategy, or insufficient design department study and development work. as outlined by [26]

The engineering design process connects the phases of basic design with detailed design with project planning and scheduling [1]. However, most times design and planning are treated separately [27]. This is a result of traditional project management and planning, where the project where the project phases are separated and carried out sequentially. This implies that when design is ready, it is thrown over the walls of the planners, who would rely on design information to generate project plans. In this regards, a sequential process is not able to able to properly handle changes and disturbances that do not naturally belong to that phase [28].

Design uncertainty is therefor a major driving of planning complexity in an Engineering-to-Order project where design and engineering is separated and taking place concurrently [1]. This separation have led to generation of project plans that have failed to take into account the uncertainties created by design in the project scheduling [28].

2.5. Ship Design

Ship design is a complex endeavour requiring the successful coordination of many discipline, of both technical and non-technical nature, and of individual experts to arrive at valuable design solutions [29].The ship design process is one that has very vague information content at early stages of design. The design process essentially applies iteration to satisfy the relevant requirements, such as stability, power, weight, and strength [30].

According to Storch et al. the ship design stage can be sub-divided into four stages:

- Basic Design

- Functional Design
- Transitional Design and
- Work Instruction Design [26].

Significant contribution to the science of shipbuilding was made in 1959 with the visualization of the design process, and the general design diagram known as the "Design Spiral" which captured the basic tenets of a widely accepted approach to ship design [31].The most common way to describe the ship design process has been the spiral model, capturing the sequential and iterative nature of the process. The task structure requires "select-dimensions, evaluate capacity, and performance re-design". With that, the model locks the naval architect to his first assumption and focus in the design process will be to patch and repair this single design concept rather than generate and evaluate alternative designs, therefore an approach that supports innovation and creativity is needed [32]. A major characteristic of the design spiral approach was the sequencing of design and iterative processes rather than concurrency, laborious and expensive. While some changes have been made over the years, some of these features remains unchanged [33].

Buxton introduced economic issues into the spiral [34]. The Evans design spiral is a conceptual model of a process to for effecting ship design. The major units of the spiral (conceptual design, preliminary design, detailed design etc) are central to implementing any ship design process and there are numerous ways of implementing these units. However, most formal algorithm and mathematical approaches that have been reported in the open literature are for preliminary design [33]

The system-based design however shows deviation from the design spiral model, and was first presented at the IMDC in Kobe in 1992. Since that, it has been successfully applied to the development of a large number of ship design solutions. The SBD adaption towards OSV's includes the development of appropriate breakdown structures for vessel's main function, weights, areas, and volumes [32]. With the SBD the functional design of the vessel can be developed to a high detail without premature commitment to specific specific overall dimensions, layout and arrangement. SBD can also provide a foundation for modular foundation for modular design. Combined with 3D visual sketching tools, this method can support the generation of several alternative vessel configuration fast and with much reduced design effort [32].

Storch et al. gave description of the different activities for the various activities that follows the design phases described in (2.5) with the under-listed details:
As part of the basic design phase, naval architectural calculations are performed. Among these are weight estimate, longitudinal strength, hydro statics, tank capacity, Bonjean curves, intact trim and stability data and evaluation, wake survey, resistance, and self-propelled test, electric load analysis, piping system and analysis, HVAC analysis, propeller analysis and shafting arrangements and represents the phase where the contract document

are produced, the design provides an overview of he ship to be built and consequently represents a total ship system orientation. Amongst the plans developed at the basic design phase are-the general arrangement (GA), lines, midship section, machinery arrangement, cabin plans, diagrammatic of major outfitting systems and contract specification [26].

The second stage (functional design) displays the ship function on a system diagrammatic and plans, definition of all outfitting materials required by the system, including raw materials (such as pipe, structural angle iron and electric cable), budget control lists, which addresses all concerned updated material quantities and weights prepare purchase specifications not prepared by basic designer, prepare manufacturing drawing for long-lead-time items identified during functional design, obtain owner and regulatory approval and obtain vendor's drawing [26].

Storch et al. described the third phase as the process of transferring system oriented information (functional design) into zone oriented information whose end products are yard plans. Yard plans in this context represents the way information are grouped to suit the production process [26].

2.6. Building Information Modelling

According to EUBIM, Building Information Modelling (BIM) is a digital form of construction and asset operation. It brings together technology, process improvements and digital information to radically improve the client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle [35].

A BIM model is a digital representation of an actual building project for project communication over the whole building-project lifecycle. A physical, tangible appearance of a building from a time standpoint can be represented by three categories: 'as-it-was', 'as-it-is', or 'as-to-be', [36].

AIA view of BIM, is that of a data, 3D model, linked to a data base of project information. Among other things, it contains the design information, fabrication information, erection instruction, project management and logistics information in one data base system [10].

For the public sector, BIM can be thought as 'digital' construction. It is similar to the technology and digital process revolution that entered the manufacturing sector in 1980s to improve productivity rates and output quality. It combines the use of 3D computer modelling with the whole life asset and project information to improve collaboration, coordination, and decision-making when delivering and operating public asset [35]. The concept of Building Information Modelling (BIM) emerged to address the seamless exchange of information throughout the life of a facility following early modelling efforts focused on providing providing solution to data exchange problems between CAD analysis systems [37].

Building Information Modelling is the largest generation of Object-Oriented Computer Aided Design (OOCAD) system in which all of the intelligent building object that combine to make up a building design can coexist in a single project data base or virtual building that captures everything known about the building. In theory, a building information model provides a single logical, consistent source for all information associated with the building [38].

Building Information Modelling (BIM) is a set of interacting policies, processes and technologies generating a methodology to manage the essential building design nd project data in digital format throughout the building's lifecycle [39] BIM is considered both modelling technology and associated set of processes to produce, communicate, and analyse building models [40]. The benefit of these models are better data for real-time decision making, improved design quality, shorter delivery times, and the reduction or elimination of rework after assemble has begun. In order to achieve most of these benefits, closed collaboration between the primary stakeholders including the owner, architect, engineer, general contractor, trade contractor, manufacturer, etc is required which fundamentally impacts the role and responsibility of the participants and how information is share [41].

BIM is neither a virtual representative of a real project nor a static encapsulation for project information. It provides dynamic decision-making information throughout a project lifecycle, meanwhile, its encapsulated information sychronizes with construction practices ranging from design, execution, operation, maintenance, through to renovation [42].

3. Method

The research method presents the approach, and techniques in combination with tools employed by the thesis to answering the research questions. After thoroughly studying the research questions, a mixed research method- i.e., Theoretical and Qualitative (Exploratory) Research Design techniques in combination with a multi-level literature study was used design the method.

According to Maxwell, Qualitative research design presents research as a flexible process rather than fixed, inductive, rather than following a strict sequence or derived from an initial decision. In this manner, qualitative Research Design is presented as a reflexive process operating through every stage of the project. The activities of collecting data, analyzing, developing and modifying theory, elaborating and refocusing the research questions, identifying and addressing validity threats are all going on more or less simultaneously [43]. However, the master's thesis doesn't rely wholly on just Qualitative Research Design but combines QRD and a Theoretical Review of literature within the subject area of the master's work. Hence, the adopted method shall reflect both the theoretical approach and the qualitative research method.

Thus; to develop a qualitative study, you cant just develop (or borrow) a logical strategy in advance and then implement it faithfully. You need to a substantial extent to construct and reconstruct your research and this is a major rationale in any design model. Qualitative research design to a much greater extent to Quantitative research is a do it yourself rather than an off the shelf one that involves tacking back and forth, between the different components of the design assessing their implication for one another [43].

3.1. Design of the Exploratory Study

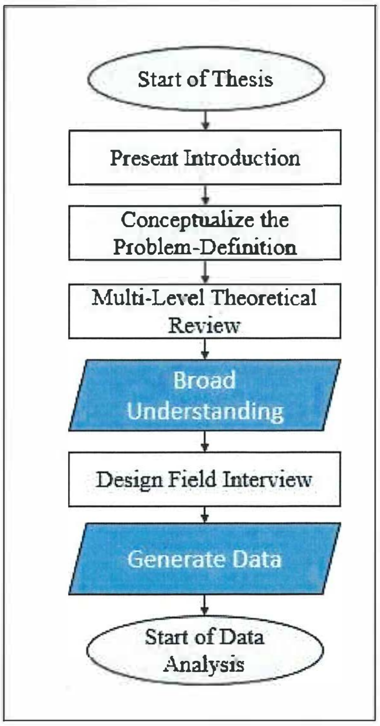

Figure 1: Research Design Process

With the aid of figure 1, the author prepares to conduct the interviews, first by identifying the More og Romsdal region of Norway as the target environment. More og Romsdal is one of the eighteen counties of Norway. The region has been carefully selected due to its strategic location and its role in the Norwegian maritime industrial cluster, housing many shipyards, naval architectural firms, product suppliers, fishing companies and strong maritime education.Aalesund, which is one of the towns in the region is a host to both the Norwegian university of science and technology and the Norsk Maritime Competence Center (NMK) amongst other key players. With that, it does provide the right environment for the exploratory/experimental research to strive.

The interview represents one of the most sensitive aspects of the master's thesis as it provides one of the key sources of data and shall and serves one of the foundation upon which the research shall base its argument on the application of Integrated Project Delivery to the process of shipbuilding. Interviews are conversations with a purpose, namely, to sit with another and learn what that particular individual can share about a topic, to discover and record what that person has experienced and what he or she thinks and feels about it [44]. The interview process shall involve different range of individuals identified in table as resources. Multiple interviews allow for maximizing the opportunity to build rapport and learn from reflections of the "informed" individuals who agree to participate in your study [44]

- The Interviewer (Author)
- Participants (i.e. Interviews)
- Area (Society, community, location etc- In this regards, More og Romsdal)
- Interview Guide (Developed from literature study, see Appendix A2)
- Data Storage Device (Data will be recorded via hand-written and audio recording transcript)
- Formally booking appointment on when and where to meet.

The interview is conducted using inductive approach. Inductive process to interview begins with an empty mind, using the research question and guide, attempt is made to draw-up a hypothesis based on the research question and the interview guide. The gross aim of this is to develop an unbiased experienced-based opinion from those participating in the process and use the outcome as a foundation for drawing-up results and conclusions.

The recorded data (transcript) is classified and shall not be made public because the author did not receive permission either from participants or agencies they represent to publicise it. Also, the issues of business confidentiality and privacy rights are among the factors considered to making the outcome classified.

3.2. Data Analysis

The data generated can be classified into two separate sources. One represents data collated through interviews and the other data collated through carefully analyzing multiple journals and articles. These two separate source of data extracted from the research reflects the design of the methodology of to the problem solving approach of the Master's thesis.

In order to adequately appropriate the right concept to the study, an in depth analysis of the collated data is required. The approach used for the analysis of the raw data is General Inductive Coding process. According to Thomas, the purposes for using an Inductive Approach are to (a) condense raw textual data into a brief, summary format; (b) establish clear links between the evaluation or research objectives and the summary findings derived from the raw data; and (c) develop a framework of the underlying structure of experiences or processes that are evident in the raw data [45].

Inductive coding begins with close readings of text and consideration of the multiple meanings that are inherent in the text. The evaluator then identifies text segments that contain meaningful units and creates a label for a new category to which the text segment is assigned. Additional text segments are added to the categories to which they are relevant. At some stage, the evaluator may develop an initial description of the meaning of a category and write a memo about the category [45].If the researcher has chosen to use inductive content analysis, the next step is to organize the qualitative data. This process includes open coding, creating categories and abstraction. Open coding means that notes and headings are written in the text while reading it. The written material is read through again, and as many headings as necessary are written down in the margins to describe all aspects of the content [46, 47, 48].

Thomas outlined the processes of the Inductive coding process as one carried with the following sequence of activities:

- To condense extensive and varied raw text data into a brief, summary format;
- To establish clear links between the research objectives and the summary findings derived from the raw data and to ensure that these links are both transparent (able to be demonstrated to others) and defensible (justifiable given the objectives of the research); and
- To develop a model or theory about the underlying structure of experiences or processes that are evident in the text data [45].

4. Results

The results of the study is a conceptual theoretical model proposed on how a shipbuilding project could be organized to suit the definition and standard of Integrated Project Delivery IPD. structured into:

- IPD at Pre-Planning
- IPD during Design Phase
- Project Execution Phase

Each gives a detailed structural, organizational and organizational approach for a shipbuilding project from project conceptualization to project completion.

4.1. Pre-Planning Phase

Integrated Project Delivery (IPD) at early stages of project otherwise called IPD at Pre-Design phase discusses the relevant processes, structures and organizational measures that parties to a given IPD-driven shipbuilding project must establish before the commencement of design process should parties seek IPD as the contractual model for the project execution.

4.1.1. Collaborative Concept Development

Concept Development is the first phase in the ship design process. For most projects executed. One very profound response received from a design manager was the scope of the process of concept development for a new vessel. Developing a new concept was reduced to a mere meeting of ship-owner's representatives and the design team. As the studies learnt latter, this narrowed scope of conceptualization had significant impact on how naval architects would subsequently approach the design task.

Collaborative Concept development demands for an expanded approach, establishing critical understanding of what the overall project seeks to accomplish in terms of time and cost. Different concepts of vessels are to be developed, at this stage, notifications could be sent to prospective shipyards to be part of the concept review process, with that, the ship-owner, yard and the design team begins an early process of relationship that will be subsequently expanded into the project cycle. The outcome would be varied concepts, with inputs from yards, then selection of concept is done and the yard whose contribution to this early phase is notified as a "secondary" builder of the vessel, while the rest are kept as "tertiary". The point is that at this phase, a building contract is yet to be signed, and the yard can not be classified or addresses as the primary builder.

With yard notification, contacts are made with varieties of product suppliers, particularly those with very high lead-time if any, choice of suppliers could be guided by a lot of factors such as: Product Platform and Complexity, care/support after sale, financial strength and the total cycle time of the products. With that, in combination with the experiences from the design team, and the secondary yard, the ship owner is presented with a clear and reliable options on how different choice combination will affect the overall project goal and most importantly, time and money, and what the implication could mean for his operation.

4.1.2. Team Assembling

Assembling the project team represents the second step in building a collaborative team in the use of Integrated Project Delivery mechanism to ship construction. Using different qualifying measures, a yard is selected and key product suppliers enlisted. These qualifying measures could range from ability to embrace open communication- desire or willingness to share different pieces of technical information (*possibly sensitive*) regarding either a product backed up by a verifiable, and documented work or build strategy. The goal of extracting these high-level commitment is that; the key to a successful Integrated Project Delivery is assembling a team that is committed to collaborative process and is capable of working together effectively [10].

Just like the approach adopted within the public sector projects in the Britain [49] where compliance to certain file format or mode of organizing information became amongst other factors, criteria for winning of project bids, the shipping industry can pegged the same. As the data suggested, poor communication within project scope was not only inherent within design but equally across the common timeline. Some of the reasons where simply software in-compatibility. Therefore, it is of interest, that at such phase of assembling team members, party's willingness to adopt such measures that enhances collaboration becomes very important in influencing the choice of potential members.

4.1.3. Project Information Management System (PIMS)

If any key-point could be described about IPD, and how it differs from other contractual model that would be "Collaboration." Collaboration in this regards will deal with how the information flow is organised across the common timeline. In accordance with the AIA standard, one way to achieve an efficient information management system will be the use of a Common Communication Protocol, and deciding on a Common Data Environment to enhance information sharing and retrieval.

Shipbuilding projects generates tonnes of data (graphical and non-graphical), data interaction is therefore one very key forms of enhancing communication. The protocol for enabling such free-flow of information exchange shall spell out *explicitly, information responsibility to both project and other stakeholders alike, define responsibilities, project's progress decision board (joint trustees), agree on modes/formats for transmitting meta-data, define the level of detail that is expected of different classes of the model and its attributes, ect.*

This protocol should be in the form of both technical, technological and a legal document and possibly should represent the first legal document to be entered before the actual contract document itself. The framework should be designed not to create a punitive measure but to extract commitment and ensure that parties are on the same platform or level of understanding regarding what has to achieved and the different roles parties owe to the shipbuilding project.

The next on the scope of the PIMS is the Common Data Environment. In general term, a Common Data Environment (CDE) is defined as a common digital project space which provide well-defined access area to project stakeholders, combined with clear status definition, and a robust work-flow definition for sharing and approval process [50] The Common Data Environment used to be deployed for a shipbuilding project shall rely on the established protocol for communication to be structured so as to deliver the required project goal already established.

As the study understood, the issues of task separation, outsourcing of responsibility (e.g. company A performs hull design and development with dynamic load assessments, company B performs structural design, local and global load assessment and company C is responsible for steal cutting and block production) if not well-managed creates the absence of synchronous pieces of information. These amongst other factors affects project performance, because there is a back-and-fort exchange of emails, calls, follow-ups and this could be very frustrating and defeats the goal of project integration.

4.1.4. Project Information Trustees

Some of the Key problem with complex construction projects like that of shipbuilding is the how the flow and exchange of information are managed. Open unstructured, and unregulated communication can be as well be as ineffective as a process with no communication links. The trustees in this regards, shall manage and coordinate the activities of the CDE and could be a retained partner with the ship-owner or a cross-party assembled individuals or individual or individuals hired for the task of manage the environment.

4.2. IPD at Ship Design Phase

The concept of early involvement of key stakeholders have been vaguely described and lacking to some degrees in content. This section is dedicated to discussing the ship-design process within a conceptual framework of Integrated Project Delivery. Ship design remains one of the most complex design task in human evolution and the stories of catastrophes originating from maritime accidents are evident of the fact that the impact of erroneous designs or misuse of design information can be very consequential through the lifecycle of the the asset. The next attempt is to prescribe on a conceptual basis how the design processes would be organize to provide the opportunity for stakeholders' integration and collaboration

4.2.1. Model Acceptable Level of Detail

To begin the ship design process with an IPD project environment, there is need to impose a certain level of detail that is required for either a local or global model. The concept of "Level of Detail" for the model in any of its dimension, refers providing minimum or maximum acceptable pieces of information for a 3D model or a 5D model either in whole or part, that is technically clear, understandable,readable with specification as *required* that is considered important and needed in making decisions within the common project timeline without creating "uncertainties", confusion and errors that could cause a re-work, unnecessary waiting, waste of time and money.

The concept was adopted from the "BIM Industry Protocol" [35]. Creating a standardized "level of detail[2]" for the ship model will not only serve as a standardize way for

[2]Level of Detail can as well be said to mean technical footprints- i.e properties of the model that is required, considered relevant and important to give a detailed explanation of the model to a so-called lame or a novice in the field of engineering design/naval architect or project management. The essence is to ensure that there is understanding across board.

model presentation and representation but can ultimately make the process of information exchange less rigorous.

Design fragmentation was was not just a mere problem originating from concurrency or separation of design from planning. Issues of lack in detailed pieces of information also created fragmentation and are more of an internal variation-order and creates an internal waste with no potential of profit generation for either the design team or any other team involved. The Level of Detail as a standard could help to create a more elaborate understanding of any of the ship systems or functional requirement. A level of detail has to be defined and agreed upon by all parties at the point of creating a Common Protocol for the project, the model should be engaging and interactive, provide assess to other parties-accessibility point, model has to show originating source, model should have restriction on who can utter its features, goals and purpose the model serves in the global project domain should be explained and other ship global properties that interacts with the model should be listed, and consequences of possible errors in its form or those of misrepresentation should be listed.

4.2.2. Design Delay Period

Integrated Project Delivery requires a cross-platform and domain participation. Theoretically speaking it could be easier to just describe without really substantiating what that actually entails and how such cross-platform participation can be made possible.

To propose a response to that, one can say that the so-called participation, collaboration and stakeholders involvement used to characterize IPD has to be enabled structurally in terms of organizational modus-operandi. The design delay period is therefore a measure imposed in-between milestones where the stakeholders carryout a comprehensive assessments of the model [3] to assess that the design details contained in the model is satisfactory and reliable in terms of supporting decision-making within the common project timeline without creating or causing any form of complexity or waste.

This proposal attempts to address the complexity created by engineering concurrency. This implies that, at those overlapping regions, the design footprints are tested using any qualifying measure developed by the project team to ensure that the model conforms with the pre-existing protocol and meets the level of detail required to support decision making and the overall actualization of project goal.

4.2.3. Collaborative Ship Design

Collaborative ship design requires that the design process integrates other key stakeholders or its accredited representative into the design workflow, provide the assess point and

[3] The model could be a local model e.g. piping systems for ventilation or part of the global/federated model e.g. bridge deck and accessories

enabler for active participation, providing answers to questions and supplying every necessary detail with regards to design footprints that parties require to successfully deliver their respective duties that are linked to the design process with an end objective of achieving overall project success.

Collaborative Design seems somewhat suitable within the contextual framework of Integrated Project Delivery (IPD). Collaborative design, will require a collaborative environment either in space, or any other form deemed fit by project participants to strive. According to Kleinsmann, collaborative design entails three key building blocks:- knowledge creation and -integration between actors from different disciplines - communication between the actors about both the design content and the design process - the creation of shared understanding about the subjects communicated [51].

With that, it's is of the opinion of the findings of this thesis that Collaborative Design approach, if adopted as the guiding process to the ship design process and other "children model[4]" alike, could discourage the act of design/planning separation.

The view that collaborative design holds the key to bridging the gap between designs and planning stem's from the works of Kalthoff et al. Which states that collaborative design is a technique, and the technique includes defining a stored data set maintained by a first entity to include a locked and an unlocked data set, and providing a second entity with access to the stored data set. The second entity has permission to view the locked data set and to change only the unlocked data set [52]. Adopting Kalthoff et al. argument to the process of ship design will entail classifying the design consortium as the first entity and other partners as the second within a common shared design environment where project planners can have access to certain footprints, make alterations, suggestions, within allowable limits.

With such collaborative system across the common project timeline, the a design process that is powered by a form of digital technology in terms of communication, that whose progression is determined by a "Pull" factor from stakeholders regarding the quality of the present, and "how" by agreed standard, the details of now can help the navigation and execution of activities of the future without disturbance. The combinatory effects of all of these, is a re-organized design process workflow, with some inherent lean-based approach and that which heavily influenced by a network of stakeholders.

4.2.4. IPD & Ship Production

From the varying degrees of concept suggested for the design phase for a shipbuilding project, it is important to explore how these concepts responds to the engineering otherwise called the production phase. Though, the study itself has been centred around the design phase, the driving goal was to use the IPD approach to limit the impacts of design change in

[4]The term "children model" has been used to describe other products that is housed within the vessel e.g. Deck cranes, with the vessel as the parent model.

the actual engineering phase so, that explains why more of the discussion has been tailored to the design phase. Equally, the production process is in itself a very elaborate engineering process hat may not fit into the scope of a single master's thesis. Therefore, the discussion here on what IPD implies for ship production will be though conceptual, and projecting based on available knowledge.

To effectively implement IPD during the production phase, more than just design and planning integration is required. Assembling an integral team without visualization of how such team will handle different activities, learn and improve, how the re-organized design process workflow could affect yard operation station by station, teams by teams and the general work attitude is important.

The contraction industry which has been very fundational to this study, have successfully moved to a point where production simulation is used to demonstrate in a virtual space a building construction in order to minimize both risk and errors. By doing this, the design information already integrated are harnessed and put to use. As rightly noted by AIA, using BIM and other tools to construct a building virtually in advance of actual construction substantially diminshes the risk of design errors and omissions [10]. This could actual be the future of ship production where relying on 3D, 2D CAD models, and aesthetic simulations are considered less sufficient to help detect clashes, accurately estimate cost of decisions either taken or not and may be somewhat insufficient to use as a decision support model properties to accurately deliver a very robust, dynamic engineering endeavour. The objective of such concept is the computerization of the whole process of ship production, at present, research on simulation-based ship production process is incomplete [53].

So the gross effect is a shipbuilding process where stakeholders are integrated and Incorporated into the both design process timeline and the common project timeline using what was described by [52] as collaborative design design environment, enabling parties access to the ship "model as designed", with the prospects of either suggesting changes within an "unlocked" design environment/area which shall then be subjected to qualification, and if that is approved by the project trustees, instead of implementation, an actual construction simulation is executed to see and learn through virtual space how such implementation will respond to the actual production in terms of man-hour, conflicting interfaces, performance, and what that could mean for the end user. This is what Integrated project entails.

4.3. Design Fragmentation Control

The identifiable causes of Project uncertainty in this study as understood from the multi-level literature study and the field interviews does not in any way differ. Uncertainty is largely a primary effect of design and planning separation, incompatibly project goals, unstructured communication, and lack of collaboration across the common project timeline.

Through the use of Integrated Project Delivery contractual model, there could be huge potentials for eliminating these causes and it's effect on the project deliverables. Though, on the preliminary basis, this is not something magical but a product of a well-thought, organized, structured and goal-driven project decision making. The following sub-sections of this chapter shall discuss on a conceptual framework proposal to handle project uncertainty emerging within an Integrated Project Delivery environment.

4.3.1. Controlling Through Integration

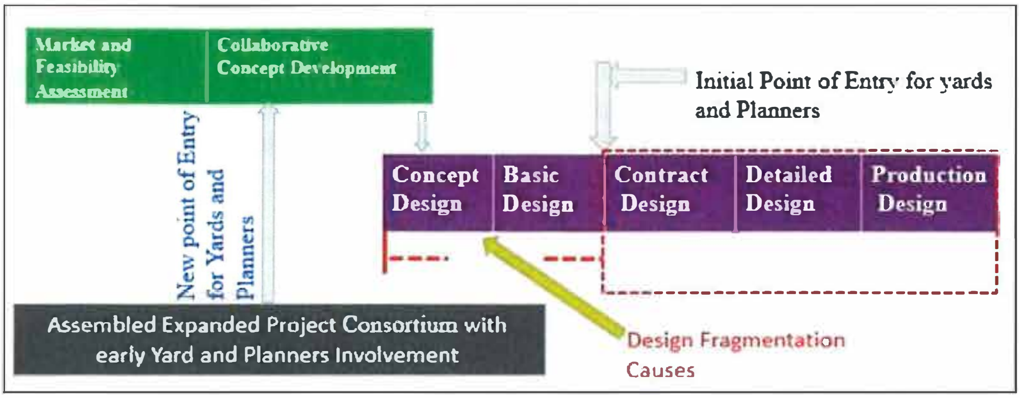

Figure 2: Design Timeline with Early Involvement

Integration of key Stakeholders into the common project timeline is one of the upsides/advantages of IPD and appears to be one key process to handling project uncertainty. Such integration in a dynamic collaborative measure that allows active participation of stakeholders, tracking of activities as they change, notification of changes to either a model or decision and a joint decision-making process with respect to any form of implementation or alteration keeps a level-playing field for all, everyone and progress driven not by one single party based on the stake they control in the project but by the sense of a "common good" of the project.

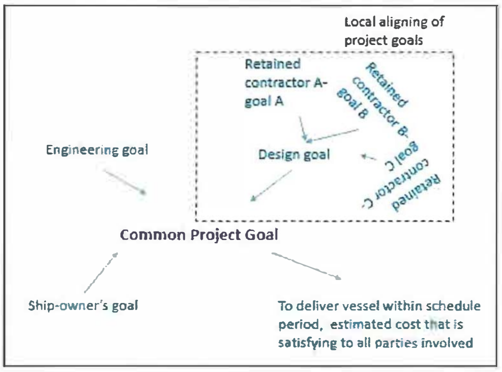

Figure 3: Aligning Project Goals

Figure 2 depicts the idea of early involvement of stakeholders, right at the concept development phase, then, the concept and basic design phase are shown to be one of the key sources of design information fragmentation, with shipyards and other project teams entering the common project timeline at the end of the basic design phase. The new approach where integration of stakeholders is key to uncertainty control should therefore discourage the practice of contracting design separately, completion of concept and basic design which is then used for bidding from shipyards. As outlined earlier, such practice is inordinate with the tenets of IPD.

For integration of stakeholders to effectively handle design project uncertainty, individual project goals needs to be aligned as shown in figure 3 and contained within the central project goal. Through the project pre-planning phase, such goal definition has to be defined, mapped, understood and contained. The idea is to create a harmonious working environment that maximizes the best potentials of participants, encourage innovation and amicable resolution of conflicting project goals and objectives.

5. Discussion

This study was designed to create a conceptual understanding for the use of Integrated Project Delivery in a shipbuilding project, the essence of which was the reduction of the impact of design changes on project performance and ease the complexity in the project planning process.

The results show a general trend suggesting that Integrated Project Delivery could be applicable to the shipbuilding projects if the right environment is provided using technologies and methods that guarantees collaborations and team integration.

The success of adopting IPD for a shipbuilding project might depend hugely on the structuring of the framework at the early stages before signing the contractual model. The implication thereof is that the Pre-Planning Phase, utilizes a semi-front end planning approach, where series of modes of operation are agreed upon by all parties and those agreements form part of the general contractual document making it binding on all parties.

The concept of collaborative design in shipbuilding as described in this thesis document shows a certain shift in the art of ship design where data and people integration is central to the design process. such processes are typical of a Building Information Modelling approach in design process management.

With BIM-driven processes such as that of Collaborative/Integrated design, the Kalthoff et al. proposed collaborative design environment, model qualification according to Level of Detail, the proposed approach for managing uncertainty and the mock-up case presented appears to describe a level of technological drive in the design processes of ship that the industry is either navigating towards or have been left out by industries such as that of building and construction. The present file formats used in exchange of meta data for most ship design processes are good enough to transmit 3D CAD or CAM files that are not intelligent, and often when exchanges of models are done, model properties distortions are visible and therefore healing are often required. This thus present collaborative design that may not be totally realizable in the ship design process because of the level of maturity of the CAD systems and the incompatibility of some of the CAD software.

Also the concept of integration and footprint qualification as a measure for fragmentation control is centred on a data driven people and system integration. At present AutoDESK BIM 360 and Siemens Team Centre offers technological platforms that can be used to achieve such measures.

6. Conclusion

The boundary, scope and standardization for Integrated Project Delivery (IPD) in shipbuilding needs to be established. To this effect, it's imperative to have a joint industry and academic response to to such research.

Conclusively, applying Integrated Project Delivery (IPD) to shipbuilding is very likely possible, it will require the re-organization of the design breakdown structure, the use of Interoperable software systems (BIM-Driven design approach) to achieve Collaborative-Integrated Design where fragmentation which is one of the key sources of project uncertainty can be eliminated through synchronised meta-data, open communication, Pull-Back to engineering concurrency and an expanded and robust analysis of design process change management and implementation.

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