Assessing value of customer involvement in engineered-to-order shipbuilding projects using fuzzy set and rough set theories

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Abstract

Customer involvement plays a crucial role in engineered-to-order (ETO) projects. The present study investigates the involvement of customers, with thorough technical knowledge, as resources and co-producers. The study also analyses the impact of customer involvement in sourcing decisions and project execution on project performance (PP) of ETO shipbuilding projects by considering project and customer characteristics. The contributions of this study to the current body of knowledge on customer involvement in ETO projects are twofold. First, it demonstrates that customer involvement at different stages of shipbuilding projects have differential impacts on PP. Customer involvement in sourcing decisions during the early stages of the project has a positive impact, whereas involvement in project execution during the later stages of the project has a negative impact on PP. Second, it reveals that project complexity and customer type together significantly affect the PP. Therefore, the role of project complexity and customer type as potential contingent factors in explaining PP is emphasised. This study also makes a significant methodological contribution by demonstrating the use of fuzzy inference system and rough set theory to analyze qualitative inputs from interviews, when conducting surveys is not possible.

Keywords: Customer involvement; engineered to order; fuzzy set theory; integration; rough set theory; shipbuilding

1. Introduction

Knowledge from customers can be captured through customer knowledge management (CKM), which focuses on knowledge obtained from the customer. Lengnick-Hall (1996) examined five customer roles namely customer as a resource, co-producer on the upstream side, buyer, user and product on the downstream side. Gibbert et al. (2002) identified five styles of CKM namely: prosumerism, team based co-learning, mutual innovation, communities of creation and joint ownership. Prosumerism focused on co-production of products and services, thereby promoting customers from being passive recipients of products to active co-creators of value (Humphreys and Grayson, 2008; Troye and Supphellen, 2012; Frow et al., 2015). In engineered-to-order (ETO) projects, customers are technically knowledgeable and can participate at all stages of the project. The present study focuses on upstream involvement of a customer as a co-producer and knowledge resource in ETO shipbuilding projects.

Several authors, for example Liew et al. (2008), Peled and Dvir (2012), Jaakkola and Alexander (2014) and Eriksson (2015) emphasised the importance of involving customers in value creation processes. However, such involvement can also have a negative impact on project performance (PP) because of scope creep, rework and schedule slippage (Bower and Christensen, 1995; Subramanyam et al., 2002; Vereecke and Muylle, 2006; Fabbe-Costes and Jahre, 2008; Peled and Dvir, 2012; Leuschner et al., 2013; Perols et al., 2013; Zhou et al., 2014). Because integration consumes resources and time, the producer and customer should be able to identify the most suitable form of integration that can lead to the desired PP.

Supply chain integration literature has primarily focused on manufacturing supply chains. Eriksson (2015) noted that few studies have investigated the management of supply chain integration in project-based supply chains. Most contributions in the project domain have been reported in the context of new product development (NPD) projects. In ETO projects, customers can be involved in both sourcing decisions (Hicks et al., 2000; Eriksson and Westerberg, 2011) and project execution (Kadefors, 2004; Peled and Dvir, 2012) this is unique characteristic of ETO projects and is not observed in other supply chains. Extant literature still lacks reports on contributions in ETO projects particularly in the shipbuilding context (Mello, 2015). More specifically, research on understanding the impact of customer involvement in sourcing decisions (CISD) and customer involvement in project execution (CIPE) and project and customer characteristics (ship type (ST) complexity, customer type (CT)) on PP of ETO projects, particularly in the shipbuilding context, is limited. The following research questions remain unaddressed: how does customer involvement at different stages of an ETO project influence PP and how do project and customer characteristics influence the possible impact of customer involvement on PP. Hence, the specific research objectives of the present study are as follows:

- To analyse the impact of CISD and CIPE on the performance of shipbuilding projects.

- To analyse whether project and customer characteristics influence the impact of customer involvement on the performance of shipbuilding projects.

The contributions of the present study to the current body of knowledge on customer involvement in ETO projects are twofold. First, it demonstrates that customer involvement at different stages of shipbuilding projects have differential impacts on PP. CISD at the early stages of the project has a positive impact, whereas involvement in project execution at the later stages of the project has a negative impact on PP. Hence, distinguishing customer involvement across the different stages of the projects is crucial to understand its impact on PP. Second, the present study reveals that project complexity (ST complexity) and CT together significantly affect PP and thus, such contingent factors must be considered while analysing the performance of shipbuilding projects. The study also makes a significant methodological contribution by demonstrating the use of fuzzy inference system (FIS) and rough set theory to analyze qualitative inputs from interviews, when conducting surveys is not possible (methodological contribution explained in details in Section 4).

The remainder of the paper is organised as follows. In Section 2, we present the literature on supply chain integration in projects and in Section 3, we present our research hypotheses. In Section 4, we present the research methodology. In Section 5, we present our analysis and results. In Section 6, we discuss our findings and offer academic as well as managerial implications. We summarise the paper and discuss steps for future research in Section 7.

2. Literature review on supply chain integration in projects

A literature review on the impact of supplier and customer integration on PP was conducted to identify research gaps. Scholarly journal articles were searched in the ABI/INFORM database by using the keywords, “customer integration” OR "supplier integration" OR “customer involvement” OR “supplier involvement” AND "project performance", scholarly journal articles were searched in ABI Inform database. The search returned 3166 hits. Two of the authors read the titles of the 3166 articles and selected 89 for further analysis. These 89 articles were chosen based on the following criteria: supplier, customer integration, involvement or performance impact was mentioned in the title or they were review papers. Then, the abstracts of these 89 articles were read by two of the authors and 53 articles were selected for further analysis. These 53 articles were read by two of the authors. Reading these 53 articles also resulted in the identification of 28 additional articles through back-referencing to be included in the review. These 81 articles were analysed and coded. The analysis showed that 31 of those 81 articles analysed supplier and customer integration from the perspective of projects, of which 24 analysed NPD projects, 4 analysed construction projects, 2 analysed complex engineering projects and only one analysed shipbuilding projects. Appendix A provides details of these 31 articles. These numbers reveal that customer and supplier integration has been thoroughly studied in the context of NPD projects. However, extant literature lacks contributions in ETO projects, particularly in the shipbuilding context.

As mentioned above, customer involvement has been thoroughly studied in NPD literature and has provided direction for ETO projects. However, these two contexts have key differences. While customer involvement in NPD provides updated information on changing customer tastes and requirements to the design team and reduces the uncertainty (Chaudhuri and Boer, 2016), customer involvement in ETO projects contributes by providing not only a more thorough understanding of product specifications, but also a more efficient method of project execution and production. NPD projects may have three forms of customer involvement: as an information source, as co-developers, and as innovators (Cui and Wu, 2016). ETO projects have an additional form of customer involvement as co-producers. Thus, in NPD projects customer input during design is extremely high however customers may or may not be a part of the production phase, as in ETO projects. Given the additional form of customer involvement in ETO projects, investigating the impact of customer involvement at different stages of ETO projects on PP is crucial.

The literature review showed that multiple measures of PP were used by researchers- product quality (Hoegl and Wagner, 2005; Koufteros et al., 2007; Eriksson and Westerberg, 2011; Wagner, 2012; Elvers and Song, 2016; Chaudhuri and Boer, 2016); development cost (Handfield et al., 1999; Hoegl and Wagner, 2005; Eriksson and Westerberg, 2011); development time or time-to-market (Handfield et al., 1999; Mishra and Shah, 2009; Eriksson and Westerberg, 2011;Wagner, 2012; Johnson and Filippini, 2013; Elvers and Song, 2016; Zhang et al., 2017); schedule adherence or avoiding project delays (Hoegl and Wagner, 2005; Eriksson and Westerberg, 2011; Mello et al., 2015); improved design (Petersen et al.,2005; Handfield and Lawson, 2007; Parker et al., 2008; Jayaram, 2008; Wagner, 2012; Jayaram and Pathak, 2013; Salvador and Villena, 2013); environmental impact, work environment, and innovation (Eriksson and Westerberg, 2011); and financial performance (Petersen et al.,2005; Handfield and Lawson, 2007; Johnson and Filippini, 2010; Feng et al., 2016; Cui and Wu, 2016). The majority of the studies have reported positive impact of buyer-supplier collaboration, supplier integration and customer integration on PP (Kadefors, 2004; Petersen et al., 2005; Hoegl and Wagner, 2005;Jayaram ,2008; Mishra and Shah, 2009; Martinsuo and Ahola, 2010; Wagner, 2012; Johnson and Filippini, 2013; Salvador and Villena, 2013; Chaudhuri and Boer, 2016; Feng et al., 2016; Zhang et al., 2017).

Customer integration has been studied in the project context. Kadefors (2004) identified the existence of informal co-operative relationships between the customer and main contractor characterised by interpersonal trust, shared values and informal understanding to improve project efficiency. Briscoe et al. (2004) examined the role of the client as the key driver of performance improvement and innovation and the most significant factor in achieving integration in the construction project's supply chain. Hoegl and Wagner (2005) showed that communication frequency and intensity have a curvilinear (inverted U-shaped) relationship with project development budget and product cost. Eriksson et al. (2007) revealed that the client's procurement procedures affect the level of subcontractor (supplier) involvement and integration in construction projects. Alderman and Ivory (2007) opined that partnering among project participants resulted in more effective communication leading to improved learning, more informed decision making and increased project effectiveness. Parker et al. (2008) distinguished between timing and extent of integration while analysing their effect on PP. Eriksson and Westerberg (2011) studied the impact of cooperative procurement procedures with project characteristics (i.e. how challenging the project is in terms of complexity, customization, uncertainty, value/size, and time pressure), as the moderating factor on PP. Peled and Dvir (2012) proposed a theoretical contingency model for the effect of customer involvement modes on project success. Jayaram and Pathak (2013) found that knowledge sharing and enrichment with customers are strongly associated with design fit and manufacturing capabilities of a firm. Eriksson (2015) noted that integration in project supply chains is multi-dimensional in nature and involves strength, scope, duration, and depth of integration. Cui and Wu (2016) analysed customer involvement as the information source, co-developer and innovators.

Mello et al. (2015) performed an in-depth case study of a shipbuilding project to identify problems causing delay in the project and examine their major causes. The authors were unable to distinguish which particular project characteristic influences the adoption of a specific coordination mechanism. Hence, further research is required to examine the effect of various coordination mechanisms across a higher number of projects (Mello et al., 2015). In ETO shipbuilding projects, customers can be involved in both sourcing decisions (Hicks et al., 2000; Eriksson and Westerberg, 2011) and project execution (Kadefors, 2004; Peled and Dvir, 2012) this is a unique characteristic of ETO projects and is not observed in other supply chains. Our analysis of the literature showed that research on customer integration over different phases of projects and particularly for ETO shipbuilding projects is limited (only one article found). Moreover, the effects of project characteristics (i.e ST complexity) in the context of shipbuilding projects and CT [domestic or foreign] on PP have not been studied.

3. Hypothesis development

Gibbert et al. (2002) opined that successful companies realise that corporate customers are more knowledgeable and consequently seek knowledge through interaction with customers. The 'prosumerism' form of CKM focuses more on co-production of products and services, thereby promoting customers from being passive recipients of products to active co-creators of value. Such a form of CKM is relevant for analysing the impact of customer involvement in ETO shipbuilding projects as customers are involved in multiple phases of the projects. One of the authors has prior experience of working in shipbuilding projects in India and the ship owner's representatives (i.e. the customers) had a dedicated office space in the shipyard premises. The customers specified their preferred suppliers for items to be procured for the project and also participated in supplier selection with the shipyard. They extensively interacted with designers to clarify technical doubts or determine pipe routings and cooperated in resolving problems during production, launching and commissioning, to ensure smooth progress of the project.

Researchers have also adopted a knowledge-based view of firms to study the effect of customer involvement on firm performance. McAdam et al. (2008) and Mishra et al. (2015) have found a significant effect of collaborative knowledge enrichment on the ability to manufacture new complex products. Jayaram and Pathak (2013) provided a fine-grained view of knowledge integration by distinguishing between the short-term knowledge sharing mechanisms and long-term and iterative knowledge enrichment mechanisms. Their findings suggested that both knowledge sharing and enrichment with customers are strongly associated with the design fit and manufacturing capabilities of the firm. Hence, CKM and knowledge-based view can be considered the theoretical bases for analysing the effects of customer involvement in shipbuilding projects. In Appendix B, Figure B1 presents the stages of a typical shipbuilding project and Table B1 details the forms of customer involvement at different stages of a shipbuilding project. Based on the aforementioned theoretical background and real practices observed in the shipbuilding industry, we develop a conceptual framework for analysing the effect of customer involvement over two phases (i.e. during sourcing decisions and during project execution) on PP as shown in Figure1.

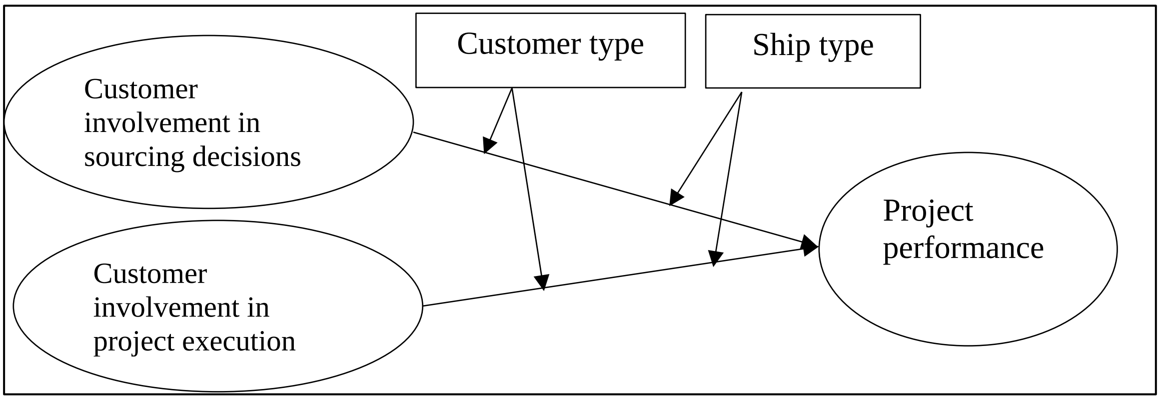

Figure 1: Framework depicting the role of customer involvement on project performance

By using the aforemetioned theoretical background, we provide support to the hypotheses.

3.1. Customer involvement in sourcing decisions

Because of the long duration of ETO projects such as shipbuilding, procurement decisions are taken at different stages of the project. Sometimes customers specify their preferred suppliers for critical items or present exclusive specifications for items that can only be satisfied by a limited number of suppliers (Hicks et al., 2000). To satisfy such technically competent customers and leverage their knowledge for a more efficient PP, collaborative supplier selection by involving both the customer and producer has been suggested by Briscoe et al. (2004); Petersen et al. (2005); Eriksson et al. (2007); Koufteros et al. (2007); Eriksson (2008); Parker et al. (2008); Martinsuo and Ahola (2010). Eriksson (2008); Martinsuo and Ahola (2010); Garengo and Panizzolo (2013) and Cui et al. (2016) have suggested continuous interaction of the customer with the primary contractor and suppliers and providing feedback and inputs from the customer to the suppliers. Richeson et al. (1995) reported a practice wherein customers visit suppliers' manufacturer plants to evaluate them. Eriksson and Westerberg (2011) suggested that cooperative procurement procedures (joint specification, selected tendering, soft parameters in bid evaluation, joint subcontractor selection, incentive-based payment, collaborative tools, and contractor self-control) have a positive influence on PP. Zheng et al. (2018) explored the conjunct roles of the client and vendor in off-shore projects and found that client process control enhances the effect of vendor outcome control, but impairs the effect of vendor process control.

However, establishing close relationships requires resources and time, which are valuable and limited. The criticality of an item and its complexity play a crucial role in determining whether close relationships are required (Kaufmann and Carter, 2006; Parker et al., 2008; Jayaram, 2008; Peled and Dvir, 2012; Millson, 2013; Park and Lee, 2014). For example, for a critical item such as a main engine which is highly engineered and customised in shipbuilding projects, the customers demonstrate a high level of involvement in sourcing decisions by specifying their preferred supplier and visiting the supplier's site during the factory acceptance test. However, for a standardised item such as a pipe, the customers do not get involved. Thus, in the present study CISD is recorded for different classes of shipbuilding items allocated (A) (highly customised specifications), allocated stock (AS) (mix of standard and customised specifications) and stock (S) (standard specifications) items (Chirillo, 1985) and then aggregated to compute overall CISD. Thus, we present our first hypothesis

H1: Customer involvement in sourcing decision has a positive effect on project performance of shipbuilding projects.

3.2. Customer involvement in project execution

Narasimhan and Kim (2002) underscored the importance of external integration of a company with its customers, through joint decision-making and problem-solving and incorporating continuous correspondence and feedback on the output delivered or to be delivered. Kadefors (2004) identified the existence of informal co-operative relationships wherein the main contractor and customer jointly handle site problems that arise by determining compromises and exchanging services. Beach et al. (2005) opined that to fully understand and incorporate customer requirements during the design stage of the project, designers, specialist sub-contractors and key manufactures must be allowed access to the customer. Eriksson and Westerberg, (2011) observed that a higher level of integration between the customer and contractors at the design stage leads to enhanced PP. Further, Olsen et al. (2005); Alderman and Ivory (2007); Gil (2009); Eriksson and Westerberg (2011) and

Mishra and Sinha (2016) have emphasized the role of physical proximity of the customer in improving the co-ordination, work environment and innovation ultimately leading to improved PP. Hence, we present our second hypothesis.

H2: Customer involvement in project execution has a positive effect on project performance of shipbuilding projects.

3.3. Role of project characteristics on project performance

Project characteristics have been an integral part of various project management decision-making models. Akinsola et al. (1997) identified that the project characteristics, namely type, size, time duration, and complexity, influence variations in building projects. Molenaar and Songer (1998) identified project complexity as one of the statistically significant factors that correlate with project success in their model for a public sector design-build project. Tatikonda and Rosenthal (2000) characterised product development projects in terms of their technology novelty and project complexity levels for studying relationships between product development project characteristics and project outcomes. Al Khalil (2002) incorporated the clarity of scope, schedule, and complexity as project characteristics in a project delivery method selection model. Mahdi and Alreshaid (2005) defined project characteristics based on the precise cost estimate before contract signing, time reduction, tight project milestone or deadlines, cost effectiveness, project budget, ability to define the project scope, and project size and complexity in the project delivery method selection problem. Chan and Park (2005) identified high technological level as the characteristic pertaining to projects that influence project cost. Elhag et al. (2005) incorporated 17 project specification related factors as project characteristics for building reliable cost models of construction tendering costs. Art Gowan Jr and Mathieu (2005) studied the intervention of specific project management practices in different types of projects that influence the direct impact of technical complexity and project size on the target date of project. Fan et al. (2008) incorporated technical complexity as one of the sub-factors of project characteristics in a model for selecting a project risk-handling strategy. Chen et al. (2011) developed an artificial neural network model for project delivery system selection, in which project characteristics were captured using factor project type (Industrial, infrastructure and building projects), project scale measured using project cost, project complexity, ability to define project scope, flexibility and disputes. Johnsen and Hvam (2018) presented a framework for quantifying the impact of project complexity associated with non-standard customisations on project costs.

The aforementioned studies have assumed a direct impact of project characteristics on the dependent variables of their models. However, some studies have reported an indirect effect. Griffin (1997) recognised that the interaction of project complexity with the formal product development process had an impact on the NPD cycle time. Tatikonda and Rosenthal (2000) found that high levels of technology novelty or project complexity were not directly associated with overall project failure, but were associated with specific project outcome elements. Clift and Vandenbosch (1999) and Lin and Germain (2004) showed that greater the project complexity is, greater is the level of customer involvement which in turn impacts PP. Gerwin and Barrowman (2002) identified complexity as a moderator between incremental approach and project schedule performance. Art Gowan Jr and Mathieu (2005) revealed that project complexity did not have a direct effect on target date of project completion. Peled and Dvir (2012) proposed a theoretical contingency model for the effect of customer involvement on project success, moderated by project complexity. Ahmad et al. (2013) reported the absence of any evidence of the direct negative relationships between project complexity and overall performance of NPD projects. However, they found that the interaction between project complexity and team integration had a statistically significant positive impact on PP. These studies provide direction for exploring the indirect effects of project complexity characteristics on PP.

In shipbuilding projects, the project complexity is defined by the final product (i.e. ST complexity). For example, a project with the final product as the tanker is more complex than a project with a bulk carrier as the final product, which in turn is more complex than a project with a barge as the final product. Thus, we present the third and fourth hypotheses.

3) Ship type significantly affects how customer involvement in sourcing decision affects project performance of shipbuilding projects.

4) Ship type significantly affects how customer involvement in project execution affects project performance of shipbuilding projects.

3.4. Role of customer characteristics on project performance

Akinsola et al. (1997) stated that client characteristics differ in terms of the nature of their business (private or public) and experience. These factors influence the decision making processes in projects. Love et al. (1998) assessed client type in terms of their experience of market and technical knowledge of the construction industry for analysing different procurement practices of different client types. Al Khalil (2002) assessed customer characteristics based on the owner's involvement by incorporating award of contract, responsibility and design control in the project delivery method selection model. To examine the choice of the project delivery method, Mahdi and Alreshaid (2005) obtained owner characteristics by using the following factors owner understanding of the project scope, owner’s control over design, owner’s benefits from cost saving and owner’s involvement in project details. Chen et al. (2011) defined owner characteristics by using the following factors: owner’s willingness to be involved, owner’s available personnel and owner’s willingness to take risks. Chan and Park (2005) incorporated the owner's level of construction sophistication as an owner characteristic in their project cost estimation model by using principal component regression. Elhag et al. (2005) ranked the following factors defining the client characteristics in decreasing order of significance for determining construction tendering costs: priority of construction time/deadline requirements, certainty of project brief, client requirements on quality, type of client (public/private/developer), project finance method/appropriate funding in place on time, partnering arrangements, experience related to procuring construction and financial ability/payment record. Peled and Dvir (2012) identified the moderating role of customer characteristics (operational orientation and technical capabilities) on the effect of customer involvement on project success.

Indian shipyards receive orders from domestic as well as foreign customers. The different CTs demonstrate different levels of technical knowledge and involvement. Thus, we present the fifth and sixth hypotheses.

5) Customer type significantly affects how customer involvement in sourcing decision affects project performance of shipbuilding projects.

6) Customer type significantly affects how customer involvement in project execution affects project performance of shipbuilding projects.

4. Research methodology

4.1. Data collection

Shipyards across India were selected based on their capacity (largest size of ship that can be constructed), life stage (new 0-30 years; moderately old 30-50 years; old >50 years) and ownership (government / private), to ensure that the present study represented all types of shipyards. The unit of analysis as a case for the study was completed or nearly completed (close to launching stage) shipbuilding project. Appendix C provides the characteristics of the selected shipyards, projects and customers [Domestic (D) / Foreign (F)]. A semi-structured interview-based approach was selected for collecting primary qualitative data because it enables capturing rich information by allowing a two-way interaction between the interviewer and managers (Saunders, 2011). Interviews of 16 shipbuilding professionals working at the vice-president, general manager, and assistant general manager level with work experience varying from 10 to 25 years were conducted. The interview protocol included explanation of the research objective and material classification (A, AS and S) adopted in the present study by the interviewer to the respondents, at the beginning of the interview. This was followed by questions related to shipyard ownership; shipyard capacity; shipyard establishment year; ship deadweight tonnage; ship type; customer type ; percentage of items by value in Class A, AS and S; levels of CISD for Class A, AS and S items and CIPE, and PP. On an average an interview lasted for almost 30-45 minutes. In each interview two interviewers were involved who took hand written notes during the interviews, which were consolidated and transcribed after the interviews.

A key challenge in fulfilling the research objectives (mentioned in Section 1) is the limited number of shipbuilding projects which are undertaken in India and the difficulty in collecting data about such projects. Thus, conducting surveys to collect sufficient samples for analysis and hypotheses testing remains the biggest challenge for conducting such research. This also explains the paucity of quantitative empirical research involving hypotheses testing on ETO projects. Few studies on ETO shipbuilding projects (Mello et al., 2015) have adopted a case study approach. The present study overcomes the obstacle of conducting survey research on ETO projects by quantifying the responses from interviews by using FIS. The research methodology uses the FIS for within-case analysis and rough set theory for cross-case analysis. It demonstrates how qualitative inputs from interviews can be used to scientifically analyse relationships between variables in the absence of survey data. Although FIS and rough sets have been used in multiple applications as decision support, application of these methods to process qualitative responses from interviewees and to test hypotheses is indeed novel and hence provides an alternative to case study research and where it is not possible to conduct surveys. Figure 2summarises the steps of methodology for within-case and cross-case analysis.

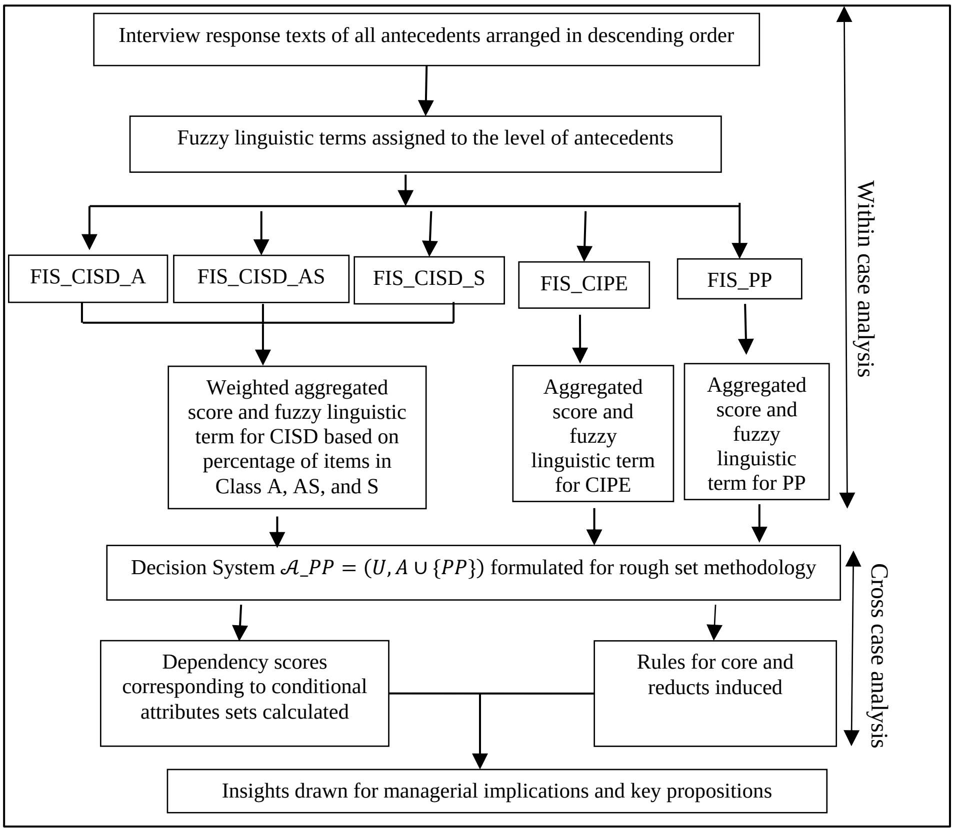

Figure 2: Steps of the methodology used for within-case and cross-case analysis

4.2. Fuzzy inference system for within-case analysis

The advantage o using FIS is that, it utilises natural language to capture managerial tacit knowledge and enables a more efficient synthesis of available data. The interview response texts corresponding to each antecedent of ST, CISD, CIPE and PP of all cases were arranged in the descending order. Some interview response texts for "Customer involvement in supplier selection for Class A items" are shown in the Table 1. Based on the information obtained by the responses relative fuzzy linguistic terms that most accurately describe the level of the actual response were assigned.

Table 1: Assigning fuzzy linguistic terms

Project name	Interview response text for “customer involvement in supplier selection for Class A items”	Fuzzy linguistic term
Project E1	The customer selected and nominated suppliers.	Extremely high
Project A5	Suppliers were decided and specified by the customer.	Very high
Project D1	The customer provided a list of preferred suppliers. However, the final supplier selection was performed by the shipyard with no customer involvement.	Nearly low
Project D2	The customer did not provide any list of preferred suppliers. Suppliers were selected by the shipyard and the selection was approved by the customer.	Low
Project X1	The customer did not provide any list of preferred suppliers. The shipyard, based on its experience and assessment of suppliers, invited bids from suppliers and selected the supplier with the lowest cost.	Nil

Three FISs namely FIS_CISD (for Class A, AS, and S items), FIS_CIPE, and FIS_PP were formulated to perform aggregation and obtain scores and fuzzy linguistic terms for CISD (for Class A, AS, and S), CIPE, and PP for each project. An FIS linguistically maps a given set of antecedents to a consequent through “Fuzzy Sets”, “Membership functions”, “Logical operators (OR/ AND)” and “If-Then rules” (Mamdani and Assilian, 1975). Table 2 presents the examples of linguistic rules of FIS_CISD, FIS_CIPE and FIS_PP. The aggregated score of CISD was obtained as the weighted sum of the outputs of (FIS_CISD_ A, FIS_ CISD_ AS, FIS_ CISD_ S). The weights are percentages of each class of items by value, obtained during interviews. The fuzzy linguistic sets for CISD, CIPE and PP as outputs of FIS_CISD, FIS_CIPE and FIS_PP respectively, are presented in Table 3.

Table 2: Constituent factors of supplier-producer-customer linkages and project performance and examples of linguistic rules

	Constituent factors	
	Rules example : IF (logical relationship between antecedents’ levels)	THEN (consequent level)

FIS Name	IF Antecedent 1 is High OR	IF Antecedent 2 is High OR	IF Antecedent 3 is High OR	IF Antecedent 4 is High OR	IF Antecedent 5 is High OR	IF Antecedent 6 is High OR	IF Antecedent 7 is High OR	IF Antecedent 8 is High OR	IF Antecedent 9 is High OR	THEN Consequent is High
FIS_CISD_A,FIS_CISD_AS,FIS_CISD_S	CI in supplier selection	CI in purchase order finalisation	CI in visits to suppliers' sites	CI in providing innovative inputs to suppliers	CI in correspondence with suppliers					CI in sourcing decisions
FIS_CIPE		CI at Design stage	CI at steel cutting stage	CI at keel laying stage	CI at block erection stage	CI in resolving onsite production problems	CI in providing innovative suggestions during project	CI at launching stage	CI in sea trials and at delivery stage	CI in project execution
FIS_PP	Cost performance	Time performance	Quality performance	Environmental friendliness	Safe working conditions	Innovations and new learnings				project performance

4.3. Rough sets theory for cross- case analysis

For cross-case analysis, the rough set theory (Pawlak, 1982; Pawlak and Rough, 1991) was adopted. To understand the concepts of rough sets interested readers are advised to refer to Komorowski et al. (1999) and Riza et al. (2015). The advantages of the rough sets approach are three fold. First, it identifies significant conditional attributes by computing the degree of dependency of the decision attribute. Second, it identifies sub-sets of significant conditional attributes in the form of reducts that have the complete ability to perform classifications equivalent to the entire set. The use of reducts reduces the number of conditional attributes to be simultaneously analysed, thus reducing the complexity of analysis, while the degree of dependency remains equal to one. Third, it can derive insights through linguistic rule induction from linguistic data.

Cross-case analyses of the shipbuilding projects were performed using the rough set package of software R (Riza et al., 2015), where, $\mathcal{A}_PP = (U, A \cup \{PP\})$is known as the decision system. $U = \{Project\ A1, Project\ A2, Project\ A3, Project\ A4, Project\ A5, Project\ B1, Project\ B2, Project\ C1, Project\ D1, Project\ D2, Project\ E1, Project\ X1, Project\ Y1, Project\ F1, Project\ F2, Project\ F3\}$is the set of all cases in the dataset known as the universe of discourse. A is a set of conditional attributes, given by $A = \{CT, ST, CISD, CIPE\}$; decision attribute $d = \{PP\} \notin A$, which denotes PP based on the cost, time, quality, environmental friendliness, safe working conditions and innovations and new learnings. The decision system that forms the input for rough set analysis is shown in Table 3.

Table 3: Decision system for rough set analysis

S.no.	Project name	Conditional attributes				Decision	S.no.	Project name	Conditional attributes				Decision
		CT	ST	CIPE	CISD	PP			CT	ST	CIPE	CISD	PP
1	Project A1	F	M	H	M	H	9	Project D1	D	L	NH	M	M
2	Project A2	F	L	H	M	M	10	Project D2	D	L	NH	VL	M
3	Project A3	F	L	H	M	M	11	Project E1	D	EH	H	SH	H
4	Project A4	D	NH	NH	NH	SH	12	Project X1	D	NH	M	Nil	H
5	Project A5	D	H	M	L	H	13	Project Y1	D	M	SH	SL	H
6	Project B1	D	H	NH	VL	M	14	Project F1	D	M	H	NL	NH
7	Project B2	F	H	NH	VL	NL	15	Project F2	F	L	H	SL	M
8	Project C1	F	SH	SH	H	NH	16	Project F3	F	L	M	VL	M

5. Analyses

By applying rough set theory on the decision system $\mathcal{A}\_PP = (U, A \cup \{PP\})$, the degree of dependency was computed, and rules were induced to analyse the relationship between the decision attribute and different sets of conditional attributes. The following sub-sections 5.1 and 5.2 present the key insights of the analyses.

5.1. Analysis based on degree of dependency of decision attributes

Table 4 presents the degree of dependency of the decision attribute PP on different sets of conditional attributes. PP has complete degree of dependency ($\gamma_{B_{11}} = \gamma_{B_{12}} = 1$) on reducts$B_{11} = \{CT, ST, CISD\}$ and $B_{12} = \{CT, ST, CIPE\}$. These reducts are the minimum set of attributes that are able to preserve classification and fully define the decision attribute. This finding reveals that not all types of integration are required simultaneously for a project. The core attributes $B_5 = \{CT, ST\}$ are common for all reducts. However, the degree of dependency of PP on the core is less than 1 i.e. $\gamma_{B_5} = 0.625$. Therefore, although the core attributes are common, PP is not fully dependent on the core. Similarly, from $\gamma_6 = 0.625$, it can be inferred that PP is not dependent only on integration attributes. Both the core attributes (CT, ST) and at least one type of integration are required for defining complete dependency.

It can be observed that PP's degree of dependency on only CT is zero (i.e. $\gamma_{B_1} = 0$). For only ST, the degree of dependency of PP is greater than zero (i.e. $\gamma_{B_2} = 0.5 > 0$) but it still does not exhibit complete dependency on ST. However, when both the core attributes are combined, the degree of dependency of PP increases (i.e. $\gamma_{B_5} = 0.625 > 0.5 > 0$), which is greater than the individual values corresponding to each isolated core attribute. When each core attribute is combined with all the integration attributes $B_{13} = \{CT, CIPE, CISD\}$; $B_{14} = \{ST, CIPE, CISD\}$ the degrees of dependency are greater than zero ($\gamma_{B_{13}} = 0.8125$; $\gamma_{B_{14}} = 0.875$), but still not equal to one. For defining complete dependency both the core attributes must be considered together, resulting in $\gamma_{B_{15}} = 1$. This shows that both the core attributes influence each other positively to determine PP's degree of dependency. When each core attribute is combined with each integration attribute B_7 - B_{10} higher degree of dependency is observed in the sets with ST as the only core attribute $\gamma_{B_7} < \gamma_{B_8}$; $\gamma_{B_9} < \gamma_{10}$. This result indicates that ST plays a more significant role than CT.

Based on the comparisons $\gamma_{B_4} > \gamma_{B_3}$; $\gamma_{B_9} > \gamma_{B_7}$ and $\gamma_{B_{10}} > \gamma_{B_8}$ the integration attributes can be arranged in the descending order of PP dependency as $CISD > CIPE$. Thus, $CISD$ can be inferred as a more important type of integration that influences PP.

Table 4: Degree of dependency of decision attribute PP

Sub-set of attributes	Elements of sub-set	Degree of dependency of PP	Sub-set of attributes	Elements of sub-set	Degree of dependency of PP
B_1	{CT}	0	B_9	{CT,CISD}	0.6875
B_2	{ST}	0.5	B_{10}	{ST,CISD}	0.875
B_3	{CIPE}	0	B_{11}	{CT,ST,CISD}	1

B_4	{CISD}	0.375	B_{12}	{CT,ST,CIPE}	1
B_5	{CT,ST}	0.625	B_{13}	{CT,CIPE,CISD}	0.8125
B_6	{CIPE,CISD}	0.625	B_{14}	{ST,CIPE,CISD}	0.875
B_7	{CT,CIPE}	0.375	B_{15}	{CT,ST,CIPE,CISD}	1
B_8	{ST,CIPE}	0.75			

5.2. Analysis based on induced rules

The induced rules are presented in Table D1 of Appendix D. To analyse the nature of dependency (positive or negative) of PP on the attributes' sets of core and reducts, rules are induced from the decision system. The core attributes $B_7 = \{CT, ST\}$are common for all the reducts and are thus crucial for understanding the dependency of the decision attribute PP. From rules B_7_Rule 1 to B_7_Rule 5 it can be observed that when $CT = D$, a change in ST level does not change or slightly changes the PP level. Thus, it can be concluded that for shipbuilding projects involving domestic customers the dependency of PP on ST is less. For $CT = F$, a change in ST level induces a marginal variation in the PP level. Thus, for shipbuilding projects involving foreign customers the dependency of PP on ST is higher than that for shipbuilding projects involving orders from domestic customers. If the rules are arranged in descending order (B_7_Rule 1, B_7_Rule 6, B_7_Rule 7, B_7_Rule 2, B_7_Rule 3, B_7_Rule 8, B_7_Rule 4, B_7_Rule 5, B_7_Rule 9) of ST (EH, SH, H, H, NH, M, M, L, L) irrespective of CT, PP decreases (H, H, L, H, H, H, H, M, M). This finding is in contrast to the notion that PP should increase with a decrease in ST. Thus, further analysis with respect to integration attributes contained in reducts is required.

Table D1 shows the induced rules of reduct *{CT, ST, CISD}*. For domestic and foreign customers as $CISD$ level decreases the decision attribute PP also decreases. Thus, for both domestic and foreign customers, $CISD$ positively impacts PP. If the rules are arranged in descending order (B_{11}_Rule 1, B_{11}_Rule 10, B_{11}_Rule 2, B_{11}_Rule 5, B_{11}_Rule 7, B_{11}_Rule 14, B_{11}_Rule 9, B_{11}_Rule 12, B_{11}_Rule 4, B_{11}_Rule 6, B_{11}_Rule 11, B_{11}_Rule 3, B_{11}_Rule 13, B_{11}_Rule 8, B_{11}_Rule 15) of ST (EH, SH, NH, H, H, H, NH, M, M, M, L, L, L, L, L) irrespective of CT, $CISD$ (SH,H, NH, L, VL, VL, Nil, M, NL, SL, M, M, SL, VL, VL) and PP (H, NH, SH, H, M, NL, H, H, NH, H, M, M, M, M, M) also exhibit a general downward trend. This trend indicates that as the ST decreases, customers exhibit lower degrees of integration in sourcing decisions which negatively impacts PP. This insight explains the counter-intuitive observation that the PP decreases with a decrease in ST.

Table D1 shows the induced rules of reduct *{CT, ST, CIPE}*. Both domestic and foreign customers predominantly exhibit high and moderate levels of involvement in project execution. If the rules (B12_Rule 2, B12_Rule 9, B12_Rule 4, B12_Rule 7, B12_Rule 12, B12_Rule 5, B12_Rule 8, B12_Rule 1, B12_Rule 3, B12_Rule 11, B12_Rule 6, B12_Rule 10, B12_Rule 13) are arranged in descending order of *ST* (EH, SH, H, H, H, NH, NH, M, M, M, L, L, L) with a decrease in *ST*, no significant decline in *CIPE* (H, SH, NH, M, NH, NH, M, SH, H, H, NH,H, M) is observed. If the rules (B12_Rule 9, B12_Rule 1, B12_Rule 11, B12_Rule 10, B12_Rule 2, B12_Rule 3, B12_Rule 12, B12_Rule 6, B12_Rule 4, B12_Rule 5, B12_Rule 8, B12_Rule 7, B12_Rule 13) are arranged in descending order of *CIPE,* no diminishing trend is exhibited by *PP* (NH, H, H, M, H, NH, NL, M, M, SH, H, H, M). Thus, a higher level of *CIPE* for all levels of ST is not translated into higher *PP*.

6. Discussion and implications

Project performance is significantly dependent on ship type complexity and, customer type and at least one type of integration. Ship type complexity and, customer type are identified as core attributes, therefore their role as potential contingent factors in explaining project performance is emphasized. For foreign customers' orders, ship type complexity plays more important role in determining project performance than for domestic customers' orders. Certainly, the significance of project complexity and customer type has been highlighted in the literature (Akinsola et al., 1997; Molenaar and Songer, 1998; Al Khalil, 2002; Mahdi and Alreshaid, 2005; Chen et al., 2011; Peled and Dvir, 2012). Customer involvement in sourcing decisions is identified as a type of integration, which has a significant positive impact on project performance. However, as the ship type complexity decreases, customers exhibit lower degree of integration in sourcing decisions which negatively influences project performance. To translate the benefits of a low ship type complexity to a high project performance, customers are recommended to ensure integration in sourcing decisions even for low complexity ships.

CIPE has a negative impact on project timeline. Both domestic and foreign (customer type) customers predominantly exhibit high and moderate level of integration in project execution. However, the same is not translated into high project performance for all ship type complexities. This finding differs from the findings of Kadefors, 2004; Alderman and Ivory, 2007; Gil, 2009; Eriksson and Westerberg, 2011; Menguc et al., 2014, who suggest that CIPE will result in improved project performance. This is can be explained by the following comments of the respondents during the interviews which stated that excessive customer involvement during project execution led to more revisions, rework and time slippage. This finding has been supported by Peled and Dvir (2012); Leuschner et al. (2013); Perols et al. (2013); and Zhou et al. (2014) who identified a negative impact of integration on a firm's performance.

Project A3: *"The timeline was delayed by 6 months because of the various modifications suggested by the owner."*
Project Y1: *"The performance of this project based on time line was moderate and the project was delivered late because the customer expressed an additional requirement of weth propulsion."*

Thus, customers need not get involved in both sourcing decisions and project execution; because excessive involvement particularly during the late phase of execution can be detrimental to project performance. Instead, the customers should play an active role in sourcing decisions and spend more resources and time during the early phase of the project to avoid rework in later phases. Based on our findings and in line with the hypotheses, we formulate the following propositions that can be tested in future empirical studies.
P1: Customer involvement in sourcing decision has a significant positive effect on project performance.
P2: Customer involvement in project execution has a significant negative effect on project performance.
P3: Ship type complexity significantly affects the impact of Customer involvement in sourcing decision on project performance.
P4: Ship type complexity significantly affects the impact of Customer involvement in project execution on project performance.
P5: Customer type significantly affects the impact of Customer involvement in sourcing decision on project performance.
P6: Customer type significantly affects the impact of Customer involvement in project execution on project performance.

The findings also have critical theoretical implications. First, customer involvement in projects must be studied over multiple phases because involvement during the earlier stages will have a differential impact on project performance compared with involvement during the later stages. Studying customer involvement for the entire project will fail to capture such a differential impact. Although customer involvement and knowledge sharing appear to have a positive impact on performance, our results indicate that active customer involvement and knowledge sharing must be exercised with caution particularly at the later stages of the project.
Furthermore, contingent factors namely project (ship type) complexity and customer type and the effect of their interaction on customer integration over different phases have important behavioral implications for project management. Less complexity encourages customers to adopt a "hands-off" approach in the early phases of the project. Such an approach combined with a higher involvement in later phases leads to significant negative performance. Thus, this contingent view must be considered while analysing the impact of customer involvement during different phases of projects.

7. Conclusion and scope for future research

Our findings demonstrate that customer involvement in the earlier phases of projects have a different impact on project performance compared to the involvement in the later phases and such involvement also gets influenced by the combined effect of contingent factors such as project complexity and, customer type. Lower involvement in the earlier phase of sourcing decision and higher involvement in project execution will have a detrimental effect on project performance. Hence, customers should neither adopt a “hands-free’ nor an “over zealous” approach while interacting with the contractor in ETO projects such as shipbuilding. Instead, they should get actively involved and share their expertise in the early stages for example in sourcing decisions but allow the contractor to execute the order and not interfere much during the later stages. Thus, the findings have important implications for managing shipbuilding projects and for the literature on supply chain integration in general and specifically for projects. The present study also makes important methodological contribution by demonstrating how qualitative inputs from interviews can be analysed using FIS and rough set approach to generate insights and test hypotheses. Such an approach will particularly be suitable for contexts where it may be practically infeasible to collect survey responses.

Few studies on supply chain integration in projects have paid attention to the multi-dimensional nature of integration involving strength, scope, duration, and depth of integration (Hoegl and Wagner, 2005; Parker et al., 2008; Jayaram and Pathak, 2013 and Cui and Wu, 2016). The present study demands more research comparing the multi-dimensional nature of different forms of customer integration in NPD and ETO projects. The study has a few limitations. It focuses only on shipbuilding projects from India as representative of ETO projects. Thus, future research should consider customer involvement across ETO industries such as capital equipment manufacturing and defence and across multiple countries. Moreover, the propositions formulated in this research must be tested through further empirical research with larger data sets of customer involvement and performance of shipbuilding projects as well as for ETO projects across industries. Furthermore, this study only considered customer involvement in ship building projects. Future research should also consider integration between the shipbuilders and their suppliers as well as internal integration between functions such as design, sourcing and project execution within shipbuilders.

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Appendix A

Literature review on supplier and customer integration for projects

Title	Authors	Journal	Year	Project context
Involving suppliers in new product development	Handfield et al.	California Management Review	1999	NPD projects
Buyer–supplier collaboration in product development projects	Hoegl and Wagner	Journal of Management	2005	NPD projects
Supplier integration into new product development: coordinating product, process and supply chain design	Petersen et al.	Journal of operations management	2005	NPD projects

Black-box and graybox supplier integration in product development: antecedents, consequences and the moderating role of firm size	Koufteros et al.	Journal of Operations Management	2007	NPD projects
Integrating suppliers into new product development	Handfield and Lawson	Research Technology Management	2007	NPD projects
Timing and extent of supplier integration in new product development: a contingency approach	Parker et al.	Journal of Supply Chain Management	2008	NPD projects
Supplier involvement in new product development projects: dimensionality and contingency effects	Jayaram	International Journal of Production Research	2008	NPD projects
Customer integration strategies for innovation projects: anticipation and brokering	Sandmeier	International Journal of Technology Management	2009	NPD projects
In union lies strength: Collaborative competence in new product development and its performance effects	Mishra and Shah	Journal of Operations Management	2009	NPD projects
Collaboration practices, strategic capabilities and performance in Japanese and American product development: Do they differ?	Johnson and Filippini	Operations Management Research	2010	NPD projects
Tapping supplier innovation	Wagner	Journal of Supply Chain Management	2012	NPD projects
Determinants of knowledge transfer in inter-firm new product development projects	Lawson and Potter	International Journal of Operations and Production Management	2012	NPD projects
Towards a contingent approach of customer involvement in defence projects: An exploratory study	Peled and Dvir	International Journal of Project Management	2012	NPD projects
A holistic view of knowledge integration in collaborative supply chains	Jayaram and Pathak	International Journal of Production Research	2013	NPD projects
Integration capabilities as mediator of product development practices–performance	Johnson and Filippini	Journal of Engineering and Technology Management	2013	NPD projects
Supplier integration and NPD outcomes: conditional moderation effects of modular design competence	Salvador and Villena	Journal of Supply Chain Management	2013	NPD projects
In pursuit of control: involving suppliers of critical technologies in new product development	Melander et al.	Supply Chain Management:An International Journal	2014	NPD projects

Partnering in engineering projects: Four dimensions of supply chain integration	Eriksson	Journal of Purchasing and Supply Management	2015	NPD projects
Conceptualizing a framework for customer integration during new product development of chemical companies	Elvers and Song	Journal of Business and Industrial Marketing	2016	NPD projects
Customer involvement and new product performance: The jointly moderating effects of technological and market newness	Feng et al.	Industrial Management and Data Systems	2016	NPD projects
The impact of product-process complexity and new product development order winners on new product development performance: The mediating role of collaborative competence	Chaudhuri and Boer	Journal of Engineering and Technology Management	2016	NPD projects
Utilizing customer knowledge in innovation: antecedents and impact of customer involvement on new product performance	Cui and Wu	Journal of Academy of Marketing Science	2016	NPD projects
Prototyping, customer involvement, and speed of information dissemination in new product success	Tih et al.	Journal of Business and Industrial Marketing	2016	NPD projects
Supplier collaboration and speed-to-market of new products: the mediating and moderating effects	Zhang et al.	Journal of Intelligent Manufacturing	2017	NPD projects
Trust in project relationships—inside the black box	Kadefors	International Journal of project management	2004	Construction projects
Client-led strategies for construction supply chain improvement	Briscoe et al.	Construction Management and Economics	2004	Construction projects
Effects of cooperative procurement procedures on construction project performance: A conceptual framework	Eriksson and Westerberg	International Journal of Project Management	2011	Construction projects
The influence of partnering and procurement on subcontractor involvement and innovation	Eriksson et al.	Facilities	2007	Construction projects
Partnering in major contracts: Paradox and metaphor	Alderman and Ivory	International Journal of Project Management	2007	Complex engineering and construction projects
Supplier integration in complex delivery projects: Comparison between different buyer–supplier relationships	Martinsuo and Ahola	International Journal of Project Management	2010	Complex delivery systems

The role of coordination in avoiding project delays in an engineer-to-order supply chain	Mello et al.	Journal of Manufacturing Technology Management	2015	Ship building project

Appendix B

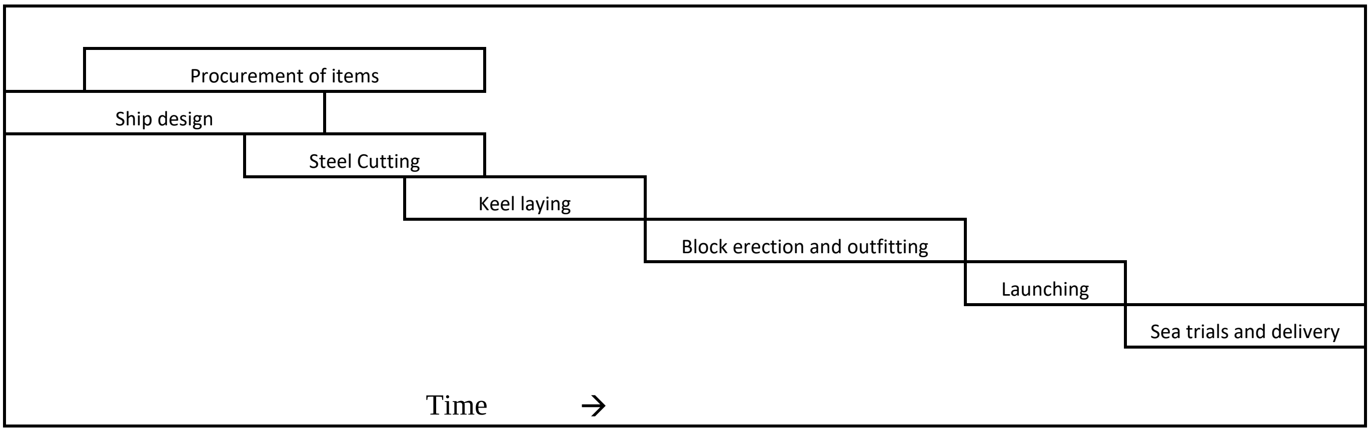

Figure B1: Stages of a typical shipbuilding project

Table B1: Forms of customer involvement in different stages of a shipbuilding project

Stage of shipbuilding project	Type of customer involvement	Form of customer involvement	Example
Procurement of items	Customer involvement in sourcing decisions	In supplier selection	Customer specified the suppliers.
		In purchase order finalisation	Customer's role in finalizing technical specifications was high. But customers played no role in lead time and price negotiations.
		In visits to suppliers' sites	The customer visited windlass and mooring winches' suppliers' site.
		In providing innovative inputs to suppliers	Customers provided innovative inputs to supplier to modify rudder lubrication line. Also suggested modification of ramp designs.
		In correspondence with suppliers	Customer checked the source of raw material supply. Continuously interacted till completion of project.

Ship Design	Customer involvement in project execution	In Design stage	The customer took the responsibility of basic design. The shipyard outsourced the 3-D design to a third party and customer regularly interacted with them also.
Steel Cutting		In Steel cutting stage	Quality inspections done by customer.
Keel laying		In Keel laying stage, in providing innovative suggestions during project	The customer was fully involved checking the quality of weld. The customers even gave inputs on how to weld girders, brackets in critical areas like curves.
Block erection and outfitting		In Block erection stage, in resolving onsite production problems, in providing innovative suggestions during project	The customer suggested improved manufacturing sequence of blocks that improved the productivity.
Launching		In Launching stage	The customer was fully involved. Went through the entire report of inclining experiment.
Sea trials and delivery		In Sea trials and delivery stage	The customer was fully involved. Did all performance criteria checking.

Appendix C

Shipyards, Projects and Customers information

Shipyard Information				Project Characteristics			Customer characteristics
Shipyard Name	Shipyard Capacity Dead Weight Tonnage (DWT)	Shipyard Ownership	Shipyard Set up year	Project Name	Ship Type	Ship Dead Weight Tonnage (DWT)	Ship owner (Customer Type)
Shipyard A	20000	Private	1985	Project A1	Cement Carrier	4000	Foreign
Shipyard A	20000	Private	1985	Project A2	Anchor handling tug	3000	Foreign
Shipyard A	20000	Private	1985	Project A3	Offshore vessel	15000	Foreign

Shipyard A	20000	Private	1985	Project A4	Interceptor boats	102	Domestic
Shipyard A	20000	Private	1985	Project A5	Bulk Carrier	2250	Domestic
Shipyard B	75000	Private	2004	Project B1	Bulk Carrier	54000	Domestic
Shipyard B	75000	Private	2004	Project B2	Bulk Carrier	32000	Foreign
Shipyard C	30000	Private	2006	Project C1	Ro-Ro Vessel	20000	Foreign
Shipyard D	400000	Private	1997	Project D1	Offshore supply vessel	1500	Domestic
Shipyard D	400000	Private	1997	Project D2	Barge	4300	Domestic
Shipyard E	7000	Government defense shipyard	1960	Project E1	Naval warship	3300	Domestic
Shipyard F	100000	Government defense shipyard	1972	Project F1	Patrol vessel	1000	Domestic
Shipyard F	100000	Government defense shipyard	1972	Project F2	Offshore Supply vessel	3000	Foreign
Shipyard F	100000	Government defense shipyard	1972	Project F3	Barge	5000	Foreign
Shipyard X	50000	Private	2004	Project X1	Multi utility triple screw Barge	4000	Domestic
Shipyard Y	4500	Private	1963	Project Y1	Crane Barge	2900	Domestic

Appendix D: Rules induced

Table D1: Rules induced

Induced rules for core {*CT*, *ST*}				
Rule No.	IF CT	and ST is		THEN d_PP is
B_7_Rule 1	D	EH		H
B_7_Rule 2	D	H		H
B_7_Rule 3	D	NH		H
B_7_Rule 4	D	M		H
B_7_Rule 5	D	L		M
B_7_Rule 6	F	SH		H
B_7_Rule 7	F	H		L

B_7_Rule 8	F	M		H
B_7_Rule 9	F	L		M
Induced rules for reduct*{CT, ST, CISD}*				
Rule No.	IF CT is	and ST is	and CISD is	THEN *d_PP* is
B_{11}_Rule 1	D	EH	SH	H
B_{11}_Rule 2	D	NH	NH	SH
B_{11}_Rule 3	D	L	M	M
B_{11}_Rule 4	D	M	NL	NH
B_{11}_Rule 5	D	H	L	H
B_{11}_Rule 6	D	M	SL	H
B_{11}_Rule 7	D	H	VL	M
B_{11}_Rule 8	D	L	VL	M
B_{11}_Rule 9	D	NH	Nil	H
B_{11}_Rule 10	F	SH	H	NH
B_{11}_Rule 11	F	L	M	M
B_{11}_Rule 12	F	M	M	H
B_{11}_Rule 13	F	L	SL	M
B_{11}_Rule 14	F	H	VL	NL
B_{11}_Rule 15	F	L	VL	M
Induced rules for reduct*{CT, ST, CIPE}*				
	IF CT is	and ST is	and CIPE is	THEN *d_PP*
B_{12}_Rule 1	D	M	SH	H
B_{12}_Rule 2	D	EH	H	H
B_{12}_Rule 3	D	M	H	NH
B_{12}_Rule 4	D	H	NH	M
B_{12}_Rule 5	D	NH	NH	SH
B_{12}_Rule 6	D	L	NH	M
B_{12}_Rule 7	D	H	M	H
B_{12}_Rule 8	D	NH	M	H
B_{12}_Rule 9	F	SH	SH	NH
B_{12}_Rule 10	F	L	H	M
B_{12}_Rule 11	F	M	H	H
B_{12}_Rule 12	F	H	NH	NL
B_{12}_Rule 13	F	L	M	M

Appendix E

Full form of acronyms and meaning of symbols

Acronym / Symbol	Full form of acronym / meaning of symbol
ST	Ship type complexity
CT	Customer type
CISD	Customer involvement in sourcing decisions
CIPE	Customer involvement in project execution
PP	Project performance
$\mathcal{A}\_PP$	Decision system
U	Universe of discourse
A	Set of conditional attributes
d	Decision attribute
B_i	Sub-set i of conditional attributes
γ_{B_i}	Degree of dependency of PP on sub-set i of conditional attributes