
# A Joint Modeling and Exploratory Framework for Intra-firm Collaboration within Construction and Mining Equipment Industry



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**Response to reviewer's comments**

The authors are extremely indebted to the esteemed reviewers for their comments and observations in this round of revision as well. These comments aided us greatly to augment the paper quality further. All the changes are highlighted in YELLOW color within the manuscript, tables, and figures.

***REVIEWER 1***

**(REVIEWER 1; COMMENT 1)**: Final touch with a proofreader would be recommended.

**RESPONSE:** We have proofread the entire manuscript along with the appendix, tables, and figure. Updates have been made through the paper to ensure grammatical correctness.

***REVIEWER 2***

**(REVIEWER 2; COMMENT 1)**: The newly added section 3.4.2 "the method" could undergo revision for proper technical language in this section.

**RESPONSE**: We have revised this section to ensure adherence to technical communication. Section 3.4.2 looks are follows now.

***3.4.2. The method***

Each of the focus group sessions was facilitated and moderated in that each session was recorded, transcribed, and analyzed. Initially, certain open-ended questions were posed to the focus groups. Some of these questions were: (1) what is your understanding of the term "collaboration"? (2) do you practice tenets of collaboration in your organization? (3) if you practice collaboration within your organization, in what ways do you collaborate? (4) does your collaborative behavior impact your organization at a strategic, tactical, and operational levels?

The objectives of posing such open-ended collaboration were two-fold. First, in responding to these questions, participants' apprehensions mitigated quickly, and they started viewing their respective focus groups as one cohesive entity (rather than a group of 6 to 7 individuals). Second,

during the initial twenty to thirty minutes of the time allotted for focus groups to respond to such open-ended questions, the major aim was to also enable evolution of broad-based consensus (Sweeney et al., 2018).

**(REVIEWER 2; COMMENT 2):** The revision of this paper has strengthened the clarity of the study. The new logical flow of the paper seems to be a better presented version. It may be useful for the authors to undergo another round of editing for technical writing especially the newly added parts for a smoother paper.

**RESPONSE**: We have proofread the entire manuscript along with appendix, tables, and figure. Updates has been made through the paper to ensure grammatical correctness. Emphasis on the newly created sections during R1 has been given during proofreading.

# A Joint Modeling and Exploratory Framework for Intra-firm Collaboration within Construction and Mining Equipment Industry


## *Abstract*

**Purpose**: In this research, collaboration attributes related to the firm's intrinsic and extrinsic facets at pertinent levels (i.e., enterprise, strategic, operational, and tactical levels) for construction equipment OEMs (original equipment manufacturers) operating in India have been quantified and modeled.

**Design/methodology/approach**: For modeling the intra-firm collaboration at respective organizational levels, relevant attributes have been populated employing literature review followed by subsequent validation from pertinent focus groups. The focus groups comprising of professionals working in the construction and mining equipment industry in India aided us in estimating the extent of interdependencies and influences within/amongst collaboration attributes. The collaboration attributes and respective interdependencies/influences are modeled employing the concept of graph theory where-in the individual attributes are represented using vertices and influences/interdependencies are represented using edges. The collaboration indices resulting from the variable permanent matrix have been derived as well.

**Findings**: Scenario and subsequent sensitivity analysis are performed. This research discusses the significance and aspects related to various collaborative attributes and the interrelations amongst them. Further, the research also evolves quantitative measures of collaboration indices at enterprise, strategic, tactical, and operational levels by employing a graph-theoretic approach (GTA). We have also extricated and discussed a number of meaningful implications from both the perspectives of interorganizational relationships (IORs) and the normative theory of organizations using a cross-case analysis of five firms having operations in India.

**Originality/value**: The research would aid organizations (particularly those belonging to the construction equipment sector) measure the efficacy of collaboration in respective value-chains at strategic, tactical, and operational levels. From the theoretical perspective, the integration of the IORs and normative theory of organizations enables us to look at the intra-firm collaboration

problem from a multi-dimensional standpoint involving activities, performance measures, action initiation, communication, shades of top management, level of activity, etc.

**Keywords**: Collaborative Engineering, Information sharing, Construction and Mining Equipment Industry, Focus Group

## 1. Introduction

Improving intra-firm relationships driven by effective collaboration amongst pertinent functional agencies has been argued as a proven strategy by companies to consolidate their respective competitive advantages (Despoudi et al., 2018, Mehdikhani, et al., 2019, and Li et al., 2022). Organizational collaboration is one of the driving forces enabling organizations to streamline their value-chain activities and maximize value creation (Chen et al., 2014, Wen, et al., 2017 and Czarnitzki et al., 2015). Effective intra-firm collaboration amongst the value-chain partners within organization results in streamlining the flow of information, money, and products across organizational boundaries (Kolfschoten, et al., 2010 and Flores-Fillol et al., 2017). This in turn improves the agility, adaptability, and predictability of value-chains (Chen et al., 2014, Tsanos et al., 2014, Tsai et al., 2015, Liu et al., 2021). In the context of an OEM (original equipment manufacturer) and at an intra-firm level, the value-chain is constituted of internal stakeholders (functional departments). Functional departments within any product-centric manufacturing firm are the pillars that support organizations in carrying out their business i.e., from ideating a product to salvaging it once the product's useful life is exceeded. In the context of a typical construction and mining equipment manufacturer (CME), typically six major functional agencies viz. *marketing, sales, product development, supply chain, manufacturing,* and *after-sales support* are responsible for tactical, operational, and strategic level execution of the firm's business objectives (Goswami *et al.,* 2014). These functional agencies within an OEM need to consider inputs pertaining to strategic, tactical, and operational dimensions in executing their short, medium, and long-term plans. These individual entities within the enterprise are entrusted to execute their respective responsibilities in that it becomes critical for these agencies to collaborate amongst themselves effectively. This in turn drives efficiency, flexibility, and sustainable competitive advantage for the firm in view of the strategic, tactical, and operational nuances (Ok et al., 2006, Cao & Zhang, 2011, Pennec et al., 2018, and Golgeci, 2019, Johnstone, 2019).

The extant literature on collaboration has some major thematic focus areas. Relational characteristics have been shown to be an important driver of collaboration both within the organization and the industry (Kong et al., 2016, Cai et al., 2016, and Castaner et al., 2020). Stakeholder and customer perspectives acting as crucial levers enabling collaboration has been also highlighted by studies such as Hofmann et al., (2009) and Zhao et al., (2016). Activity-based

perspectives such as information sharing, joint relationship effort, joint project ownership, risk sharing, dedicated investment, etc. in the context of collaboration have been studied as well in the extant research literature (Anand and Bihinipati, 2012, Zhao et al., 2016, Nix et al., 2014, Sacks et al., 2017, and Almeida et al., 2019). The desired level of collaboration amongst various functional agencies is usually contingent upon the underlying philosophy of information sharing along with related mechanisms and practices (Sandberg et al., 2007, Nebukenya et al., 2011, Badillo et al., 2016, and Chen et al., 2019, Jraisat et al., 2021, and Teng et al., 2022). Aspects such as trust and commitment across the value-chain have been found to positively influence customer satisfaction, operational, and financial performance, thus resulting in an enhanced competitive advantage for the firm (Das et al., 2015 and Salam et al., 2017). Further, the normative forces within organizations such as those related to organizational culture, organizational structures, communication philosophy, top management, etc. also influence the degree and effectiveness of collaboration. According to the normative paradigm, organizations are expected to conform to norms, prescriptions, culture, and systems considered to be legitimate by relevant professional groupings within the organization (Garcia-Sanchez, et al., 2016).

Despite being aware of the merits of collaboration as an important business strategy, many companies often fail at practical execution. The lack of matrices to evaluate collaboration is one such critical reason for failure (Kumar et al., 2014 and Lovstal et al., 2017). In the context of supply chains, the evaluation of inter-firm and intra-firm collaboration has been conceptualized by various theoretical, empirical, and analytical studies employing structured methodologies. Though many studies have evaluated collaboration focused on supply chains, the current research literature is quite scarce when it comes to evaluating intra-organizational collaboration (i.e., collaboration amongst functional agencies within a firm). This is especially important considering the need to understand interactions of strategic, tactical, and operational attributes such that, congruence of actions throughout the value-chain of the firm can be facilitated. Therefore, it is imperative for the OEM to devise a user-friendly and pragmatic framework that can model collaborative elements amongst the functional stakeholders thus facilitating more proactive use of non-financial performance-based measurement (Jääskeläinen and Thitz, 2018). Further, the proposed model should be able to capture elements related to crucial strategic, tactical, and operational-level collaborative dimensions. From a theoretical perspective, different theories have been deployed to define, explain, and describe collaboration across value-chains.

Transaction cost economics (TCE), resource dependence theory (RDT), the resource-based view (RBV), and contingency theory (CT) have been some of the dominant theories that explain collaboration within organizations (Despoudi et al., 2018). Castaner et al., (2020) have advocated for the examination of both inter-firm and intra-firm collaboration practices from the perspectives of interorganizational relationships (IORs) and the normative theory of organizations particularly considering the multi-dimensional views (such as the organization, processes, communication, etc.) of collaboration. Therefore, in keeping abreast with the recent trends in augmenting methodologies for the assessment and evaluation of intra-firm collaboration and deriving meaningful insights based on theoretical exploration, the primary objectives in this research are outlined as follows.

a) Discuss the significance and aspects related to various collaboration attributes and interrelations amongst them.
b) Evolve quantitative measures of collaboration at enterprise, strategic, tactical, and operational levels by employing a graph-theoretic approach (GTA).
c) Demonstrate our evolved methodology for an OEM and carry out a cross-case qualitative analysis based on major CME manufacturers in India and extricate key implications.
d) Explore the findings from the perspectives of the normative theory of organizations and IORs.

In this research, the CME industry is chosen as the focal sector for collaboration modeling owing to the industry's economic significance considering that this sector is one of the largest industrial sectors (perhaps after the automotive industry). Further, akin to the automotive sector, the CME industry has seen significant technological (such as networked mining and additive manufacturing) disruptions, thus making continual assessment and evaluation of intra-firm collaboration imperative.

The remainder of the article is arranged as follows. Sections 2 and 3 present the literature review and modeling of inter-firm collaboration problem respectively. Section 4 demonstrates the proposed steps. Section 5 and 6 enumerate application in India's CME sector, subsequent analysis, and discussions. Finally, the paper concludes in section 7, wherein research significance, concluding remarks along with future research directions are presented.

## 2. Literature review

In this section, we examine some of the extant research literature pertaining to enterprise collaboration. The research that we carry out in this paper broadly lies at the intersection of three broad thematic areas i.e., quantitative studies focused on the measurement of collaborative intensities, qualitative studies related to inter-firm collaboration, and the intrinsic firm's dimensions leading to collaboration.

### *2.1 Quantitative studies mapping collaborative intensities within organizations*

There have been various methodological contributions towards the development of pertinent frameworks aimed at measuring collaboration intensities within organizations spanning diverse aspects of value creation such as retailing, innovation, manufacturing, R&D (research and development) partnership, knowledge management, etc. Vieira et al. (2009) in the identification of collaboration elements and evaluation of collaboration intensities within the Brazilian supermarket retailer chain, deployed a structured questionnaire-based methodology to assess the degree of collaboration amongst partners. The study contributed to the extant research in that it revealed the indicators that produce greater collaboration intensities. Broekel (2012) examined the role collaboration plays in augmenting innovation success from an empirical perspective wherein two major collaboration measures viz. industry's average collaboration intensity and regional collaboration intensity were evolved. Bourne et al., (2002) in their research reasoned that having too many measures within organizations and a narrow focus on financial measures accompanied by short-termism and local optimization warrants broad-based development of collaborative indices at the enterprise level. Alexiev et al., (2016) developed a multi-dimensional model of how managers in the value-chain typically utilize collaboration as an organizational response system to business externalities, particularly adverse externalities. Based on a cross-sectional analysis, the study demonstrated that competitive intensity within an industry is associated with less organizational collaboration. Ramanathan *et al.,* (2014) in their research argued that the effects of collaborative planning, forecasting, and replenishment in supply chain performance assessment are augmented further by other collaborative factors. Using elaborate data obtained through questionnaire-based surveys focused on customers of a Textile company, this research identified that firms interested in end-to-end value-chain collaboration can consider engaging in long-term collaboration contingent on the success of the current degree of

collaboration. Li *et al.,* (2012) developed and empirically tested a framework analyzing relationships of collaborative knowledge management practices (CKMP) with emphasis on the integration of supply chain and knowledge quality. The study's design revolved around a survey-based approach in that representative data from eight manufacturing industries actively involved in inter-firm knowledge management practices in the context of value-chain partners were considered. Kong et al. (2016) examined relationships amongst internal organizational players in the context of the adoption of advanced manufacturing technologies based on data collected from 198 Chinese manufacturing companies. A key contribution of this work was that the process and product innovation was shown to have a significant mediating role as far as internal organizational collaboration is concerned. Busi et al., (2006) and Papakiriakopoulos et al. (2010) advocated for the development of collaborative indices for value-chains by considering strategic, tactical, and operational measures, thus aiding organizations to assess the level of efficiencies and effectiveness.

### *2.2 Focused qualitative studies on inter-firm collaboration*

From a qualitative standpoint, there have been contributions made in the extant research literature wherein studies have contributed towards managerial and policy recommendations (including key success factors) aimed primarily at ways in which collaboration practices within the value-chain can be augmented. While much of these studies have contributed towards collaboration within firms and within their respective supply chains; nonetheless few studies have also contributed towards emerging areas such as digital innovation, productization, servitization, etc. Carneiro *et al.,* (2013) based on the empirical study of firms in Northern Portugal made several key managerial and policy recommendations for enhancing collaboration across enterprises' value-chains. At the policy level, some of these recommendations pertained to the promotion of virtual organizations, adoption of technological infrastructure, and assimilation of best-in-class collaborative practices. Eksoz *et al.,* (2014) proposed and corroborated ten distinct hypotheses using empirical testing in the context of organizational collaboration. This work was particularly useful for food supply-chain managers in discovering problems related to collaborative forecasting and furthering a deeper understanding of the integration of supply chains, information sharing, and forecasting methodologies. In particular, this study builds upon the findings of Carneiro et al., (2013) in that the aspects related to the adoption of a digital

ecosystem as a means to orchestrate operational level collaboration was established empirically. Cai et al., (2016) devised a robust model to test the relationships between supply chain collaboration and organizational responsiveness, thus concluding that the value creation process gets catalyzed when collaboration as a measure to improve organizational response is deployed. Salam et al., (2017)'s work focusing on the fast-moving consumer goods (FMCG) sector established that technology when moderated through trust enhances the supply chain capabilities thus resulting in enhanced operational performance. This work empirically modeled supply chain collaboration and operational performance in the context of a developing country. It was found that as opposed to developed economies, collaboration mechanisms and their impacts are often unpredictable in developing economies. Palmieri et al., (2020) employing scenario analysis considered the operational dimensions of logistics and identified barriers and key success factors in the context of logistics service providers (LSPs) in both within- and cross-case settings. The study identified that the success factors pertain to industry and customer, while the barriers pertain to trust and competency. Ukko et al. (2020) employing the case-study approach for industrial collaboration identified three key areas having the most influence on organizational performance. These identified areas were external dimensions, customer-related dimensions, and internal organizational dimensions. These three dimensions can also have strategic, tactical, and operational nuances.

Within the emerging areas, some recent studies have also contributed significantly in terms of qualitative aspects related to collaboration. For instance, Valtakoski et al., (2016) particularly emphasized the role of cross-unit collaboration in the orchestration of collaboration for service productization. Adhering to the notion of cross-unit collaboration (though in a different setting), Pershina et al., (2019) advocated for cross-domain collaboration by bridging analog and digital expertise. Employing qualitative methodologies including semi-structured interviews, the study cross-fertilized two disparate areas i.e., knowledge management and collaboration within organizations. Janssen et al., (2022) in the context of research and development (R&D) advocated for collaborative innovation through key enabling technologies and missions such that geographically disparate sets of capabilities could be harnessed effectively.

### *2.3 Collaboration, firm-related dimensions, and emerging theories*

The study carried out by Vazquez-Casielles et al. (2013) emphasized the role of collaboration considering strategic aspects for both the intra-firm and inter-firm settings. Specifically, this study considered a case of the manufacturer-distributor relationship in that the role of governance in the context of strategic information sharing was examined. The study analyzed the role of collaboration from the theoretical lens of both governance and strategic information sharing. Tseng (2014) underscored the role of technological collaboration and various innovations aimed at enhancing the efficacy of the value-chains for organizations belonging to Gulf Cooperation Council countries. The study concluded that effective knowledge resource is essential for enhancing the innovation capabilities that ultimately bears fruits for organizations. Dingler et al. (2016)'s findings illustrated that organizations could develop socialization to further knowledge transfer amongst different industry verticals by implementing innovative practices. Further, this study also revealed that socialization facilitates the internationalization of knowledge in different industries. In particular, the study contributed to the theory in that it enabled an understanding of the role socialization plays in fostering knowledge transfer amongst partners originating from different industries. Herazo et al. (2015) based on the study of the influences of green building certifications in collaboration and innovation processes emphasized the role of effective mitigation of four types of tensions i.e., strategic-tactical, collaborative-competitive, participative-effective, and individual-collective such that mitigation of these tensions can enhance collaboration and therefore innovation. Oberg et al., (2016) in their study of organizational collaboration identity illustrated whether internal and external parties involved in collaboration share collaboration-level identities. The study employed cross-case analysis in the graphics and web design domain. The study found that the history prior to establishing collaboration negatively affects the perception of a shared identity. The study contributed toward the identity conceptualization within organizations wherein identities related to values, units, and influence/coexistence were explored in a collaborative setting characterized by formalization, duration, and agendas.

Certain studies have addressed firm collaboration (both intra- and inter-firm) from a stakeholder (internal and external) perspective. From the customer-related perspectives, Hofmann et al., (2009) argued for the involvement and commitment of participants within the organizational value-chain to common goal(s) such that customer satisfaction and competitiveness can be enhanced. Involving customers in the collaboration process so that cognitive exercise in design

processes can be applied for translating customer views, results in enhanced customer satisfaction (Bourne et al., 2000). From the perspective of internal organizations, collaboration often revolves around measuring and managing common goals and responsibilities in the context of the intra-organizational flow of products and related information (Bititci et al., 2012). The efficiency of internal and extended value-chain processes and benchmarked performance with respect to peers in the industry also drive the level of collaboration within firms' value-chains. Externalities have been also found to be driving collaboration in that Kulmala et al. (2006) argued for monitoring the external environment, relations, and their influences on the organizational value-chains.

Collaboration as a lever of competitive advantage is increasingly becoming complex both within and across organizations in that extant studies have advocated for the exploration of collaboration from multi-dimensional perspectives related to organizations, processes, communication, and technology (Zhang et al., 2021 and Teng et al., 2022). Castaner et al., (2020) in their study related to collaboration, coordination, and cooperation amongst organizations established distinctive meanings, particularly in the context of interorganizational relationships. The study developed a taxonomy pertaining to collaboration wherein different thematic areas related to collaboration and their manifestations were discussed. The major themes in relation to collaboration pertained to types of relationship (dynamic, semi-dynamic, or static), types of activity (joint activity or coordinated), performance measures (disparate or joint), dimensions of action initiation (joint or collective), types of communication (two-way communication, open communication), distinct levels of activity within the organization (strategic, tactical, operational). From the perspective of interorganizational relationships, the collaboration aspect (in the context of the intra-firm, inter-firm, supply chain, etc.) has been addressed through multiple theoretical perspectives as well. Some of these theories have been contingency theory, institutional theory, process perspective, social embeddedness theory, etc. (Castaner et al., 2020).

The need to take a multi-dimensional perspective also arises from the fact that in evolving quantitative measures of collaboration at multiple levels (enterprise, strategic, tactical, and operational), the interplays of such dimensions on collaboration measures need to be well understood. Therefore, we also discuss the normative theory of organizations along with the theory of interorganizational relationships as these two paradigms have been advocated to be

promising particularly in a multi-dimensional setting of organizations characterized by different levels of collaboration (Castaner et al., 2020 and Chatterjee et al., 2021).

***2.4 Research gaps, associated novelties, and contrast with respect to relevant research***

Based on the research literature presented above, we observe certain important research gaps that we seek to fulfill through our work. First, most of the work lying at the intersection of the manufacturing industry and organizational collaboration is essentially grounded in empirical investigations and qualitative studies requiring elaborate empirical settings both longitudinally and cross-sectionally. Second, extant studies such as Pennec et al. (2018), and Johnstone (2019) have advocated for considering operational, tactical, and strategic dimensions in a synergetic manner, thus considering the tenets of both vertical and horizontal collaboration simultaneously. Third, in doing so we develop intra-firm collaboration indices that not only focus on localized measures (such as financial and operational measures), but also at a macro-level, provide some sense of the degree of effectiveness and efficiency of the intra-firm collaboration (Papakiriakopoulos et al., 2010 and Alexiev et al., (2016). Fourth, considering the exploratory nature of the part of our study would also aid us to generalize important findings in relation to the case companies that we consider, leading to contributions towards the theory of interorganizational relationships and normative theory of organizations. This is especially important given the need to map specific facets of collaborations within specific themes of IORs as advocated by Castaner et al., (2020). Finally, most of the extant studies have been carried out in the context of developed economies wherein the interrelations and impacts related to enhanced organizational collaboration are often predictable. Therefore, in order to address the aforementioned research gaps, we contribute to the extant research literature in the following major ways.

a) Most of the extant studies focused on collaboration across the enterprise value-chain are devoid of measures related to the quantification of the propensities of collaboration intensities at pertinent levels viz. at enterprise, strategic, tactical, and operational levels. Our work is one such abridging attempt that seeks to model and quantify the collaboration intensities considering both endogenic and exogenic factors related to a manufacturing ecosystem (the CME industry).

b) In evolving the collaboration indices at enterprise, strategic, tactical, and operational levels, we capture the intricacies within and amongst endogenic and exogenic factors explicitly in terms of the extent of influences and extent of interdependencies (Zhang et al., 2021). By carrying out a detailed scenario analysis, we seek to aid manufacturing enterprises to gauge the current level of collaboration and identify gaps at respective level(s). Further, cross-case analysis enables us to identify key implications grounded in firm-level characteristics for intra-firm collaboration.

c) In particular, as opposed to the extant research literature, we also discuss the findings related to collaboration indices across firms from the normative perspectives of organizational systems and IORs. This would enable us to establish links amongst the findings of the study with underpinnings related to the normative theory of organizations as well, thus uncovering dimensions such as organizational culture, communication, organizational structure, top management, etc. In essence, such an exploratory approach anchored to the two theories enables us to take a multi-dimensional perspective in relation to the development of collaborative indices.

Table 1 presents a summary contrasting our research with some recent research literature in that apart from the contrasting aspects of extant research literature, pertinent research context, and theoretical perspectives are also presented.

<<Insert Table 1 here>>

**3. Modeling and exploration of intra-firm collaboration problem**

Since the problem that we address in our study revolves around the development of collaboration indices and subsequent exploration of findings from the theory of both IOR and normative theory of organizations, therefore a mixed-method approach is warranted in our study. In particular, during the development of collaboration indices at enterprise, strategic, tactical, and operational levels, owing to the capabilities of graph-theoretic setting, we employ graph theory to lay out the collaboration attributes and their interdependencies amongst each other. In particular, the sub-attributes at pertinent levels are depicted as vertices while the edges represent interdependencies. Further, employing qualitative inputs from the focus groups, we substantiate the quantitative inputs and assess the magnitude of collaboration indices. Since the qualitative study of intra-firm

collaboration particularly from the theoretical lens of IOR and the normative theory of organizations is rather fragmented, thus it requires a connection with the theory. To this end, multiple cases belonging to the CME domain are considered.

### *3.1 Selection of collaboration attributes*

To begin the quantitative modeling of intra-firm collaboration, it is imperative that collaboration attributes based on a relevant survey of extant research literature be identified and validated through expert elicitation and brainstorming. Brainstorming sessions held with the industry professionals emphasized primarily the strategic, tactical, and operational dimensions of the OEMs operating in the CME industry with an objective to identify major (may not be exhaustive) collaboration attributes. These attributes function as the elements of collaboration between and amongst the functional agencies within the organization. Such collaboration attributes can have both quantitative and qualitative characteristics. For example, at the operational level, we can have a rather objective attribute such as the *financial health of the firm*, while at a strategic level, the collaboration attribute can pertain to *reputation within the industry* (Ip *et al.*, 2003). Subsequent sections discuss the attributes at strategic, tactical, and operational levels both from the theoretical and practical perspectives.

#### *3.1.1 Strategic attributes*

These are the kind of collaborative attributes that are essentially anchored to the strategic dimensions of a firm meant to strengthen the company in the long run. From the theoretical perspective, strategic attributes associated with a firm are a manifestation of the future orientation, strategic intent, strategic objectives, and competitiveness considering the dynamic business and economic environment (Johnson et al., 2012 and Magnani et al., 2018). The future orientation of the firm represents long-term strategic considerations (rather than short-term considerations). Similarly, the firm's strategic intent dictates dominance over competitors and winning competitively (Magnani et al., 2018). A case in point is the Bharat Stage – 6 (BS-VI) emission norms implemented in the year 2020 in the automotive sector in India. To curb the burgeoning level of pollution in the Indian subcontinent, the Government of India had brought forward the mandatory adoption of BS-VI emission norms (which was earlier to be implemented in 2022) by 2 years. This decision compelled automotive manufacturers to race to rapid

technological development and subsequent commercialization such that they can continue to sell regulatory-compliant products beyond the year 2020. Some of the critical dimensions driving the industry landscape may relate to the general growth outlook in that industry, the extent of competition in that industry, the chances of any disruptive event happening in that industry, and so on. The inclusion of the industry landscape is also especially important considering that resource-sharing amongst intra-firm stakeholders, scope of collaboration, level of collaboration, time horizon, etc. are often driven by the industry structure (Anand et al., 2012). Similarly, the state of the economy is another crucial driver for the firm's strategic outlook and goals. A bearish market would call for effective risk mitigation strategies, whereas a bullish market would warrant market-driven policies to maximize the sales revenues of firms. Along similar lines, the reputation that a firm enjoys within a particular industry is a function of the extent to which effective collaborative strategies can be adopted and implemented. Therefore, in line with the theoretical perspectives and pragmatic dimensions considering the strategic level within the organization, in this study, the high-level strategic attribute is characterized by three sub-attributes namely: *industry landscape*, *state of the economy*, and *industry reputation*.

### *3.1.2 Tactical attributes*

Tactical attributes associated with a firm pertain to an immediate lower-level decisional paradigm wherein execution of the strategic plans at the tactical plane assumes primacy (Chofreh et al., 2018). The measures pertaining to the tactical dimensions (as opposed to the strategic dimensions) tend to assume a medium-term outlook wherein the objective of the firm is to gain competitive advantage and drive customer satisfaction in such a way that organizations can continue to operate considering statutory, legal, and regulatory norms (Ukko et al., 2020). Collaborative exchanges both between and amongst internal and external stakeholders have been advocated as an instrument for ensuring customer satisfaction as well as onboarding new customers (Kadic-Maglajlic et al., 2018). Yen et al. (2018) argued that regulatory pressures and the need for compliances often dictate deeper collaboration amongst functional players so that firms can continue to do business in the marketplace subject to regulatory norms. Further, the tactical attributes pertain to actions focused on meeting firms' goals in the medium-term such as enhancing the market share beyond a certain threshold, measures taken to achieve organic/inorganic growth, and so forth. Consider an example of the passenger car segment in

India. The passenger car segment in India has evolved (from 2005-2006) from a scenario wherein the entry-level segment constituted around 50% of total sales. Fast forwarding to the contemporary time, the entry-level segment only accounts for around 25%; while the next higher segment i.e., the mid-size and SUV (sport utility vehicle) segment contributes to around 50% of total annual sales (Raj, 2017). Further, these market shares are subject to the manufacturers meeting the regulatory norms (in terms of Bharat stage emission mandates). Such changes in the industry landscape have resulted in refined tactics as far as passenger car manufacturers in India are concerned in that most of the manufacturers have been accordingly upgrading their facilities so that higher numbers of mid-sized cars can be produced. The tactical attributes would be characterized by key sub-attributes such as the ability of the firm to not just meet the requirements of the customers but to also delight them. Therefore, in line with the theoretical perspectives and pragmatic dimensions, while considering the tactical level within the organization, in this study, the high-level tactical collaboration attributes are constituted of three sub-attributes namely: *customer satisfaction, regulatory compliance,* and *competitive advantage*.

### *3.1.3 Operational attributes*

Operational attributes are typically a manifestation of tactical planning and decisions in that such attributes associated with the firm are short-term in nature and do have an immediate impact on operational indicators. Dimensions related to operational aspects such as efficiencies, competitiveness, systems, activities, outcomes, etc. characterize the operational attributes (Afum et al., 2020). Further, there are several indicators related to cost, quality, delivery, flexibility, and riskiness that are determinants of the operational effectiveness of an OEM and corresponding project delivery (Franz, 2018 and Belekoukias *et al.*, 2014). Operational excellence as a paradigm of efficiency and effectiveness of operations is influenced deeply by the degree of collaboration and shared responsibilities (Cui et al., 2022). Further, the manner in which operational performance contrasts with respect to the peers in the same industry and the intended benchmarked performance (functional as well as financial) act as an important pathway to collaboration amongst internal organizational entities (Grace et al., 2017). The competitiveness of cost structures, control over overheads involved in production processes, and financial judiciousness are some of the key elements governing financial health of the OEM (Kim *et al.*, 2015). Therefore, in line with the aforementioned theoretical underpinnings, we consider three

primary sub-attributes influencing the operational performance of a firm. The first sub-attribute pertains to *operational excellence* within the firm predominantly dealing with efficiency (productivity), effectiveness (customer/market orientation), and optimization of production processes (Jaeger *et al.,* 2014). The second and third sub-attribute considered in the study refers to financial health and benchmarked performance with respect to peers.

When we formalize collaboration within a firm at strategic, tactical, and operational levels, it is not just 'hard' technical nuances that are of the essence; there are cultural and social nuances involved as well (Aguiar et al., 2017). For instance, Bello *et al.,* (2012) advocated for the need of having a socio-technical system of collaboration for minimizing value-chain risks in modern-day enterprises as opposed to purely relying upon the 'hard' technical strategies.

The attributes identified at the three levels and corresponding anchoring to the extant research literature have been listed in Table 2(a).

<<Insert Table 2 about here>>

***3.1.4 Enterprise-level collaboration***

The normative theory of organizations reflects that organizational culture, organizational structures, and communication philosophy do have a strong influence in dictating the level of collaboration within organizations whether the organization has predominantly digital or traditional methods of collaboration (Garcia-Sanchez et al., 2016, and Snow et al., 2017). Since, the enterprise level (the most macro-level) view of collaboration itself would be driven by the strategic, tactical, and operational facets of collaboration, therefore, we posit the extent of enterprise-level collaboration as contingent upon the magnitude of collaboration across the three facets i.e., strategic, tactical, and operational. Further, from the normative perspective, although it is difficult to objectively ascertain the influence of organizational culture, organizational structures, communication philosophy, etc. on enterprise level collaboration; nonetheless, the enterprise level collaboration (as a function of collaboration at strategic, tactical, and operational level) does have implications for the normative theory of organizations (Ricciardi et al., 2012). Further, within the firm, the theory of IOR also takes multi-dimensional perspectives within the organizations, particularly in relation to qualitative settings.

### *3.2 Interdependencies amongst collaboration attributes*

Within the strategic, tactical, and operational collaboration attributes, some of the sub-attributes are in some manner related (and, thus, interdependent) in some form to some other sub-attributes in another cluster. Consider for example the sub-attribute "competitive advantage" within the cluster "tactical". This particular sub-attribute is strongly related to the sub-attribute "operational excellence" within the cluster "operational" in that operational excellence is a key driver of enhancing the competitive advantage i.e., capabilities of a firm with respect to its peers (Liu and Liang, 2015). In this context, the sub-attribute "operational excellence" *supports* firms in gaining "competitive advantage". The sub-attribute "competitive advantage" in turn *enhances* the sub-attribute "benchmarked performance wrt. peers" within the "operational" cluster (Horta *et al.*, 2014). Interdependencies can be also observed within a particular cluster as well. A case in point would be the "*complementary*" form of interdependency within the cluster "strategic" wherein sub-attributes "state of the economy" and "industry landscape" (Lieder *et al.*, 2016) are at a structural level complementary to each other. Table 2(b) summarizes the interdependencies among the collaboration attributes.

### *3.3 Case study approach*

The five-company-focused case-study approach deployed in this work revolves around analyzing the relative positioning of these companies wrt. intra-firm collaboration and reflecting upon key firm-level characteristics grounded in IORs and the normative theory of organizations. The objectives are to logically understand and capture complex phenomena of collaboration within the organization at the strategic, tactical, and operational levels through a thorough study of multi-dimensional perspectives involving accompanying processes, organizational structures, market segments, product varieties, organizational cultures, and so forth. Therefore, a qualitative (exploratory) research approach integrated with quantitative modeling for quantification of intra-firm collaboration is adopted in this study. The methods for the study of intra-firm collaboration align with systematic approaches for studies on strategic, tactical, and operational levels coupled with individual firm-level characteristics (Li et al., 2016). These have not been yet investigated sufficiently in the extant research literature. Therefore, an exploratory approach would be warranted in such a context. Considering the potential impact of contingencies, the use of case studies is the most appropriate for this purpose. The availability of five case studies as individual

projects is considered well-accepted as action research principles allow for an in-depth investigation focused upon the assessment of intra-firm collaboration for each of these five firms.

### *3.4 Focus group and exploratory inputs*

Each of the five cases represents an in-depth study of 6 to 7 months comprising both analyses of company-specific firm-level characteristics (October 2021 to March 2022). From a data collection perspective, since the extant research literature is limited to warrant a strong conceptual foundation, we employ a focus group research approach based on direct and interactive methods (Bettley *et al.*, 2005). This choice is grounded in the fact that specific experiences of participants in focus groups would be reliable, valid, and value-adding (Anand and Bihinipati, 2012). First, respondents from the CME industry are identified and are clubbed in the categories viz. top management, senior management, and middle management. Specifically, job roles are mapped against the corresponding level of responsibilities emanating from the pertinent business dimensions i.e., strategic, tactical, or operational. From our understanding of the organizational structure, it is obvious to map top-management, senior-management, and middle-management to strategic, tactical, and operational levels respectively. Participants belonging to the top management, senior management, and middle management possessed on average around 30, 22, and 15 years of professional experience respectively across various functional domains within their respective organizations. The participants were also asked to provide pertinent insights from their prior engagement within their current/erstwhile organizations working in the industry. Further, during the data collection stage, participants were assured anonymity so as to avoid getting influenced in talking about their experiences. Thus, we had five different focus groups belonging to five different companies. Respondents of these groups were discouraged from interacting with each other.

#### *3.4.1 The participants*

Corresponding to each of the five focus groups (representing the respective five companies from the CME industry), a typical focus group consisted of a mix of professionals from the top, senior, and middle management such that each focus group had 6 to 7 members. These members belonged to different functional areas in that they had significant cross-functional experience as well. Table A (1) in the Appendix section captures pertinent details about the participants within

the respective focus groups. Referring to Table A (1), it can be observed that typically a top management professional has had higher exposure to cross-functional domains as opposed to senior- and middle-management professional within a typical focus group. The focus groups were created in such a way that participants within a focus group possessed similarities pertaining to the industry to which they belonged. However, at the same time, constituting a focus group from respective professionals from top-, senior-, and middle-management enables the focus group to bring perspectives related to strategic, tactical, and operational level attributes of collaboration.

### *3.4.2. The method*

Each of the focus group sessions was facilitated and moderated in that each session was recorded, transcribed, and analyzed. Initially, certain open-ended questions were posed to the focus groups. Some of these questions were: (1) what is your understanding of the term "collaboration"? (2) do you practice tenets of collaboration in your organization? (3) if you practice collaboration within your organization, in what ways do you collaborate? (4) does your collaborative behavior impact your organization at a strategic, tactical, and operational levels?

The objectives of posing such open-ended collaboration were two-fold. First, in responding to these questions, participants' apprehensions mitigated quickly, and they started viewing their respective focus groups as one cohesive entity (rather than a group of 6 to 7 individuals). Second, during the initial twenty to thirty minutes of the time allotted for focus groups to respond to such open-ended questions, the major aim was to also enable evolution of broad-based consensus (Sweeney et al., 2018).

## 4. The proposed steps for quantification of intra-firm collaboration indices

The steps for modeling of intra-firm collaboration problem consist of the five steps listed below.

Step 1: Develop diagraphs and delineate interdependencies

Step 2: Derive variable permanent matrix

Step 3: Establish permanent representation

Step 4: Quantify elements of VPM (variable permanent matrix) matrix

Step 5: Rationalize the VPM matrix

The methodology starts with the development of diagraphs and delineation of interdependencies. To this end, graph theory is used. Thereafter, in the next step, the variable permanent matrix (VPM) is derived. The variable permanent matrix has two types of elements: diagonal elements representing the relative importance of a particular attribute and non-diagonal elements representing interdependencies amongst attributes or sub-attributes. In case there is no interdependency, the non-diagonal elements assume a value of zero. Once, the permanent matrices are derived, the next task is to establish permanent representation based on the method devised by Grover (2004, 2005, and 2006). Employing inputs from the respective focus groups, we quantify elements of VPM matrices. Finally, VPM matrices (owing to their multi-nomial properties) are rationalized using a logarithmic scale.

The quantitative inputs from the focus groups revolved around considering those inputs that were based on a consensus. In particular, focus groups were asked to adhere to the guiding questions based on the synthesis of IORs and the normative theory of organizations. These developed questions are presented in Table A (2) of the Appendix section.

Figure 1 delineates the various stages of our research study.

<<Insert Figure 1 here>>

In the next section, an application for one company (out of the five case companies) is detailed using the proposed steps. Subsequently, sensitivity and exploratory cross-case analysis are also carried out.

## 5. Application in India's CME sector

In order to demonstrate the methodology and distinguish one CME manufacturer from the other, we consider five such OEMs operating in India. These five OEMs amongst themselves command a market share of more than 90% of the CME market in India. In order to ensure anonymity, the names of the companies under study are not being disclosed. For the sake of representation, we term these companies as A, B, C, D, and E.

Table 3 distinguishes these companies in terms of some critical differentiators.

<<Insert Table 3 about here>>

Referring to Table 3, we identify six differentiating dimensions viz. structure of the firm, sectors served, product variety level, end customer type, technological capabilities, and composition of top management.

We have had five different focus groups such that each member belonged to a different functional area of the respective organization. Since it is customary that organizations often work through a number of CFTs (cross-functional teams), therefore we cogently assume that respondents belonging to the focus groups were actively involved in collaborative initiatives of the respective organizations (Franz et al., 2017). Thus, as representatives of the five organizations whose intra-firm collaboration intensities (IFCs) need to be measured, the respective focus group deployed the evolved attributes, interdependencies, and diagraphs to determine corresponding IFCs. In particular, the respondents were asked to rate the attributes based on their conviction/perception of intra-firm partners for actual collaborative relationships. For the sake of brevity, a step-by-step illustration of the proposed methodology is demonstrated below for company-A.

### *5.1 Developing diagraphs and delineating interdependencies*

From the pertinent focus group, the identified interdependencies as depicted in Table 2(b) for both the top-level collaboration attributes and sub-attributes are represented diagrammatically in the form of directed graphs (diagraphs) using Figure 2.

<<Insert Figure 2 here>>

Figures 2(a), 2(b), 2(c), and 2(d) diagrammatically capture the interdependencies considering enterprise level, strategic level, tactical level, and operational level attributes respectively.

The forms of interdependencies at the sub-attribute level are also enumerated in Table 4.

<<Insert Table 4 about here>>

Table 4(a), 4(b), 4(c) represent interdependencies amongst sub-attributes for strategic, tactical, and operational dimensions respectively. Similar to the study of Anand *et al.* (2012), this study views that evolved interdependency configurations (of both collaboration attributes and sub-attributes) have merits of adaptability and flexibility.

### *5.2 Deriving variable permanent matrix (VPM)*

We rely on the studies of Grover *et al.,* (2004, 2005, 2006) for developing a variable permanent matrix (VPM). The VPM at our attribute level is depicted by *B* or *VPM-B* based on the digraph evolved in Figure 2(a) and is demonstrated in matrix convention employing equation 1.

$$B = VPM - B = \begin{bmatrix} B(1) & b_{12} & b_{13} \\ b_{21} & B(2) & b_{23} \\ b_{31} & b_{32} & B(3) \end{bmatrix} \quad (1)$$

Individual elements *B(i)s* represent the respective high-level attributes. For instance, B(1), B(2), and B(3) denote the effectiveness of degree of collaboration along strategic, tactical, and operational attributes respectively within the organization as ascertained by the respective focus group. The scales that the focus group would use to qualify these diagonal elements are defined in Table 5(a) such that a value of 1 implies an 'extremely low' magnitude of collaboration, while a value of 9 signifies an 'extremely high' magnitude of collaboration for the pertinent collaboration attribute. $b_{ij}$*s* represent the degree to which an attribute "*i*" influences a different attribute "*j*". For example, $b_{12}$ denotes the degree to which strategic attributes impact tactical attributes. To this end (and for this non-diagonal element), the scale formalized in Table 5(b) would be of utility in that a value of 1 as assigned by the focus group implies, 'very weak' independency between strategic and tactical attributes, while a value of 5 signifies 'very strong' independency.

B(1), B(2), and B(3) are at the diagonal positions in the VPM matrix. The rest of the non-diagonal elements are ascertained based on the relationship between the attributes such that in case of no relationship, the corresponding non-diagonal element would be '0'.

Similarly, the VPM matrices for the sub-attributes are obtained and illustrated through the following set of equations.

$$B_{str} = VPM - B_{str} = \begin{bmatrix} B(1)_1 & b(1)_{12} & b(1)_{13} \\ b(1)_{21} & B(1)_2 & b(1)_{23} \\ 0 & 0 & B(1)_3 \end{bmatrix} \quad (2)$$

$$B_{tac} = VPM - B_{tac} = \begin{bmatrix} B(2)_1 & 0 & b(2)_{13} \\ b(2)_{21} & B(2)_2 & b(2)_{23} \\ b(2)_{31} & 0 & B(2)_3 \end{bmatrix} \quad (3)$$

$$B_{opr} = VPM - B_{opr} = \begin{bmatrix} B(3)_1 & b(3)_{12} & b(3)_{13} \\ b(3)_{21} & B(3)_2 & b(3)_{23} \\ 0 & b(3)_{32} & B(3)_3 \end{bmatrix} \quad (4)$$

In equations 2, 3, and 4, $b(i)_{mn}$ represents the degree of interdependency between sub-attribute "*m*" and "*n*" of attribute "*i*". For instance, $b(1)_{12}$ represents the degree of interdependency between the sub-attribute "*industry landscape*" and "*state of the economy*". Equations 2, 3, and 4 are related to Figure 2(b), 2(c), and 2(d) respectively.

### *5.3 Permanent representation*

The VPM of B as demonstrated through equation 1 is multi-nomial and is presented as Per(B). The permanent of a matrix is able to aggregate the values of the collaboration attributes and pertinent interdependences and, thus yields a composite score (Baykasoglu et al., 2014). The composite score gives a sense of the effectiveness of collaboration in relation to pertinent levels whether enterprise, strategic, tactical, or operational. The higher the permanent value of the corresponding matrix, the higher the magnitude of collaboration in relation to that particular collaboration attribute. The VPM of B is represented as follows (a polynomial function).

$$Per(B) = B(1)\times[B(2)\times B(3)+b_{32}\times b_{23}]+b_{12}\times[B(1)\times B(3)+b_{31}\times b_{13}]+ b_{13}\times[b_{21}\times b_{32}+b_{31}\times B(2)] \quad (5)$$

Similarly, other VPMs are derived and demonstrated through the following set of equations.

$$Per(B_{str}) = B(2)_1\times[B(2)_2\times B(2)_3+0\times b(2)_{23}]+0\times[b(2)_{21}\times B(2)_3+b(2)_{31}\times b(2)_{23}]+ b(2)_{13}\times[b(2)_{21}\times B(2)_3+b(2)_{31}\times b(2)_{23}] \quad (6)$$

$$Per(B_{tac}) = B(2)_1\times[B(2)_2\times B(2)_2+0\times b(2)_{23}]+0\times[b(2)_{21}\times B(2)_3+b(2)_{31}\times b(2)_{23}]+ b(2)_{13}\times[b(2)_{21}\times 0+b(2)_{31}\times B(2)_2] \quad (7)$$

$$Per(B_{opr}) = B(3)_1\times[B(3)_2\times B(3)_3+b(3)_{32}\times b(3)_{23}]+b(3)_{12}\times[b(3)_{21}\times B(3)_3+0\times b(3)_{23}]+ b(3)_{13}\times[b(3)_{21}\times b(3)_{32}+0\times B(3)_2] \quad (8)$$

To compute the values of permanent matrices of equations 5 to 8, values for individual terms are needed in that these were derived from the five focus groups. The required permanent values would have to be ascertained after quantifying B(*i*)s, $b_{ij}$s, and $b(i)_{mn}$ s.

### *5.4 Quantification of B(i)s, $b_{ij}$s, and $b(i)_{mn}$ s.*

For ascertaining *B(i)*s and $b_{ij}$*s* in the *VPM-B* matrix represented by equation 1, the developed digraphs illustrated in Figure 2 are employed. Adhering to the steps detailed in Section 5.2 and section 5.3, VPMs for sub-attributes are ascertained and are represented as $VPM - B_{str}(B_{str})$, $VPM - B_{tac}(B_{tac})$, and $VPM - B_{opr}(B_{opr})$. The values of *B(i)*s in a particular variable permanent matrix demonstrate the extent of importance that can be obtained using a suitable scale in that we adopt this scale {listed in Table 5(a)} from Saaty's (1980) relative scale of importance used in analytical hierarchy process (AHP).

<<Insert Table 5 about here>>

The pertinent focus group i.e., focus group 1 (FG1) representing company–A performed the evaluation based on the degree to which respondents in the focus group believe that high-level collaboration attributes are interdependent on one another by relying upon their respective industry experience. The group further ascertained that to what extent individual attributes should be allocated the due importance value. The guiding questions in Table A (2) enable the focus group to come together at a consensus value. Based on the assessment from the focus group, computed values are determined for the $VPM - B$ matrix.

$$B = VPM - B = \begin{bmatrix} 7 & b_{12} & b_{13} \\ b_{21} & 6 & b_{23} \\ b_{31} & b_{32} & 9 \end{bmatrix} \quad (9)$$

Referring to the above equation, values for diagonal elements are provided, however for the rest of the elements, to ascertain corresponding values, we rely upon Anand *et al.* (2012). The scale is presented in Table 5(b).

The completed *VPM-B* (considering both diagonal and non-diagonal elements) is illustrated in equation 10.

$$B = VPM - B = \begin{bmatrix} 7 & 5 & 3 \\ 4 & 6 & 5 \\ 3 & 4 & 9 \end{bmatrix} \quad (10)$$

Referring to equation 10, $b_{12}$ has been allocated a value of 5 i.e., 'very strong' implying that "strategic attribute" influences "tactical attribute" very strongly. To put this value in perspective, the business dynamics in the construction and mining equipment industry (be it a developed

economy or an emerging economy) are characterized by a high degree of cyclicality (Shunko *et al.*, 2017). To minimize the impact of such cyclicality on their core business, both global and specific region-focused OEMs typically offer a diverse range of product portfolios. Consider for example Caterpillar Inc. (a global leader) and Tata Hitachi (market leader in the Indian construction and mining equipment industry). Both companies have diversified product portfolios catering to varying needs of diverse market segments such as mining equipment, excavators, roadmaking equipment, building and road construction equipment, canaling equipment, and so forth. The broad range of product offerings necessitates varying tactical approaches for functional level decisions such as strategic sourcing and procurement, adoption of regulations related to product safety, productive spare part stock keeping, etc.

Similar to the aforementioned approach, the *VPM-B* matrix is computed as below.

*Per (VPM-B)* = 885.

Similar to the above-detailed approach, the diagonal and non-diagonal values correspond to four VPMs and their permanent values are determined.

### *5.5 Rationalization of variable permanent matrices*

The rationalized permanent values of all four VPMs are represented in terms of the below presented logarithmic scale.

a) $Log_{10}\{Per(VPM\text{-}B)\} = 2.946$
b) $Log_{10}\{Per(VPM\text{-}B_{str})\} = 2.900$
*c)* $Log_{10}\{Per(VPM\text{-}B_{tac})\} = 2.832$
*d)* $Log_{10}\{Per(VPM\text{-}B_{opr})\} = 2.785$

The values (i.e., a, b, c, and d) represent the intra-firm collaboration index (IFC), strategic level collaboration index (SLCI), tactical level collaboration index (TLCI), and operational level collaboration index (OLCI) respectively.

Similarly, using the approach as illustrated for the company–A, values of IFC, SLCI, TLCI, and OLCI for the remaining four companies are determined. The permanent and logarithmic values are enlisted in Table 6.

<<Insert Table 6 about here>>

## 6. Analysis and Discussions

### *6.1 The intra-firm analysis*

The extent of implementation and importance of various collaboration initiatives within OEMs influence the values of collaboration indices at all pertinent levels i.e., firm level, strategic level, tactical level, and operational level. To determine the range within which values of IFC, SLCI, TLCI, and OLCI remain, it is imperative that an appropriate scenario analysis be performed. We illustrate the scenario analysis for company–A.

#### *6.1.1 Scenario analysis*

To perform scenario analysis, we segregate both $b_{ij}s$ and $b(i)_{mn}s$ in terms of the lowest and highest value. For example, $b_{ij}$ would vary between 1 and 9; similarly, $b(i)_{mn}$ would vary between 1 and 5. In the context of the scenario analysis, four specific cases arise as depicted in Figure 3.

<<Insert Figure 3 here>>

*Case-I*

Here, the pertinent focus group (FG1) assigned the lowest importance to the relevant non-diagonal elements. The resulting matrices are illustrated below.

$$B = VPM - B = \begin{bmatrix} 7 & 1 & 1 \\ 1 & 6 & 1 \\ 1 & 1 & 9 \end{bmatrix} = 2.604\,;\; B_{str} = VPM - B_{str} = \begin{bmatrix} 6 & 1 & 1 \\ 1 & 8 & 1 \\ 0 & 0 & 5 \end{bmatrix} = 2.389$$

$$B_{tac} = VPM - B_{tac} = \begin{bmatrix} 7 & 0 & 1 \\ 1 & 5 & 1 \\ 1 & 0 & 9 \end{bmatrix} = 2.505\,;\; B_{opr} = VPM - B_{opr} = \begin{bmatrix} 5 & 1 & 1 \\ 1 & 8 & 1 \\ 0 & 1 & 9 \end{bmatrix} = 2.574$$

Specifically, this case pertains to the situation wherein from the perspectives of IOR and the normative theory of organizations, the firm struggles to establish collaborative practices and mechanisms in that information flow remains rather static in nature amongst the internal stakeholders. Silo-based structures characterize the organization in that a joint ownership structure to ensure collaboration amongst different functional areas of the organization does not exist. Further, the culture of an organization is this case would be relatively rigid that does not promote collaboration. Therefore, the interactions amongst strategic, tactical, and operational-

level collaboration attributes are established to be minimal leading to the least degree of overall intra-firm collaboration.

*Case-II*

Here, the focus group has assigned the highest importance to $b_{ij}$s i.e., non-diagonal elements (in the VPM-B matrix). The permanent values of *VPM-B*$_{str}$, *VPM-B*$_{tac}$, and *VPM-B*$_{opr}$ matrices remain the same as that in *case I.*

$$B = VPM - B = \begin{bmatrix} 7 & 9 & 9 \\ 9 & 6 & 9 \\ 9 & 9 & 9 \end{bmatrix} = 3.558$$

This case pertains to specifically those contexts within the organizations wherein though a certain degree of collaboration exists amongst respective organizational levels (for example within top management for strategic level dimensions or within middle management for operational level dimensions); however, across levels, strong communication and collaboration exists as well. This means that the strategic level dimensions and corresponding implications get seamlessly disseminated at both tactical and operational levels. From the perspective of the normative theory of organizations, such organizations are often characterized by strong top management support for organizational endeavors and strong multiple-level communication culture (Ricciarrdi, 2012).

*Case-III*

In this case, the focus group has assigned the highest importance to $b(i)_{mn}$s i.e., non-diagonal elements (i.e., in the case of *VPM-B*$_{str}$, *VPM-B*$_{tac}$, and *VPM-B*$_{op}$). The permanent value of the VPM matrix remains the same as in the case of *Case I.*

$$B_{str} = VPM - B_{str} = \begin{bmatrix} 6 & 5 & 5 \\ 5 & 8 & 5 \\ 0 & 0 & 5 \end{bmatrix} = 2.603;\ B_{tac} = VPM - B_{tac} = \begin{bmatrix} 7 & 0 & 5 \\ 5 & 5 & 5 \\ 5 & 0 & 9 \end{bmatrix} = 2.531$$

$$B_{tac} = VPM - B_{tac} = \begin{bmatrix} 5 & 5 & 5 \\ 5 & 8 & 5 \\ 0 & 5 & 9 \end{bmatrix} = 2.922$$

This specific setting pertains to the fact that from the IOR perspective, the collaboration amongst the functional agencies revolving around strategic, tactical, and operational dimensions assumes the highest degree of effectiveness in that information flow and associated dynamism, coordination, information quality, project ownership etc. remain at the optimal levels.

*Case-IV*

In this case, the focus group has assigned the highest importance to $b_{ij}$s and $b(i)_{mn}$s i.e., non-diagonal elements in case of *VPM-B* matrix and non-diagonal elements in case of *VPM-*$B_{str}$, *VPM-*$B_{tac}$, and *VPM-*$B_{opr}$. The permanent values *VPM-*$B_{str}$, *VPM-*$B_{tac}$, and *VPM-*$B_{opr}$ matrices remain the same as in the case of *Case III*.

$$B = VPM - B = \begin{bmatrix} 7 & 9 & 9 \\ 9 & 6 & 9 \\ 9 & 9 & 9 \end{bmatrix} = 3.558$$

This particular setting corresponds to the fact that from both normative theory of the organizations and IOR perspective, the effectiveness and efficiency of collaboration amongst functional stakeholders are at optimal levels. Further, the information dissemination amongst strategic, tactical, and operational collaboration attributes also assumes optimal states. The major dimensions pertaining to collaboration viz. relational, jointness /coordination of activities, performance measures, action initiation, communication, etc. remain at the most effective state.

### *6.1.2 Sensitivity analysis*

The sensitivity analysis of four VPMs conceptualized in this research with respect to the five different scenarios i.e., case I – case IV and practical case (of company-A) considered in Section 5 has been carried out and is depicted graphically in Figure 4(a).

<<Insert Figure 4 here>>

Figure 4(a) thus provides the bounds of IFC, SLCI, TLCI, and OLCI for the type of industry considered in this research.

### *6.1.3 Discussions*

We obtain values of IFC, SLCI, TLCI, and OLCI for different scenarios so that the individuals belonging to relevant focus groups considered in this study can utilize these indices to make a

realistic assessment of the level of collaboration within their respective organizations at enterprise, strategic, tactical, and operational levels.

Consider, for example, the (*VPM – B*) matrix. For the practical case under consideration, we have obtained the rationalized value of the matrix as 2.946. However, employing scenario analysis, we obtained the highest value expressed in the rationalized scale as 3.558 (*case-IV*). This obtained value of 3.558 can be used as a benchmark index for enterprise-wide collaboration. The gap between the minimum and maximum permanent value of (the *VPM – B*) matrix signifies difference between the focal organization (company-A) and best-in-class organization in terms of collaboration initiatives. However, the focal organization scores well in terms of the permanent values for matrices *(VPM – $B_{str}$)* and (*VPM – $B_{tac}$*), when benchmarked with respect to the case I – case IV. This signifies that the case organization under consideration in this study seems to be adopting sound collaborative practices at the strategic and tactical levels. These strategic and tactical level collaborative practices can assume several dimensions. For example, at the tactical level, the collaboration intensity can pertain to state-of-art mechanisms such as collaborative planning, forecasting, replenishment, the adaptation of enterprise resource planning, electronic data interchange, etc. to name a few (Ivanov, 2010 and Wu et al. 2010).

### *6.2 Cross-firm analysis and observations*

We plot the rationalized values of each of the four indices corresponding to the five companies considered in the research using a uniform classification scale to relatively position each of these five companies. Figure 4(b) demonstrates the classification scale contrasting the relative position of each of these five companies.

Referring to Figure 4(b), we have positioned the four indices corresponding to the five companies in three clearly demarcated buckets viz. low-level, medium-level, and high-level. These three levels have been identified in consultation with the members of the senior management belonging to five focus groups. We present the following discussions and observations contextualized with respect to the key differentiating dimensions listed in Table 3 and from the perspectives of IORs and the normative theory of organizations. Further, we also adhere to the framework as illustrated in Figure 5.

<<Insert Figure 5 here>>

Intra-firm enterprise level collaboration (IFC): IFC is the least and highest for the company-C and company-D respectively in that the permanent (as well as log of it) is least and highest for company-C and company-D respectively. The reason for this is that the company-C's B matrix was reported by the respective focus group to have much lower values of diagonal and non-diagonal elements as opposed to the reported values for the company-D' B matrix by the corresponding focus group. From the perspective of the firm's structure, company-C and company-D have Indian and foreign ownership respectively. We further explored with senior management of company–C to ascertain whether ownership structure plays a role in lower collaboration scores. An important aspect to be considered here is that Indian corporate culture (in-fact Asian cultures) is typically known for having relatively introverted communication styles as opposed to that of Western organizations. This specific facet can also be observed in lower IFC scores of company-A and company-B {having Asian partners in joint venture (JV)} compared to those of company-D and E. We further ascertained that in company-D (as opposed to company-C), employees receive more frequent communications from the top management of the firm in the form of periodic newsletters, strategic documents, and town-hall meetings. Further, in the case of company D (as opposed to company-C), top management is much more invested in tactical and operational matters. Another important dimension that distinguishes company-D (from company-C) is that this particular company even though having a higher product variety level has a relatively flatter organizational structure. Based on the above discussions, we posit the following case-based assertions.

***Assertion 1: Extrovert cultural realms are more likely to augment enterprise-wide collaboration as opposed to cultures that are characterized by introvertism.***

***Assertion 2: Frequent communication from the top management is more likely to enhance enterprise-wide collaboration.***

***Assertion 3: Flatter organizational structures are more conducive to attaining a higher degree of collaboration for an organization.***

Assertion 1 and assertion 2 are supported to some extent by the study of Choo et al. (2013) wherein frequency and openness in communication have been theorized as crucial levers for the effectiveness of intra-firm collaboration. The study of Voet et al., (2014) pointed to the relationship between greater bureaucracy and lower effectiveness of collaboration within a firm – a finding somewhat supporting assertion 3. Further, the aforementioned assertions find support in

the normative theory of organization (Ricciardi, 2012) in that it has been argued that organizational cultures that are relatively open in nature (as opposed to closer organizational cultures) tend to have much better mechanisms to take collective ownership for tasks and activities (particularly critical ones). This in turn automatically, enables a higher degree of trust amongst different stakeholders leading to a higher level of collaboration. Further, the normative theory of organizations also entails that as opposed to a prescriptive setting (wherein the top management may dictate), in relatively flatter organizations with healthy communication culture, the collaboration amongst internal stakeholders results in sustained benefits (Beer, 2021).

Strategic level collaboration (SLCI): Strategic level collaboration intended to create maximum value for the concerned stakeholders and establish strategic synergy within a firm is often relatively difficult to execute (as opposed to operational and tactical-level collaboration) owing to higher fuzziness related with strategic dimensions. Referring to Figure 4(b), it can be observed that company-A, B, D, and E are proximate to each other in terms of the permanent of $B_{str}$ value. However, company-D clearly has a much lower $B_{str}$ score compared to those of the four companies. Further, from the structure of the firm perspective, company-C being an indigenous firm seems to score a below-par collaboration score as opposed to the firms that are either foreign-owned or have a JV. Further, the structure of these firms also influences the composition of top management in that company-C is associated with purely Indian top management, while company A and B is characterized by a mix of both Indian and foreign professionals. We further ascertained from the pertinent focus groups that, while companies A, B, D, and E export their products, company-C essentially caters to only Indian and South Asian markets. This supports the fact that element values in the $B_{str}$ matrix for the strategic attributes "industry landscape" and "industry reputation" is much lower for company-C as opposed to the rest of the four companies. Further given the fact that company-C has scored inferior to others on attributes "industry landscape" and "industry reputation" implies that company-C's ability to deal with the shocks related to attribute "state of the economy" would be rather limited (as opposed to the other four companies). This particular facet in conjunction with a lower SLCI score for company-C points to the proposition that a broader customer base with varying product-related functional and regulatory requirements enable OEMs to collaborate better internally at a strategic level. This proposition is further supported somewhat in that company-C serves only three primary sectors

with lower product variety levels as opposed to the other four companies serving four sectors with medium to higher product variety levels. In view of these discussions, we posit the following two assertions.

***Assertion 4*: Diverse and heterogenous products offered by firms necessitate a higher level of collaboration at a strategic level.**

***Assertion 5*: Heterogeneity in top management aids in higher collaboration scores at a strategic level.**

Assertion 5 can be supported by the study of Liu et al., (2013) and Heyden et al. (2013) underscoring the positive relationship between top management diversity and organizational ambidexterity. In particular, assertion 4 has found support in the study of Marion et al., (2021) wherein it is argued that a wide variety of products and processes within an organization leads to knowledge and information inefficiency. Further, from an IOR perspective, in order to mitigate such knowledge and information inefficiencies, collaboration amongst stakeholders involved in such a variety of products and processes would be the critical instrument (Castaner et al., 2021).

Intra-firm tactical and operational level collaboration: We now discuss tactical and operational level collaboration together as these two are more closely related than perhaps strategic and operational or strategic and tactical. TLCI and OLCI scores for the five companies aid us in concluding that a higher level of technologies at each of these companies does not correlate with higher tactical and operational level scores. In fact, company-D despite having a broad range of technologies at its discretion scores lower at tactical level collaboration. Further, company-C despite having relatively low-end design and manufacturing technologies scores higher on operational level collaboration. A caveat here pertains to the fact that technological capabilities under consideration is related primarily to assembly, design, and manufacturing technologies. The five focus groups did not reveal the tools specifically aimed at promoting intra-functional collaboration such as PLM (product lifecycle management). In view of such observations, we populate the following assertions.

***Assertion 6*: Technologies pertaining to design, manufacture, and assembly designated for the realization of the physical product do not influence collaboration scores at tactical and operational levels.**

The above assertion finds support in the IOR theory, particularly from the perspective of jointness of action which suggests that collaboration with the internal stakeholders works best in the context of activities or tasks that may have significant ambiguity due to organizational dynamics and externalities. The jointness of action aspect further suggests that in the context of specific tangibles such as manufacturing technologies, processes, etc., collaboration for the sake of it does not enhance the effectiveness of joint or collective action (Lakshminarasimha et al., 2017 and Castanet et al., 2021).

Product variety level does not seem to influence the collaboration scores at a tactical and operational level (with company-D being an aberration). However, there seems to be a possible relationship between the number of sectors a firm serves and collaboration in that the higher the number of sectors served, the higher the collaboration scores at tactical and operational levels. The level of product variety in conjunction with diversified products points to the fact that a higher level of variety within a product type does not necessitate a higher level of collaboration at a tactical and operational level. However, when the company has a diverse product portfolio, a higher level of collaboration is warranted amongst pertinent functional agencies due to desired interoperability amongst functional agencies leading to the following assertion.

***Assertion 7: A higher level of product variety associated with a particular product type does not warrant a higher level of collaboration.***

A supporting argument here pertains to the dynamics of after-sales service in the CME industry. Serving a higher number of market segments automatically implies a higher number of distinct parts that need to be replenished continuously at the customer's work site. This challenge cannot be met unless there is superior coordination amongst function agencies at tactical and operational levels. This is particularly imperative from the perspective of implementation of Industry 4.0 technologies in modern value-chains (Gebhardt et al., 2021). Company-D and E (associated with higher scores of OLCI) were also found to have a fairly lower level of task ambiguity in terms of clearer organizational structures, standardized project handling procedures i.e., both for handling newer products or upgradation of older products, better knowledge perseveration mechanisms, and a higher degree of process modularity (Castaner et al., 2020).

## 7. Research significance, concluding remarks, and future research direction

The collaboration indices evolved in this research i.e., *IFC, SLCI, TLCI,* and *OLCI* are significant from the viewpoint of evaluating the degree of collaborative relationships in that these four indices capture the extent of influences and interdependencies by:

a) signifying relative positioning or compatibilities of the concerned functional players within an enterprise with respect to the concerned roles within the organization. For instance, obtaining the collaboration index for a particular enterprise at the operational level would entail understanding the interplays of dimensions related to operational excellence, financial health, and benchmarked performance with respect to its peers.

b) gauging collaboration gaps between the focal enterprise and best-in-class organizations at strategic, tactical, and operational planes. The ability of the developed indices to capture gaps, for instance, between the organization's technological competencies and strategic orientation can serve as a collaboration augmentation roadmap for the functional stakeholders within the given organization. This would also hold true in the context of the external stakeholders including customers and suppliers (Liu et al., 2013).

c) qualifying the influences and interdependencies amongst the collaboration attributes by the respective focus groups in the study from the standpoint of both the interorganizational relationships and normative theory of organizations.

In this research, we have quantified and modeled the collaboration attributes for the OEMs operating in the construction equipment and mining industry in India considering factors both internal and external to the enterprise at pertinent levels i.e., at enterprise, strategic, operational, and tactical. First, identification of collaboration attributes at respective organizational levels using extant literature is carried out. Thereafter, employing inputs from the respective focus groups, we estimate the extent of interdependencies and influences within/amongst collaboration attributes using diagraphs grounded in graph theory. Once diagraphs are detailed, by deploying variable permanent matrices, collaboration indices for the focal organization and the remaining four organizations are ascertained. Using scenario and sensitivity analysis, we also identify collaboration gaps considering a focal organization and the best-in-class organization. Further, we also assess the five companies under examination in the study in terms of key differentiating parameters. Based on the collaboration scores, a number of contextual assertions with accompanying discussions are populated. These assertions have significant implications related

to the role of culture, collaborative mechanisms within a firm, organizational ambidexterity, etc. To the best of the authors' knowledge, this study is one of the first to identify, discuss, and formalize the dimensions of intra-firm collaboration from the perspectives of interorganizational relationships and the normative theory of organizations.

The study carried out in our paper has several implications for both theory and practice. From the theoretical perspective, the integration of the theory of IORs and the normative theory of organization enables us to look at the intra-firm collaboration problem (at respective levels) from a multi-dimensional standpoint involving activities, performance measures, action initiation, communication, shades of top management, level of activities, etc. Further, inputs from the focus groups also provide certain insights about the conditions at which collaboration attributes assume lower and higher values. From a practitioner's perspective, the development of collaboration indices enables the top management to quickly deploy our devised method to arrive at some sort of non-financial yet effective measure to assess the efficiency and effectiveness of collaboration in an intra-firm setting.

Like any research, our research is also not devoid of its limitations that can be addressed through future research. A key limitation of our work pertains to significant heterogeneity across focus groups in that some focus groups belonged to completely indigenous firms, while some other focus groups belonged to foreign-owned firms. These obvious divergences in organizational mindset, processes, and value systems have definite implications for the institutionalization of collaborative practices. The seven assertions conceptualized are rather contextual in nature and might require more statistical testing before these can be generalized and extended to other product-based industries. In particular, it would be interesting to deploy our evolved modeling and exploratory framework to a wider setting of supply chain collaboration. Further, another variable of interest would be to examine the difference between the qualitative assessment of different focus groups and individual respondents in relation to intra-firm collaboration.

## References

Afum, E., Agyabeng-Mensah, Y., Sun, Z., Frimpong, B., Kusi, L., Y., Acquah, I., S., K., 2020, "Exploring the link between green manufacturing, operational competitiveness, firm reputation and sustainable performance dimensions: a mediated approach", *Journal of Manufacturing Technology Management*, 31(7), 1417-1438.

Alexiev, A., S., Volberda, H., W., and Bosch, F., A., J., V., d., 2016, "Interorganizational collaboration and firm innovativeness: Unpacking the role of the organizational environment", *Journal of Business Research*, 69(2), 974-984.

Almeida, R., Teixeira, J., M., da Silva, M., M., and Faroleira, P., 2019, "A conceptual model for enterprise risk management", *Journal of Enterprise Information Management*, 32(5), 843-868.

Anand, G., and Bihinipati, B., K., 2012, "Measuring horizontal collaboration intensity in supply chain: a graph-theoretic approach", *Production Planning and Control*, 23(10-11), 801-816.

Aguiar, L., and Gagnepain, P., 2017, "European cooperative R&D and firm performance: Evidence based on funding differences in key actions", *International Journal of Industrial Organization*, 53(2017), 1-31.

Badillo, E. R., and Moreno, R., 2016, "Are Collaborative Agreements in Innovation Activities Persistent at the Firm Level? Empirical Evidence for the Spanish Case", *Review of Industrial Organization*, 49(1), 71-101.

Baykasoglu, A., 2014, "A review and analysis of "graph theoretical-matrix permanent" approach to decision making with example applications", *Artificial Intelligence Review*, 42(2014), 573-605.

Belekoukias, I., Garza-Reyes, J., A., and Kumar, V., 2014, "The impact of lean methods and tools on the operational performance of manufacturing organisations", *International Journal of Production Research, 52*(18), 5346-5366.

Bello, D., and Leah, B., 2012, "Collaboration analysis: Joint resolution of problems in global supply networks", *Information Knowledge Systems Management*, 11(1-2), 77-79.

Beer, M., 2021, "Reflections: Towards a Normative and Actionable Theory of Planned Organizational Change and Development", *Journal of Change Management*, 21(1), 14-29.

Bettley, A., Mayle, D., and Tantoush, T., 2005, "Operations Management: a strategic approach", London: Sage.

Bititci, U., S., Garengo, P., Dorfler, V., and Nudurupati, S., 2012, "Performance measurement: challenges for tomorrow, International Journal of Management Review, 14(3), 305-327.

Bourne, M., Mills, J., Wilcox, M., Neely, A., and Platts, K., 2000, "Designing, implementing, and updating performance measurement systems, *International Journal of Operations and Production Management*, 20(7), 754-771.

Bourne, M., Neely, A., Platts, K., Mills, J., 2002, "The success and failure of performance measurement initiatives: Perceptions of participating managers, *International Journal of Operations and Production Management*, 22(11), 1288-1310.

Broekel, T., 2012, "Collaboration Intensity and Regional Innovation Efficiency in Germany—A Conditional Efficiency Approach", *Industry and Innovation*, 19(2), 155-179.

Busi, M., Bititci, U., S., 2006, "Collaborative performance management: present gaps and future research, *International Journal of Production and Performance Management*, 55(1), 46-60.

Cai, Z., Huang, Q., Liu, H., and Liang, L., 2016, "The moderating role of information technology capability in the relationship between supply chain collaboration and organizational responsiveness: Evidence from China", *International Journal of Operations and Production Management*, 36(10), 1247-1271.

Cao, M., and Zhang, Q., 2011, "Supply chain collaboration: impact on collaboration advantage and firm performance", *Journal of Operations Management*, 29(3), 163-180.

Carneiro, L., M., Soares, A., L., Patricio, R., Lopes, Azevedo, A., L., de Sousa, J., P., 2013, "Case studies on collaboration, technology and performance factors in business networks", *International Journal of Computer Integrated Manufacturing,* 26(1-2), 101-116.

Castaner, X., and Oliveira, N., 2020, "Collaboration, Coordination, and Cooperation Among Organizations: Establishing the Distinctive Meanings of These Terms Through a Systematic Literature Review", *Journal of Management*, 46(6), 965-1001.

Chatterjee, S., Rana, N., Tamilmani, K., and Sharma, A., 2021, "The effect of AI-based CRM on organization performance and competitive advantage: An empirical analysis in the B2B context", *Industrial Marketing Management*, 97(2021), 205-219.

Chen, Y-H., Lin, T-P., and Yen, D., C., 2014, "How to facilitate inter-organizational knowledge sharing: The impact of trust", *Information & Management*, 51(5), 568-578.

Chen, C., Gu, T., Cai, Y., Yang, Y., 2019, "Impact of supply chain information sharing on performance of fashion enterprises", *Journal of Enterprise Information Management*, 32(6), 913-935.

Chofreh, A., G., Goni, F., A., and Klemes, J., J., 2018, "Sustainable enterprise resource planning systems implementation: A framework development", *Journal of Cleaner Production*, 198(2018), 1345-1354.

Cui, L, Gao, M., Dai, J., and Mou, J., 2022, "Improving supply chain collaboration through operational excellence approaches: an IoT perspective", *Industrial Management and Data Systems*, 122(3), 565-591.

Choo, C., W., 2013, "Information culture and organizational effectiveness*", International Journal of Information Management*, 33(5), 775-779.

Czarnitzki, D., Hussinger, K., and Scheider, C., 2015, "R&D Collaboration with Uncertain Intellectual Property Rights", *Review of Industrial Organization*, 46(2), 183-204.

Das, M., Cheng, J., C., P., and Law, K., H., 2015, ""An ontology-based web service framework for construction supply chain collaboration and management", *Engineering, Construction and Architectural Management*, 22(5), 551-572.

Despoudi, S., Papaionnou, G., Saridakis, G., and Dani, S., 2018, "Does collaboration pay in agricultural supply chain? An empirical approach", *International Journal of Production Research*, 56(13), 4396-4417.

Dingler, A., and Enkel, E., 2016, "Socialization and innovation: Insights from collaboration across industry boundaries", *Technological Forecasting and Social Change*, 109(2016), 50-60.

Eksoz, C., Mansouri, S., A., and Bourlakis, M., 2014, "Collaborative forecasting in the food supply chain: A conceptual framework", *International Journal of Production Economics*, 158(2014), 120-315.

Franz, B., Leicht, R., Molenaar, K., and Messner, J., 2017, "Impact of Team Integration and Group Cohesion on Project Delivery Performance", *Journal of Construction Engineering and Management*, 143(1), 1-12.

Franz, B., 2018, "Total Construction Management: Lean Quality in Construction Project Delivery Engineering, Construction and Architectural Management", *Engineering, Construction and Architectural Management*, 25(2), 295-296.

Flores-Fillol, R., Iranzo, S., and Mane, F., 2017, "Teamwork and delegation of decisions within the firm", *International Journal of Industrial Organization*, 52(2017), 1-29.

Gazley, B., 2017, "The current state of interorganizational collaboration: Lessons for human service research and management", *Human Service Organizations: Management, Leadership & Governance*, 41(2017), 1-5.

Gebhardt, M., Kopyto, M., Birkel, H., 2021, "Industry 4.0 technologies as enablers of collaboration in circular supply chains: a systematics literature review*", International Journal of Production Research,* DOI: ttps://doi.org/10.1080/00207543.2021.1999521.

Golgeci, I., Gilgor, D., M., Tatuglu, E., and Arda, O., A., 2019, "A relational view of environmental performance: What role do environmental collaboration and cross-functional alignment play?", *Journal of Business Research*, 96(2019), 35-46.

Goswami, M., and Tiwari, M., K., 2014, "A predictive risk evaluation framework for modular product concept selection in new product design environment", *Journal of Engineering Design*, 25(1-3), 150-171.

Grace, P., and Camarinha-Matos, L., M., 2017, "Performance indicators for collaborative business ecosystems — Literature review and trends", *Technological Forecasting and Social Change*, 116(2017), 237-255.

Garcia-Sanchez, I., M., Caudrado-Ballesteros, B., Frias-Aceituno, J., V., 2016, "Impact of the Institutional Macro Context on the Voluntary Disclosure of CSR Information", *Long Range Planning*, 49(1), 15-35.

Grover, S., Agrawal, V.P., and Khan, I.A., 2004, "A digraph approach to TQM evaluation of an industry", *International Journal of Production Research*, 42 (19), 4031–4053.

Grover, S., Agrawal, V.P., and Khan, I.A., 2005, "Human resource performance index in TQM environment", *International Journal of Management Practice*, 1 (2), 131–151.

Grover, S., Agrawal, V.P., and Khan, I.A., 2006, "Role of human factors in TQM: a graph theoretic approach", *Benchmarking: An International Journal*, 13 (4), 447–468

Herazo, B., and Lizarralde, G., 2015, "The influence of green building certifications in collaboration and innovation processes", *Construction Management and Economics*, 33(4), 279-298.

Heyden, M., L., M., Doorn, S., v., Reimer, M., 2013, "Perceived Environmental Dynamism, Relative Competitive Performance, and Top Management Team Heterogeneity: Examining Correlates of Upper Echelons' Advice-Seeking", *Organization Studies*, 34(9), 1327-1356.

Hofmann, E., and Locker, A., 2009, "Value-based performance measurement in supply chains: a case study from the packaging industry", *Production Planning and Control*, 20(1), 71-87.

Horta, I., M., and Camanho, A., S., 2014, "Competitive positioning and performance assessment in the construction industry", *Expert Systems with Applications*, 41(4), 974-983.

IP, W., H., Huang, M., Yung, K., L., and Wang, D., 2003, "Genetic algorithm solution for a risk-based partner selection problem in a virtual enterprise", *Computers and Operations Research*, 30(2), 213-231.

Ivanov, D., 2010, "An adaptive framework for aligning (re)planning decisions on supply chain strategy, design, tactics, and operations", *International Journal of Production Research*, 48(13), 3999-4017.

Jääskeläinen, A., and Thitz, O., 2018, "Prerequisites for performance measurement supporting purchaser-supplier collaboration", *Benchmarking: An International Journal*, 25(1), 120-137.

Jaeger, A., Matyas, K., Sihn, W., 2014, "Development of an Assessment Framework for Operations Excellence (OE), based on the Paradigm Change in Operational Excellence (OE)", *Procedia CIRP*, 17(2014), 487-492.

Janssen, M., J., and Abbasiharofteh, M., 2022, "Boundary spanning R&D collaboration: Key enabling technologies and missions as alleviators of proximity effects?", *Technological Forecasting and Social Change*, 180(2022), 121689.

Johnson, J., L., Martin, K., D., Saini, A., 2012, "The role of a firm's strategic orientation dimensions in determining market orientation", *Industrial Marketing Management*, 41(4), 715-724.

Johnstone, L., 2019, "Theorising and conceptualising the sustainability control system for effective sustainability management", *Journal of Management Control*, 30(1), 25-64.

Jraisat, L., Upadhyay, A., Ghalia, T., Jresseit, M., Kumar, V., and Sarpong, D., 2021, "Triads in sustainable supply-chain perspective: why is a collaboration mechanism needed?", *International Journal of Production Research*, https://doi.org/10.1080/00207543.2021.1936263

Kadic-Maglajlic, S., Boso, N., and Micevski, M., 2018, "How internal marketing drive customer satisfaction in matured and maturing European markets?", *Journal of Business Research*, 86(2018), 291-299.

Kim Y., H., and Wemmerlov, U., 2015, "Does a Supplier's Operational Competence Translate into Financial Performance? An Empirical Analysis of Supplier–Customer Relationships", *Decision Sciences*, 46(1), 101-134.

Kolfschoten, G., L., Vreede, G-J. de., Briggs, R., O., and Sol, H. G., 2010, "Collaboration 'Engineerability'", *Group Decision and Negotiation*, 19(3), 301-321.

Kong, T., Feng, T., and Ye, C., 2016, "Advanced Manufacturing Technologies and Green Innovation: The Role of Internal Environmental Collaboration", *Sustainability*, 8(10), 1056-1071.

Kumar, G., and Banerjee, R., N., 2014, "Supply Chain Collaboration Index: An Instrument to Measure the Depth of Collaboration", *Benchmarking: An International Journal*, 21(2), 184-204.

Kulmala, H., L., and Lonnqvist, A., 2006, "Performance measurement of networks: towards a nonfinancial approach, *International Journal of Network Virtual Organization*, 3(3), 299-316.

Lakshminarasimha, A., 2017, "Collaboration, Coordination, and Cooperation Among Organizations: Establishing the Distinctive Meanings of These Terms Through a Systematic Literature Review", *Journal of Supply Chain Management*, 14(2017), 26-48.

Li., Y., Tarafdar, M., and Rao, S., S., 2012, "Collaborative knowledge management practices: Theoretical development and empirical analysis", *International Journal of Operations and Production Management*, 32(4), 398-422.

Li, X., Zheng, Y., Wang, C. L., 2016, "Inter-firm collaboration in new product development in Chinese pharmaceutical companies", *Asia Pacific Journal of Management*, 33(1), 165-193.

Li, Y., Wang, Y., Wang, L., Xie, J., 2022, "Investigating the effects of stakeholder collaboration strategies on risk prevention performance in a digital innovation ecosystem", *Industrial Management and Data Systems*, DOI: 10.1108/IMDS-12-2021-0805.

Lieder, M., and Rashid, A., 2016, "Towards circular economy implementation: a comprehensive review in context of manufacturing industry", *Journal of Cleaner Production*, 115(1), 36-51.

Liu, Y., and Liang, L., 2015, "Evaluating and developing resource-based operations strategy for competitive advantage: an exploratory study of Finnish high-tech manufacturing industries", *International Journal of Production Research*, 53(4), 1019-1037.

Liu, W., Liang, Y., Wei, S., and Peng, W., 2021, "The organizational collaboration framework of smart logistics ecological chain: a multi-case study in China", *Industrial Management and Data Systems*, 121(9), 2026-2047.

Liu, F-H., Tsou, H-T., and Chen, L-J., 2013, "The impact of OEM supplier initiatives on buyer competence development: The moderating roles of collaborative relationship and competitive environment", *Asia Pacific Journal of Management*, 30(4), 1285-1303.

Lovstal, E, and Jontoft, A-M., 2017, "Tensions at the intersection of management control and innovation: a literature review", *Journal of Management Control*, 28(2017), 41-79.

Magnani, G., Zucchella, A., and Floriani, D., E., 2018, "The logic behind foreign market selection: Objective distance dimensions vs. strategic objectives and psychic distance", *International Business Review*, 27(1), 1-20.

Mehdikhani, R., and Valmohammadi, C., 2019, "Strategic collaboration and sustainable supply chain management: The mediating role of internal and external knowledge sharing", *Journal of Enterprise Information Management*, DOI 10.1108/JEIM-07-2018-01661741.

Montoya-Torres, J. R., and D. A. Ortiz-Vargas. 2014. "Collaboration and Information Sharing in Dyadic Supply Chains: A Literature Review Over the Period 2000–2012", *Estudios Gerenciales*, 30 (133): 343–354. doi:10.1016/j.estger.2014.05.006.

Nix, N., W., Zacharia, Z., G., 2014, "The impact of collaborative engagement on knowledge and performance gains in episodic collaborations", *The International Journal of Logistics Management*, 25(2), 245-269.

Nebukenya, J., Bammel, P. V., Proper, H., A., and Vreede, G-J, D., 2011, "An Evaluation Instrument for Collaborative Processes: Application to Organizational Policy-Making", *Group Decision and Negotiation*, 20(4), 465-488.

Oberg, C., "What creates a collaboration-level identity?" 2016, *Journal of Business Research*, 69(9), 3220-3230.

Ok, S., C., and Sinha, S., K., 2006, "Construction equipment productivity estimation using artificial neural network model", *Construction Management and Economics*, 24(10), 1029-1044.

Palmieri, A., Pomponi, F., and Russo, A., 2020, "A triple-win scenario for horizontal collaboration in logistics: Determining enabling and key success factors", *Business Strategy and the Environment*, 28(6), 1166-1178.

Patel, P., C., Parida, V., Jayaram, J., and Oghazi, P., 2018, "Task equivocality and process modularity in R&D offshore collaboration projects", *Journal of Business Research*, 93(2018), 12-22.

Papakiriakopoulos, D., and Pramatari, K., 2010, "Collaborative performance measurement in supply chain", *Industrial Management and Data Systems*, 110(9), 1297-1318.

Pennec, M., L., and Raufflet, E., 2018, "Value Creation in Inter-Organizational Collaboration: An Empirical Study", *Journal of Business Ethics*, 148(4), 817-834.

Pershina, R., Soppe, B., and Thune, T., M., "Bridging analog and digital expertise: Cross-domain collaboration and boundary-spanning tools in the creation of digital innovation", *Research Policy*, 48(9), 103819.

Raj, A., 2017, "Passenger vehicle sales up 15% to 277,000 units in April: Siam data", Livemint.com Available at **http://www.livemint.com/Industry/3dN81K6JGuVANkOrPRW3SK/Passenger-vehicle-sales-up-15-to-277000-units-in-April-Si.html**

Ramanathan, U., and Gunasekaran, A., 2014, "Supply chain collaboration: Impact of success in long-term partnerships, *International Journal of Production Economics*, 147(B-2014), 252-259.

Ricciarrdi, F., 2012, "Design and Normative Claims in Organization Studies: A Methodological Proposal", *Designing Organizational Systems*, Springer.

Saaty, T., L., 1980, "The analytic hierarchy process: planning, priority setting, resource allocation, 1st ed, Newyork: Mcgraw-Hill.

Sacks, R., Seppanen, O., Priven, V., and Savosnick, J., 2017, "Construction flow index: a metric of production flow quality in construction", *Construction Management and Economics*, 35(1-2), 45-63.

Salam, M., A., 2017, "The mediating role of supply chain collaboration on the relationship between technology, trust and operational performance: An empirical investigation", *Benchmarking: An International Journal*, 24(2), 298-317.

Sandberg, E., 2007, "Logistics collaboration in supply chains: practice vs. theory", *The International Journal of Logistics Management*, 18(2), 274-293.

Snow, C. C., Fjeldstad, O. D., Langer, A., M., 2017, "Designing the digital organization", *Journal of Organization Design*, DOI: 10.1186/s41469-017-0017-y.

Sweeney, E., Grant, D. B., and Mangan, D. J., 2018, "Strategic adoption of logistics and supply chain management", *International Journal of Operations and Production Management*, 38(3), 852-873.

Teng, T., Tsinopoulos, C., Tse, Y., K., 2022, "IS capabilities, supply chain collaboration and quality performance in services: the moderating effect of environmental dynamism", *Industrial Management and Data Systems*, DOI: 10.1108/IMDS-08-2021-0496

Tsanos, C., S., Zografos, K., G., and Harrison, A., 2014, "Developing a conceptual model for examining the supply chain relationships between behavioural antecedents of collaboration, integration and performance", *The International Journal of Logistics Management*, 25(3), 418-462.

Tsai, J-S., and Chi, C., S., F., 2015, "Learning for Win-Win Collaboration", *Journal of Construction Engineering and Management*, 141(7), 301-323.

Tseng, C-Y., 2014, "Technological innovation capability, knowledge sourcing and collaborative innovation in Gulf Cooperation Council countries", *Innovation*, 16(2), 212-223.

Ukko, J., and Saunila, M., 2020, "Understanding the practice of performance measurement in industrial collaboration: From design to implementation", *Journal of Purchasing and Supply Management*, 26(1), 100529.

Valtakoski, A., and Jarvi, K., 2016, "Productization of knowledge intensive services Enabling knowledge sharing and cross-unit collaboration", *Journal of Service Management*, 27(3), 360-390.

Vieira, J., Yoshizaki, H., and Ho, L., 2009, "Collaboration intensity in the Brazilian supermarket retail chain", *Supply Chain Management: An International Journal*, 14(1), 11-21.

Voet, J. van der, 2015, "Change Leadership and Public Sector Organizational Change: Examining the Interactions of Transformational Leadership Style and Red Tape", *The American Review of Public Administration*, 46(6), 660-682.

Vazquez-Casielles, R., and Iglesias, V., 2013, "Collaborative manufacturer-distributor relationships: the role of governance, information sharing and creativity", *Journal of Business and Industrial Marketing*, 28(8), 620-637.

Wu, J., and Pangarkar, N., 2010, "The bidirectional relationship between competitive intensity and collaboration: Evidence from China", *Asia Pacific Journal of Management*, 27(3), 503-522.

Wen, Q., Qiang, M., and An, N., 2017, "Collaborating with Construction Management Consultants in Project Execution: Responsibility Delegation and Capability Integration", *Journal of Construction Engineering and Management*, 143(7), 212-229.

Yen, Y.-X., 2018, "Buyer–supplier collaboration in green practices: The driving effects from stakeholders", *Business Strategy and the Environment*, 27(8), 1666-1678.

Zhang, J., Gou, J., Jiang, J., Wu, X., Jiang, R., 2021, "Moderating effect of requirements uncertainty on task interdependence and NPD performance", *Industrial Management and Data Systems*, 121(2), 456-477.

Zhao, X., Hwang, B.-G., Low, S., P., 2016, "An enterprise risk management knowledge-based decision support system for construction firms", *Engineering, Construction and Architectural Management*, 23(3), 369-384.

## Appendix

**Table A (1):** Profile of the participants in respective focus groups

| Focus group | Organizational dimensions | Member 1 | Member 2 | Member 3 | Member 4 | Member 5 | Member 6 | Member 7 |
|---|---|---|---|---|---|---|---|---|
| FG1 | Current designation | Chief Engineer (Design and development) | Head (Supply chain management) | Divisional Manager (Production) | Divisional Manager (Projects) | Senior Engineer (Quality) | Engineer (Production) | |
| | Previous functional experience | Production, Projects, Finance, and Aftersales | Production, Design, Testing | Quality control, testing, corporate | Corporate, production, marketing | N/A | N/A | |
| | Total work experience in years | 36 | 31 | 25 | 26 | 8 | 5 | |
| FG2 | Current designation | Head (Production and Assembly) | General Manager (Products and projects | Specialist (Production planning) | Engineering specialist (Design) | Demand analyst | Senior Associate Engineer (Testing) | Associate Engineer |
| | Previous functional experience | Supply Chain, Supplier development, Product design, marketing | Finance, Projects, Logistics, Quality, Corporate | Product testing, providing ground, Quality | Supply chain, projects, marketing | Supply chain | N/A | Testing, Product design |
| | Total work experience in year | 32 | 28 | 18 | 15 | 8 | 12 | 16 |
| FG3 | Current designation | Vice-president (Corporate) | Senior vice-present (Operations) | Project manager (Facilities) | Engineering Manager (Design) | Divisional Manager (Aftersales) | Manager (Testing) | Manager (Supplier development) |
| | Previous functional experience | Design, Production, Supply chain | Aftersales, production, quality, marketing | Supply chain, quality, aftersales | Virtual manufacturing, Logistics | Design, product lifecycle management | Projects, facilities, production | Quality assurance, Supplier quality |
| | Total work experience | 29 | 31 | 25 | 28 | 22 | 17 | 18 |
| FG4 | Current designation | Chief operating officer (Operations) | Head (Marketing) | Divisional manager (Production) | Project Leader (Infrastructure) | Marketing analyst | Engineer (Assembly) | Engineer (testing) |
| | Previous functional experience | Supply chain, design, marketing | Production, Aftersales, Corporate | Quality, Testing, Design | Design, facility layout | Design, Technology development | N/A | Quality control |
| | Total work experience | 37 | 32 | 27 | | 11 | 12 | 8 |
| FG5 | Current designation | Head (Marketing) | Head (Production) | Corporate Planner | Senior Manager | Manager (Stores) | Engineer (Development) | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | (Budgets) | (Supply chain) | | | |
| | Previous functional experience | Design, Virtual technologies, supply chain | Planning, design, quality | Finance, Supply chain | Quality, projects, materials | Supply chain, logistics | Testing, product quality | |
| | Total work experience | 32 | 28 | 16 | 18 | 17 | 8 | |

**Table A (2)**: The guiding questions for qualitative responses

| Theoretical construct | Elements of the construct | Guiding questions | | | Anchoring to the literature |
|---|---|---|---|---|---|
| | | Strategic attributes | Tactical attributes | Operational attributes | |
| Interorganizational relationships (IOR) / Normative Theory of organization (NOR) | Relationship type | 1. How well within your organization, does information flow amongst concerned internal stakeholders? (IOR)<br>2. How impactful are the dynamism within your organization as far as information handling is concerned? (NOR)<br>3. How is information shared amongst concerned internal stakeholders within your organization? (IOR)<br>4. How well are collaboration and mechanisms in managing common goals and responsibilities in managing common goals and responsibilities understood in your organization? (IOR)<br>5. What is the impact of the aforementioned on strategic, tactical, and operational collaboration attributes? | | | Hofmann et al., (2009), Garcia-Sanchez, et al., (2016), Gazley et al., (2017) and Castaner et. (2020) |
| | Activity type and action initiation | 1. Does critical activities within your organization happen in a joint or coordinated manner? (IOR)<br>2. How effective are the coordination mechanisms within your organization? (NOR)<br>3. Are the critical activities within your organization driven by project ownership structure or joint ownership structure? (IOR)<br>4. Does an effective activity planning/coordination/communication infrastructure exist in your organization? (IOR)<br>5. How do such infrastructures assist in information sharing, and ensure high quality and timely information? (IOR)<br>6. How do the aforementioned impact strategic, tactical, and operational attributes? | | | Garcia-Sanchez, et al., (2016), Ukko et al., (2020), Castaner et al., (2020) |
| | Communication and Culture | 1. How much is the top management committed to disseminating constantly its philosophy to collaboration? (NOR)<br>2. How effectively the difficulties in developing a collaborative culture and appropriately dealing with respect to performance measures are mitigated in your organization? (IOR)<br>3. How much lack of leadership and resistance to change in adopting collaborative practices impede intra-firm collaboration? (NOR)<br>4. What kind of communication paradigms such as frequency, one-way/two-way, open communication ethos, etc. exist in your organization? (NOR)<br>5. How would you characterize the organizational structure such as flat/hierarchical etc. within your organization? (NOR) | | | Garcia-Sanchez, et al., (2016), Castaner et al., (2020) |

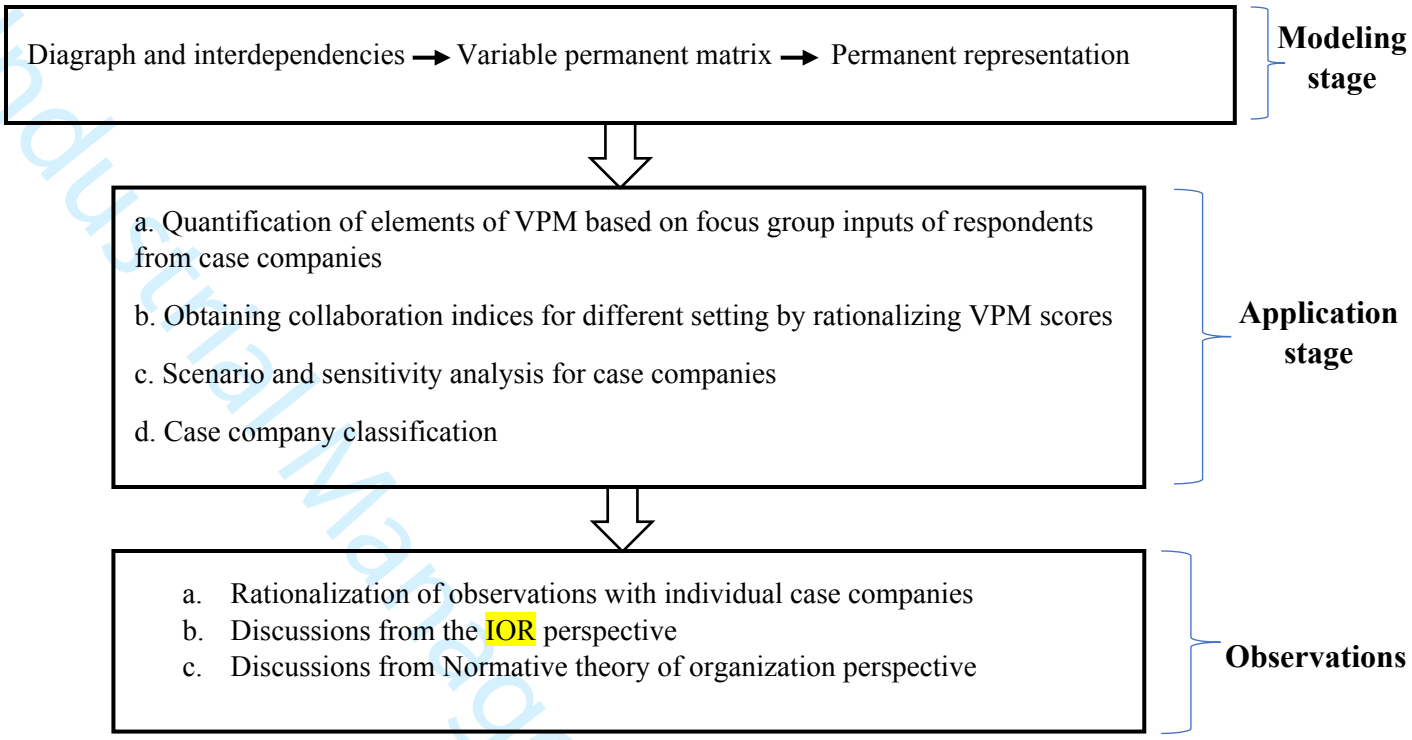


**Figure 1**: Step by step approach of current research study

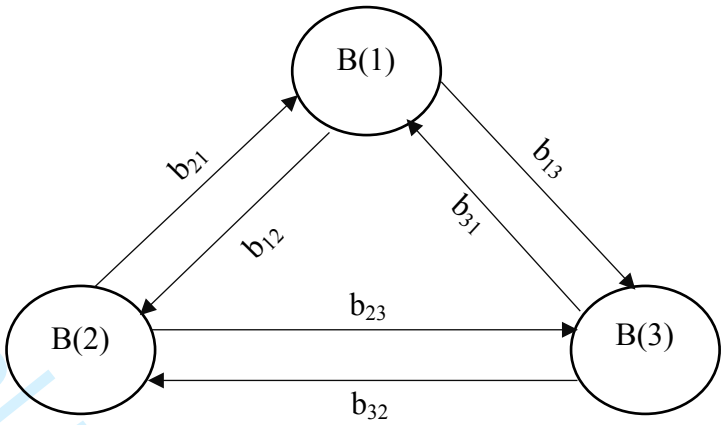


**Figure 2(a)**: Diagraph capturing the interdependencies among collaboration attributes $\{B(i)_s\}$

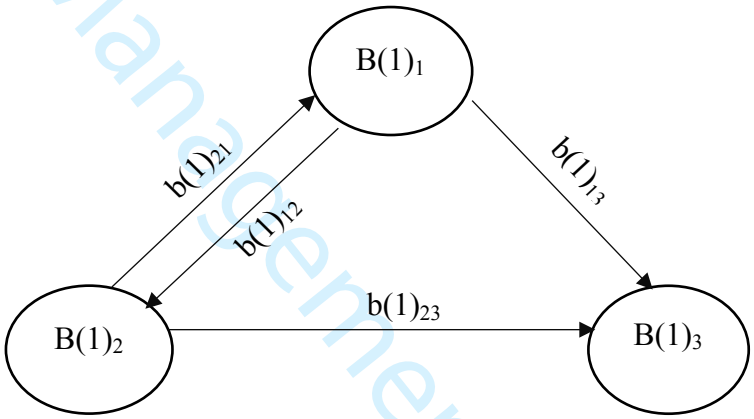


**Figure 2(b)**: Diagraph capturing the interdependencies among sub-attributes of the "strategic" collaboration attributes

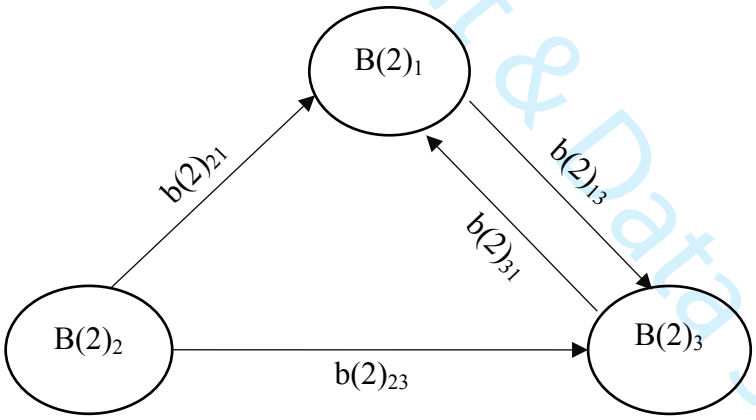


**Figure 2(c)**: Diagraph capturing the interdependencies among sub-attributes of the "tactical" collaboration attributes

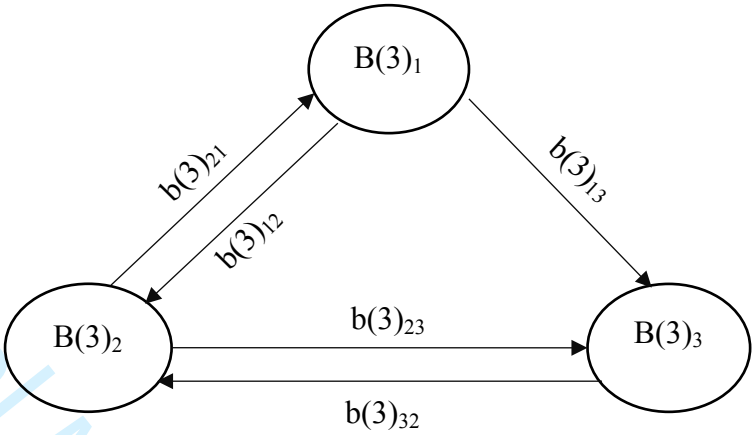


**Figure 2(d)**: Diagraph capturing the interdependencies amongst collaborative attributes and sub-attributes of "operational" level collaboration attributes

**Figure 2**: Diagraphs at firm and attribute level

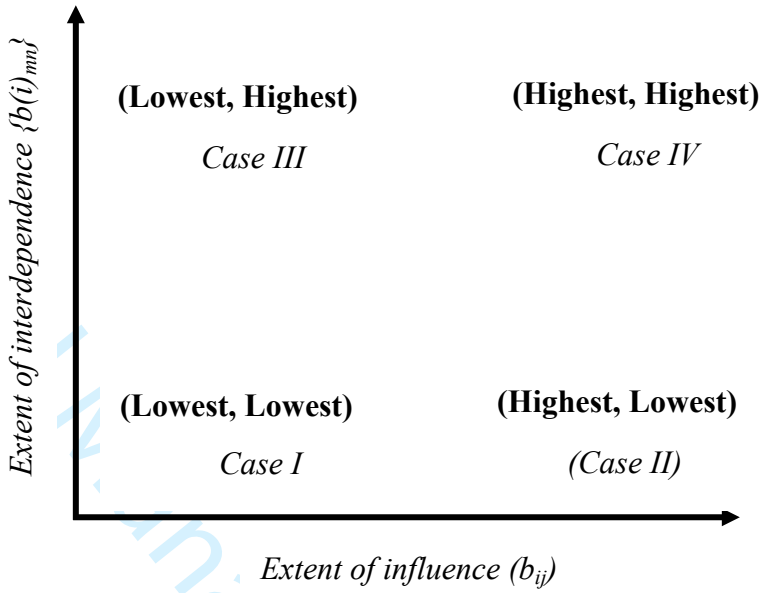


**Figure 3**: Bounds for extent of influence and interdependence

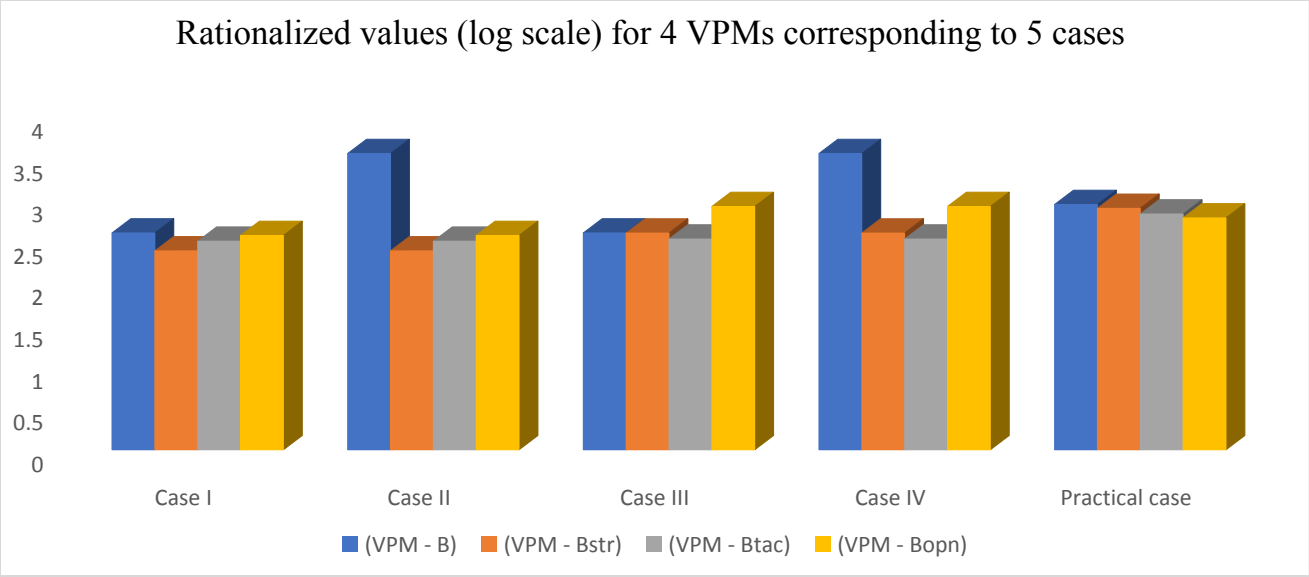


**Figure 4(a)**: Sensitivity of the four VPMs with respect to the five cases for firm A

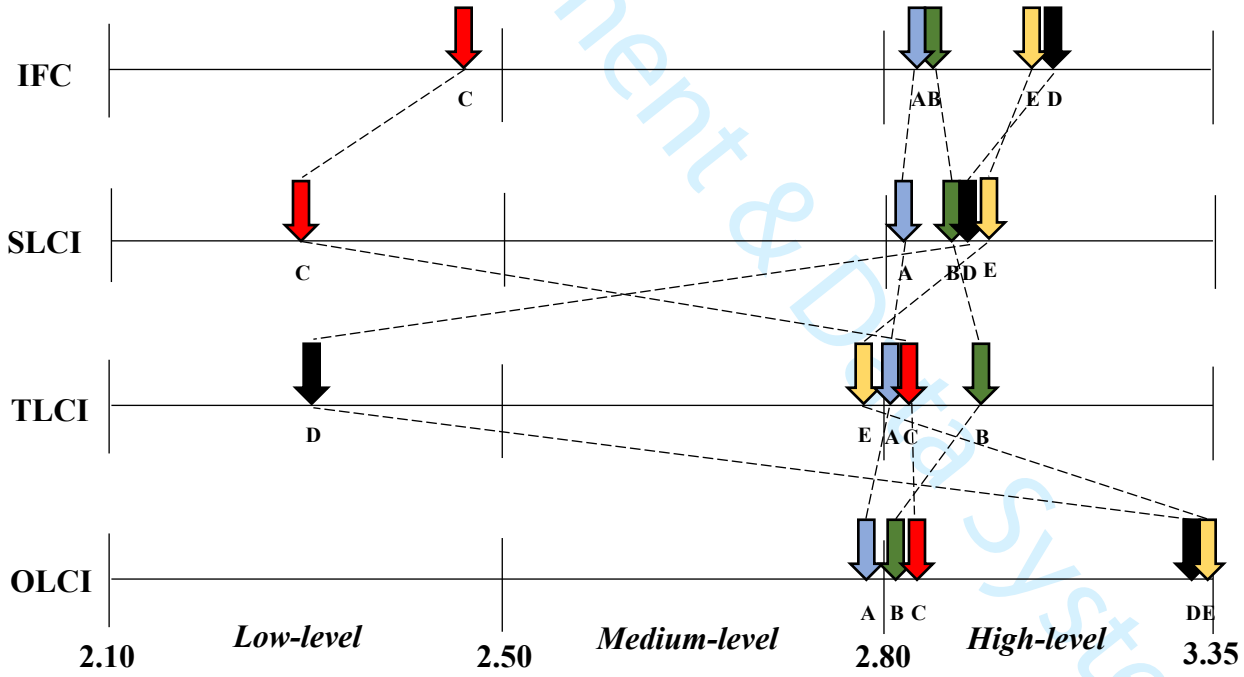


**Figure 4(b)**: Scale of classification and comparison of companies

**Figure 4**: Sensitivity analysis and classification


**Figure 5**: The discussion framework

**Table 1**: Comparison of our work with respect to extant literature

| Research articles | Research context | Methodology of study | | | Business dimensions considered | | | Scope of study | | Theoretical perspective |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Empirical based | Focus group based | Case-based | Strategic | Tactical | Operational | Developing economy | Developed economy | |
| Li et al., (2022) | Collaboration strategies in a dynamic environment considering digital settings | ✓ | | | ✓ | ✓ | | | | Technological, organizational, and environmental dimensions of collaboration |
| Teng et al., (2022) | Supply chain collaboration and quality performance in services | ✓ | | | ✓ | | | | ✓ | Resource-based and dynamic capabilities view considering environmental dynamism |
| Janssen et al., (2022) | R&D collaboration considering enabling technologies | ✓ | | | ✓ | | | | ✓ | Geographic and cognitive boundaries technology enabled collaborative setting |
| Zhang et al., (2021) | Collaboration considering task interdependence in product development | ✓ | | | | | ✓ | ✓ | | Social interdependence theory in interorganizational collaboration |
| Liu et al., (2021) | Organizational collaboration in smart logistics ecological chains | | | ✓ | | | | ✓ | | Digital technology, peer competition, and demand personalization |
| Jraisat et al., (2021) | Collaboration mechanism in sustainable supply chains | | | ✓ | | | ✓ | | ✓ | Transaction cost theory for contextual factors considering dyadic collaboration |
| Gebhardt et al., (2021) | Collaboration amongst supply chain stakeholder in circular economy | ✓ | | | | ✓ | ✓ | | ✓ | Directional collaboration (vertical, horizontal, lateral, and systemic) theory |
| Despoudi et al., (2018) | Collaboration practices in agricultural supply chains | ✓ | | | | ✓ | ✓ | | ✓ | Goals congruence in supply chains |
| Jääskeläinen et al., (2018) | Performance measurement in a purchaser-supplier collaboration | | | ✓ | | | ✓ | | ✓ | Theory of co-creation in context of non-financial performance measures |
| Pennec et al., (2018) | Empiricism for value -creation in inter-organization collaboration | | | ✓ | | ✓ | ✓ | ✓ | | Organizational partnerships to enable value creation |
| Salam et al., (2017) | Impact collaboration on relationship amongst technology and operations | ✓ | | | | | ✓ | | ✓ | Perspective of operational performance and technology adoption in supply chain collaboration |
| Alexiev et al., (2016) | Organizational environment conceptualization in collaboration | ✓ | | | ✓ | ✓ | ✓ | | ✓ | Environmental turbulence, market heterogeneity, and firm innovation |
| Cai et al., (2016) | Assessing the link between collaboration and organizational responsiveness | ✓ | | | | ✓ | ✓ | ✓ | | Information system and dynamic capability theory |
| Kong et al., (2016) | International environmental collaboration for technologies | | | ✓ | | ✓ | ✓ | ✓ | | Process, design, and planning perspective for green innovation |
| Liu et al., (2015) | Initiatives for implementation operational capabilities | ✓ | | ✓ | | ✓ | ✓ | | ✓ | Resource based and competitive advantage in operational and tactical dimensions |
| Current research | | | ✓ | | ✓ | ✓ | ✓ | ✓ | | |

✓ Implies that the particular dimension was considered in the study

**Table 2**: Collaboration attributes and interdependencies

**Table 2(a)**: Collaboration attributes and related references

| The collaboration attributes | **Key references** |
|---|---|
| **Strategic attribute (SA),** B(1) | |
| Industry landscape (IL) | Anand et al., (2012) |
| State of economy (SE) | Lieder et al., (2016) and Castaner et al., (2020) |
| Industry reputation (IR) | Anand et al., (2012) |
| **Tactical attribute (TA),** B(2) | |
| Customer satisfaction (CS) | Ukko et al., (2020) and Kadic-Maglajlic et al., (2018) |
| Regulatory compliance (RC) | Ukko et al. (2020) and Castaner et al., (2020) |
| Competitive advantage (CA) | Anand et al., (2012) |
| **Operational attribute (OA),** B(3) | |
| Operational Excellence (OE) | Salam et al., (2017) and Teng et al., (2022) |
| Financial health of firm (FH) | Anand et al., (2012) and Kim et al., (2015) |
| Benchmarked performance wrt. peers (BP) | Ukko et al., (2020) and Grace et al., (2017) |

**Table 2(b)**: Interdependencies

| **Sl no.** | **Interdependency** | **Attributes pairs** | **Interdependence characteristics** |
|---|---|---|---|
| 1 | $b_{12}$ | B(1)/B(2) | B(2) is controlled by B(1) |
| 2 | $b_{21}$ | B(1)/B(2) | B(1) is furthered by B(2) |
| 3 | $b_{23}$ | B(2)/B(3) | B(3) is supported by B(2) |
| 4 | $b_{32}$ | B(2)/B(3) | B(2) is controlled by B(3) |
| 5 | $b_{13}$ | B(1)/B(3) | B(3) is controlled by B(1) |
| 6 | $b_{31}$ | B(1)/B(2) | B(1) is complemented by B(2) |

**Table 3**: Characteristics of the five companies

| Key dimensions | Companies | | | | |
|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** |
| Structure of the firm | Joint venture between India and foreign conglomerate | Joint venture between India and foreign conglomerate | Indian company | Foreign company having facilities in India | Foreign company having facilities in India |
| Sectors served | Construction, Mining, Infrastructural, Attachments | Construction, Mining, Quarry, Attachments | Roadmaking, Capital goods, Attachments | Construction, Mining, Agricultural, Attachment | Construction, Mining, Quarry, Attachment, Agricultural |
| Product variety level | Medium | | Low | High | |
| End customer type | Large as well as local customers | | Mainly local customers | Large as well as local customers | Mainly large customers |
| Product related technological capabilities | Wide ranging from high end to low end | | Mainly low end | Wide ranging from high end to low end | |
| Composition of top management | Mix of both Indian and foreign | | Mainly Indian | Mainly foreign | |

**Table 4**: Interdependencies among sub-attributes

**Table 4(a)**: Interdependencies among sub-attributes of collaboration attribute "strategic"

| Sl no. | Interdependency | Attributes pairs | Interdependence characteristics |
|---|---|---|---|
| 1 | $b(1)_{21}$ | $B(1)_2/B(1)_1$ | $B(1)_2$ controls $B(2)_1$ |
| 2 | $b(1)_{12}$ | $B(1)_1/B(1)_2$ | $B(1)_1$ furthers $B(2)_2$ |
| 3 | $b(1)_{13}$ | $B(1)_1/B(1)_3$ | $B(1)_1$ supports $B(1)_3$ |
| 4 | $b(1)_{23}$ | $B(1)_2/B(1)_3$ | $B(1)_2$ controls $B(1)_3$ |

**Table 4(b)**: Interdependencies among sub-attributes of collaboration attribute "tactical"

| Sl no. | Interdependency | Attributes pairs | Interdependence characteristics |
|---|---|---|---|
| 1 | $b(2)_{21}$ | $B(2)_2/B(2)_1$ | $B(2)_2$ complements $B(2)_1$ |
| 2 | $b(2)_{23}$ | $B(2)_2/B(2)_3$ | $B(2)_2$ complements $B(2)_3$ |
| 3 | $b(2)_{13}$ | $B(2)_1/B(2)_3$ | $B(2)_1$ supports $B(2)_3$ |
| 4 | $b(2)_{31}$ | $B(2)_3/B(2)_1$ | $B(2)_3$ furthers $B(2)_1$ |

**Table 4(c)**: Interdependencies among sub-attributes of collaboration attribute "operational"

| Sl no. | Interdependency | Attributes pairs | Interdependence characteristics |
|---|---|---|---|
| 1 | $b(3)_{12}$ | $B(3)_1/B(3)_2$ | $B(3)_1$ supports $B(3)_2$ |
| 2 | $b(3)_{21}$ | $B(3)_2/B(3)_1$ | $B(3)_1$ controls $B(3)_2$ |
| 3 | $b(3)_{23}$ | $B(3)_2/B(3)_3$ | $B(3)_2$ controls $B(3)_3$ |
| 4 | $b(3)_{32}$ | $B(3)_3/B(3)_2$ | $B(3)_3$ furthers $B(3)_2$ |
| 5 | $b(3)_{13}$ | $B(3)_1/B(3)_3$ | $B(3)_1$ furthers $B(3)_3$ |

**Table 5**: Scale of importances

**Table 5(a)**: Extent of important for respective individual collaboration attribute (Saaty, 1980)

| Degree of importance | Associated scale |
|---|---|
| Extremely low | 1 |
| Very low | 2 |
| Low | 3 |
| Marginally low | 4 |
| Average | 5 |
| Marginally high | 6 |
| High | 7 |
| Very high | 8 |
| Extremely high | 9 |

**Table 5(b)**: Interdependency and influence scale (Saaty, 1980)

| Qualitative measure of interdependency | Assigned value |
|---|---|
| Very strong | 5 |
| Strong | 4 |
| Medium | 3 |
| Weak | 2 |
| Very weak | 1 |

**Table 6:** Permanent and logarithmic values for the five companies

| Values | Company – A | Company – B | Company – C | Company – D | Company - E |
|---|---|---|---|---|---|
| *Per (VPM – B)* | 883 | 968 | 302 | 1219 | 1037 |
| $Log_{10}\{Per\ (VPM - B)\}$ | 2.946 | 2.986 | 2.48 | 3.086 | 3.016 |
| $Per\ (VPM - B_{str})$ | 794.3 | 1178 | 178 | 1340 | 1537 |
| $Log_{10}\{Per\ (VPM - B_{str})\}$ | 2.900 | 3.071 | 2.25 | 3.127 | 3.186 |
| $Per\ (VPM - B_{tac})$ | 679 | 1340 | 741 | 679 | 603 |
| $Log_{10}\{Per\ (VPM - B_{tac})\}$ | 2.832 | 3.127 | 2.87 | 2.35 | 2.78 |
| $Per\ (VPM - B_{opr})$ | 609 | 946 | 1042 | 610 | 2178 |
| $Log_{10}\{Per\ (VPM - B_{opr})\}$ | 2.785 | 2.976 | 3.018 | 3.326 | 3.338 |