Assessing risk dimensions in dry port projects: prioritization, interdependence and heterogeneity

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Abstract

Purpose - We identify and further aggregate into dimensions, the most commonly engaged risk factors in dry port projects. Noting the importance of developing a multi-perspective of risk, we further assess the priority, interdependency, and heterogeneity of the identified risk dimensions.

Design/methodology/approach – We identify from the literature, 44 risk factors which are aggregated via Exploratory Factor Analysis (EFA) into eight major risk dimensions. We employ a Fuzzy-based DEMATEL relationship map to articulate various relationships among the risk dimensions.

Findings – '*Cost'* emerges as the most important risk influencing the success of dry ports project, followed by '*Location'*, '*Accessibility'*, '*Infrastructural'*, and '*Operational'*, which were also ranked prominently.

Originality/value - This study offers significant insight to the management of risk in dry port projects. By aggregating key risk factors into distinct dimensions, we develop a structured framework for effective risk assessment and management. Insights gleaned from the study extend globally as it serves as a concrete knowledge base to understand potential barriers to successful dry port projects.

Keywords: Dry port projects; Risk Identification; Priority; Interdependencies; Heterogeneity; Multi-stakeholder perspective.

1. Introduction

Dry ports are considered an essential node within the container shipping system, replicating several services performed at a seaport such as customs clearance, container storage and depot, cargo consolidation, de-consolidation, tracking services, among others (Roso, 2007; Kwateng *et al*., 2017; Rodrigues *et al*., 2021a). Dry ports are major infrastructure facilities. However, their development is often marred by numerous reported instances of dry port failure (see Alam, 2016; Jeevan, 2016; Catve, 2020; Rodrigues *et al*., 2024). These failures can occur at various stages of their development and operations (Rodrigues *et al*., 2024).

The development and operation of dry ports has been extensively discussed in previous literature (Roso and Lumsden, 2010; Khaslavskaya and Roso, 2020; Miraj *et al*., 2021). A major area of research interest in dry ports relates to risks (Nguyen *et al*., 2022). Here, we draw on Marshall and Ojiako (2013) to define 'risks' as "*…possible future states of the world, which will negatively impact exposed subject*" (p. 1227). Conversely, we drawn Rodrigues *et al*. (2024) to define 'risk factors' as "*…the broad associability of risk with causes and outcomes that are capturable together via quantitative research*" (p. 2). Risk management are actions that can be employed to mitigate the potential adverse consequences of risks (Marshall *et al*., 2019). Risk management comprises several stages, including 'identification', 'prioritization', 'analysis', 'evaluation', 'treatment', 'monitoring and control' (Bryde *et al*., 2023). Our present study focuses on risk identification and prioritization set within the context of dry ports.

Dry port operations literature, specifically related to risk is not fully developed. There are several reasons for this including its complex nature. One area of associated complexity relates to stakeholder heterogeneity and multiplicity. Several stakeholder groups are involved in dry port project operations (Jeevan *et al*., 2022). They include transporters, haulers, shippers, consignees, and forwarders. They not only perform very diverse roles (e.g., trucking, loading/unloading, shipping, payment and consolidating), but also have very different interest. Dry port stakeholder heterogeneitys inevitably will lead to varying perspectives on the relevance, priority and interdependence of risks (Marshall *et al*., 2019). This variance among stakeholders groups and individuals within each group is based on differences in knowledge, information, positions, interests, and values held by stakeholders (Machiels *et al*., 2023). To ensure coherent and effective risk management, it is necessary that a coincise understanding of relevant risks is developed. Categorizing risks into broader dimensions can facilitate their effective management (Khan *et al*., 2021). Considering the evidence that dry ports projects are highly susceptible to failures (Rodrigues *et al*., 2021a, 2024), we aim in this study to examine the priority, interdependency and heterogeneity of the most commonly engaged risk dimensions that may affect dry port project and, hence, their operational success. To address this aim, we present three research questions:

RQ1. How can risk factors be aggregated into dimensions in dry port projects?

RQ2. What are the interdependencies of commonly engaged risk dimensions in dry port project?

RQ3. How do multi-stakeholder heterogeneity perspectives influence the prioritization of risk dimensions in dry port projects?

The rest of the paper is structured as follows. Following this introduction, section 2 presents a brief overview of the literature of dry port project and risk management interdependency and heterogeneity. Section 3 describes our six-staged methodology. The results are presented in Section 4. We discuss the findings in Section 5 and conclude it in Section 6 with suggestions for future studies.

2. Literature review

Several prior studies have explored risk factors in dry ports. Some of these risks may be *internal*. For example, Dadvar *et al*. (2011) explored on regulations and customers' outlook, Lättilä *et al*. (2013) and Chang *et al*. (2019) focused on cost considerations, and van Nguyen *et al*. (2020) focused on geographic location decision. Other risks may be *external*. For example, Rodrigues *et al*. (2021a) highlights political risks, Ng *et al*. (2013) highlights the country regulatory landscape while Wang *et al*. (2022a) identifies the the dynamics of the seaport-hinterland system as external risks to dry port projects.

Prior studies specifically focused on risk management in dry port projects include Ciortescu and Pǎvǎlașcu (2012), who sought to explore of the theoretical foundations of risk assessment and management in dry port operations. Their study interest was on how risk management strategies serve as the foundation for efforts directed at enhancing the economic performance of dry ports. Wang *et al*. (2022b) focused on concurrent exploration of diversity risks in dry ports from the perspective of asymmetric risk behaviors of key dry port stakeholders. Wang *et al*. (2022b) was further extended in Wang *et al*. (2022c) with the development of a two-period model that takes into consideration asymmetric and ambigious stakeholder risk behaviors. Employing *fuzzy* analytic hierarchy process to develop a continuous risk matrix model, Hsu *et al*. (2023) undertook a risk assessment of work safety in dry ports. While the study by Wide *et al*. (2023) does not explicitly focus on risk management, it is relevant in that it explores how operational disruptions (which can be construed as a form of risk), in dry ports can be managed using with support of information. A scenario-based simulation model was developed with results showing that resource utilisation can be increased through the exploitation of relevant support information. A recent study that has examined risk management in dry port projects and operations is Rodrigues *et al*. (2024). Focusing on the interface between facility completion and commencement of the operations phase of dry ports (i.e., handover to the operations phase), they examine and prioritize transitionary risk at the handover stage of dry ports. Their study further highlights potential implications of transitory 'blind spots' that can arise at important moments of dry port handover.

3. Methodology

The six-staged methodology employed in this study is drawn from Chipulu *et al*. (2019) and Al-Mazrouie *et al*. (2021). We show the steps in Figure 1.

Figure 1: Diagrammatical representation of the research approach.

3.1 Stage 1: Study context

We commenced the study by setting out our study context which is set in Brazil. With a territory spanning approximately 8.5 million square kilometers, Brazil stands as the fifth largest country in the world in terms of land area. Brazil's coastline spans approximately 7,491 kilometers, ranking as the 16th longest globally (CIA, 2020). Brazil significantly contributes to global international trade and maritime cargo transportation (Rodrigues *et al*., 2023a, b), standing as the world's 20th largest economy in terms of container handling (UNCTAD, 2022).

In Brazil, there are currently 56 dry ports in operation, mainly situated in the southeast (29) and south (17) regions of the country. These dry ports are classified according to Roso (2007) as '*close'* (28), *'midrange'* (19), and '*long distance'* (9), with average distances from seaports by road being approximately 30 km, 248 km, and 831 km, respectively (Rodrigues *et al*., 2021b). Furthermore, 31 dry ports are city-based, 20 are seaport-based, and 5 are border-based. In terms of configuration, 10 of these dry ports are bimodal, 9 are connected by railway and one by barge, with the remaining 46 being unimodal. Dry ports in Brazil operate under concession or permission regimes, overseen by fiscal auditors of the Federal Revenue, enabling customs clearance and additional services within the same facility (Ng *et al*., 2013).

3.2 Stage 2: Identification of risk factors

Adopting an approach similar to that of Chipulu *et al*. (2019), and replicated in Al-Mazrouie *et al*. (2021) and Doyle *et al*. (2020), we identified the initial risk factors from the literature. The literature search was undertaken in the Scopus and Web of Science databases. We focused on articles published in English, Spanish and Portuguese between 2000 and 2019. We considered an approximate 20 year period sufficient to produce a relevant, yet comprehensive range of risk factors that will still be relevant. Keyword searches were conducted using '*Dry ports'*, and the following variants: '*Intermodal freight centre'*; '*Intermodal freight terminal'*; '*Freight nodal terminal*'; '*Inland port'* and '*Container freight station'*. The rationale for this selection being that they are all these variants known as associated with the dry port concept past (Rodrigue and Notteboom, 2022). We conducted additional searches for 'Dry port success', 'Dry port implementation', '*Dry port risk'*, '*Dry port project'*, '*Dry port operations'*, and '*Dry port readiness*'.

The search generated 254 publications. A total of 86 duplicate articles were subsequently removed. Next, we conducted separate appraisals of the remaining articles to ensure agreement on their suitability. We adopted a selection criteria described in more detail in Chipulu *et al*. (2019). This involved each of the co-authors estimating the extent to which they viewed the publications as relevant according to the study criteria based on assigned relevance; '*not relevant*' papers were assigned a value of '0'; '*perhaps relevant'* papers were assigned a value of '1' and '*definitely relevant'* were assigned a value of '2'. Total values were summated, with papers of value of either '0' or '1' being eliminated (90 publications were eliminated). This left us with 78 articles.

Next, a full and comprehensive collation (from a detailed review of each of the publications) of identified risk factors from the selected 78 articles was undertaken, and then they were organized into risk dimensions. These dimensions served as the foundation for this risk typology of dry port project. In terms of organizing the risk factors from the publications into themes, the process followed was similar to that adopted during the database filtering. Each of the 78 publications was reviewed by the co-authors of this study, ensuring that all risk factors derived from each paper were identified and recorded.

We then examined face validity of the identified risk factors highlighted in the 78 articles. Using responses of '0' for '*not at all'*, '1' for '*somewhat matches'* and '2' for '*very closely matches*', the identified risk factors were grouped thematically. In sum, from the 44 risk factors identified, eight dimensions were generated, namely: '*Cost*', '*Location*', '*Infrastructure*', '*Accessibility*', '*Operational*', '*Economic*', '*Political and Social*', and '*Environment*'.

3.3 Stage 3: Instrument development and pilot test

A survey comprising of three sets of closed questions was then developed using Google Forms. Apart from respondent biographical information, respondents were presented with 52 questions against a 5-point Likert-type scale ranging from '0' ('*very low importance*') to '5' ('*very high importance*'). Two set of pilot exercises were conducted in March 2020. One with two senior managers with relevant experience in dry port operations. This was followed by a pilot exercise conducted with 13 doctoral and master's candidates at the Universidade Federal de Pernambuco, Recife (Brazil) were then contacted to test the reliability and validity characteristics of the research instrument.

3.4 Stage 4: Data collection

Following the completion of the instrument development piloting, data were collected from three stakeholder groups involved in dry port operations in Brazil; (i) '*Dry port entities*' (DPEs), (ii) '*Customers*', which includes shippers and forwarders, and (iii) the 'Federal Revenue Superintendence' (*FRS*), a government entity regulating dry port projects and operations in Brazil. Data was collected April 2020 and July 2020. For the *DPEs*, all 38 companies managing the 56 dry ports in Brazil were contacted. From this group, we obtained 34 valid responses. For the '*Customers*' group, noting that there are no dry port customer databases in Brazil, we contacted shippers and consignees from a database obtained from the CIB (2016) and Brazilian Suppliers (2020). This database contained the details of 8556 companies. From this database, we obtained 42 responses. We subsequently contacted the 10 *FRS* superintendence offices receiving responses from 7 offices responses. Table 1 provides an overview of the sample.

Table 1: Sample characteristics

3.5 Stage 5: Data analysis

Data analysis was conducted in two steps. We first sought to aggregated the 44 risk factors into 8 risk dimensions using Exploratory Factor Analysis (EFA). Specifically, we conducted 8 separate

EFAs using FACTOR 10.10.03 software. The model was iteratively adjusted until parameter fitting was appropriate to demonstrate validity and reliability. Each EFA evaluated unidimensionality and factor loading, categorizing the 44 factors into eight risk dimensions. Using fuzzy-based DEMATEL, was then employed to analyze the data, elucidating the priority, heterogeneity, and interdependency of risk dimensions. The essence of this process is to capture the practical rationality and actions of the involved stakeholders in their preferred terms. This stage of the study involves constructing the resulting causal diagram risk dimensions ranking, considering the three major stakeholder perspectives that contribute to the input of practical rationalities. Based on the results from fuzzy-based DEMATEL, the risk dimensions in dry port project were ranked, and their heterogeneity and interdependency were identified. The phases for applying the fuzzy-based DEMATEL method are outlined in the following section.

3.5.1 fuzzy-based DEMATEL

We commenced on the assumption that the membership functions have a triangular shape (Mangla *et al*., 2018). Triangular fuzzy numbers use a triplet (a, b, c) where a, b, and c represent the smallest, most promising, and largest possible values, making it easier to model and understand uncertainty in fuzzy logic applications (Khompatraporn and Somboonwiwat, 2017). Hence, we utilized triangular fuzzy numbers to handle fuzzy linguistic values in the influence scoring process of the DEMATEL method. The definition of triangular fuzzy numbers is outlined in Table 2.

Table 2: Fuzzy linguistic scale

Our use of fuzzy-based DEMATEL method is based on the five staged as set out in Khompatraporn and Somboonwiwat (2017). Phase 1 evaluates the relationships between risk dimensions using a fuzzy linguistic scale. Respondents were presented with a linguistic judgments survey as asked to evaluate the degree to which risk dimension i is likely to affect dimension j. The resulting influence scores were then converted into fuzzy linguistic values using triangular fuzzy numbers, as depicted in Table 2.

We then (Phase 2) established the group direct-influence fuzzy matrix $\tilde{Z} = [\tilde{z}_{ij}]_{nxn}$. Through linguistics judgments converted into fuzzy values, a fuzzy pair-wise comparison matrix

$\tilde{Z}_k$ was consntructed for each expert. Subsequently, individual matrices $\tilde{Z}_k = (k = 1,2,...,l)$ were created. The group direct-influence fuzzy matrix $\tilde{Z} = [\tilde{z}_{ij}]_{n\times n}$ was then calculated by aggregating all the experts' judgments. In this matrix, $\tilde{z}_{ii}$ is represented as a triangular fuzzy number in the form (0,0,0), and $\tilde{z}_{ij}$ is determined as follows:

$$\tilde{z}_{ij} = (\tilde{z}_{ij1}, \tilde{z}_{ij2}, \tilde{z}_{ij3}) = \frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij}^{k} = \left(\frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij1}^{k}, \frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij2}^{k}, \frac{1}{l}\sum_{k=1}^{l} \tilde{z}_{ij3}^{k}\right)$$

We then (Phase 3) generated the normalized direct-influence fuzzy matrix $\tilde{X}$ by:

$\tilde{X} = \frac{\tilde{Z}}{r}$,

where

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & \tilde{x}_{nn} \end{bmatrix},$$

$$r = \max_{i,j}\left[\max_{1\le i\le n}\left(\sum_{j=1}^{n} z_{ij3}\right), \max_{1\le j\le n}\left(\sum_{i=1}^{n} z_{ij3}\right)\right]$$

Phase 4 obtains the total-influence fuzzy matrix $\tilde{T} = [\tilde{t}_{ij}]_{n\times n}$ by:

$$\tilde{T} = \lim_{h\to\infty}\left(\tilde{X}^1 + \tilde{X}^2 + \dots + \tilde{X}^h\right) = \tilde{X}\left(1 - \tilde{X}\right)^{-1}$$

when

$$\lim_{h\to\infty} \tilde{X}^h = 0$$

Here $\tilde{t}_{ij} = (\tilde{t}_{ij1}, \tilde{t}_{ij2}, \tilde{t}_{ij3})$ and

$$T_1 = [\tilde{t}_{ij1}]_{n\times n} = X_1(I - X_1)^{-1}$$

$$T_2 = [\tilde{t}_{ij2}]_{n\times n} = X_2(I - X_2)^{-1}$$

$$T_3 = [\tilde{t}_{ij2}]_{n\times n} = X_3(I - X_3)^{-1}$$

in which $X_1 = [x_{ij1}]_{n \times n}$, $X_2 = [x_{ij2}]_{n \times n}$, $X_3 = [x_{ij3}]_{n \times n}$, and I is an identity matrix. The elements of triangular fuzzy numbers in the matrix $\tilde{T}$ are divided into T_1, T_2, and T_3, and $T_1 \prec T_2 \prec T_3$, when $x_{ij1} < x_{ij2} < x_{ij3}$ for any $i,j \in \{1,2,\ldots,n\}$.

Lastly, in we produced (Phase 5) a Influential Relation Map (IRM). After obtaining the total-influence matrix $\tilde{T}$, the $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i - \tilde{C}_i$ variables are calculated, where $\tilde{R}_i$ and $\tilde{C}_i$ are the sum of rows and the sum of columns, respectively, within the matrix, $\tilde{T}$. Subsequently, the fuzzy numbers of $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i - \tilde{C}_i$ are converted into crisp values using the defuzzification method CFCS, as follows (Opricovic and Tzeng, 2003).

$$\gamma_i = L + \Delta \times \frac{(m_i - L) \times (\Delta + u_i - m_i)^2 \times (R - l_i) + (u_i - L)^2 \times (\Delta + m_i - l_i)^2}{(\Delta + m_i - l_i) \times (\Delta + u_i - m_i)^2 \times (R - l_i) + (u_i - L) \times (\Delta + m_i - l_i)^2 \times (\Delta + u_i - m_i)}$$

where y_i denotes the defuzzified value of the fuzzy number $\tilde{y}_i = (l_i, m_i, u_i)$, $L = min\, l_i$, $R = \max u_i$, $\Delta = R - L$.

To complete the fuzzy-based DEMATEL, the IRM is drawn by mapping the ordered pairs of $(\tilde{R}_i + \tilde{C}_i)^{def}$ as a horizontal axis vector named 'Prominence', and $(\tilde{R}_i - \tilde{C}_i)^{def}$ as a vertical axis vector named 'Relation'.

Once the total-influence fuzzy matrix $\tilde{T}$ was obtained, the results were interpreted from the sums of rows ($\tilde{R}$) and columns ($\tilde{C}$) within the total-influence matrix. More specifically, the fuzzy 'prominence' degree ($\tilde{R} + \tilde{C}$) was utilized to express the strength of influences that are given and received for each dimension in the system. Similarly, the 'relation' degree ($\tilde{R} - \tilde{C}$) was utilized to express the net effect that each risk dimension exerts upon the system. Then, the fuzzy numbers were converted into crisp values ($R + C$) and ($R - C$) by the defuzzification method detailed above. If ($R - C$) is positive, then this indicates that the risk dimension has a net influence on the other dimensions and can therefore be categorized into a 'cause' group. Conversely, if ($R - C$) is negative, then this suggests that the risk dimension is being influenced by the other dimensions as a whole and should therefore be categorized into an 'effect' group instead (Si *et al*., 2018).

4. Results

4.1 Risk identification

Identification of the pertinent risk factors based on a literature survey resulted in 44 risk factors (see Table 3). For their validation, EFA was conducted across eight structures, each segregated by dimensions. Parallel Analysis (PA) was utilized to determine the number of dimensions extracted, a method recommended over the eigenvalues-greater-than-1-rule (Timmerman and Lorenzo-Seva, 2011). Ensuring the suitability of the survey data, the Kaiser-Meyer Olkin (KMO) measure for sampling adequacy and the Bartlett's Test of Sphericity for assessing the suitability of using EFA for data reduction resulted in values higher than 0.5 and p-value < 0.05, respectively, indicating the adequacy of the sample size (Field, 2013).

Table 3: EFA results

The first risk dimension identified as representing a meaningful category for assessing project outcomes was '*Cost'*. As a major risk in dry port projects, cost is important because of its role in economic decisions (i.e., evaluation) associated with dry ports. Costs also serves as a major driver for value creation, ensuring that dry port projects are not only completed on time, but are fully aligned with strategic goals. The second risk dimension identified was '*Location'*. Viewed geographically as an intermodal hub or platform, the success of dry ports projects also face risks in terms of their physical location. Wang *et al*. (2017) for example opines that location is often the chief determinant of competitive success of dry ports. In particular, a well-located dry port will offer a number of advantages including cargo volume optimization.

The third risk dimension identified was '*Infrastructure'*. Infrastructure is arguably a key driver for cargo handling effectiveness and efficiency, especially considering the importance of congestion avoidance for dry port operation effectiveness (Chang *et al*., 2019). The fourth risk dimension identified was '*Accessibility'*. It focuses on how easily different inland transport infrastructures can be connected to the dry port (Nguyen and Notteboom, 2016). Accessibility can be measurable by some combination of distance to the nearest intermodal exit, average daily traffic, and level of service. the functioning and development of most dry ports around the world (Jeevan *et al*., 2017). We also identified the '*Operational'* as a risk dimention (fifth). These are risk associated with defective events, policies, processes and systems that serve to disrupt dry port operations. 'Economic' was also identified as a risk dimension (sixth). These are risks which touch upon potential adverse changes in economic circumstances. They are important because dry ports are of significant national economic importance (Khaslavskaya and Roso, 2020).

We identified as the seventh dimension '*Political and social'* imperatives. These are risks that are predominantly associated with changes in national power structures of government. Political risks arise primarily because dry ports serve a significant economic as major trade gateways. Dry ports can also serve a social role, creating employment opportunities which are critical for economic and social development (Xiahou *et al*., 2018). The final risk dimension was '*Environment'.* Dry ports and railway connections offer significant environmental benefits, particularly in reducing congestion and associated carbon emissions, making them a critical component of the sustainability efforts of any country (Varese *et al*., 2022; Beyene *et al*., 2023).

4.2 Risk interdependency, heterogeneity, and priority

On the basis of the fuzzy-based DEMATEL, the total effects for risk dimensions, as ordered by (i) '*DPE'*, (ii) '*Customers',* (iii) '*FRS'*, and (iv) aggregated by all stakeholders is shown in Table 4.

Table 4: Total effects given and received by risk dimensions

The total effect from the '*DPE'* perspective indicates that D1, D3, D2, and D5 were the most prominent effect dimensions, and D6, D7, and D8 were classified as cause dimensions. From the '*Customers'* perspective, the most prominent effect dimensions are D1, D2, D5, and D4, whith D7 and D8 emerging as cause dimensions. Regarding '*FRS'* perspective, D1, D3, D5, and D4 are the most prominent effect dimensions associated with dry ports projects, while D6 and D7 are categorized as cause dimensions. The results points to some incongruences in the risk perception among stakeholders. To summarize the results for all three groups of stakeholders, the total-influence fuzzy matrix $\tilde{T}$ was aggregated, highlighting D1, D3, D5, and D2 as the most prominent effect dimensions for dry ports projects. However, these dimensions are also affected by D6, D7, and D8, classified as key cause dimensions.

The result of the net influence matrices for each stakeholder group is shown in Table 5. These matrices illustrate the influences of risk dimensions listed by row relative to those listed by column. Positive values indicate influences of row dimensions on column dimensions, while negative values indicate influences in the reverse direction. Values highlighted in grey indicate influence above the net influence value averages, which are 0.029 for DPE, 0.042 for 'Customer', 0.023 for FRS, and 0.0305 for the 'Aggregated' result.

Table 5: Net influence matrices by each stakeholder group

Based on our analysis of the Influential Relation Map (IRM) which sought to map the dataset of prominence $(\mathrm{R}+\mathrm{C})$ and relation $(\mathrm{R}-\mathrm{C})$, Figures 2 (a), (b), (c), and (d) present the IRMs for '*DPE*', '*Customers*', '*FRS*', and '*aggregated*', respectively, dividing the graph into four quadrants by the mean of $(\mathrm{R}+\mathrm{C})$ and $(\mathrm{R}-\mathrm{C})$:

(i) Risk dimensions in quadrant 'I' are identifiable as core dimensions since they have high 'prominence' and 'relation' significance.

(ii) Risk dimensions in quadrant 'II' are identifiable as driving dimensions because they have low 'prominence' but high 'relation' significance.

(iii) Risk dimensions in quadrant 'III' are low in both 'prominence' and 'relation' significance and are therefore relatively disconnected from the mapped system.

(iv) Risk dimensions in quadrant 'IV' have high 'prominence' but low 'relation' significance, which means they are impacted by relatively heterogeneous dimensions and therefore cannot be directly improved through specific and focused managerial interventions (Si *et al*., 2018).

Figure 2: Influential Relation Map

To draw the net influence on IRM, represented by the blue arrows, twice the average net influence values were used as the threshold for building each net influence matrix: 0.057 for '*DPE*', 0.084 for '*Customer*', 0.046 for '*FRS*', and 0.061 for '*aggregated*'. This representation enriches the IRM visualization by highlighting the dimensions that most affect others on the net. It is intended to emphasize what should weigh most on the minds of practitioners. Accordingly, Figure 2 summarizes the prominence and relation levels, as well as the most important net influences, for each risk dimension (addressing *RQ2*).

The IRM also offers a visualization of the heterogeneity of risk perspective among the different groups of stakeholders (addressing RQ3). Figure 2(a) and 3(b) unveil similarities in '*prominence'* and '*relation'* between the *DPE* and *Customers* stakeholder groups, showcasing how '*Political and Social' and 'Environment*' primarily impact '*Cost'*. Additionally, dimensions in the quadrant IV indicate those dimensions influenced by the others, emphasizing the for a systematic approach to risk assessment.

Table 6 demonstrates that, in terms of prominence, the '*DPE'* stakeholder group indentifies '*Cost'*, '*Infrastructure'*, and '*Location'* as the most important dimensions, respectively. At the same time The '*FRS'* stakeholder group also prioritizes '*Cost'* and '*Infrastructure'*, while the '*Customers'* group emphasize '*Location'* as the second most important dimension. From an aggregated perspective, the '*Operational'* dimension emerges as the third most important risk dimension.

Table 6: Prioritization of risk dimensions by stakeholders groups

5. Discussion

Our study commenced with the identification of 44 dry port risk factors that were subsequently aggregated into eight primary latent risk dimensions (*RQ1*). Awareness of these identified risk factors present a level of granularity that will aid different aspects of risk management, especially its analysis, evaluation, and treatment. Drawing from Marshall *et al*. (2019), these aggregated risk dimensions may serve as the first major step towards developing a comprehensive template for concrete risk knowledge on dry ports. Reducing the risk factors into dimensions will prove further important to relevant decision making. In particular, it enables more straightforward understanding of risk patterns, allowing managers to develop deeper insights and make informed decisions based on stakeholder expectations and interests (Bjørnsen and Aven, 2019).

Finding '*Cost'* as the most significant risk dimension for dry port projects is consistent with existing dry port literature (Lirn and Wong, 2013; Chang *et al*., 2019). It is also consistent with the wider literature on major infrastructure projects (e.g, Caffieri *et al*., 2018). With an appreciation that costs is the core foundation of economic thinking, featuring as a key element of assessment of economic outcomes, this finding serves to reiterate the decision to develop and operate a dry port must be one not taken lightly. In further finding *'Cost'* as most influenced by other dimensions, particularly the '*Economic'*, '*Political and Social*', and '*Environment'* dimensions, our finding serves as a restatement of its central role in economic, political/social and environmental ways of thinking about their development and operations (*RQ2*).

The dynamic nature of the risk dimensions emphasizes their heterogeneity based on the perspectives of different stakeholders. Whether these stakeholders share common goals or have conflicting interests, it is evident that the interconnectedness of the risk dimensions presents an opportunity for collaboration. By recognizing these interdependencies, stakeholders can foster a cooperative environment, wherein the impact of each risk dimension on others is carefully assessed and managed. Such collaboration not only enhances the value proposition for all involved parties but also serves to ensure the success of dry port projects. This may be pertinent as the study findings suggests congruences and divergences in the perception of risk among the different stakeholder groups (*RQ3*).

For example, congruence was observed between '*Dry port entities'* and '*Customers'* groups. Considering '*Customers'* as shippers and consignees who import and export containerized cargo, and '*Dry port entities'* as logistical operators that offer services to facilitate this process, congruence in risk perception may help build a collaborative environment for dry port project development. Despite the 'Federal Revenue Superintendence*'* (*FRS*) being associated with divergent perspectives, as a regulatory agent, this information may also prove useful in preventing development and eventual operational failures by communicating the priorities that should be considered, thus preventing regulatory problems during ongoing operations.

Taking all the above into consideration, the identified risk factors and dimensions may serve as the basis for re-channelling risk management efforts towards more proactivity in exploring a complex risk ecosystem that is typically the case in dry ports. Herein, we opine that the transfer of what is in effect abstract risk knowledge (i.e., the knowledge we have about dry port risks as gleaned from literature), into concerte risk knowledge (i.e., the knowledge we have about dry port risks as gleaned from our empirical study) enhances our ability to develop a comprehensive risk-management template that is capable for superior capability when engaging in the threats dry ports are most susceptible to.

Of particular relevance is our willingness to dispel with what is a dominant traditional approach to previous studies looking to examine dry port risks. Aside from stakeholder heterogeneity and multiplicity, the reality is that risk management in dry ports can be further complexified by the peculiarities of risks. In practice, most risk dimensions are interdependent (Li *et al*., 2019). However, while conventional risk management still widely assumes that risks are independent, the lack of ability to capture the nature of direct and indirect relationships between risks factors and dimensions potentially limits risk management efficacy. While we acknowledge that reliability practices may already be engaging in enabling risk identification and prioritization, surfacing these risk interdependencies in a timeously and grounded in everyday dry port practice, allows for more aptness to effective strategy formulation and the development eventual successful operations of dry ports in a manner which will aid managers mitigate and manage relevant risks.

6. Conclusions

Our study makes contribution to management and theory. In terms of management practice, our study offers valuable insights on risk factors and dimensions most commonly engaged in dry port projects that transcend Brazilian boundaries, particularly in the global south. Brazil's dry port challenges mirrors some of those being experienced by countries such as China, South Africa and the United Arab Emirates who have a keen interest in expanding their dry port footprint. On these basis, our findings has potential to resonates across these countries. Insights gleaned from our study can also be leveraged to potentially offers a broad roadmap for effective risk management across the domain of multi-stakeholder infrastructure projects. By systematically analyzing risk factors, aggregating them into key dimensions, and prioritizing them based on stakeholder perspectives, project managers working on these projects can potentially enhance decision-making processes, allocate resources more efficiently and drive more collaborative risk management efforts.

Our study also makes theoretical contributions to the field of risk management, particularly in the context of dry ports. Firstly, by elucidating the interdependencies among various risk dimensions, we have contributed to advance understanding of the complex stakeholder dynamics inherent in multi-stakeholder infrastructure projects. Out study also make a contribution to the broader literature on stakeholder literature by underscoring the importance of considering diverse stakeholder perspectives in risk prioritization and management.

As expected our study has some limitations. First, we did not consider probability and impact in the analysis of risk dimensions. This may have implications for the accuracy and comprehensiveness of the risk assessment. Furthermore, the study is subject to limitations associated with the methodologies employed, particularly EFA and DEMATEL. For example, EFA, while useful for identifying underlying factors within a dataset, relies on subjective interpretation and may overlook certain nuances or interrelationships among variables. Similarly, DEMATEL, despite its utility in exploring causal relationships among factors, may be influenced by the biases of the experts involved in the process and may not capture the full complexity of stakeholder interactions and risk interdependencies in dry port projects. Additionally, it is worth noting that variety of risk events that may reflect the risk factors were not listed in the study, with their inclusion varying according to the specifics of each case. Therefore, the reliance on these methodologies suggests the need for caution in interpreting the results and underscores the importance of exploring alternative approaches to enhance the robustness of risk assessment in the context of dry port projects.

Finally, as a call for future research, there is a critical need to focus on designing and exploring risk category architectures with efficiency in mind, particularly for collaborative project risk management in dry ports. Perhaps most importantly, there is a potential for future studies with an expanded stakeholder grouping. While we had adopted a stakeholder grouping which resonates with prior studies, is may be beneficial to undertake future studies with a more granular grouping of stakeholders. Future studies may also be undertaken in a comparative manner that is able to explore potential similarities and differences in risk factor and dimensionality. Such cross-country comparisons will enable more valuable insights into the effectiveness of different risk identification, prioritization and management strategies.

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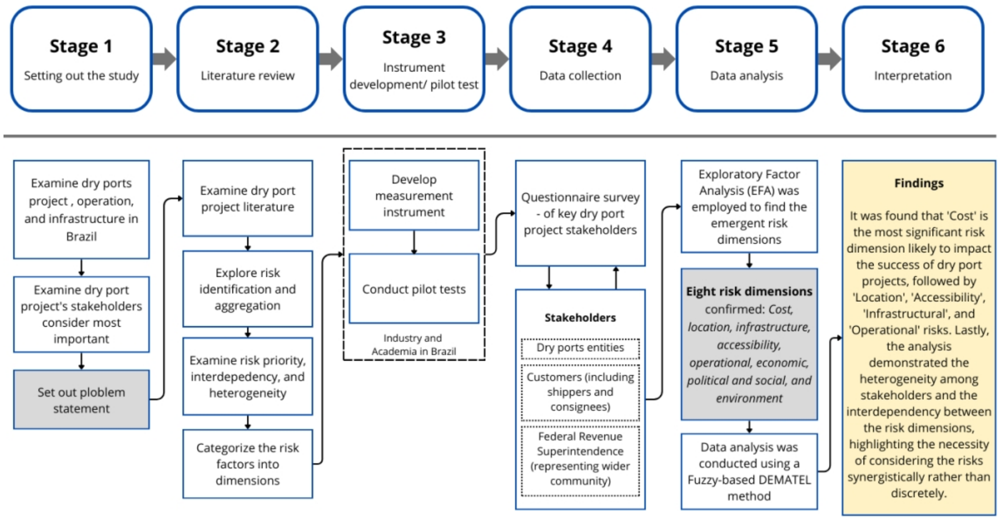

Figure 1: Diagrammatical representation of the research approach.

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Table 1: Sample characteristics

Sample Characteristic		Dry Port Entities	Customer	FRS	Total
Sample	Participants	31*	39	7	77
	Population	38	-	10	-
Actuation zone	Southeast	18	20**	3	41
	South	7	31**	-	38
	Northeast	6	12**	2	20
	Middle-west	-	10*	1	11
	North	-	9*	1	10
Gender	Male	28	34	6	68
	Female	3	5	1	9
Age	More than 50 years	12	7	2	21
	Between 40-49 years	7	17	4	28
	Between 30-39 years	11	10	1	22
	Between 20-29 years	1	5	-	6
Experience	More than 20 years	14	16	4	34
	Between 15-19 years	8	8	-	16
	Between 10-14 years	3	6	2	11
	Between 5-9 years	3	4	1	8
	Between 0-4 years	3	5	-	8
Position	Owner	-	8	-	8
	CEO/Director	8	6	-	14
	Superintendent	-	-	7	7
	Senior Manager	17	10	-	27
	Specialist	6	15	-	21
Educational Level	Post Graduate	20	22	3	45
	Graduate	9	17	4	30
	Other	2	-	-	2

*31 participants from 26 dry port entities
**Customers act in many regions of the country

Table 2: Fuzzy linguistic scale

Linguistic description	Influence score	Triangular fuzzy numbers
No influence	0	(0, 0, 0.25)
Low influence	1	(0, 0.25, 0.5)
Medium influence	2	(0.25, 0.5, 0.75)
High influence	3	(0.5, 0.75, 1)
Very high influence	4	(0.75, 1, 1)

Table 3: EFA results

Code	Dimensions/Factors	Factor loadings	Dimensions (PA)	KMO	Bartlett's sphericity Chi-square	df	p-value	Explained variance	Cronbach's alpha
D1	**Cost**		1	0,730	209,6	10	0,000	65,39%	0,804
F1	Facility cost	0,510							
F2	Transportation cost	0,691							
F3	Storage cost	0,937							
F4	Additional services cost	0,884							
F5	Congestion cost	0,638							
D2	**Location**		1	0,790	100,4	6	0,000	77,40%	0,757
F6	Demand for dry port's services (Excluded in run 2)	0,496							
F7	Distance between dry port and customers	0,745							
F8	Distance between dry port and seaport	0,613							
F9	Proximity with other logistic facilities	0,753							
F10	Size of hinterland population (Excluded in run 1)	0,463							
F11	Cargo transportation time	0,749							
D3	**Infrastructure**		1	0,678	919,1	6	0,000	82,72%	0,827
F12	Dry ports' total area	0,834							
F13	Dry ports' yard capacity	1,014							
F14	Dry ports' warehouse capacity	0,771							
F15	Dry ports' expansion capacity	0,629							
F16	Multimodal infrastructure (Excluded in run 2)	0,378							
F17	Equipment infrastructure (Excluded in run 1)	0,378							
D4	**Accessibility**		1	0,793	431,4	28	0,000	63,24%	0,860
F18	Accessibility to airports	0,777							
F19	Accessibility to seaports	0,875							
F20	Accessibility to railways	0,665							
F21	Accessibility to highways	0,700							
F22	Accessibility to other facilities	0,731							
F23	Accessibility to customers	0,606							
F24	Transportation capacity between dry port and Seaport	0,847							
F25	Quality of network transportation infrastructure	0,763							
D5	**Operational**		1	0,810	221,6	15	0,000	74,33%	0,798
F26	Set of operational services offered	0,789							
F27	Container handling capacity (per day)	0,745							
F28	Information and technology system	0,596							
F29	Operational execution time	0,806							
F30	Cargo security and monitoring	0,742							
F31	Dry port's occupation (yard and warehouse)	0,689							
D6	**Economic**		1	0,781	126,6	6	0,000	78,63%	0,804
F32	Gross Domestic Product (GDP) rate	0,848							
F33	Dollar rate	0,646							
F34	Trade market (export and import)	0,770							
F35	Purchasing power of hinterland population	0,735							
D7	**Political and Social**		1	0,799	159,6	10	0,000	70,56%	0,788
F36	Customs' rules	0,582							
F37	Job creation	0,750							
F38	Government financial incentive	0,757							
F39	Political and business environment	0,861							
F40	Bureaucracy for opening new companies and dry ports	0,653							
D8	**Environment**		1	0,799	243,7	6	0,000	86,01%	0,891
F41	Urban and environmental impact due to dry port facility	0,812							
F42	Noise reduction and visual impact in seaport cities	0,916							
F43	Environmental politics	0,899							
F44	Reduction of congestion and CO2 emissions	0,845							

Table 4: Total effects given and received by risk dimensions

i) Dry Port Entities (DPE)

Dimension	Code	Fuzzy R	Fuzzy C	Fuzzy R+C	Fuzzy R-C	Crisp R+C	Crisp R-C	Role
Cost	*D1*	(0,83; 2,24; 9,74)	(0,99; 2,52; 10,26)	(1,83; 4,76; 20,01)	(-9,43; -0,28; 8,74)	7,19	-0,31	Effect
Location	*D2*	(0,80; 2,19; 9,54)	(0,85; 2,26; 9,78)	(1,66; 4,45; 19,33)	(-8,97; -0,07; 8,69)	6,86	-0,14	Effect
Infrastructural	*D3*	(0,82; 2,21; 9,61)	(0,85; 2,27; 9,77)	(1,67; 4,48; 19,38)	(-8,95; -0,05; 8,76)	6,89	-0,11	Effect
Accessibility	*D4*	(0,76; 2,10; 9,32)	(0,76; 2,11; 9,49)	(1,53; 4,21; 18,81)	(-8,72; -0,01; 8,55)	6,61	-0,08	Effect
Operational	*D5*	(0,75; 2,07; 9,23)	(0,82; 2,23; 9,65)	(1,58; 4,30; 18,88)	(-8,89; -0,15; 8,40)	6,68	-0,21	Effect
Economic	*D6*	(0,79; 2,15; 9,47)	(0,71; 2,03; 9,24)	(1,51; 4,18; 18,72)	(-8,44; 0,12; 8,76)	6,57	0,06	Cause
Political and Social	*D7*	(0,61; 1,83; 8,80)	(0,49; 1,62; 8,23)	(1,11; 3,46; 17,04)	(-7,61; 0,21; 8,31)	5,76	0,17	Cause
Environment	*D8*	(0,61; 1,85; 8,86)	(0,49; 1,60; 8,17)	(1,10; 3,45; 17,03)	(-7,55; 0,24; 8,36)	5,75	0,21	Cause

ii) Customers

Dimension	Code	Fuzzy R	Fuzzy C	Fuzzy R+C	Fuzzy R-C	Crisp R+C	Crisp R-C	Role
Cost	*D1*	(0,87; 2,50; 12,93)	(1,06; 2,86; 13,78)	(1,93; 5,37; 26,71)	(-12,9; -0,35; 11,86)	8,86	-0,4	Effect
Location	*D2*	(0,85; 2,47; 12,91)	(0,94; 2,64; 13,45)	(1,80; 5,12; 26,37)	(-12,6; -0,16; 11,96)	8,61	-0,24	Effect
Infrastructural	*D3*	(0,84; 2,46; 12,82)	(0,91; 2,59; 13,41)	(1,76; 5,06; 26,24)	(-12,5; -0,12; 11,90)	8,55	-0,22	Effect
Accessibility	*D4*	(0,84; 2,45; 12,93)	(0,83; 2,43; 12,89)	(1,68; 4,88; 25,82)	(-12,0; 0,02; 12,10)	8,35	-0,03	Effect
Operational	*D5*	(0,87; 2,51; 13,11)	(0,88; 2,54; 13,24)	(1,76; 5,05; 26,36)	(-12,3; -0,03; 12,22)	8,56	-0,09	Effect
Economic	*D6*	(0,84; 2,45; 12,94)	(0,83; 2,44; 13,01)	(1,67; 4,89; 25,95)	(-12,1; 0,01; 12,11)	8,38	-0,06	Effect
Political and Social	*D7*	(0,76; 2,31; 12,54)	(0,57; 1,94; 11,49)	(1,34; 4,25; 24,03)	(-10,7; 0,36; 11,97)	7,59	0,34	Cause
Environment	*D8*	(0,75; 2,26; 12,49)	(0,61; 1,99; 11,38)	(1,36; 4,25; 23,88)	(-10,6; 0,27; 11,88)	7,58	0,29	Cause

iii) Federal Revenue Superintendence (FRS)

Dimension	Code	Fuzzy R	Fuzzy C	Fuzzy R+C	Fuzzy R-C	Crispy R+C	Crispy R-C	Role
Cost	*D1*	(0,52; 1,35; 6,99)	(0,64; 1,57; 7,42)	(1,16; 2,92; 14,41)	(-6,89; -0,21; 6,35)	4,8	-0,22	Effect
Location	*D2*	(0,38; 1,16; 6,48)	(0,47; 1,30; 6,80)	(0,86; 2,47; 13,28)	(-6,41; -0,14; 6,00)	4,28	-0,16	Effect
Infrastructural	*D3*	(0,58; 1,44; 7,15)	(0,54; 1,40; 7,09)	(1,12; 2,84; 14,24)	(-6,50; 0,04; 6,61)	4,72	0,01	Cause
Accessibility	*D4*	(0,42; 1,20; 6,43)	(0,47; 1,30; 6,85)	(0,90; 2,51; 13,28)	(-6,42; -0,10; 5,95)	4,32	-0,15	Effect
Operational	*D5*	(0,51; 1,34; 6,88)	(0,53; 1,39; 7,11)	(1,05; 2,73; 14,00)	(-6,60; -0,05; 6,34)	4,6	-0,09	Effect
Economic	*D6*	(0,38; 1,13; 6,27)	(0,28; 0,99; 5,99)	(0,66; 2,12; 12,26)	(-5,60; 0,14; 5,99)	3,86	0,12	Cause
Political and Social	*D7*	(0,26; 1,01; 6,02)	(0,09; 0,67; 4,97)	(0,36; 1,68; 10,99)	(-4,70; 0,33; 5,92)	3,3	0,36	Cause
Environment	*D8*	(0,10; 0,70; 5,08)	(0,13; 0,70; 5,07)	(0,23; 1,41; 10,16)	(-4,97; 0,00; 4,95)	2,94	-0,02	Effect

iv) Dimensions Aggregated

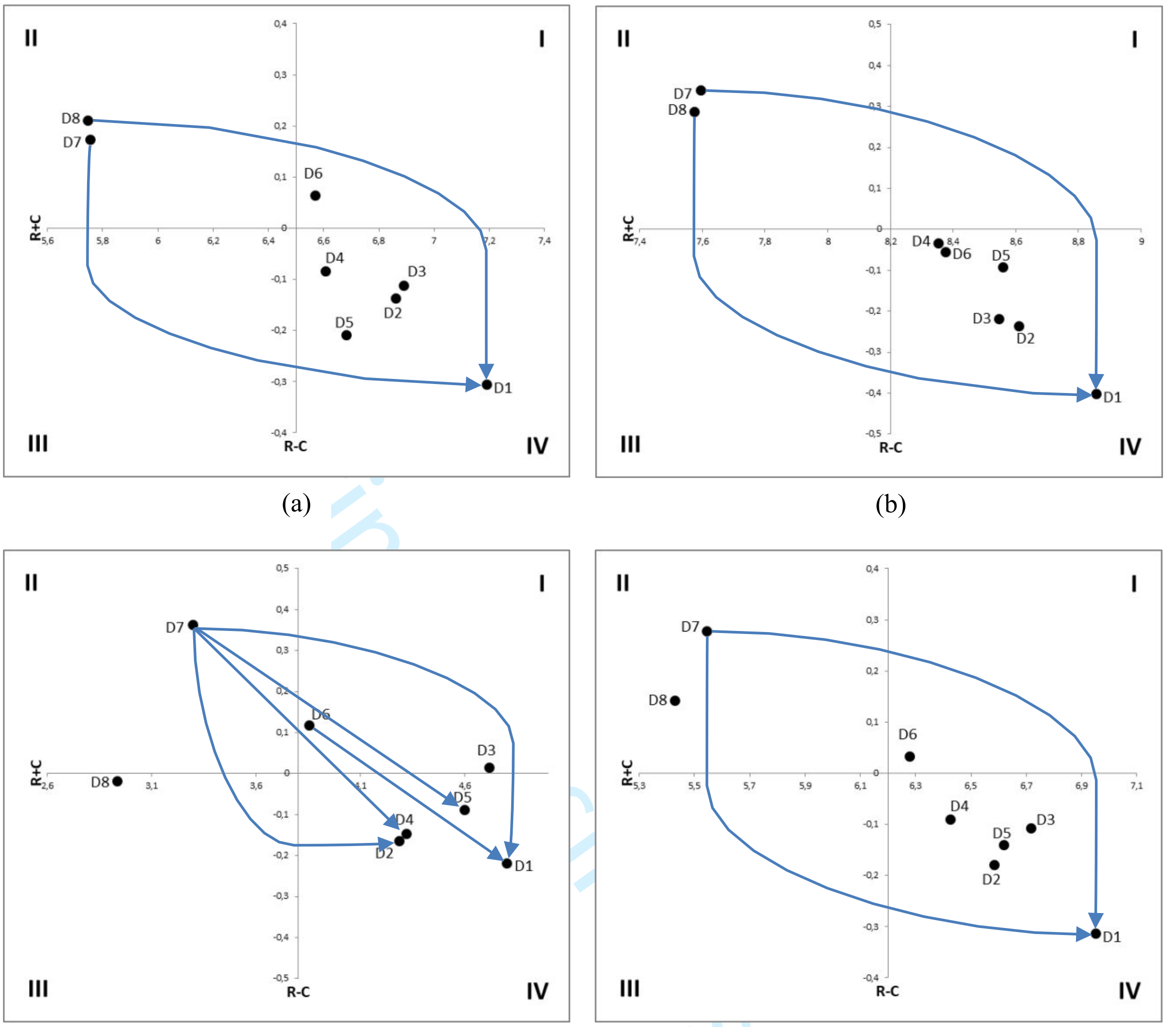
Dimension	Code	Fuzzy R	Fuzzy C	Fuzzy R+C	Fuzzy R-C	Crispy R+C	Crispy R-C	Role
Cost	*D1*	(0,74; 2,03; 9,91)	(0,89; 2,31; 10,51)	(1,64; 4,34; 20,42)	(-9,76; -0,28; 9,01)	6,95	-0,31	Effect
Location	*D2*	(0,68; 1,94; 9,67)	(0,75; 2,06; 10,02)	(1,43; 4,00; 19,70)	(-9,34; -0,12; 8,91)	6,59	-0,18	Effect
Infrastructural	*D3*	(0,75; 2,04; 9,89)	(0,76; 2,08; 10,10)	(1,51; 4,12; 19,99)	(-9,35; -0,04; 9,12)	6,72	-0,11	Effect
Accessibility	*D4*	(0,67; 1,91; 9,58)	(0,68; 1,94; 9,75)	(1,36; 3,86; 19,34)	(-9,08; -0,02; 8,89)	6,42	-0,09	Effect
Operational	*D5*	(0,71; 1,97; 9,76)	(0,75; 2,05; 10,03)	(1,46; 4,02; 19,79)	(-9,31; -0,08; 9,01)	6,62	-0,14	Effect
Economic	*D6*	(0,67; 1,91; 9,59)	(0,61; 1,81; 9,43)	(1,28; 3,73; 19,02)	(-8,76; 0,09; 8,97)	6,28	0,03	Cause
Political and Social	*D7*	(0,54; 1,70; 9,13)	(0,38; 1,41; 8,24)	(0,93; 3,11; 17,37)	(-7,69; 0,29; 8,74)	5,54	0,28	Cause
Environment	*D8*	(0,48; 1,59; 8,81)	(0,41; 1,43; 8,24)	(0,89; 3,03; 17,06)	(-7,76; 0,16; 8,40)	5,43	0,14	Cause

Table 5: Net influence matrices by each stakeholder group

Dimension	DPE								Customer							
	D1	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*	*D8*	*D1*	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*	*D8*
D1	-								-							
D2	0,024	-							0,024	-						
D3	0,031	0,012	-						0,030	0,008	-					
D4	0,027	0,012	0,004	-					0,050	0,030	0,032	-				
D5	0,021	-0,008	-0,004	-0,019	-				0,049	0,023	0,024	-0,003	-			
D6	0,053	0,028	0,033	0,021	0,038	-			0,054	0,027	0,025	0,001	0,014	-		
D7	0,064	0,037	0,036	0,035	0,049	0,021	-		0,098	0,078	0,075	0,052	0,058	0,057	-	
D8	0,067	0,051	0,047	0,043	0,055	0,023	0,000	-	0,089	0,071	0,066	0,050	0,053	0,048	0,000	-

Dimension	FRS								Aggregated							
	D1	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*	*D8*	*D1*	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*	*D8*
D1	-								-							
D2	0,010	-							0,020	-						
D3	0,028	0,020	-						0,030	0,013	-					
D4	-0,003	0,007	-0,020	-					0,025	0,017	0,006	-				
D5	0,025	0,023	-0,006	-0,002	-				0,031	0,012	0,004	-0,009	-			
D6	0,059	0,045	0,021	0,032	0,037	-			0,054	0,032	0,025	0,017	0,030	-		
D7	0,086	0,081	0,029	0,061	0,058	0,044	-		0,081	0,064	0,046	0,048	0,054	0,039	-	
D8	0,018	-0,005	-0,005	0,026	0,011	0,004	-0,039	-	0,056	0,037	0,034	0,037	0,039	0,024	-0,013	-

Figure 3: Influential Relation Map



(a) (b) (c) (d)

Table 6: Prioritization of risk dimensions by stakeholders groups

Risk Dimension		R+C								R-C							
		DPE	Rank	Customer	Rank	FRS	Rank	Aggregated	Rank	DPE	Rank	Customer	Rank	FRS	Rank	Aggregated	Rank
Cost	*D1*	7,19	1	8,86	1	4,8	1	6,95	1	-0,31	8	-0,4	8	-0,22	8	-0,31	8
Location	*D2*	6,86	3	8,61	2	4,28	5	6,59	4	-0,14	6	-0,24	7	-0,16	7	-0,18	7
Infrastructural	*D3*	6,89	2	8,55	3	4,72	2	6,72	2	-0,11	5	-0,22	6	0,01	3	-0,11	5
Accessibility	*D4*	6,61	5	8,35	6	4,32	4	6,42	5	-0,08	4	-0,03	3	-0,15	6	-0,09	4
Operational	*D5*	6,68	4	8,56	4	4,6	3	6,62	3	-0,21	7	-0,09	5	-0,09	5	-0,14	6
Economic	*D6*	6,57	6	8,38	5	3,86	6	6,28	6	0,06	3	-0,06	4	0,12	2	0,03	3
Political and Social	*D7*	5,76	8	7,59	7	3,3	7	5,54	7	0,17	2	0,34	1	0,36	1	0,28	1
Environment	*D8*	5,75	7	7,58	8	2,94	8	5,43	8	0,21	1	0,29	2	-0,02	4	0,14	2