Supply chain integration barriers in port-centric logistics – An emerging economy perspective

Title Page

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Abstract

Despite the growing interest in supply chain integration and port performance in the maritime literature, there is a lack of detailed studies into the barriers to integration in port-centric logistics. This study explores the barriers to port-centric supply chain integration from an emerging economy and multi-stakeholder perspective by using the *DEMATEL (*Decision Making-Trial and Evaluation Laboratory) analysis technique. The findings indicate that institutional requirements, lack of awareness by stakeholders, and port-centric supply chain integration all significantly impact supply chain projects that have been designed to offer maximum value to customers at a low cost. Other crucial barriers include the absence of benchmarking standards and lack of an innovation culture. The policy and managerial implications are explained.

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1. Introduction

Global supply chains require a high level of stakeholder co-operation to achieve a seamless operation. Thus, supply chain integration refers to the degree of strategic collaboration that takes place between stakeholders to manage internal and external processes effectively and achieve unified control over independent systems (Flynn et al. 2011; Frohlich and Westbrook 2001). Recent research has established the role of integration in helping to drive large-scale supply chain projects that offer maximum value to customers and high speed at a low cost (Yuen and Thai 2016). Although integration as a concept is well explored in industries such as involve fast-moving consumer goods (FMCG), pharmaceuticals, and electronics (Sabet et al. 2018), it is considered to be a utopian task in other operating environments due to the current mix of non-linear relationships (Childerhouse and Towill 2011). Specifically, the challenge is to drive external integration by involving actors other than customers and suppliers (Palmieri et al. 2019).

In the port industry, the supply chain integration concept is relatively new (Tseng and Liao 2015; Yuen and Thai 2016) and seaports are complex and multipart ecosystems. Over time many have evolved into essential and integral activity centers that are recognized to be a primary asset of national economies (Paniyides and Song 2009; Sol and Taneja 2013). Recently, the role of ports has changed from being that of a simple loading/unloading point to being an essential node that offers value-added services that may include warehousing, packing, and consolidation/ deconsolidation (Mangan et al. 2008; Ng et al. 2016). Over time and by linking up markets and distribution functions, these activities may lead to expansion of the port’s physical boundaries. Thus, if a port-centric logistics hub is to be achieved, seamless integration is required.

Despite its growing importance to ports, the academic literature has not explored supply chain integration in-depth (Palmieri et al. 2019).

Port integration differs from manufacturing supply chain integration in many respects. Firstly, the involved stakeholders are different. While manufacturing mainly involves integrating with customers and suppliers (De Martino et al. 2015; Mangan et al. 2008; Monios and Wilmsmeier 2012; Ng and Liu 2014; Sujeta and Navickas 2014), ports engage with exporters, importers, customs services, freight companies, and their agents at multiple levels (Bichou 2015). This may lead to a logistics cluster evolving within which many actors need to collaborate as the port system becomes more complex and unique compared with those encountered in manufacturing industries. Secondly, while the manufacturing industries usually focus on a discrete and product-oriented conversion process, a typical port system is entirely different due to having public and private firms offering a range of services from packaging to cross-docking, to storage, and acting as distribution centers (World Bank Report 2007).

The integration challenges at ports are also significantly different from those encountered in manufacturing supply chains. Ports are often under pressure to integrate services by instituting a multifaceted service environment, whereas manufacturing focuses on streamlining production and on managing suppliers and customers. Also, ports in a logistics cluster are challenged to move beyond merely allocating berth space and cargo handling, to focus more on managing distribution and value-added logistics services (de Langen et al. 2013; Falkner 2006; Feng et al. 2012; Mangan et al. 2008; Wall 2007). None of this activity is mandatory in manufacturing settings. Ports also face problems when re-engineering/reorienting traditional practices within an integrated enterprise and are keen to control operational costs in the hinterland and marine port operations (Ascencio et al. 2014). Many such integration challenges in port-logistics are still to be researched thoroughly, so it is interesting to consider the economic and social dimensions of integration barriers to improved logistical efficiency from a regional perspective (Álvarez-SanJaime et al. 2015; Cariou et al. 2015). Moreover, the port-logistics and integration domains are open to empirical research (Baines et al. 2011 2013; Han 2018; Johnson and Mena 2008; Kastalli and Van Looy 2013; Neely 2008; Panayides and Song 2009; Zhen 2012).

The present study fills some of the gaps in the literature. It explores the supply chain integration barriers concerning port stakeholders and prioritizes them with the aid of the *DEMATEL* (Decision Making-Trial and Evaluation Laboratory) analysis technique. India is one of the top four emerging economies and, by focusing on the Indian maritime space, it is expected that the findings might be used as a benchmark for the other emerging economies. This study aims to address the following research questions: a) *What are the main barriers to port supply chain integration in a port-centric logistics domain?* b) *How do the main barriers to port supply chain integration interact?*

To the best of our knowledge, this is one of the first port-centric supply chain integration studies to utilize a mixed-methods approach. It also adopts a multi-stakeholder perspective, when classifying the barriers, which helps to overcome the peripherality that can lead to the development of unbalanced regional and national port systems. It contributes to the port-logistics literature by advancing the port development and integration perspectives and thereby significantly contributes to policy-making efforts in the port logistics domain.

The remainder of this paper is organised as follows. Section 2 provides an overview of port logistics development, competitiveness, Indian port conditions, and barrier analysis techniques. Section 3 describes the research methodologies utilized. Section 4 presents the findings, which are then discussed in Section 5. Section 6 deliberates the implications, and Section 7 concludes the study with limitations and suggests research opportunities.

2. Literature Review

This review first describes the extant supply chain integration literature before turning attention to operations and integration in port-centric logistics, followed by the Indian port environment study context.

2.1 Supply chain integration

Supply chain (SC) integration describes how firms collaboratively manage intra- and inter-organizational processes with partners (Flynn et al. 2010; Frohlich 2002; Liu et al. 2011) and firms need to be selective when deciding the integration pathways to adopt. SC integration may improve process efficiency and operational coordination by utilizing real-time information exchanges (Rosenzweig 2009), as a result leveraging partner resources and capabilities and reducing supply chain complexity. This may also enhance innovativeness and control of the business operations (Wiengarten et al. 2016). Additional advantages include lower costs, shorter lead times, and enhanced levels of customer service. SC integration also improves stakeholder relationships; effectively promoting a form of vertical integration without having it in the physical sense (Handfield and Nicols 2002; La Londe and Masters 1994; Prajogo and Olhagar 2012). Frohlich and Westbrook (2001) propose five arcs of integration, the preferred one being 'outward-facing', which demands customer and supplier integration. However, many researchers argue that even this does not yield the desired performance level (Wiengarten 2016) as it does not involve the other stakeholder interactions.

The extant literature is still dominated by individual firm-level studies, which are recently being extended beyond the organizational boundaries to explain the importance of integration across partners operating in different cultures (De Maritino et al. 2012; Wong et al. 2011). These firms may gain easy access to the resources of other actors and participate in value co-creation (Liao et al. 2017; Normann and Ramirez 2012). Consequently, SC integration is a pivotal contributor to supply chain performance (Prajogo and Olhagar 2012). A contingency perspective that aims to link integration and performance highlights the importance of internal and external supply chain conditions including such contextual environments as country-level logistical capabilities (Drazin and Van de Ven 1985; Weingarten et al. 2014; Wong et al. 2011).

2.2 Port-centric logistics operations and integration

Marine ports are identified as critical logistical and transshipment hubs due to their performance, efficiency, and critical role in global competitiveness (Coyle et al. 2009; Cullinane et al. 2002; IAPH 1996; Jiang et al. 2015; Mangan et al. 2008; Sanchez 2006; Tongzon et al. 2007 2009; UNESCAP and KMI 2005; Wanke et al. 2011; Yuen et al. 2012). They identify as one of the main service-integrating and value-adding platforms for supply chains (Pak et al. 2015; Tongzon et al. 2009); hence, are recognized as clusters and networking sites of heterogeneous firms with diverse service objectives (Bichou and Gray 2004; Tseng et al. 2015). Marine ports may provide full-package, integrated solutions, handling both the forwarding and clearing of goods during export and import as an integral part of supply chains and growing economies (Paixao and Marlow 2003; Song and Panadyis 2008).

While studies into port efficiency and productivity predominate, the literature on port management strategy and competitiveness from the stakeholders' perspective has gained in prominence over the last decade (Heaver et al. 2001; Paixao and Marlow 2003; Song 2003; Tongzon 2009; Tongzon et al. 2009; Yap and Lam 2004). For example, there has been a shift to considerations of whether to adopt co-operative or competitive strategies (Bichou and Gray 2004; Robinson et al. 2002). Also, infrastructure studies aimed at sustaining port competitiveness have increased in line with the growth of international trade (Clott and Hartman 2016). Specifically, there is growing interest in systems approaches for developing strategic and regional perspectives (De Martino et al. 2008 2013; Song and Panayides 2008; Song and Parola 2015), the effects of supply chains on ports and impacting factors like structural changes to the industry (Notteboom 2004; Notteboom and Winklemans 2001), operational efficiency in view of intensified port competition (Wang et al. 2006), and horizontal integration (Heaver et al. 2001).

Port-centric supply chain integration involves connecting stakeholder entities by sharing resources and information (Katunzi 2011; Robinson 2002; Slack 2005). While port infrastructure facilitates ship operations, temporary storage, and intra-port operations (Song and Paniyides 2008), it can also link stakeholders having similar or diverse interests. As evidenced by the increasing quantity of literature on port value creation and competitiveness (Robinson 2002; Tongzon and Heng 2005; Tongzon et al. 2009; Vitsounis and Pallis 2012), many value-adding service opportunities are afforded by SC integration. These go well beyond normal port operations to influence overall port performance (De Martino et al. 2013; Slack and Fermont 2005), Bichou and Gray (2004) propose inter-modalism and organizational integration as two main factors for overall value-creation. Wang et al. (2015) describe the different patterns of integration in the context of Chinese ports, while Larroque (1995) links the concept of services the port concept; stating that ports may serve as a means to lower overall transport costs and provide organized land channels; for example, by sharing arrival notices and daily schedules between the terminal operators, port authorities, multimodal transport operators, warehouse service providers, shippers, and carriers-– which may also improve the port’s efficiency and reduce operational costs (Clott and Hartman 2016).

Further, De Martino et al. (2015) highlight the possibilities of using the hinterland ‘s activities and resources, such as road/rail access, customized services, and cargo handling. They describe two critical considerations when co-creating value in the port sector; whether to utilize inter-modal transport in tandem with hinterland development or whether to match the resources of such upstream and downstream entities as shipping companies and port authorities, and the various service companies involved with warehousing, stevedoring, freight forwarding, and transport (Ascencio et al. 2014). In a similar study, Clott and Hartman (2016) analyzed supply chain integration involving hinterland and port accessibility in the US context and discussed the role of corridor stakeholders and the importance of partnerships and investments for driving supply chain integration.

Recent literature has seen an increase in turnaround strategies that involve the restructuring of port management and stakeholder relationships (Song and Parola 2015). A notable development is the enlarged role of transnational terminal operators (TTOs) that offer integrated services, which leads to port services becoming less differentiated in today's global marketplace (Slack and Fermont 2005). Advocating for a complete transformation of service package design through horizontal integration has challenged the operating practices that impact profits in port businesses (Bascombe 1998; Slack and Fermont 2005), triggering a service focus that forces ports to offer integrated, value-added logistics services that align closely with those of other actors in the supply network (Tongzon et al. 2009). Essentially, the port becomes a service coordinator, facilitator, and integrator (Centin 2012). Petit et al. (2009) trace the transformation of ports into multiple activity centers, a development that may lead to process innovations, new service offerings, shorter time to reach markets, and the adoption of new technologies to improve the efficiency of the port system. Eventually, these activities will trigger intra- and inter-port competition (Parola et al. 2014).

Reconfiguration of the relationships between the members of the supply network and port authorities, into an efficient integrated network, requires effective and efficient coordination and utilization of enabling information systems (Almottariri et al. 2009; Carbone et al. 2003; Herz et al. 2014; Notteboom and Rodrigue 2008; Lam et al. 2011; Panayides and Song 2009; Rodirgue et al. 2008; Song and Panayides 2008; Woo et al. 2011; Zhang et al. 2014). Implementation concerns those elements constituting the range and quality of services offered by the port; elements that are crucial for shipping companies and shippers when they select ports of choice.

Other research reports on the parameters that enable a port to evolve from a simple transshipment point to a hub with a bundle of services, and explore port efficiency and the relationships between service users and providers, including port operators (Brooks et al. 2007; Mangan et al. 2008; Ng 2006). Also, focal firm supply chain strategy, which needs to complement the competitive performance of the port by focusing on customer value and satisfaction (Brooks et al. 2006; Mangan et al. 2008), is highly dependent on the degree of transport integration that exists within the port system (Ducruet and Van Der Horst 2009).

In summary, a port as an operating environment can be considered an intersection with the hinterland that triggers competition (Cuadrado et al. 2004). Although studies into the impacts of integration and port performance have begun to appear (Han 2018), port integration remains a naïve subject of research. Supply chain integration in port-centric logistics is a crucial area to explore; especially the operational dynamics that create long-term strategic relationships. The extant literature advocates for service-level research that explores the perspectives of transnational terminal operators (TTOs), focal companies, and suppliers and customers (Palmieri et al. 2019). Hence, the scope of our research aims to explore port service strategy and deliberate the barriers to port=centric supply chain integration from an emerging economy perspective (Panayides and Song 2009; Song and Panayides 2008).

2.3 The Indian Port Environment

India is the sixteenth-largest maritime economy. It has 7,517 kilometers of coastline, twelve major ports, and around 200 notified non-major ports that handled 43 percent of total maritime freight traffic in 2016 (Ministry of shipping 2017). Overall, 95 percent of the nation's trade volume (68 percent by value) is shipped through the maritime environment (Ministry of Shipping 2017), and the government has a policy roadmap for creating more capacity and increasing port performance. With a target capacity of 3,130 million metric tons by 2020 (IBEF Report 2016), various initiatives have already reduced average port turnaround times from 4.24 days in 2000/01 to 2.11 days in 2016/17.

Since the turn of the century, many initiatives have been proposed to improve logistics infrastructure via an integrated approach. These typically envision the development of a coastal freight corridor, enhanced last-mile connectivity, the development of transshipment hubs and accelerated port development. The government is keen to develop new greenfield ports in various states (Maritime Summit 2016). A mega-port infrastructure project named *sagarmala* (meaning string of ports) has recently been initiated, also directed at port-centric logistics infrastructure to drive port-led industrial and coastal community development. The new initiative also encourages private sector participation, and the Indian government has encouraged foreign direct investment in the port sector with a ten-year tax holiday period (IBEF Report 2016; Ministry of Shipping 2017). As a result, port operations have moved from the traditional model of services ports (mostly owned by the government) to a model of landlord ports that invite international port operators to adopt a build, operate, and transfer (BOT) model. This is a significant development in the national logistics landscape aimed at boosting the port infrastructure of major and minor ports (Panigrahi and Pradhan 2012). Although these structural changes have the potential to be highly beneficial in terms of redefining port efficiency; achieving the needed integrated growth in an environment of economic uncertainty and complex socio-technical infrastructures is highly challenging (Taneja et al. 2010).

2.4 Research gap

The above discussion establishes the importance of ports as integral parts of global distribution channels (Panayides and Song 2009). However, Panyides et al. (2012) highlight the research gap that exists regarding the factors that limit integration in port-centric logistics supply chains. Song and Panayides (2012) also highlight that there has been minimal empirical research into the interrelationships that are involved in achieving the integration of ports with supply chain services, and Woo et al. (2009) emphasize the scope for analyzing the services to be offered in such a port system.

The extant literature also leaves scope for exploring the Indian environment, a vital maritime destination for global supply chains. Previous studies have been mainly confined to exploring integration strategy and its relationship with port performance (Han 2018; Song and Panayides 2008; Tongzon et al. 2009; Woo et al. 2013). On the other hand, the shipping industry has recently initiated detailed deliberations on integration (Clott and Hartman 2016; Palmieri et al. 2019; Tseng et al. 2015). While the Yuen and Thai (2016) study into the barriers to integration, from a container shipping firms' perspective, is significant, integration outcome performance is highly dependent on the different stakeholders at various operational stages. Hence, our research aims to study the barriers to supply chain integration in port operating environments by adopting a structured approach, a multi-stakeholder perspective, and a focus on value creation.

3. Methods

The methodology has mixed research and validation steps (Table 1). In a key main step, we administered a *Delphi* technique to shortlist 11 critical factors from the stakeholders' input. In the other key step, the shortlisted barriers are analyzed using the fuzzy *DEMATEL* technique, followed by sensitivity analysis and triangulation. The following two subsections describe these methods.

[Insert **Table 1** here]

3.1 The Delphi method

The *Delphi* technique provides a systematic approach to collect expert opinions and arrive at a consensus among a group of participants across disciplines by giving values to the relative importance of the factors (ranking) (Buckley 1995; Couger 1988; Czinkota and Ronkainen 2005; Linstone *et al.* 1975; Schmidt 1997). It is judged suitable for the present study as it enables the communication process to be moderated and assures participant anonymity. The technique is frequently used for strategic decision making, policy drafting, and drawing together a convergence of the opinions expressed (Czinkota and Ronkainen 2005, Grisham 2009). Moreover, it can yield subjective judgements to identify the barriers to *supply chain integration* by maintaining the heterogeneity of the participants. The study is administered in multiple rounds, allowing the experts to revise their answers considering other moderated opinions (Okoli and Pawlowski 2004). There are three distinct phases: discovery of factors (in multiple rounds), focus on central issues and ranking of the resulting factors (Schmidt 1997). Also, it provides researchers with more information on the selected problems or factors. While a survey method could have been used, the pioneering nature of the study favored the *Delphi* technique because of its ability to elicit in-depth opinions on select factors from the practical context. Moreover, it is economical and not limited by geographical boundaries (Linstone and Turoff 2002).

3.2 Fuzzy DEMATEL Method

DEMATEL is a widely used multi-criteria method in the decision research domain. Table 1 lists representative Fuzzy DEMATEL works from the logistics literature. The technique is primarily used to establish cause-effect relationships among the study variables (Kaur et al. 2018; Luthra et al. 2017). As used in the present study, DEMATEL uses triangular fuzzy numbers (TFNs), as recommended by fuzzy set theory, to represent vague, probabilistic, and imprecise information, as decision-makers' judgments are usually characterized by ambiguity in real-life scenarios (Chen 1992; Zadeh 1965). These TFNs are expressed as triplets (e, f, and g) which depict the smallest, most likely and largest possible values respectively. The DEMATEL method has a seven-step execution process (Venkatesh et al. 2017), which is outlined in Appendix 2.

[Insert **Table 2** here]

4. Data collection

Data collection for the study uses a Delphi technique with three steps: a) expert panel formation, b) barrier identification, and c) implementation of two rounds of discussion to finalize the essential barriers (Schmidt 1997). A specific participant selection criterion (being a minimum of ten years of experience in a port environment), as purposive sampling, was applied to achieve a genuinely heterogeneous expert panel of internal and external stakeholders, and reduce the possibility of potential bias. Initially, the research targeted 45-50 participants based on their availability and willingness to participate. While executing the study a constant comparison method was used to identify the data saturation point of sampling beyond which no new insights were being added. The theoretical saturation point was reached by the twenty-sixth participant and confirmed by continuing with four other participants (Strauss and Corbin 1998).

Table 3 shows the profiles of the thirty participants involved in the study [Appendix 1 contains further details]. The participant sample includes forwarding agents, container freight station (dry port) managers, traffic managers, customs agents, shipping line representatives, warehouse owners and operators, port business development managers, and senior port operations managers. These professionals are all directly connected to logistics operations within the port environment. For example, the forwarding agents and container freight station professionals are the primary stakeholders responsible for planning, consolidating, and loading containers. They typically coordinate with a range of stakeholders employed by the shipping lines, local customs services, and ports to ensure on-time shipping. Similarly, the port operations professionals and warehouse managers integrate downstream and upstream stakeholders to drive operational efficiencies, and the consultants have experience with specific port-related projects. Consequently, they are all considered to be essential stakeholders in this study

[Insert **Table 3** here]

Given the absence of a comprehensive list of integration barriers specific to port operations in the extant literature, an initial list of barriers was extracted from the general services literature and adapted for the Indian maritime environment. The participants provided feedback on this tentative list via two rounds of Delphi interviews (Baines et al 2009a; Brax 2005; Cook et al. 2006; Dipeso 2000; MacDonald et al. 2011; Maxwell et al. 2006; Mont 2002; Peillon et al. 2015; Vandermerwe and Rada 1989; Vandermerwe 1994; White et al. 1999). A naturalistic enquiry method was used to explore the research phenomenon in its natural setting without manipulating the research outcome a priori (Bowen 2008). The responses were analyzed systematically via an abduction reasoning methodology to yield more insights (Coffey & Atkinson 1996; Richardson & Kramer 2006). Through the *Delphi* interactions, eleven barriers [Table 4] were shortlisted based on the generated convergence scores in consultation with the practitioners. The following sub-section discusses them in detail.

[Insert **Table** 4 here]

4.1 Identified Barriers

B1: Lack of awareness of supply chain integration and its potential benefits: Supply chain integration as a concept has not matured much beyond the manufacturing domain. Davies et al. (2006 2007) argue the need for a clear understanding of the deliverables for the success of major integration projects. In the present study, most of the participants agree that there is ambiguity in defining the real meaning of 'supply chain integration' in the port industry, with the concept still viewed as product-centric value creation rather than service-oriented value creation. Moreover, there is agreement that awareness is lacking about the advantages of driving value creation via an integrated approach, and about how the benefits to stakeholders in port development projects.

B2: Regulatory environment and lack of government support: The process of integration involves bringing together multiple stakeholders, and requires specific/special regulatory approvals (for sites, dangerous chemicals handling…). The participants concurred on the complexity of the procedures, and on the delays involved in securing bureaucratic approvals, as these kinds of project require engagement with several hinterland stakeholders and may involve land valuation and acquisition, support from regional governments, and revenue authority involvement at village level. The single-window system of approvals works slowly in India, despite governmental efforts to increase the pace of infrastructure projects, including port development. In many forums the stakeholders expressed their desire to see continuous government support for such value-creation projects, but the response from the government has been slow given the lack of a clear maritime policy roadmap. For example, while the government has expressed its willingness to develop the *sagarmala* project within the maritime policy framework (2010-2020, it has not clarified the operating guidelines, which leaves the system somewhat obscure.

B3: Conflicts among the stakeholders: Bendetttini and Neely (2013) emphasise the complexities that develop through stakeholder conflicts within an integrated environment. Although these conflicts are resolved on an ad hoc basis, they still negatively impact the service system (Song and Sakao 2016). In port-centric logistics, there are multiple stakeholders (such as clearing and forwarding agents, customs houses, packaging firms, and container freight station operators) with varied interests and objectives. Many private operators tend to focus on their business priorities in handling port operations (Cullinane and Song 2002)., which can lead to discriminatory treatment and conflicts. The participants affirmed the difficulties encountered in a multi-actor, interactive environment when conceptualizing and designing services needing a shared understanding of the offerings. This significantly impacts the power relationships between the stakeholders and affects services and customer relationships that can lead to conflicts within the service ecosystem.

B4: Lack of benchmarking service standards: Donselaar and Kolkman (2010) discuss the importance of standardizing knowledge in a port service environment. Although some reports define global port industry service standards, these are of limited value as they relate to entirely different conditions (Chhetri et al. 2014; Cullinane et al. 2006; Vanden Berg and De Langen 2011). In short, there is a lack of relevant data on the integration of services. The participants agreed on the lack of (integrated) performance data relating to the Indian logistics landscape. More importantly, they observed a lack of interest among the stakeholders in defining the service standards for port-centric logistics systems. The absence of benchmarking standards could be a significant hurdle for any port integration project.

B5: Stakeholders' multiple interests: In general, any integration environment will have multiple ecosystems with varied demands (Álvarez-SanJaime et al. 2015; Bendetttini and Neely 2012). Similarly, in any port network, multiple parties need to accomplish tasks with a high degree of associated uncertainty that may impact the pace of projects and cause a delay. The participants agreed that service levels would also be different for different stakeholders, which makes it difficult for individual firms to align themselves with overall targets without compromising their commercial interests. For example, a packing operator may have a service requirement and delivery route that does not fit well into the overall scheme of delivery and thereby impacts the operator's commercial viability. This may result in services being offered over multiple routes, which may adversely impact the overall integration objectives.

B6: Lack of pace in adopting global standards and practices: Adaptability to changing marketplace forces and global practices are a critical determinant of port competitiveness (Notteboom and Winkelmans 2001; Tongzon and Heng 2005). Participants in our research, while acknowledging the importance of this attribute for supply chain integration, expressed concern with the pace of adopting global standards that could profoundly impact port services capability and reliability. Stated reasons include lack of interest from stakeholders who fear cost escalations (such as costs of installing advanced systems) and an untrained workforce incapable of the design and implementation of new best practices needed to deliver the agreed service package.

B7: Lack of strategic thinking on integration: Supply chain integration begins with a new vision and with a change in organizational structures, thereby creating a supportive ecosystem and processes for primary and support functions (Chase and Garvin 1989; Olivia and Kallenberg 2003). The participants expressed the concern that, so far, the concept of integration only involves short-term tactical planning at the operational level of the firm. The stakeholders lack the long-term strategic planning that is necessary to create and enable an integrated port-centric ecosystem, and many are only interested in satisfying their immediate value chain partners.

B8: Investments in integrating the services: Stakeholders must invest resources in improving operational service-related capabilities and must implement the appropriate processes to integrate services (Barney 1991; Peteraf 1993). The participants acknowledge the limited role of the government to provide adequate financial support and the often demanding conditions as regards mobilizing required funds. This is mainly due to the difficulty of connecting with the right investment partners (angels/venture capitalists) that would give impetus to unique supply chain infrastructure projects. Therefore, it is necessary to overcome this financing barrier to advance the integration targets (Kastalli and Looy 2013).

B9: Locational and infrastructure barriers: Integration is highly dependent on infrastructure requirements and availability (Redding and Baines 2013). For port integration projects, the requirements include access to the necessary amenities for port-centric facilities. Another requirement is access to data highways, teleports, and satellite communication centres within the port area. If not already available these would probably involve long-term development projects.

Moreover, ports may have limited ability to influence the decisions made by rail partners and warehouse service providers (Clott 2016). The participants echoed these concerns and agreed that there are frequently only weak threads connecting multi-modal transportation and other allied activities within the port service area. Activities may also be constrained by geographical limitations such as availability of water, the soil type, and access to other resources that delay approvals and developmental activities.

B10: Financial incentives: Any firm that is willing to become a member of an integrated ecosystem will face the challenge of pricing mechanisms in the value creation process so that companies have begun to analyze the financial viability of long-term supply chain integration projects (Elfving and Urquhart 2013). In present port ecosystems, financial incentives are not available via focused revenue-sharing practices. There is also inconsistency in operating cost behavior within the port environment that depends on various factors, including port size.

B11: Restriction on innovation culture: Innovation is a key integration component and an essential trigger point for an organization's capability and processes for creating new value Neely (2008). The oganizational culture and environment are also crucial to driving integrative thinking, and Schmenner (2009) argues that innovation in any part of operations directly affects integration efficiency. The participants are deeply concerned about the level of freedom they are given to think freely and innovate best practices for the benefit of all the stakeholders in a port-centric supply chain environment. Participants related how the actors are influenced by the commercial requirements of powerful service partners in the value chain and how innovation is given insufficient attention in a practical sense. For example, container freight stations generally would like to innovate new methods of stacking and stowing containers to optimize the use of space. However, they may be restricted by the strict guidelines for stacking and storage by other stakeholders outside of their port environment.

After shortlisting the above barriers, the panel was requested to make pair-wise comparisons of the impact of the barriers. Appendix 2 details the DEMATEL steps that were undertaken at this point and includes sensitivity analysis. Two final rounds of triangulation with five practicing professionals who were involved earlier assisted the researchers in making meaningful interpretations of the DEMATEL findings, which are discussed next.

5. Findings and Discussion

[Insert **Figure 1** here]

Figure 1 shows the DEMATEL analysis of the study factors. It classifies the identified barriers into causal and effect clusters. While the ranking offers insights on the level of impact, the significant relationships also reveal barrier behavior via further analysis. Table 9 gives the influence scores. It classifies B1, B2, B4, B9, B10, and B5 as causal barriers, which all show positive scores of R-C. From these, B1, B2, and B4 are identified as the significant causal barriers, as their total direct relationship scores are above the proposed threshold value. The barriers with negative R-C values (B6, B8 and B3) are identified as the critical effect barriers. Barriers B5 and B11 cannot be distinctly classified as type causal or effect, based on their (R-C) scores, as their impact (0.10) and effect (-0.22) are both minimal. Although barrier B7 has a minimal negative R-C value (-0.03), it has a significant effect on three effect variables; hence, it is reasonable to classify it into the causal variable section. Finally, the findings identify eleven significant relationships (B1- B7; B1-B3; B1-B6; B1-B8; B2- B6; B2- B8; B3-B6; B4- B6; B7-B3; B7-B6; and, B7-B8). These interactions are deliberated in the discussion section.

It is important to note that the main barriers detected by the DEMATEL analysis, being the ones that most impact supply chain integration in port logistics, are not always the ones most frequently reported by the participants. For example, the barrier B5 (S*takeholders' multiple interests*) was the barrier most reported in the Delphi round, but it is less prominent in the DEMATEL analysis than other barriers, such as B1 (*Lack of awareness of supply chain integration and its potential benefits*), B2 (*Regulatory environment and lack of government support*), and B4 (*Lack of benchmarking service standards*). In other words, the use of a prioritizing technique like DEMATEL is crucial for policy-implication studies as it would be incorrect to state the raw Delphi findings. Based on our findings the barrier B1, lack of awareness of supply chain integration and its potential benefits, is the one that is most profoundly impacting port integration projects.

Further interpretations based on discussions with the industry professionals reveals that many Indian stakeholders are unaware of the potential of supply chain integration, although this situation is improving backed by government initiatives. Hence, this finding establishes the critical role of government to drive port-centric supply chain integration projects, which is consistent with earlier research by Wang et al. (2015) in their China-based study. The failure of stakeholders (such as private terminal operators) to move beyond their boundaries and educate other investors is mainly due to a service domain that is ungoverned by a professional ecosystem. Thus, if the government tries to convince the forwarding agents and packing units to be part of an integrated port system they will be very reluctant to co-operate; mainly due to the fear of losing personal power within the service environment and facing competition by being judged on their performance. This barrier drives others, such as B7 (*Lack of strategic thinking on integration*); B3 (*Conflicts among the stakeholders*); B6 (*Lack of pace in adopting global standards and practices*); and, B8 (*Investments in integrating the services*).

This study points to the critical need for port-logistics integration strategies to be outward-facing and aligned with stakeholders' needs. This is different from manufacturing environments where inward-facing (inside organization) strategy often dominates (Frohlich and Westbrook 2001). The study also highlights the absence of institutional collectivism in port environment, which is an essential factor to drive integration at speed, since it defines the degree to which the organizational and societal practices encourage resource distribution and collective action within any integration exercise (House et al. 2004). In our study, the lack of speed in implementing global standards and the lack of financial incentives and distribution of investments signal the absence of institutional collectivism. The findings also partially support the view that having a long-term relationship with suppliers has a positive relationship on integration (Prajago and Olhager 2012), as the sharing of information and joint-decision making with suppliers leads to better operational performance (Rosenzweig et al. 2003; Wong et al. 2011). However, these perspectives are based on manufacturing environments that primarily focus on direct integration with customers and suppliers. Nevertheless, ports have unique and complex dynamics compared with manufacturing environments, which warrant having close interactions in multiple directions at physical, economic, strategic and organizational levels (Paniyedes et al. 2006). The participants further highlight the role of other factors such as stakeholder alignment, investment climate, infrastructure problems, global standards, and governance framework on the integration projects.

This study also recognizes the role of political environments that could impact supply chain integration efficiency (Wong et al. 2017). As evidenced by recent initiatives in India, the government has a critical role to play in improving logistics infrastructure. Only recently has 100 percent direct foreign investment been allowed in the ports and shipping industry. However, to-date, this regulatory change is primarily focused on direct port operations such as operation and maintenance of the port, ship repair facilities, and inner port development (Make in India Report 2016). The regulations are less clear on associated industries such as warehousing service providers and hinterland transport service providers. Also, even though the government is trying to promote a single-window approval system, the regulatory initiatives are not gaining traction due to the multiplicity of bureaucratic steps that slow the pace of project development. It appears that the absence of a long-term vision for a productive service environment is both creating conflicts between stakeholders and failing to attract the required investments. Thus, it is reasonable to conclude that non-alignment between the participants is one of the essential causal factors that impair overall delivery of the project deliverables in terms of speed and quality.

There is a misconception that India does not need mega port projects and that projects of this kind would not help the industry because coastlines are not within international maritime corridors. Added to this, the reluctance to achieve global standards and a desire to retain a traditional labour-oriented economy adds to the non-alignment and impacts the nation's strategic vision.

Focal firms are often restricted in their ability to innovate their port logistics operations due to the operations being dictated by legal and customer requirements. This finding is supported by the barrier B11 (*Restriction on innovation culture)* appearing in the effect cluster. Although it has a relatively small influence score, this is a real causal barrier to port integration projects. Likewise, stakeholders that have multiple and possibly conflicting interests create a causal barrier, as evidenced by the influence of barrier B5 (S*takeholders' multiple interests)*. Thus, operators in the port logistics chain will tend to react in different ways (Álvarez-SanJaime et al. 2015), which ultimately weakens the stakeholders' integration culture (Venkatesh et al. 2017). Of course, different reactions can also be due to non-alignment between stakeholders' business priorities.

Moreover, supply chain integration projects face substantial locational and infrastructure barriers; for example, the Indian government is yet to grant ports a special economic status and financial institutions do not yet recognize them as critical infrastructure projects. Also, the absence of widely-recognised specific operating standards such as are adopted by Singapore and Dubai hinders the scaling of port projects to a global standard. The Indian government is aware of the potential and significance of developing the ports and integrating them with their operating environment. Such integration will help port supply chains to improve cost, delivery quality, and lead time (Cousins and Menguc 2006).

6. Theoretical contribution and practical implications

6.1 Theoretical contributions

This study has important implications for those researching the determinants of port competitiveness. It is a pioneering work that extends supply chain integration knowledge into the domain of seaports, by focusing exclusively on the barriers to port-centric supply chain integration. Firstly, it helps to distinguish the port environment from (linear) customer-supplier integrations due to the presence of multiple actors and complex dynamics (Song and Lee 2012). The study also recognizes the value of relational dynamics within the port environment as distinct from the information and process integration steps that are also important.

Secondly, it extends the resource-based and contingency perspectives into the port integration environment and reveals that the optimal result for any project is mostly determined by the availability of internal and external resources and the associated conditions. Ports represent an open environment with multiple actors that have diverse requirements needing to be satisfied, and the study acknowledges how the organizational, economic, and strategical interactions between stakeholders may impact the success of integration projects.

Thirdly, from an emerging economy perspective, the study establishes that infrastructure problems, lack of capital investment, and an absence of stringent regulations may impact large scale projects. The study also confirms the role of national culture in designing and executing port integration projects when the operations extend to the local populace (Sousa and Woss 2008; Wong et al. 2017).

6.2 Managerial implications

This research will help various stakeholders to design strategies that accelerate their port-centric supply chain integration efforts. This is especially valuable because the rivalry between supply chains, especially those involving a port, has become highly intensified (Song and Panyides 2008). The findings offer direction concerning the barriers that act to reduce the pace of supply chain integration projects. For example, to improve the efficiency of the overall logistics system, liner shipping companies may choose to engage directly with port operators and stakeholders to reduce the impact of the barriers identified by this study. Also, in emerging economy environments in which the government is encouraging private participation in port logistics development, this study directly helps private terminal operators both to understand the operating conditions and to design highly-integrated service environments by using appropriate benchmarking. Also, private port-cum-terminal operators may work with the government and other stakeholders to promote a healthy investment culture and reduce the inherent conflicts.

6.3 Policy implications

The findings highlight the negative impacts of having poor government support and cumbersome regulatory approvals processes. Thus, it is recommended that existing approval systems be restructured to provide open debate and foster transparency around port integration projects. The Indian government may also revisit its policy of sharing statutory powers with regional state governments to drive project milestones and receive regular updates on progress with large-scale integration projects. For example, the government’s recent initiative to promote coastal shipping as one of the transport modes in India (Venkatesh et al. 2017) would undoubtedly provide momentum to port integration projects.

This research also identifies the potential to classify projects based on their size and desired level of their integration. This would help financial institutions and the government to plan for their support activities and needed policy decisions. The government and terminal operators should also prioritize the establishment of standards for India-specific port operations, and need to be transparent regarding likely impacts on stakeholders.

Integration projects between small and medium-sized ports are becoming popular in other countries (Wang et al. 2015), with emerging economies expected to follow suit. The barriers discussed in this study will be highly relevant during those initiatives. Moreover, to provide impetus to port-centric integration projects, this study recommends functional cooperation between private and public stakeholders (infrastructure firms, port authorities, information technology, land transport operators, shipping companies, shippers, and providers of value-added services such as container management, packing and warehouse services). This will serve to strengthen relationships between stakeholders (Álvarez-SanJaime et al. 2015) and help achieve agreement on the performance targets for service partners, thereby also to avert potential conflicts within the operating environment.

As the study identified a general lack of awareness of the advantages of supply chain integration, the Indian government may consider designing and promoting awareness and training programs. Also, regular mid-career training programs for port professionals and exposure to leading ports, such as Shanghai and Singapore, is recommended. This would enable benchmarking against world-class port-centric business environments and suggest solutions to thornier integration issues.

7. Conclusion

Over the last decade, there has been a growing focus on the Indian maritime corridor and associated initiatives, including coastal shipping and port city developments. In addition to government, private stakeholders are now involved in developing service ecosystems based around port operations. Although there is a very positive environment, and the port industry has become an open market, there remain substantial barriers to achieving a port-centric logistics supply chain that are well integrated. This study adopted a multi-stakeholder perspective on port service ecosystems in emerging economies. The research analyzed eleven barriers that were elicited from expert feedback and prioritized them using a sophisticated fuzzy DEMATEL technique. It also attempted to establish the relationships between barriers based on their dominance scores. The findings show that lack of awareness of supply chain integration by stakeholders and lack of government support in drive such large-scale projects is negatively influencing their success, even though the government is keen to strengthen port services through integration projects. Moreover, the findings identify the need to establish performance benchmarking standards for port operations.

Studies into the dynamics of port-centered supply chain integration are almost absent in the literature and, to the best of our knowledge, this is the first time that a DEMATEL prioritization technique has been applied to the emerging Indian port logistics environment to analyze the integration barriers.

The research inevitably has limitations. Firstly, the barriers identified are primarily in the Indian context, and may not equally apply to other developing economies because of contextual differences. Secondly, the study attempts a multi-stakeholder perspective, which may generalize the barriers list, although with less focus on domain-specific issues. Consequently, it is recommended that research can usefully analyze the barriers from individual stakeholder perspectives, perhaps using large-scale surveys. This research may also trigger interest in exploring further the dynamics of project implementation by analyzing the delays, how to control them for risk. Last and by no means least, a new perspective that seeks to characterize the temporal pathways, spatial patterns, and dynamics of port-centric supply chain integration, may also be usefully explored.

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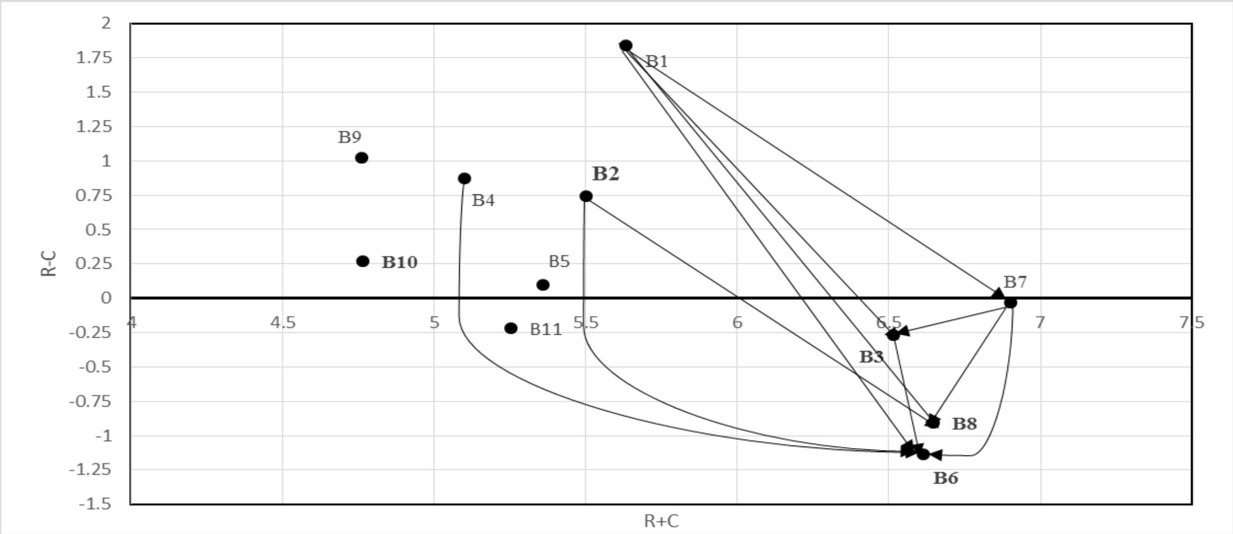
FIGURE



Lack of awareness on integration and its potential benefits (B1)	Lack of strategic vision to engage supply chain integration (B7)
Regulatory environment and lack of government support (B2)	Investments in integrating the services (B8)
Conflicts among the stakeholders (B3)	Locational and infrastructure barriers (B9)
Lack of benchmarking service standards in port system(B4)	Less financial incentives (B10)
Stakeholders' multiple interests (B5)	Restriction on innovation culture (B11)
Lack of pace in adopting global standards and practices (B6)	

Figure 1. DEMATEL Prominence-causal relationship diagram

Table 1 Research and Validation steps

S.No	Steps	Description	Key references
1	Purposive sampling	Thirty participants of different backgrounds and with rich experience in shipping and logistics were selected to provide the rich multi-stakeholder perspectives	Patton (1990)
2	Delphi technique	A two-round systematic feedback technique is used in our study to finalize the port-logistics integration barriers.	Okoli and Pawlowski (2004), Schmidit (1997)
3	Theoretical saturation	We continued collecting and analyzing data until no new information appear and, thus, no additional data is needed in the current study theoretical saturation was achieved with 26th participant in our study.	Strauss and Corbin (1998)
4	Fuzzy DEMATEL technique	Causal - effect classification of barriers	Kaur et al. (2018); Luthra et al. (2017)
5	Triangulation	The findings were validated with five practitioners (through interviews and access to resources) to validate the finalized variables and their causal-effect relationships It also enhanced the holistic understanding of port-logistics integration barriers.	Denzin (2012)

Table 2 Representative DEMATEL studies in logistics literature

Author	***DEMATEL applications in logistics domain***
Yang et al. (2019)	Coordinated development path of metropolitan logistics
Raj and Sah (2019)	Drone logistics
Mangla et al. (2018)	Benchmarking the implementation
Bouzon et al. (2018)	Reverse logistics implementation
Ho et al. (2017)	Container shipping lines selection criteria for the forwarders
Govindan & Chauduri (2016)	Service risks and their inter-relationships
Prakash & Barua (2016)	Third party reverse logistics service provider selection
Shaik & Abdul-Kader (2014)	Reverse logistics performance measurement.
Lee and Lin (2013)	Cognition map of financial ratios of shipping companies

Table 3 Participants' profiles for Delphi process

Industry sector	**Number**
Clearing and forwarding Agents (CFAs)	5
Container freight Station/dry port– Senior Professionals	4
Port operations professionals including business development managers	5
Shipping line representatives including Ship agents and customs agents	6
Consultants (transportation and civil) involved in mega projects	3
Academicians having logistics background	3
Warehousing and distribution professionals (Including consolidators, and Packaging Specialists)	4
Total	30

Table 4 Identified barriers in *DEMATEL* analysis

No	Potential Barriers	Convergence
B1	Lack of awareness on supply chain integration and its potential benefits	92 %
B2	Regulatory environment and lack of government support	92 %
B3	Conflicts among the stakeholders	100 %
B4	Lack of benchmarking service standards in port system	86 %
B5	Stakeholders' multiple interests	73%
B6	Lack of pace in adopting global standards and practices	73 %
B7	Lack of strategic vision to engage supply chain integration	92 %
B8	Investments in integrating the services	73 %
B9	Locational and infrastructure barriers	92 %
B10	Less financial incentives	86 %
B11	Restriction on innovation culture	86 %

Appendix 1 Participants profile

	Designation/Position	Affiliated firm	Years of experience
1	Head- Operations	Freight forwarding company, India	Over 24 years
2	Regional Manager, South	Freight forwarding company, India	Over 25 years
3	General Manager (customer service)	Non-vessel operating common carrier and Freight forwarding company, Chennai, India	Over 15 years
4	Business Development Manager	Leading clearance and forwarding agency in South India	Over 15 years
5	General Manager – Operations	Leading global freight forwarding agency (Subsidiary of a leading shipping line)	Over 20 years
6	Deputy General Manager- Commercial	Container freight station, Chennai	Over 30 years
7	Senior Operations Executive	Container freight station, Chennai	Over 10 years
8	Business Development Manager	Container freight station, Chennai	Over 15 years
9	Customer Service manager	Container freight station, Chennai	Over 15 years
10	Senior Manager – Traffic	Leading port in South India	Over 10 years
11	General Manager – Port development and operations	Leading port in South India	Over 15 years
12	Senior Manager, Container yard and port operations.	Leading port in west coast of India.	Over 10 years
13	General Manager	Leading port in west coast of India.	Over 15 years
14	Senior Executive – Business Development	Private port in east coast of India	Over 10 years
15	Regional Manager, South India	One of the leading shipping lines in the world	Over 25 years
16	Customer Service Manager	One of the leading shipping lines in the world	Over 5 years
17	Senior manager - Operations	Shipping line office in Tuticorin, India	Over 15 years
18	Liaising Manager	Shipping line office in Tuticorin, India	Over 10 years
19	Independent customs agent	Offering services in Chennai, Tirupur, and Tuticorin.	Over 20 years
20	Principal customs liaising officer	EXIM agency based in Tuticorin, India	Over 20 years
21	Port Planner / Consultant	Leading multinational construction consulting company	Over 15 years
22	Logistics Consultant	Consulting company	Over 10 years
23	Consultant – Transportation	Leading consultancy services provider	Over 8 years
24	Visiting faculty – Shipping	Expertise in logistics	Over 25 years
25	Academician & senior professional	Expertise in logistics and supply chain with a specialization in automobile supply chains	Over 20 years
26	Visiting faculty	Expertise in global trade	Over 20 years
27	Senior General manager – Warehouse	Leading retail chain, Bengaluru, India	Over 20 years
28	Senior Executive – Operations	International movers company in Delhi, India	Over 15 years
29	Vice – President – Logistics	Third party logistics service provider based in Bengaluru, India	Over 20 years
30	Regional Head- Warehousing	Leading Third-party warehousing and packaging company	Over 20 years

Appendix 2 DEMATEL steps

Step 1: Defining the expert panel and assessment criteria

In this step, a panel of experts was formed to provide opinions on relevant issues. Barriers to integrating the services in the port-centric logistics domain were identified using the Delphi technique for assessment criteria.

Step 2: Constructing a fuzzy pair-wise comparison matrix

In this step, pair-wise comparisons were made to develop the initial direct relation matrix using a scale from 0-4 (0 = no influence; 1 = very low influence; 2 = low influence; 3 = high influence; 4 = very high influence). The experts were asked to make linguistically-expressed judgments from which to develop a relation matrix of evaluation criteria. To capture the fuzziness in the judgments, a positive TFN was used. Table A2.1 shows the fuzzy linguistic scale used (Wu, 2012) in this research.

Table A2.1. Fuzzy linguistic scale

Preference in terms of score	**Description of linguistic variable**	**Equivalent TFNs**
0	No influence (No)	(0,0,0.25)
1	Very low influence (VL)	(0,0.25,0.5)
2	Low influence (L)	(0.25,0.5,0.75)
3	High influence (H)	(0.5,0.75,1.0)
4	Very high influence (VH)	(0.75,1.0,1.0)

Step 3: Obtaining the fuzzy initial direct relation matrix (A)

A TFN is denoted by a triplet, i.e. (e_{ij}, f_{ij}, g_{ij}). Suppose $x_{ij}^{k} = e_{ij}^{k}, f_{ij}^{k}, g_{ij}^{k}$ where $1 \leq k \leq K$, to be the evaluation of the k^th^ expert of the degree to which barrier i impacts barrier j. If there are K experts on a panel to estimate causality x_{ij}^{k} between the *n* identified barriers, the inputs have to be an $n \times n$ matrix, i.e., $X^{k} = x_{ij}^{k}$; where k = 1, 2, 3, 4, ..., K (number of experts in the decision panel).

$$a_{ij} = \frac{1}{k \sum x^{k}_{ij}} \tag{1}$$

Fuzzy numbers are not appropriate for matrix operations. To proceed, fuzzy numbers are transformed to crisp numbers through a defuzzification process, using the weighted average method depicted in below Eq. (2).

$$I_T = \frac{1}{6}(e + 4f + g) \qquad (2)$$

Step 4: Developing the normalized initial direct relation matrix (D)

$$m = \min\left[\frac{1}{\max \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max \sum_{i=1}^{n} |a_{ij}|}\right] \qquad (3)$$

$$D = m \times A \qquad (4)$$

In this step, the normalized initial direct relation matrix is computed using equations (3) and (4).

Step 5: Constructing the total-relation matrix

$$T = (I - D)^{-1} \qquad (5)$$

Where I: Identity matrix; T: Total relation matrix, $T = [t_{ij}]_{n \times n}$

Step 6: Calculating the sum of rows (R) and the sum of columns (C)

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1} \qquad (6)$$

$$C = \left[\sum_{i=1}^{n} t_{ij}\right]_{1 \times n} \qquad (7)$$

R stands for the overall effects produced by barrier (i) on barrier (j). C represents the overall effects experienced by barrier (i) from barrier (j).

Step 7: Drawing a cause and effect graph by mapping the dataset of (R+C; R-C) with significant relationships

The prominence value (R+C) and net causal-effect value (R-C) were also calculated. While the former quantifies the significance of barriers and shows their total effects in terms of their influenced and influential power, the latter represents the cause-and-effect relationships between barriers. If (R-C) is positive, that particular barrier falls into the cause group. If (R-C) is negative, the barrier belongs to the effect group (Lin, 2013; Patil and Kant, 2014). In an additional step to establish the relationships among the barriers, the threshold value (ϕ) is calculated by adding one to two standard deviations to the mean of the total relation matrix (T) for effective decision making. The values above ϕ in the T matrix are recognized as significant relationships.

Table A2.2. The linguistic assessment data by experts

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	0	2	4	3	0	3	4	4	2	1	3
B2	0	0	0	2	0	3	3	4	2	2	2
B3	0	2	0	1	4	3	3	2	2	1	1
B4	1	4	2	0	3	4	4	4	2	2	3
B5	3	0	4	2	0	2	1	3	2	1	2
B6	0	0	4	1	0	0	2	3	0	3	3
B7	3	2	3	3	3	4	0	4	4	2	4
B8	0	3	3	2	2	4	3	0	3	3	4
B9	0	0	4	2	3	3	4	3	0	2	1
B10	0	2	4	3	3	3	3	4	3	0	3
B11	3	3	3	2	4	3	3	3	2	0	0

Table A2.3. Fuzzy assessment numbers

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	0.0,0.0,0.25	0.25,0.5,0.75	0.75,1.0,1.0	0.5,0.75,1.0	0.0,0.0,0.25	0.5,0.75,1.0	0.75,1.0,1.0	0.75,1.0,1.0	0.25,0.5,0.75	0.0,0.25,0.5	0.5,0.75,1.0
B2	0.0,0.0,0.25	0.0,0.0,0.25	0.0,0.0,0.25	0.25,0.5,0.75	0.0,0.0,0.25	0.5,0.75,1.0	0.5,0.75,1.0	0.75,1.0,1.0	0.5,0.75,1.0	0.25,0.5,0.75	0.25,0.5,0.75
B3	0.0,0.0,0.25	0.25,0.5,0.75	0.0,0.0,0.25	0.0,0.25,0.5	0.75,1.0,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.25,0.5,0.75	0.25,0.5,0.75	0.0,0.25,0.5	0.0,0.25,0.5
B4	0.0,0.25,0.5	0.75,1.0,1.0	0.25,0.5,0.75	0.0,0.0,0.25	0.5,0.75,1.0	0.75,1.0,1.0	0.75,1.0,1.0	0.75,1.0,1.0	0.25,0.5,0.75	0.25,0.5,0.75	0.5,0.75,1.0
B5	0.5,0.75,1.0	0.0,0.0,0.25	0.75,1.0,1.0	0.25,0.5,0.75	0.0,0.0,0.25	0.25,0.5,0.75	0.0,0.25,0.5	0.5,0.75,1.0	0.25,0.5,0.75	0.0,0.25,0.5	0.25,0.5,0.75
B6	0.0,0.0,0.25	0.0,0.0,0.25	0.75,1.0,1.0	0.0,0.25,0.5	0.0,0.0,0.25	0.0,0.0,0.25	0.25,0.5,0.75	0.5,0.75,1.0	0.0,0.0,0.25	0.5,0.75,1.0	0.5,0.75,1.0
B7	0.5,0.75,1.0	0.25,0.5,0.75	0.5,0.75,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.75,1.0,1.0	0.0,0.0,0.25	0.75,1.0,1.0	0.75,1.0,1.0	0.25,0.5,0.75	0.75,1.0,1.0
B8	0.0,0.0,0.25	0.5,0.75,1.0	0.5,0.75,1.0	0.25,0.5,0.75	0.25,0.5,0.75	0.75,1.0,1.0	0.5,0.75,1.0	0.0,0.0,0.25	0.5,0.75,1.0	0.5,0.75,1.0	0.75,1.0,1.0
B9	0.0,0.0,0.25	0.0,0.0,0.25	0.75,1.0,1.0	0.25,0.5,0.75	0.5,0.75,1.0	0.5,0.75,1.0	0.75,1.0,1.0	0.5,0.75,1.0	0.0,0.0,0.25	0.25,0.5,0.75	0.0,0.25,0.5
B10	0.0,0.0,0.25	0.25,0.5,0.75	0.75,1.0,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.75,1.0,1.0	0.5,0.75,1.0	0.0,0.0,0.25	0.5,0.75,1.0
B11	0.5,0.75,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.25,0.5,0.75	0.75,1.0,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.5,0.75,1.0	0.25,0.5,0.75	0.0,0.0,0.25	0.0,0.0,0.25

Table A2.4. The average fuzzy initial direct relation matrix for barriers

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	0.04	0.63	0.85	0.65	0.54	0.82	0.77	0.55	0.41	0.39	0.46
B2	0.31	0.04	0.23	0.63	0.15	0.72	0.59	0.79	0.54	0.7	0.47
B3	0.09	0.5	0.09	0.54	0.82	0.83	0.75	0.64	0.26	0.16	0.47
B4	0.47	0.21	0.39	0.04	0.56	0.75	0.79	0.78	0.22	0.29	0.3
B5	0.24	0.08	0.88	0.38	0.05	0.59	0.46	0.76	0.32	0.34	0.36
B6	0.42	0.29	0.74	0.3	0.33	0.04	0.64	0.76	0.11	0.33	0.43
B7	0.67	0.43	0.75	0.58	0.68	0.59	0.04	0.5	0.4	0.52	0.45
B8	0.18	0.69	0.64	0.12	0.32	0.69	0.7	0.04	0.37	0.47	0.46
B9	0.16	0.37	0.61	0.17	0.74	0.71	0.58	0.61	0.04	0.37	0.39
B10	0.22	0.61	0.47	0.06	0.13	0.69	0.28	0.87	0.33	0.04	0.4
B11	0.47	0.2	0.19	0.16	0.26	0.63	0.58	0.55	0.3	0.29	0.04

Table A2.5. Average fuzzy normalized initial direct relation matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	0.01	0.10	0.13	0.10	0.08	0.13	0.12	0.09	0.06	0.06	0.07
B2	0.05	0.01	0.03	0.10	0.02	0.11	0.09	0.12	0.08	0.11	0.07
B3	0.01	0.08	0.01	0.08	0.13	0.13	0.12	0.10	0.04	0.03	0.07
B4	0.07	0.03	0.06	0.01	0.09	0.12	0.12	0.12	0.03	0.05	0.05
B5	0.04	0.01	0.14	0.06	0.01	0.09	0.07	0.12	0.05	0.05	0.06
B6	0.07	0.04	0.12	0.05	0.05	0.01	0.10	0.12	0.02	0.05	0.07
B7	0.10	0.07	0.12	0.09	0.11	0.09	0.01	0.08	0.06	0.08	0.07
B8	0.03	0.11	0.10	0.02	0.05	0.11	0.11	0.01	0.06	0.07	0.07
B9	0.03	0.06	0.10	0.03	0.11	0.11	0.09	0.10	0.01	0.06	0.06
B10	0.03	0.10	0.07	0.01	0.02	0.11	0.04	0.13	0.05	0.01	0.06
B11	0.07	0.03	0.03	0.03	0.04	0.10	0.09	0.08	0.05	0.04	0.01

Table A2.6. The average total direct relationship matrix

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
B1	0.19	0.310	**0.44**	0.30	0.33	**0.48**	**0.44**	**0.44**	0.24	0.27	0.300
B2	0.20	0.200	0.30	0.25	0.23	**0.41**	0.36	**0.41**	0.23	0.28	0.260
B3	0.17	0.250	0.28	0.24	0.32	***0.42***	0.38	0.39	0.19	0.20	0.260
B4	0.22	0.210	0.32	0.17	0.28	**0.40**	0.38	0.39	0.17	0.21	0.230
B5	0.17	0.180	0.36	0.20	0.19	0.35	0.31	0.37	0.17	0.20	0.220
B6	0.20	0.210	0.34	0.19	0.23	0.28	0.34	0.30	0.15	0.20	0.230
B7	0.26	0.270	**0.40**	0.27	0.33	**0.42**	0.31	**0.40**	0.22	0.27	0.280
B8	0.17	0.270	0.33	0.17	0.24	0.38	0.35	0.28	0.19	0.23	0.250
B9	0.17	0.230	0.34	0.18	0.30	0.38	0.34	0.36	0.14	0.22	0.240
B10	0.1	0.240	0.28	0.14	0.18	0.35	0.26	0.36	0.17	0.15	0.220
B11	0.18	0.170	0.23	0.15	0.19	0.32	0.290	0.300	0.150	0.170	0.150

- Highlighted are above threshold value (0.4) for establishing significant relationships at (mean + 1.5 σ)

Table A2.7. (R+C) and (R-C) datasets of barriers

Barriers	**R**	**C**	**R+C**	**Rank**	**R-C**	**Rank**
B1	3.74	1.90	**5.63**	5	**1.84**	1
B2	3.12	2.38	**5.50**	6	**0.74**	4
B3	3.12	3.39	**6.51**	4	**-0.27**	9
B4	2.99	2.11	**5.10**	9	**0.87**	3
B5	2.73	2.63	**5.36**	7	**0.10**	6
B6	2.74	3.88	**6.61**	3	**-1.14**	11
B7	3.43	3.47	**6.90**	1	**-0.03**	7
B8	2.87	3.78	**6.65**	2	**-0.91**	10
B9	2.89	1.87	**4.76**	11	**1.02**	1
B10	2.52	2.25	**4.76**	11	**0.27**	5
B11	2.52	2.74	**5.25**	8	**-0.22**	8

Table A2.8. Weights assigned to six experts during sensitivity analysis

Runs	**Domain 1 (CFAs)**	**Domain 2 (CFS operator)**	**Domain 3 (Business Developme nt)**	**Domain 3 (Shipping Line)**	**Domain 4 (Consultant)**	**Domain 5 (Academician)**	**Domain 7 (DC managers)**
Run 1	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Run 2	0.1	0.4	0.1	0.1	0.1	0.1	0.1
Run 3	0.1	0.1	0.4	0.1	0.1	0.1	0.1
Run 4	0.1	0.1	0.1	0.4	0.1	0.1	0.1
Run 5	0.1	0.1	0.1	0.1	0.4	0.1	0.1
Run 6	0.1	0.1	0.1	0.1	0.1	0.4	0.1
Run 7	0.1	0.1	0.1	0.1	0.1	0.1	0.4