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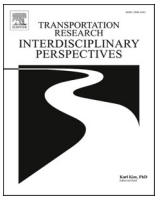

Project risks and regulation in transport infrastructure: A study in Brazilian agencies concessions planning process

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ABSTRACT

Concession of transport assets has been widely adopted in transport infrastructure projects to improve efficiency. In developing countries, e.g., Brazil, many concessions have been conducted with the goal of contributing to improve the country's competitiveness. The concession of transport infrastructure assets is complex and involves many stages, from planning to the end of the contract. In the planning stage, the project's potential risks can be identified, and strategies to mitigate them can be defined. Many studies have been published recently discussing risks in transport concessions, however, the practices of regulatory agencies in risk identification and mitigation are incipient. In this scenario, this study debates the inclusion of potential project risks in real concession projects in a developing country. The first step to achieving our goal is identifying the main risks in Public-Private Partnership (PPP) published studies through a literature review. As a main result of this phase, 78 risks are presented and classified as measurable and unmeasurable. In a second step, we have selected recent Brazilian transport concession appraisal studies: an airport, a road, and a port terminal. Comparing the risks from the literature review with the Brazilian regulator's appraisal studies, we have observed no pattern for items to be discussed in the studies and that the results are mainly presented as discrete variables in all cases. The results can give insights into improving the planning process for future concessions.

1. Introduction

Public-Private Partnerships (PPPs) are long-term agreements between public and private bodies, making it possible for governments to invest in infrastructure through private investment (Grimsey & Lewis, 2002). In the transportation sector, it is widely used due to the necessity of capital-intensive and long-living duration (Sresakoolchai & Kaewunruen, 2020). Risks in PPPs are widely discussed in the transportation literature. Recent publications discuss risks in specific types of infrastructure operations operated by private partners, such as railways (Bugalia et al., 2021; Gangwar & Raghuram, 2015; Lee et al., 2022), ports (Chen et al., 2017; Xiao & Lam, 2019; Yang et al., 2020), airports (Engel et al., 2018; In et al., 2017; Sugimura & Kato, 2022), roads (Garg & Dayal, 2020; Hoang-Tung et al., 2021; Sun et al., 2019), and public transportation (Chang & Phang, 2017; Papaioannou et al., 2020; Pedro & Macário, 2016). Cross-sectional analyses are also present in the literature (Macário et al., 2015; Sresakoolchai & Kaewunruen, 2020), however, they are more scarce than the specific studies.

There are also discussions regarding risks from the point of view of different actors, such as finance bodies (Demirag et al., 2011), investors (Roumboutsos & Pantelias, 2021; Siemiatycki, 2015), and taxpayers (Bel et al., 2017). Other papers discussed specific types of risks in transport PPPs, such as financial risks (Andreeva et al., 2019; Jin et al., 2019; Zhang et al., 2021), disaster risks (Jain, 2015), revenue risks (Liu et al., 2020; Liu et al., 2017; Roumboutsos & Pantelias, 2015), and environmental risks (Grasman et al., 2014).

One topic related to transport infrastructure investment and risks is transport planning. Whether involving PPPs or not, transport planning is an important topic in recent literature (Combs & Pardo, 2021; Löfgren, 2020; Wang & Levinson, 2023). In the planning stage, the items that can vary (representing risks to the project) are defined, and qualitative or quantitative techniques are used to preview and treat them (Lyons et al., 2021). Thus, it is important that transport planning and risk analysis are aligned. Appraisal studies are one of the most important elements in this context since, in these studies, economic, operational, and environmental aspects (among others) are discussed, and the costs and benefits of the projects are measured and compared (Wang & Levinson, 2023).

Although relevant studies analysing risks on transportation PPPs

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have been carried out, a question that emerges – especially in developing countries, due to their difficulties regarding budget constraints and fiscal problems (Ahmadabadi & Heravi, 2019b) – is: how are regulatory agencies including risk identification and mitigation in their project appraisal processes? To help elucidate the question, this study has two goals: i) identifying the main risks discussed in previous PPP literature; and ii) comparing the identified risks with recent projects conducted by Brazilian transport regulatory agencies. In Brazil, transport infrastructure has been considered a restriction, and it is common sense to improve it (Amann et al., 2016). It is observed that since 2000, PPPs have become widespread worldwide, and these projects are conducted and managed by regulatory agencies responsible for appraisal and regulation processes (Cui et al., 2018).

Build, Operate, Transfer (BOT) contracts are among the most common types of PPP contracts in transport infrastructure in the country (Amann et al., 2016). In this arrangement, the private partner is responsible for constructing and exploring the infrastructure assets, charging fees for its use during the contract period. This type of arrangement is complex and involves many stages, beginning with the planning and finishing with transferring assets to the government after the concession period (Zhang et al., 2018). The planning stage involves elaborating appraisal studies, approvals and permits, and contract design. Regulatory agencies are commonly the bodies responsible for managing concession contracts, and they are responsible for the elaboration of appraisal studies for the projects (Kang et al., 2013). It is important to mention that, in Brazil, appraisal studies can be outsourced, financed by a public body, and recovered with the grant value during the concession.

In order to achieve the goal of investigating risk inclusion in appraisal studies on infrastructure projects, we have done a literature review of recently published studies (published after 2010) and a document analysis using ten appraisal studies for concessions of port terminals, airports, and roads published by Brazilian transport regulatory agencies from 2019 to 2022. It is important to highlight that the appraisal studies selected for this analysis were part of concessions that had their public consultation phase already finished. The participant agencies are responsible for concessions of terrestrial, air, and maritime transport infrastructure assets. Comparing the risks identified in the literature with the real projects from the agencies can be important to discuss the criteria for new concession appraisals and give insights to improve project planning for future concessions.

Our study identified 78 risks on the PPP literature as the main results. These risks were classified as measurable or unmeasurable and were compared to ten appraisal studies of airports, roads, and port terminals from Brazilian transportation agencies. From this comparison, it is possible to observe that the studies are not patterned and that the results are mainly presented as discrete variables.

This paper is organised in the following sections: Section 2 discusses project risk management in infrastructure and the history of transport regulation in Brazil, focusing on the agencies participating in this study. Section 3 presents the method utilised to achieve the proposed goals. Section 4 presents and discusses the results of the study. At last, the conclusions, policy implications, limitations, and future research directions are presented.

2. Literature review

2.1. Project risk management and risk classification

Project risk management plays a central role in the successful execution of PPP projects. As already exposed in Section 1, many studies were published in the last decades discussing different perspectives of risk in PPPs. It lacks, however, a discussion regarding the identification of risks in the planning stages of PPPs. As delineated by the Project Management Institute (PMI, 2017), the project risk management process encompasses a multi-stage framework, with the following stages: i) risk management planning; ii) identification; iii) qualitative analysis; iv) quantitative analysis; v) risk response planning; vi) risk response implementing; and vii) monitoring.

The initial phase involves allocating responsibilities for handling project risks, a central topic when discussing risks in PPPs, which is already discussed in the literature (Carbonara et al., 2015; Chou et al., 2012). An appropriate risk allocation is considered a crucial issue in the success of PPPs (Davidoff & Gomez-Ibanez, 2006; Grimsey & Lewis, 2002). Usually, in BOT contracts, the government assumes risks such as public credit and regulation, and risks such as demand and costs are assumed by private enterprises (Bugalia et al., 2021). However, these configurations may change according to the specific project.

The second stage in the project risk management framework is risk identification. In the context of PPPs, identifying risks is crucial to improving project decision-making (Liu et al., 2017; Welde, 2011). Risk identification is crucial for public decision-makers by ensuring project goal attainment and for private partners by mitigating investment risk perception. Moreover, a broader societal understanding of the project is enhanced with better project risk identification. Many studies discussed specific types of risks and their influence on PPP infrastructure projects' results, such as Babatunde & Pereira (2017), Bugalia et al. (2021), Liu et al. (2017), and Welde (2011), which discussed demand and costs risks, and Bjelland & Aven (2013), which discussed safety risks. These studies stated the necessity of improvement in risk identification and analysis in the planning stages of PPPs in transport projects. Bjelland & Aven (2013) even stated that the absence of a structured regulatory framework for risk analysis in transport infrastructure projects can lead to compromised decision-making processes, potentially leading to inadequate risk mitigation. As shown in Section 1, the literature can serve as a benchmark for evaluating risks for new projects due to the variety of recently published papers discussing risks in this field.

The other stages of the project risk management process involve risk analysis (qualitative or quantitative), risk response, and monitoring. The distinction between qualitative and quantitative risks is important to assign the adequate analysis method since some methods are more suitable than others for each type, for example, interviews with specialists for qualitative risks and sensitivity analysis for quantitative risks (Anelli & Tajani, 2023). Therefore, the identification of risks can already include the possibility of measuring probabilities of occurrence of each risk, anticipating the type of each identified risk (qualitative or quantitative) to improve risk analysis.

In conclusion, the project risk management process is complex and central to implementing PPPs in transport projects. While previous research has extensively explored various dimensions of risk in PPPs, the discussion is limited in addressing risk identification during the planning stages in real projects. This study contributes to the literature by initiating this discussion using Brazilian projects as examples to understand if there are patterns in risk identification.

In addition to discussing risk management processes in projects and emphasising the significance of identifying risks in transportation concession projects, it is essential to highlight the classification of risks present in the literature. Given the multitude of risks inherent in transportation infrastructure projects, categorising risks can benefit risk analysis and management processes.

Li et al. (2021) deliberated on risk typologies and concluded that the discussion of risk types is intrinsically linked to the very definition of risk. In their review, they arrived at various risk classifications contingent on the focus of the analysis. Nevertheless, the review pointed to categories of risks prevalent in large-scale projects, namely: i) market; ii) technological; iii) financial; iv) environmental; v) organisational; vi) social; and vii) turbulence risks. These categories encompass general risks in large-scale projects that may manifest at different stages and impact outcomes diversely.

However, beyond risks associated with projects in general, specific risks can occur in the context of PPPs. De Palma et al. (2012) discuss the typology of risks in PPPs. In this context, the primary categorisation of

risks is made from the perspective of who assumes each risk. Thus, the categories used are: i) private information of the firm (with perception bias by the government); ii) symmetric information (with possible perception bias by all parties, including voters); and iii) private information of the government (with perception bias by the firm). Each category encompasses risks related to projects (such as financial and demand risks, for instance) and risks related to the PPP project structure (such as renegotiation and political risks).

Various classifications have been adopted in recent literature discussing risks in PPPs in the transportation infrastructure sector. Authors generally consider project risks and risks related to the PPP structure. An example of this is the study by Ortega et al. (2016), which divides risks into: i) construction; ii) design/technical; iii) environmental; iv) revenue/demand; v) financial; vi) force majeure; vii) operating; viii) project default; and ix) regulatory/political. In this case, it is observed that categories i, ii, iii, v, vi, and vii pertain to inherent project risks. In contrast, categories iv, viii, and ix are related to the project's structure as a PPP, encompassing risks such as combinations of risks that led to project bankruptcy and changes in law/policy affecting revenue, for example. Another study that establishes risk categories involving project risks and PPP-related risks is Lee et al. (2022), which divides risks into: i) construction and procurement; ii) design; iii) finance; iv) operate and maintain; and v) general/project environment. In this case, categories ii and iii are linked to project-specific risks, while categories i, iv, and v involve risks associated with the project's PPP structure, including intra-consortium counterparty risk, legal risks, and ridership projection risk.

Additionally, some articles classify risks according to the phase in which they occur. Demirag et al. (2011) and Carbonara et al. (2015) classify risks based on the phases in which they are observed, ranging from planning periods (project development phase in Carbonara et al. (2015)), construction and operation (construction of infrastructure and operational phase in Demirag et al. (2011) or construction, operation, and project life cycle phases in Carbonara et al. (2015)), to the project handover or closure phase (pre-financial close phase in Demirag et al. (2011) or transfer phase in Carbonara et al. (2015)).

Another trend identified in recent literature on the subject is the division of risks into categories that pertain to the allocation of risks among the public and private entities involved in the project, as seen in Zembry-Mary (2017). This study divides risks into the following categories: i) risks assumed by the private provider and ii) risks assumed by the public authority. Albornoz et al. (2021) also create similar categories, dividing risks into i) authority and ii) concessionaire.

Some risk categories are common among recent works published in the field, such as: i) construction (Carbonara et al., 2015; Cruz & Marques, 2012; Demirag et al., 2011; Lee et al., 2022; Ortega et al., 2016); ii) demand (Babatunde & Perera, 2017; Cruz & Marques, 2012; Iseki & Houtman, 2012; Kumar et al., 2018); iii) design (Cruz & Marques, 2012; Ortega et al., 2016); iv) environmental (Cruz & Marques, 2012; Ortega et al., 2016); v) economic/financial (Cruz & Marques, 2012; Kumar et al., 2018; Lee et al., 2022; McCarthy et al., 2019; Ortega et al., 2016); vi) force majeure (Cruz & Marques, 2012; Iseki & Houtman, 2012; Ortega et al., 2016); vii) operational (Cruz & Marques, 2012; Lee et al., 2022; Ortega et al., 2016; Yuan & Li, 2018); and viii) political (Cruz & Marques, 2012; McCarthy et al., 2019). These categories encompass project-specific risks and risks related to the PPP project structure, except for the design (which encompasses project-specific risks) and political (which involves risks linked to the PPP project structure) categories. Please refer to the Supplementary Material for a detailed breakdown of the categories identified and their associated risks.

There is no consensus in the literature regarding the typology of risks in PPPs, which can be classified based on the type of analysis the authors undertake. Nevertheless, some categories are more prevalent in the literature and are more closely related to the types of risks, whether inherent to projects or related to the structuring of the project as a PPP.

2.2. The regulation of transport in Brazil

In Brazil, the process of modernisation of transport infrastructure started in the 1990 s. The entire infrastructure sector was considered undeveloped and deficient (Galvão et al., 2013). Concession of assets to private companies was the main method used in BOT contracts, considering the lack of public funds (Amann et al., 2016). Some of these occurred even before the creation of regulatory agencies, as seen in Fig. 1. The agencies responsible for the regulation of transportation sectors at a federal level are ANTAQ (Brazilian Waterways Regulatory Agency, in Portuguese acronym), ANTT (Brazilian Terrestrial Transportation Agency, in Portuguese acronym), and ANAC (Brazilian Civil Aviation Agency, in Portuguese acronym).

Fig. 1 shows the timeline for modernising transport infrastructure management in Brazil. In the port and road sectors, the first concessions were made even before the creation of regulation agencies (De Paula & Avellar, 2008). While the first road concession occurred in 1995, in the port sector since 1970, there were leasing contracts for port areas to operate specific cargo.

The port sector passed through a reform in 1990 that extinguished the government-owned company previously responsible for port management and operation. With the reform of the port sector, the operations of public ports were transferred to private companies, while the Port Authorities (PAs) were responsible for port management (Galvão et al., 2017). In this context, PAs managed the contracts with private companies, following the landlord port model (World Bank, 2010). In 2013, the "New Law for Ports" was approved and increased private participation in the sector by creating private ports. Regarding the regulation of concessions in port terminals, the new law substituted the foreign (from 1993), establishing new roles for the agents involved in the port sector: the PA (Port Authority) is responsible for the management, while ANTAQ is responsible for the regulation and controlling of concession contracts. In this context, it is important to mention that the Grant Authority for concession contracts in the port sector is the Ministry of Ports and Airports (replacing the Ports Secretariat) (Galvão et al., 2017). In addition, it is important to state that the ports in Brazil are under the responsibility of the federal government, which is always the Grant Authority, however, their management and exploration can be delegated to States and Municipalities. ANTAQ has conducted 33 public tenders to concession port terminals until 2019 (ANTAQ, 2020). The agency also regulates ports and waterway transportation, including maritime carriers and service providers involved in the sector. In 2019, the agency published a manual to evaluate appraisal studies for port terminal concessions in public ports, and in this document, there are the minimum items required and instructions for regulators to analyse them (ANTAQ, 2022).

In the road sector, the first concessions started in the decade of 1990 due to the difficulty of investing in infrastructure (Queiroz & Motta, 2012). ANTT has been responsible for the concession of 22 roads since its creation. The concession program has four phases (the first started in 1994, the second in 2007, the third in 2013, and the fourth in 2018), and in the most recent phase, seven auctions were already finished (ANTT, 2020). Besides the concession of roads, the agency is responsible, among other functions, for the concession of railways and permissions or authorisations for carriers. It is important to cite that unlike the port and airport sectors, in the road sector in Brazil, there are federal and state roads, and ANTT is the agency responsible for federal roads. Some state agencies manage their roads, some of which passed through concession in the past decades.

In the airport sector, modernisation and reform were the last to occur. The concession of airports only started in the 2010 decade, after the agency responsible for regulating the sector was created. ANAC conducted 12 public tenders for the concession of airports in 2019. The agency is also responsible for regulating airfields and inspecting aircraft and air carriers. The concession program had seven phases since 2011, and the last phase (initiated in 2019) includes three auctions and two

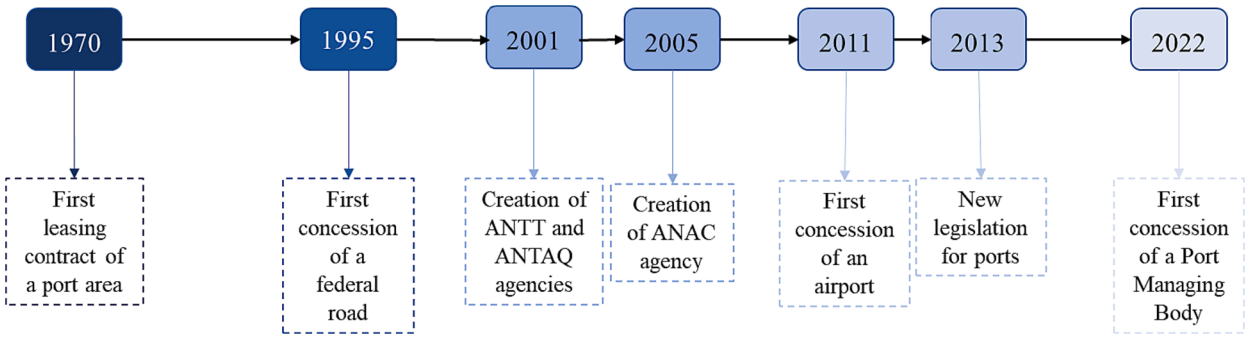

Fig. 1. Timeline of concessions in transport infrastructure in Brazil.

public consultations concluded (ANAC, 2020).

All the agencies in the transport sector are subordinated to the Ministry of Transport, which defines each sector's policies and is the Grant Authority (de Oliveira, 2017). Since their creation, transport regulation agencies have faced problems, mainly due to weak regulatory governance, autonomy, political influence, and low investment capacity (Amann et al., 2016; De Paula & Avellar, 2008).

The concession of transport infrastructure assets follows a general workflow for the three agencies shown in Fig. 2. The first stage is the planning phase when appraisal studies are conducted. As mentioned in Section 1, these studies can be done by the agency or outsourced, financed by a public body, and recovered with the grant value. There is no formal model for the elaboration of appraisal studies common for all agencies, and they must follow the guidelines provided by them for the specific project. The second stage is a public consultation when the appraisal studies are available for contributions from society. The following stage is the audition, made by the Court of Auditors (TCU, in Portuguese acronym). If the project is approved, then the public tender is conducted, and after that, the contract is signed between the public and private parties (Espinheira & Tribunal de Contas da União, 2018).

This study focuses on the first stage of this process, when appraisal studies are made. These studies evaluate financial, technical, and environmental criteria and should indicate if the project is suitable. The structure typically employed in appraisal studies of projects in Brazil follows a standardised format and is divided into topics, which include: i) market analysis, encompassing the description and economic analysis of the region where the infrastructure will be located; ii) engineering and operational, involving technical and operational parameters definitions and discussions; iii) environmental, encompassing studies of environmental impacts; iv) economic and financial, involving cost and revenue projections and the economic outcomes of the project.

2.3. Risk classification framework

Comparing the risk classification categories from the literature (Section 2.1) with the structure observed in feasibility studies of transportation infrastructure concession projects in Brazil (Section 2.2), it is evident that there is a convergence. Fig. 3 illustrates the theoretical framework, considering the primary risk categories identified in the literature and the structure of appraisal studies for transportation infrastructure concession projects in Brazil.

As demonstrated in Fig. 3, a significant portion of the categories observed in the literature about project risks or risks related to the structure of PPP projects can be compared with the topics discussed in appraisal studies.

The market category can encompass topics related to demand projections, which typically involve analyses of local consumption patterns and socioeconomic characteristics. In appraisal studies, market studies usually project the demand for the infrastructure in question, considering economic and social conditions and employing techniques such as the four-step model.

The engineering and operational category is the one that can encompass a great number of risk categories from the literature. This is because appraisal studies typically discuss and define the infrastructure's construction procedures and operational parameters. Therefore, all categories involving construction, operation, performance, and quality can fit into this category.

The environmental category can encompass topics related to permits, environmental risks, and force majeure, which are usually linked to natural causes that may disrupt the operation of the infrastructure. Appraisal studies typically involve discussions about required permits, environmental impacts, the necessary structure for environmental management, and the environmental characteristics of the area in question.

The economic category includes risks related to revenue and cost projections, as well as the economic outcomes of the project. In appraisal studies, this stage consolidates the information gathered in previous stages, discusses the project's economic and financial parameters, and projects the cash flow over the concession period, estimating the economic results in the form of indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR), for example.

However, one category not present in appraisal studies but discussed in the literature is the political category. These items are typically not discussed in appraisal studies because the study is already in a phase where legal and regulatory definitions are pre-established, following the legal norms of regulatory agencies. In this context, appraisal studies seek to demonstrate the project's viability to a private entity interested in it and to project the benefits generated for the community through the improvement of the infrastructure in question. Furthermore, the specific bureaucratic rules to be followed in each concession are defined in the

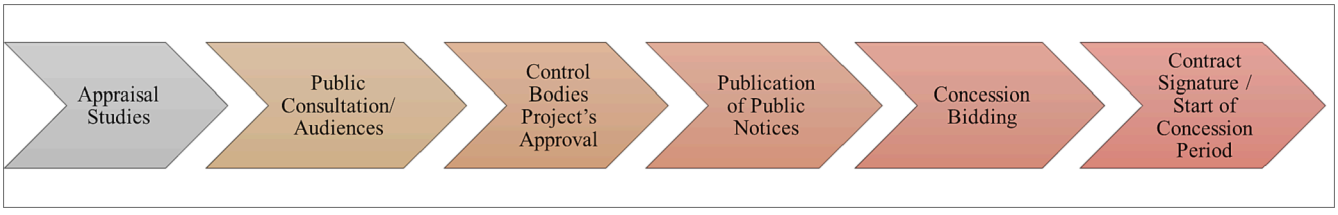

Fig. 2. Process of transport infrastructure concessions in Brazil.

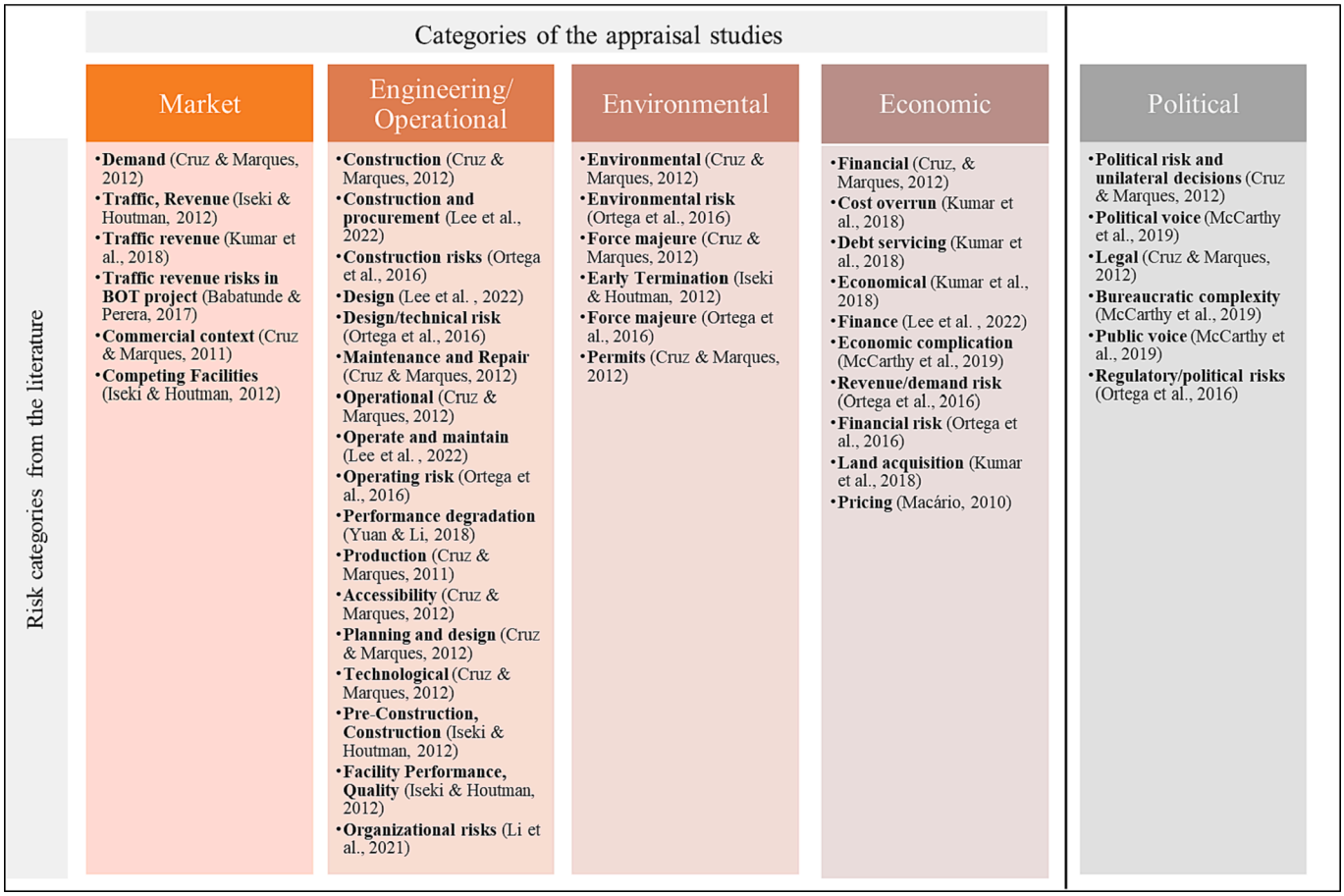

Fig. 3. Risk classification framework comparing categories from the literature with topics discussed in appraisal studies.

contract, which is drawn up, discussed with society, and signed later in the concession process (as discussed in Section 2.2).

Therefore, the categories to be used for comparisons between the items present in appraisal studies and the literature studies that classify risks lead to a possibility of dividing risks into five main categories: i) market; ii) engineering/operational; iii) environmental; iv) economic; and v) political. This will be the structure used for the comparison conducted in this study.

3. Method

This study identifies risks in the PPP literature and compares them with appraisal studies for transport infrastructure concessions in Brazil. The method used to achieve this goal is a qualitative exploratory study. Qualitative studies are common in PPP research (Chen et al., 2016) and usually involve policy discussions.

To conduct this study, we adopted the following steps: first, a traditional literature review was conducted to generate a list of risks that could be observed in PPP projects. Besides, research through the Brazilian transportation regulator's practices was made to understand the topics discussed in an appraisal study. Then, we compared the results of the two previous steps and discussed the results. The following sections detail the method.

3.1. Identification of risks presented in the literature

The literature review to identify the risks cited in recent papers was conducted as this study's first step. The scientific basis of Scopus, Web of Science, and Science Direct were used to search for the papers to be analysed in this step. Fig. 4 shows the steps of the identification of risks in the literature. The search was done for the body of the paper, and the keywords were: "risk" AND ("concession" OR "PPP") AND "infrastructure" AND "project*" AND "transport*". The search was done, including restrictions to select only journal articles written in English and published after 2010. The chosen period is justified due to a previous review by Cui et al. (2018), in which it was observed that the search for papers in the PPP literature had an expressive growth from this year. The first search returned 628 papers; however, 57 files were identified as book chapters, 15 were published before 2010, 10 were identified as papers presented in workshops, one was not available in English, and 32 were duplicated, with 513 papers remaining.

As seen in Fig. 4, after reading the abstract, it was identified that 330 were not applied in transport industries, 56 did not discuss PPPs, and 14 did not discuss risks. These 14 papers discussed PPPs in other contexts, such as critical success factors, and risks were not included (Ullah & Thaheem, 2018). As a result, 113 papers were selected to participate in the study. These papers discuss PPP project risks, often reviewing previous studies and listing risks identified in these past cases. However, 72 papers did not list risks. These papers discussed risks but focused on other aspects of the projects (such as the analysis of concessions programs in Sugimura & Kato (2022)), and the identification of risks is not the main focus of the study.

This step aimed to create a list of risks that could be compared to real cases of transport concessions appraisal studies in Brazil. Thus, an organisation of the results from the literature search had to be made to make it possible. The following steps were followed to generate the risks list: i) the risks identified in the literature were organised using MS Excel sheets; ii) the risks were grouped by similarity of their names; and iii) common risks were grouped according to their meaning. The research team conducted these steps.

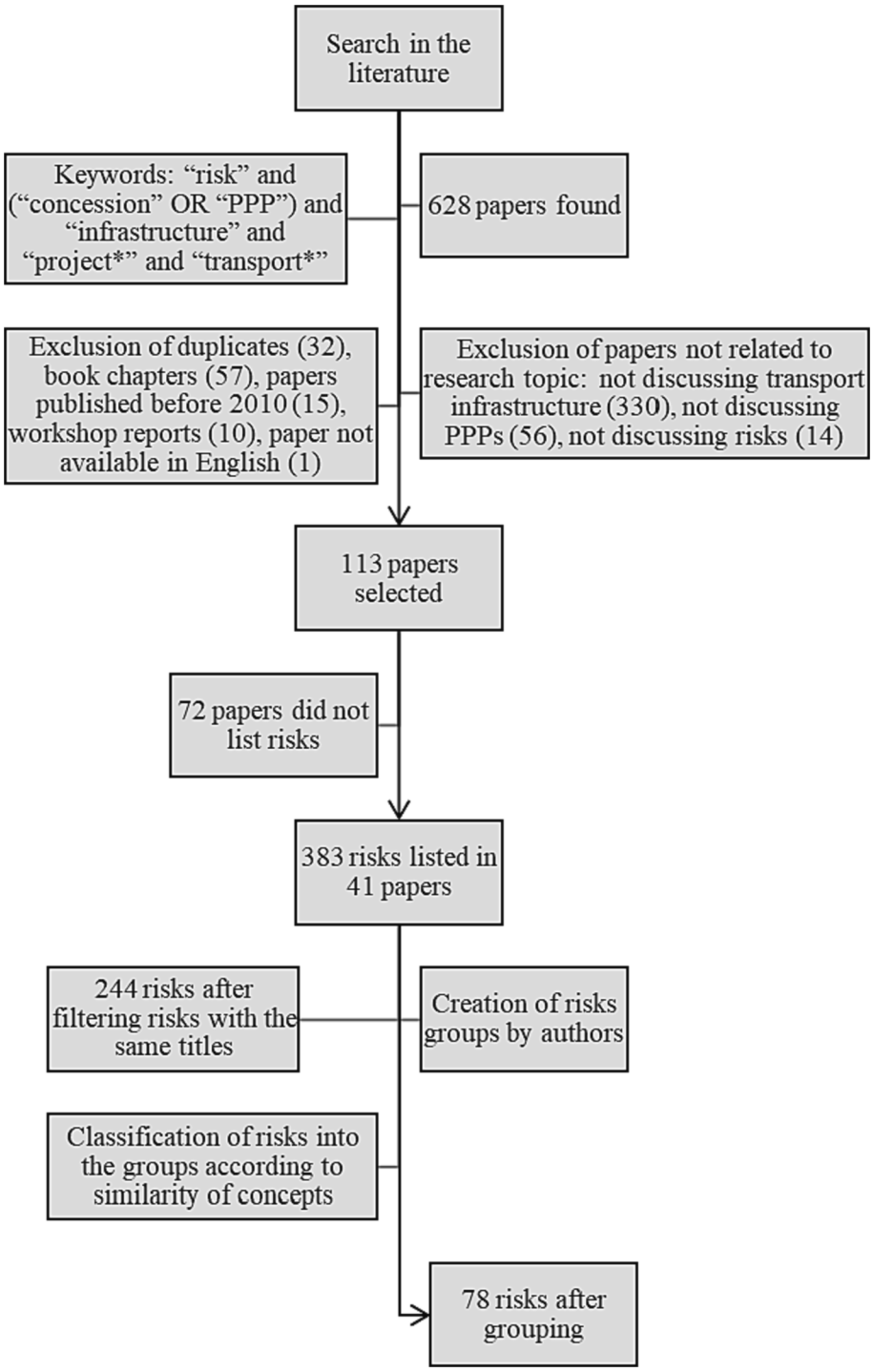

Fig. 4. Method of paper selection and identification of risks in the literature.

In addition, to facilitate the comparison among the list of risks from the literature and the cases, the risks were classified as measurable or not. The goal was to help understand if the risks could be presented in the appraisal studies quantitatively or if it would be only possible to discuss them more broadly. It is important due to the characteristics of the appraisal studies, which aim to present possible scenarios for investors and the community, emphasising the possible costs and benefits related to the projects. In this context, measurable risks are more likely to be discussed in these studies, while not measurable risks are more difficult to discuss at this stage. Two researchers individually made this classification; their results were compared and joined in one list by the research team. Another classification made to facilitate the comparison was regarding the general topic related to each risk: the risks were grouped into environmental, economic, operational, market, and legal risks by the researchers.

The study's second phase was to collect and analyse the information from the regulatory agencies.

3.2. Collection of data from transportation agencies

This stage had as its goal the data collection from recent transport infrastructure appraisal studies from Brazilian regulatory agencies. The

search for recent studies publications was made on websites of agencies and government bodies such as the Court of Auditors (TCU). The criteria employed for the selection of participant studies were as follows: i) inclusion of studies linked to a concession process that has undergone a public audience or public consultation phase, ensuring the integration of studies tied to feasible projects; ii) availability of the study on the agency's official website; iii) inclusion of projects of the most recent phases of concession programs of each agency, to ensure the capturing contemporary practices in the formulation of appraisal studies. In instances involving the concession of port terminals, a standardised manual for evaluating appraisal studies was utilised, and a recent study was chosen for comparative analysis against this manual. Consequently, ten distinct documents were identified and subjected to content analysis: i) an appraisal study concerning the concession of a solid bulk-operating port terminal at Itaguaí port, published in 2019 (CDRJ & Mind, 2019), alongside the latest version of the agency's manual for assessing appraisal studies (ANTAQ, 2023); ii) four appraisal studies for road concessions (BR 163, BR 116, BR 153, BR 163, and BR 364), published between 2017 and 2022 (EGP, 2017; EPL, 2019a, 2019b; Hidrovias do Brasil & Logit, 2019a, 2019b, 2019c,); iii) four appraisal studies for airport concessions (Viracopos and three concessions of clusters of airports encompassing 15 airports in total), released from 2022 to 2023 (Bacco et al., 2022a, 2022b, 2022c, GCA, 2022a, 2022b, 2022c, 2022d, 2022e, 2022f). In the case of the studies from clusters of airport concessions, there are individual studies for each airport, and a final executive report for the whole cluster is published. Thus, one study of each cluster was analysed in detail, and the executive report with the results for the cluster was included. The documents from the agencies consolidate previous studies related to the concession of an asset before the public consultation, as already discussed in Section 2.2. It has to be highlighted that, however, the studies have a standard form, and each study discussed each topic in its specific context since each market has its specific characteristics. The examples used in this study are BOT contracts with at least 20 years of duration.

The process of analysis of the documents followed the steps: i) reading each document and collecting the topics discussed using MS Excel sheets; ii) describing each topic, highlighting which variables were quantitatively included in the documents; iii) consolidation of the topics

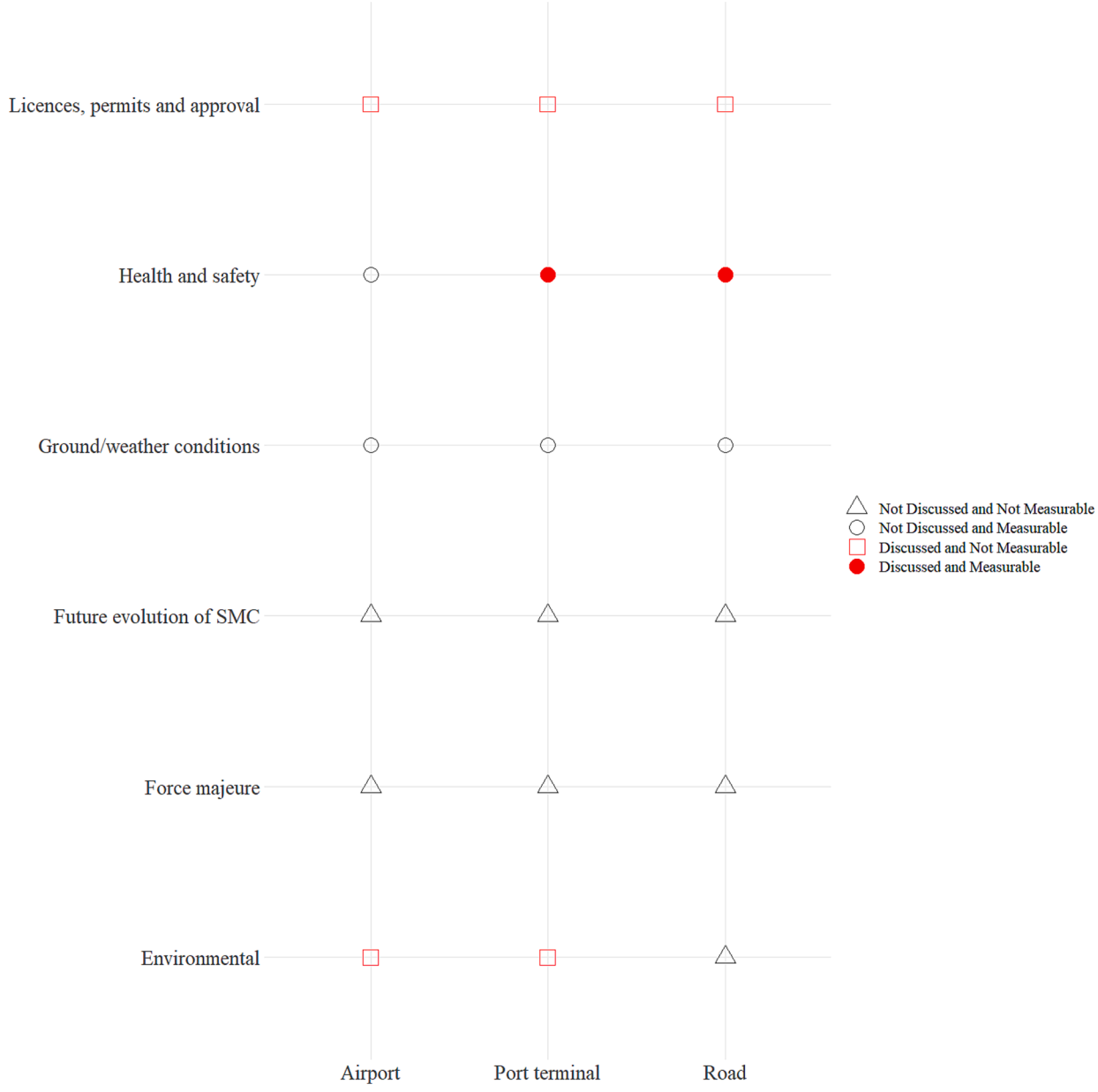

Fig. 5. Comparison among environmental risks and appraisal studies.

discussed in the documents, classified in market, operational, environmental, political, and economic topics, as discussed in Section 2.3.

4. Results

This section presents and discusses the results of this study. The results facilitate discussion using the classification of the topics mentioned in Section 2.3: environmental, economic, operational, market, and political risks. The complete results of this study's first step, including the risk grouping discussed in Section 3.1 and the sources of each risk, are shown in Appendix A.

Figs. 5 to 9 present the presence or absence of the risks covered by the literature in the appraisal studies in each group of risks. Fig. 5 shows the results for environmental risks.

Fig. 5 shows six risks identified in the literature regarding environmental or climate issues. Four risks (licenses, permits, and approvals, future evolution of Social Marginal Costs (SMC), force majeure, and environmental) were not measurable. It happened due to the difficulty of relating quantitative functions of measure of impacts for these risks. On the other hand, health and safety and ground/weather conditions were considered possible since they could be related to previous data on accidents and climate conditions, for example.

All airport appraisal studies cite two risks in this category (licenses, permits and approvals, and environmental). It has to be highlighted that, in all of the airport appraisal studies, environmental risks are discussed in detail, with a list of possible risks qualitatively discussed, using scales for the probability of occurrence and their impacts: the risks are related to licenses delays, disqualification of assets as historical heritage, acoustic insulation of public assets, and delays in expropriation processes. The road studies discussed two risks, with qualitative discussion for licenses, permits and approvals and quantitative estimations for the health and safety impacts of 0.2 % of the assured value of the project. The port terminal study discussed three risks (licenses, permits and approvals, health and safety, and environmental), in which the environmental topic is detailed, listing the main risks, their impacts (physical, biotic, and socioeconomic), and probabilities of occurrence using scales to measure them. It is important to mention that this structure of evaluating environmental risks is the same as indicated in the manual

Fig. 6. Comparison of economic risks and appraisal studies.

Fig. 7. Comparison of operational risks and appraisal studies.

for appraisal studies from ANTAQ.

It can be highlighted that environmental risks are mostly unmeasurable, and the concern with licenses and permits is the most important issue discussed in appraisal studies in transport infrastructure concessions. Fig. 6 shows the results for economic risks.

Fig. 6 shows that five risks (private partner, insufficient financial audit, financial, delay in project financing, and commercial) were considered unmeasurable. The other twelve risks (revenue, preinvestment, payment, macroeconomic, interest rate, inflation, government credit, foreign exchange and convertibility, exchange and interest rate, cost related to hedging and debt management, cost, and capital) were considered measurable, due to the possibility of attributing functions based on historical data from past concessions.

Regarding these risks discussed in the appraisal studies, one can note that five (capital, revenue, private partner, financial, and cost) are present in airport studies. However, it can be highlighted that there is variability in airport studies, in which three of the studies presented scenarios for economic analysis, including variations in the concession period, economic inputs (i.e., costs and revenues), and financial inputs (financing options and attractiveness for the private partner). The private partner risk is present only in the airport studies.

The port terminal study discusses five risks (revenue, financial, cost, macroeconomic, and commercial). These topics are discussed, and the results are presented quantitively, however, in the study, there are no variations in these sections of the study, contrary to what is recommended by the manual. The manual recommends that the macroeconomic scenarios are evaluated and their impacts be defined. The road studies discussed three risks (financial, cost, and commercial). It can be highlighted that, in this case, one study adopted scenario analysis in which the demand and revenue results varied in three scenarios (optimist, base, and pessimist). The other three studies did not present these variations.

Fig. 7 presents the results for operational risks.

Fig. 7 presents the operational category, which is the one with more related risks. Thirteen (utilities-related, tourism business prosperity, technological, social, planning, operation, maintenance, initial planning and negotiation time overrun, inadequate infrastructure, geological, failure of toll collection equipment, cost related to delay or faulty

Fig. 8. Comparison of market risks and appraisal studies.

techniques, and accident) were considered not measurable due to the difficulty of generalising impacts or using models to estimate the quantitative results.

Comparing the studies' items, we found that airport studies had fifteen items. Road studies had fourteen items, and port terminal studies had eleven. In the airport studies, there is variability in social risks, considering that three of the studies presented an analysis of the social and economic impacts of the projects. There was no variation in items discussed for the road and terminal studies.

It can be highlighted that nine risks were discussed in all of the studies (utilities-related, traffic, social, operation, inadequate infrastructure, existing structures failure, construction cost overrun, capacity, and asset level). Two risks in this category (failure of toll collection and toll-related risks) are related to the specific context of road concessions and were not discussed in the appraisal studies. Other risks (e.g., traffic and operation) are discussed in all of the studies in their context, adapted to each type of activity.

Thirteen risks (tourism business property, toll-related, technological, technical, supply, residual assets, quality standards, maintenance, geological, failure of toll collection equipment, engineering or design failures, availability, and accident) were absent in all the studies. Availability risk could be interpreted as not part of this stage of the concession project since the assets must be available in the appraisal studies stage, in which costs and benefits are being evaluated.

It is important to note that, considering only the measurable risks, seven are presented in the airport and road studies, and five are presented in the port terminal study. Despite their presence in the studies, these risks are not varied in scenarios. The appraisal studies focused on technical requirements in each project, not including sources of variation that could impact their costs and benefits.

Fig. 8 presents the results for market risks.

Fig. 8 shows that five risks (market, inaccurate demand forecasts, demand, competition related to exclusive rights, and competition) were considered measurable. The other seven risks (regional and international trade, recessionary impacts, media, material and labour non-availability, integration with facilities, communal fees, and collection) were not measurable in appraisal studies.

Regarding the items in the studies, seven were present in the airport

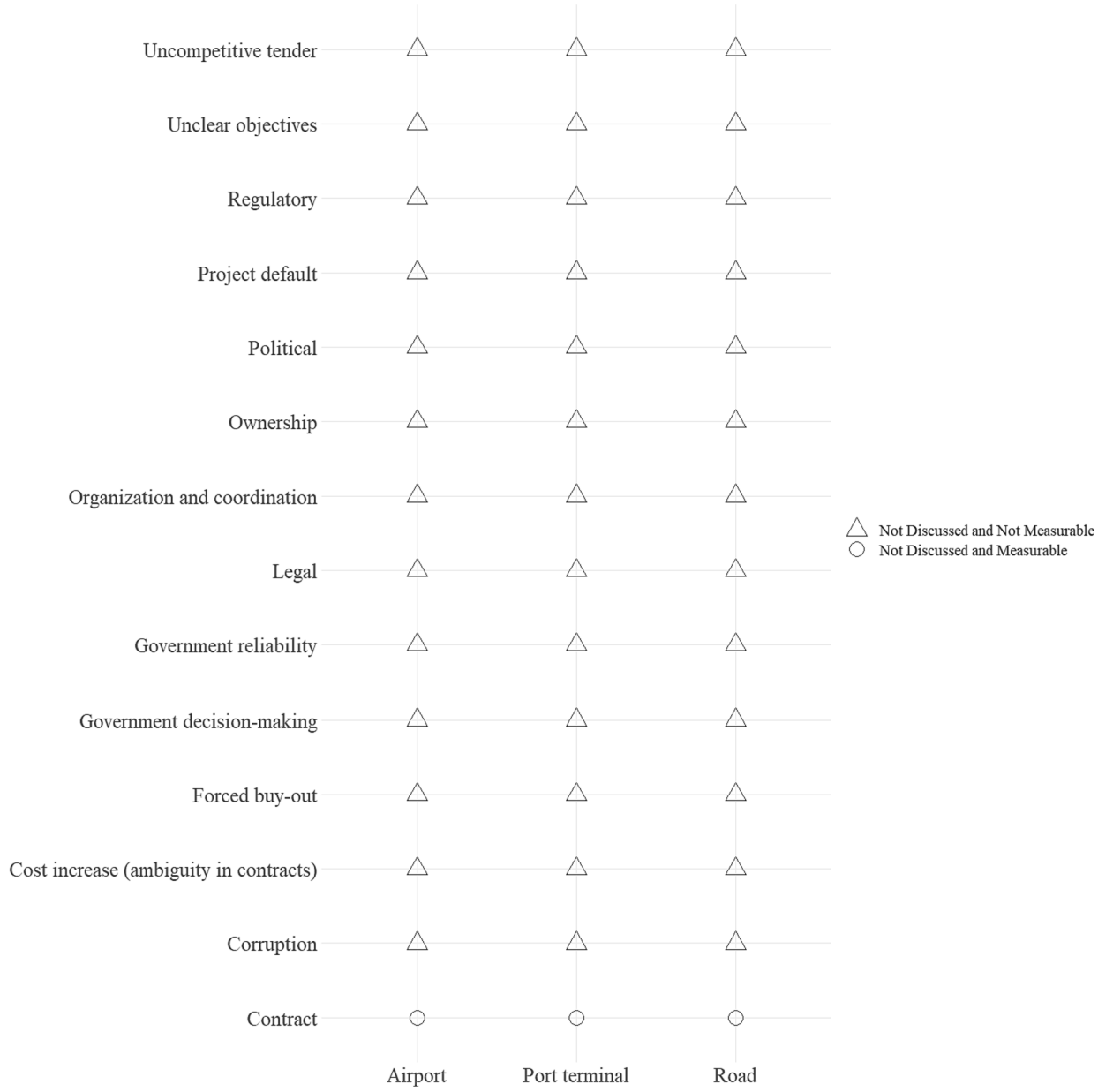

Fig. 9. Comparison of political risks and appraisal studies.

studies, and six were in the port terminal and road studies. It is possible to highlight that the four-step travel and econometric models estimate the demand in the studies. Another important issue regarding demand estimation is that, in at least one study of each agency, scenarios for demand estimations are adopted (with three scenarios: optimistic, base, and pessimist). In airport studies, all studies presented scenarios, and two presented simulations for demand estimation considering restrictions in competing airports. In addition, all airport studies divided the demand projections for cargo and passengers, normal and peak demand. For the roads, one study presented scenarios for demand estimations. The port terminal study scenarios for demand estimations were presented in consonance with the manual.

Fig. 9 shows the political risks.

Fig. 9 consolidates the political risks in PPP literature, although unrelated to the concession projects' appraisal study stage. It is justified due to the nature of these risks, which can be observed in the early stages of project decision-making, related to decisions before adopting PPP contracts (Macário, 2010; Tsamboulas et al., 2013). Once these risks are related to the structural definitions from the government and are not specific to each project, they cannot be discussed in appraisal studies (as discussed in Section 2.3). It is important to point out that even though these risks are not expected to be discussed in the appraisal studies, they were present in the literature. Only one risk was considered able to be measured, the contract risk, since this risk could be related to previous cases in which different types of contracts were adopted, however, it was not present in any of the participant studies.

In summary, one can note that there is no pattern for elaborating appraisal studies in transport infrastructure concessions in Brazil. For example, there is no defined criterion to define which variables would be varied to construct a scenario analysis. The analysis of the documents pointed to differences in the presentation of results, and, using the economic category as an example, one can note that some elements are quantified (such as costs) in all of the studies. However, one road, the port terminal, and three airport studies had scenarios for the financial results, using the variation of at least one variable input. Considering these results, one can observe that not all economic inputs were varied, leading to results that do not improve decision-making (Lyons et al., 2021). A complete risk analysis in appraisal studies could even improve

the decision-making by the private partner, which is another important goal for appraisal studies (Meidute & Paliulis, 2011).

The environmental category was another in which it was possible to observe a risk analysis in all appraisal studies. However, for example, for the environmental risk, in the port terminal and airport studies, a list of risks related to the environmental area were listed, with their probabilities of occurrences classified according to scales (e.g., likely, not likely) and their possible impacts with scales of classification (e.g., high or low impact). Both cases do not include these impacts in the projects' financial results. In the road studies, a health and safety risk is considered (with the estimation of 0.2 % of the assured value of the project). It must be emphasised that each project has a specific context, and each appraisal study would detail different points according to the project characteristics. It is, however, important to ensure that some minimum elements are present in all studies to standardise the concessions and enable performance assessment (Liyanage & Villalba-Romero, 2015; Santos et al., 2021).

Finally, reviewing the literature and classifying risks as measurable and not measurable allows us to identify that most of the identified risks are not measurable (42 risks, or 54 %). Operational risks had the highest number of measurable risks, with 16. Legal risks, on the other hand, was the category with the higher presence of unmeasurable risks, with 13. This classification can be helpful in the discussion of which risks can be included in appraisal studies and which can be part of a quantitative risk analysis or the construction of scenarios, for example.

5. Discussion

The appraisal studies participants of this analysis are comprehensive since they discuss aspects such as market, environmental, operational, and economic aspects of the concessions. The documents analysed in this study present well-established methods in the literature for the analysis (such as the four-step method for demand estimation). Quantitative analysis estimates project results, such as NPV and IRR. However, this study identifies some opportunities to improve planning processes.

In project risk management in PPPs, risk identification is a crucial part of the process (Liu et al., 2017; Welde, 2011). Our analysis shows no standardised approach for risk identification in the planning stages for PPPs in transport infrastructure in Brazil. With the increase in private participation in transport infrastructure services in Brazil (as pointed out in Section 2.2), it is important to understand if the risks that could be present in concession projects are being identified in appraisal studies. Because of the lack of standard practices for their identification and mitigation, these projects can have results different from those planned in appraisal studies.

Establishing a theoretical framework proves advantageous in this context, aiming to streamline the organisation and assess risks that may manifest in transportation infrastructure projects. As demonstrated in this study's analysis, future research endeavours can leverage the presented framework as a starting point for comprehensive examinations. Likewise, analysts and decision-makers can employ this framework as an initial tool to facilitate the management of similar risks in forthcoming projects.

Regarding the classification of risks into measurable or unmeasurable, our analysis pointed out that 42 of the 78 risks identified in the literature can be considered not measurable, which means that these risks could be discussed in appraisal studies but probably would not be associated with a probability for deviating from estimated results. These risks could be treated with qualitative risk treatment methods. The other 36 risks are considered measurable, which means that these could be treated quantitatively in the planning stage of the projects. However, whether the risk is qualitative or quantitative, they have to be identified in the appraisal stage of the project in order to enable decision-makers to understand the general level of risks in each project. The category exhibiting the highest proportion of quantifiable risks is the economic category, with 71 % of its associated risks deemed quantifiable. This observation is substantiated by the inherent potential for employing quantitative methodologies to include economic and financial variables fluctuations. Given the predominantly quantitative nature of these risks, there is an opportunity to enhance the comprehensiveness of project results by applying scenario analyses or other methodologies for risk evaluation within this category.

Among the categories examined in this study, the one with the highest number of risks addressed in the reports is the market category, with 67 % of the risks discussed in at least one of the analysed studies. The operational category is the second most prevalent, with 59 % of its risks discussed in at least one of the studies. Conversely, the environmental and economic risks categories exhibited the lowest percentages of discussed risks, standing at 50 % and 41 %, respectively. It is noteworthy to emphasise that political risks were not addressed in any appraisal studies.

In summary, it was possible to observe in the ten documents analysed in this study that there are differences among the documents of responsibility of the same agency (variability intra-agency) and differences among the studies of responsibility of the agencies (variability among agencies). An example of variability intra-agency is the comparison between the study for a port terminal concession and the manual of the ANTAQ agency. In this case, the appraisal study does not present a scenario analysis in the economic and financial section as the manual recommends. In the study, the scenarios are constructed only for market analysis, simulating different scenarios for cargo attraction. Another example of intra-agency variability is for road concession projects, in which three of the four studies did not present scenarios for demand. In the airport concessions studies, three of the four presented scenarios for variations in concession period and cost variations, for example.

For the variability among the agencies, it can be highlighted that there is no pattern among the agencies for risk identification in appraisal studies. Each project has its specific risks related to the services that are being provided, however, some risks could be generalised (such as demand risks) and could be analysed in the specific context of all projects. Some initiatives can be pointed out, such as the creation of scenarios for the economic analysis, however, compared with the risks presented in the literature, there are opportunities for improving risk identification in the planning stages of PPPs in transport infrastructure in Brazil. In addition, risk identification can mean opportunities identification since inputs can have a positive variation and improve projects' benefits.

The lack of a pattern for evaluating projects in the planning stage can lead to poor decision-making, and it is important to establish references in regulatory bodies to improve project appraisal (Bjelland & Aven, 2013). Regardless of the natural differences among the projects analysed in this study, selecting the most important risks (i.e., those that could change their viability) and including some methods to identify their probability and/or impact in the appraisal study is important.

The complexity of the appraisal studies analysed in this study is well-recognised. Observing the literature review results (with 78 risks), it is evident that incorporating them into a single analysis would be challenging. However, this discussion aimed to underscore the necessity of establishing priorities for including variations in input data. The objective was to ensure that decisions regarding the feasibility of these projects are transparent to public authorities, private entities, and society at large.

6. Conclusions, policy implications, and limitations and future research opportunities

The present study aimed to critically compare the appraisal studies in transport infrastructure concession projects in Brazil with the literature regarding risks in PPPs. In order to achieve this goal, a review of the literature and a review of concession appraisal studies in Brazilian transportation regulation agencies were conducted. In addition, a risk classification framework was established, highlighting the

classifications used in the literature and the organisation of appraisal studies in Brazil. The literature review resulted in a list of 78 risks. Appraisal studies for the concession of four roads, one port terminal (and a manual for appraisal studies analysis), and four airports were compared to the list of risks from the literature, highlighting measurable and unmeasurable risks.

The results pointed out a lack of pattern in the elaboration of the appraisal studies, both considering studies of the same mode of transport (and consequently, under the responsibility of the same agency) and considering different modes, making it difficult to evaluate the quality of the estimations. Another important conclusion of this study is that 46 % of the risks in the literature can be considered measurable, especially when considering economic and operational. It can be important to identify which risks could be included as criteria in appraisal studies, considering that measurable variables are suitable for quantitative analysis. It can improve the decision-making for private partners and risk treatment. In addition, one can note the lack of variability of the variables included in the studies. Including cost and benefit estimation variations can be important to improve risk analysis.

The findings point to a better understanding of risk identification and regulatory processes in concession projects in transport infrastructure. The comparison of risks reported in previous studies and by practitioners can be cited as theoretical contributions, leading to a discussion of the practicability of theoretical studies. In addition, the present study contributes to the discussion of the possibility of including risks as criteria for discussion in appraisal studies.

6.1. Policy implications

The results found in this study pointed to an important issue in the planning process for a concession of transport infrastructure assets: the inclusion of risks identified in the literature as criteria for the analysis of new concession projects. Risks in PPPs in transport infrastructure are widely discussed in the literature. Several studies have discussed the impact of different risks in these projects (Babatunde & Pereira, 2017; Bugalia et al., 2021; Liu et al., 2017; Welde, 2011; Bjelland & Aven, 2013). Besides that, the literature has a variety of studies recently published discussing risks in different modes of transport (Lee et al., 2022; Yang et al., 2020; Sugimura & Kato, 2022; Hoang-Tung et al., 2021). Thus, the literature can be a benchmark for risk identification in new projects in the field.

The theoretical framework can also be deemed a significant contribution to analysts and decision-makers involved in concession processes. Leveraging the provided structure can streamline the identification of potential risks in future projects. Since it is adaptable, similar risks not explicitly listed in the literature can be incorporated as needed to cater to the specific requirements of each project.

Additionally, it is essential to have a structured project risk management system, incorporating well-defined stages for risk identification, analysis, and treatment (PMI, 2017). In this context, risk identification is a crucial phase deserving the attention of regulators. During this stage, potential sources of variations in input data that could impact project outcomes need to be identified. As PPPs in transportation infrastructure hold particular significance within the context of developing countries (Ahmadabadi & Heravi, 2019b), the implementation of risk assessment standards in concession projects becomes paramount.

It is recognised that investments are required within regulatory agencies to incorporate risk analysis stages into their procedures. This step is essential for comprehending the sensitivity of new projects to variations in input parameters. Risk identification can improve projects' results for the government, private partners, and society.

6.2. Limitations and future research opportunities

Finally, several questions remain to be answered. Future studies can explore the viability of standardising, including more variables in the analysis, and including variability in appraisal studies. Applying the proposed framework in other contexts is another identified research opportunity. Other research opportunities are related to identifying the most relevant risks and their impact measurement in specific areas or concession types. It would help agencies, private partners, and society understand the risks and improve transport infrastructure planning.

This study has some important limitations that must be mentioned. The main limitation lies in the fact that the appraisal studies used in these analyses are part of concession projects in Brazil, and the results cannot be generalised to other countries. Furthermore, this study is limited by the information published by the agencies regarding these concession projects. Despite its limitations, the study adds to our understanding of the risks involved in the planning stages of transport infrastructure concession projects.

CRediT authorship contribution statement

Erica Caetano Roos: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Joana Siqueira de Souza:** Formal analysis, Writing – review & editing, Supervision, Funding acquisition. **Francisco José Kliemann Neto:** Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A

Table A.1
Risks from the literature and risk grouping made by the authors.

Risk grouping	Risk	Reference
Accident	Accident damage	Akbiyikli (2013)
	Disruptions due to accidents/breakdown	Babatunde & Perera (2017)
Asset service level	Asset service level risks	Carbonara et al. (2015)
Availability	Availability risk	Albornoz et al. (2021)
Capacity	Capacity	Cruz & Marques (2011)
Collection	Collection	Cruz & Marques (2011)
Commercial	Commercial risk	Regan et al. (2017), Sugimura et al. (2017)

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Table A.1 (*continued*)

Risk grouping	Risk	Reference
	Import/ export restrictions	Ahmadabadi & Heravi (2019a)
	Regional and international trade prosperity	Hamzah et al. (2014)
Communal fees	Communal fees	Šeba (2015)
Competition	Competition	Cruz & Marques (2011)
Competition (exclusive right)	Competition (exclusive right)	Chou et al. (2012), Hamzah et al. (2014)
Completion	Completion risk	Wang et al. (2020)
	Hand back inspections	Akbiyikli (2013)
	Other termination	Akbiyikli (2013)
	Termination for contractor default	Akbiyikli (2013)
Construction cost overrun	Construction cost overrun	Šeba (2015), Iseki & Houtman (2012)
Construction	Construction delays risk not attributable to public sector	Lee et al. (2022)
	Construction risk	Albornoz et al. (2021), Cabrera et al. (2015), Carbonara et al. (2015), Chou et al. (2012), Cruz & Marques (2011), Šeba (2015), Guasch et al. (2016), Hamzah et al. (2014), Makovšek & Moszoro (2018), Regan et al. (2017)
	Construction time overrun	Šeba (2015)
	Construction/operation changes	Chou et al. (2012)
	Improper construction and concession time estimation	Ahmadabadi & Heravi (2019a)
Contract	Contract risk	Wang et al. (2020)
	Documentation/contractual risks	Hamzah et al. (2014)
	Improper contracts	Chou et al. (2012)
	Improved contract terms	Wang (2015)
	Inadequate contract terms	McCarthy et al. (2019)
Corruption risks	Corruption risks	Chou et al. (2012), Hamzah et al. (2014), Wang et al. (2020)
Cost and time increase because of ambiguity in contracts	Cost and time increase because of ambiguity in contracts	Ahmadabadi & Heravi (2019a)
Cost escalation due to delay or faulty techniques	Cost escalation due to delay or faulty techniques	Ortega et al. (2016)
Cost of inadequate revenue hedging and debt management	Cost of inadequate revenue hedging and debt management	Ortega et al. (2016)
Cost	Cost overrun	Albalate et al. (2015)
	Cost risk	Wang et al. (2020)
	Costly operation and life cycle maintenance	Ortega et al. (2016)
	Lifecycle costs	Regan et al. (2017)
	Overruns in duration and costs; quality standards; geological risks; environmental among others	Cruz & Marques (2012)
	Unforeseen construction cost overruns risk	Lee et al. (2022)
Delay in stakeholder's project financing	Delay in stakeholder's project financing	Ahmadabadi & Heravi (2019a)
Inaccurate demand forecasts	Inaccurate demand forecasts	McCarthy et al. (2019)
Demand	Change in market demand	Wang et al. (2020)
	Demand risks	Albalate et al. (2015), Burke & Demirag (2015), Burke & Demirag (2017), Cruz & Marques (2011), Cruz & Marques (2012), Šeba (2015), Macário (2010), Makovšek & Moszoro (2018), Regan et al. (2017)
	Improper demand estimation	Ahmadabadi & Heravi (2019a)
	Off-take risks (quantity, pay in time)	Hamzah et al. (2014)
	Uncertainties due to volumes and characteristics of cargo	Cruz & Marques (2012)
	Uncertainty about future traffic demands	Kumar et al. (2018)
	Unexpected changes in market demand	McCarthy et al. (2019)
Engineering or design failures	Engineering or design failures	Ortega et al. (2016)
	Existing structures failure	Akbiyikli (2013)
Initial planning and negotiation time overrun	Initial planning and negotiation time overrun	Ahmadabadi & Heravi (2019a)
Unclear objectives	Unclear objectives	Chung et al. (2010)
Design	Design (technical) risk	Šeba (2015)
	Design and construction risk	Burke & Demirag (2017)
	Design and development	Demirag et al. (2011)
	Design risk	Albornoz et al. (2021), Carbonara et al. (2015), Cruz & Marques (2011)
	Design specification change	Ahmadabadi & Heravi (2019a)
	Design/technical risk	Guasch et al. (2016)
	Faulty project structuring	Babatunde & Perera (2017)
	Mismatch between the terminal characteristics and the objectives	Cruz & Marques (2012)
	Project uniqueness	Wang et al. (2020)
	Relocation of existing infrastructure from motorway corridor	Šeba (2015)
	Replacement of drain, signs, barriers, etc	Akbiyikli (2013)
	Ridership projection risk	Lee et al. (2022)
	Subjective evaluation	Chou et al. (2012)
	Unforeseen defects (including pavement failure)	Akbiyikli (2013)
Environmental	Damage and liability/mitigation costs from adverse environmental events	Ortega et al. (2016)
	Environment	Ahmadabadi & Heravi (2019a)
	Environment and zoning permits risk	Lee et al. (2022)
	Environmental maintenance and major repairs	Cruz & Marques (2011)

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Table A.1 (*continued*)

Risk grouping	Risk	Reference
	Environmental protection	Chou et al. (2012)
	Environmental risk	Albornoz et al. (2021), Cabrera et al. (2015), Grasman et al. (2014), Šeba (2015), Guasch et al. (2016), Hamzah et al. (2014), Wang et al. (2020)
	Significant impact on environmental-sensitive areas	Cruz & Marques (2012)
Capital	Capital risk	Pedro & Macário (2016)
Exchange and interest rate	Exchange and interest rate	Ahmadabadi & Heravi (2019a), Lee et al. (2022)
Foreign exchange and convertibility	Foreign exchange and convertibility	Chou et al. (2012), Šeba (2015)
Future evolution of Social Marginal Costs	Future evolution of Social Marginal Costs	Macário (2010)
Government credit	Government credit	Wang et al. (2020)
Insufficient financial audit	Insufficient financial audit	Chou et al. (2012)
Payment	Payment risk	Chou et al. (2012)
Pre-investment	Pre-investment risk	Carbonara et al. (2015)
Recessionary impacts	Recessionary impacts	McCarthy et al. (2019)
Residual assets	Residual assets risk	Chou et al. (2012)
Financial	(Re-)financing risk	Šeba (2015)
	Interest rate impacting project cash flows	Kumar et al. (2018)
	Faulty financial structuring	Babatunde & Perera (2017)
	Financial risk	Albalate et al. (2015), Albornoz et al. (2021), Cabrera et al. (2015), Carbonara et al. (2015), Chou et al. (2012), Chung et al. (2010), Cruz & Marques (2012), Demirag et al. (2011), Guasch et al. (2016), Hamzah et al. (2014), Jin et al. (2019), Regan et al. (2017), Sugimura et al. (2017), Zhang et al. (2021)
	Financial viability	Wang (2015)
	Financing risk	Cruz & Marques (2011), Wang et al. (2020)
	Lower residual cash flows for debt/equity services	Kumar et al. (2018)
	Innovative financial resources	Wang (2015)
	Loan repayment risk	Šeba (2015)
	Other financial risk	Burke & Demirag (2017)
	Project bankruptcy	Ortega et al. (2016)
	Residual value risk	Burke & Demirag (2017)
Force majeure	Force majeure	Ahmadabadi & Heravi (2019a), Akbiyikli (2013), Albornoz et al. (2021), Cabrera et al. (2015), Carbonara et al. (2015), Chou et al. (2012), Chung et al. (2010), Cruz & Marques (2011), Cruz & Marques (2012), Šeba (2015), Guasch et al. (2016), Hamzah et al. (2014), Iseki & Houtman (2012), Lee et al. (2022), Wang et al. (2020)
	Loss due to prolonged force majeure events	Babatunde & Perera (2017)
	Loss from war and natural disasters	Ortega et al. (2016)
	Risk of force majeure	Zembri-Mary (2017)
Forced buy-out	Forced buy-out	Ahmadabadi & Heravi (2019a)
Geological	Geological risk	Zembri-Mary (2017)
Governance	Change orders risk	Lee et al. (2022)
	Ineffective risk transfer to developer	Wang (2015)
	Organisation and coordination risk	Chou et al. (2012)
	Poor interdepartmental co-ordination	Babatunde & Perera (2017)
	Unilateral changes	Cruz & Marques (2011)
Government	Delay in government approval	Wang et al. (2020)
	Facility turned over to public control in poor condition at end of lease	Iseki & Houtman (2012)
	Government decision-making errors	Wang et al. (2020)
	Intergovernmental conflicts	McCarthy et al. (2019)
	Lack of government commitment to the concession	Ahmadabadi & Heravi (2019a)
	Lack of support from government officials	Babatunde & Perera (2017)
	Loss due to adverse government decisions/policies	Babatunde & Perera (2017)
	Poor political decision making	Chou et al. (2012)
Inflation	Inflation risk	Chou et al. (2012), Cruz & Marques (2011), Šeba (2015)
	Inflation rate lower than what has been assumed in the financial model	Kumar et al. (2018)
Infrastructure	Inability to make transportation improvements in region	Iseki & Houtman (2012)
	Inadequate infrastructure	Wang et al. (2020)
	Lack of supporting infrastructure	Ahmadabadi & Heravi (2019a)
	Renewal and replacement of Structures and Infrastructures	Akbiyikli (2013)
	Site risks (land use and acquisition/resettlement and rehabilitation risk, site condition, site preparation)	Carbonara et al. (2015), Iseki & Houtman (2012)
	Sufficiency of site condition data	Iseki & Houtman (2012)
Interest rate	Interest rate risk	Chou et al. (2012), Lee et al. (2022), Wang et al. (2020)
Land acquisition	Delays in land acquisition	Kumar et al. (2018)
	Expropriation	Chou et al. (2012), Cruz & Marques (2011)
	Inadequate adjoining land for expansion	Hamzah et al. (2014)
	Land acquisition	Ahmadabadi & Heravi (2019a), Albalate et al. (2015), Albornoz et al. (2021), Chou et al. (2012), Šeba (2015), Hamzah et al. (2014), Ortega et al. (2016)
	Nationalisation or expropriation	Ahmadabadi & Heravi (2019a)
	Property acquisition and right of way delays risk	Lee et al. (2022)
Legal	Change in law	Ahmadabadi & Heravi (2019a), Chou et al. (2012)
	Effective legislation	Wang (2015)

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Table A.1 (*continued*)

Risk grouping	Risk	Reference
	Ineffective legislation	Wang (2015)
	Lack of legal/regulatory framework	Ahmadabadi & Heravi (2019a)
	Legal risks	Albornoz et al. (2021), Burke & Demirag (2017), Cruz & Marques (2011), Cruz & Marques (2012), Lee et al. (2022), Wang et al. (2020)
Licence	Approval and permit	Chou et al. (2012)
	Issuance of necessary permits	Šeba (2015)
	Licences, permits and approval risks	Hamzah et al. (2014)
	Complex process of obtaining licences	Cruz & Marques (2012)
	Administrative risk related to land and environmental works	Wang (2015)
Macroeconomic	Macroeconomic risks	Lee et al. (2022)
Maintenance	Maintenance risk	Yuan & Li (2018), Zembri-Mary (2017)
Market	Market risks	Chou et al. (2012), Hamzah et al. (2014)
Media	Media risk	Chung et al. (2010)
Network	Integration with other connecting facilities	Hamzah et al. (2014)
	Network risk	Chung et al. (2010)
Failure of toll collection equipment	Failure of toll collection equipment	Babatunde & Perera (2017)
Material/labor non availability	Material/labor non availability	Ahmadabadi & Heravi (2019a)
Supply	Supply risks	Hamzah et al. (2014)
Operation	Improper operation and maintenance	Ahmadabadi & Heravi (2019a)
	Inadequate performance of sub-contractors	Akbiyikli (2013)
	Loss due to operational problems	Babatunde & Perera (2017)
	Operating risk	Burke & Demirag (2017), Cabrera et al. (2015), Carbonara et al. (2015), Šeba (2015), Guasch et al. (2016)
	Operation risks	Albornoz et al. (2021), Chou et al. (2012), Cruz & Marques (2011), Demirag et al. (2011), Hamzah et al. (2014), Zembri-Mary (2017)
	Pavement patching	Akbiyikli (2013)
	Poor access control due to multiple entry/exit	Babatunde & Perera (2017)
	Productive (or operating) risk	Pedro & Macário (2016)
	Staff costs	Akbiyikli (2013)
	Supporting utilities risk	Chou et al. (2012)
	Maintenance and repair activities	Cruz & Marques (2012)
	Equipment or labour disputes	Hamzah et al. (2014)
	Trespassing through the road	Babatunde & Perera (2017)
Ownership	Ownership	Demirag et al. (2011)
	Risk associated with ownership	Chung et al. (2010)
Performance	Performance	Cruz & Marques (2011)
	Performance below public agency's standards	Iseki & Houtman (2012)
Planning	Planning risk	Burke & Demirag (2017), Cruz & Marques (2011)
	Poor project company management	Wang et al. (2020)
Government reliability	Government reliability	Ahmadabadi & Heravi (2019a), Chou et al. (2012)
Political	Government inaction due to political/social reasons	Babatunde & Perera (2017)
	Government intervention in operation and construction	Ahmadabadi & Heravi (2019a)
	Government's intervention	Chou et al. (2012)
	Ideological opposition	McCarthy et al., (2019)
	Local politics risks	Hamzah et al. (2014), McCarthy et al. (2019)
	Political concerns of foreign takeover	Wang (2015)
	Political concerns with privatisation	Wang (2015)
	Political risk	Ahmadabadi & Heravi (2019a), Albornoz et al. (2021), Babatunde & Perera (2017), Chung et al. (2010), Hamzah et al. (2014), McCarthy et al. (2019), Zembri-Mary (2017)
	Political stability and spending pattern	Hamzah et al. (2014)
	Political transition/ legislative change	McCarthy et al., (2019)
	Presence of competing projects	McCarthy et al., (2019)
	Reduced political risk by public campaign	Wang (2015)
	Severe shortfalls lead to public takeover	Wang (2015)
	Sovereign risk	Chung et al. (2010)
	Transnational law	Ahmadabadi & Heravi (2019a)
	Value For Money (VFM) determination	Regan et al. (2017)
	Uniteral decisions by government	Cruz, Marques (2012)
Private	Consortium inability	Ahmadabadi & Heravi (2019a)
	Continued negligence of operation by concessionaire	Babatunde & Perera (2017)
	Exit strategy for private default or convenience	Iseki & Houtman (2012)
	Inability of private sector contractors	Ahmadabadi & Heravi (2019a)
	Intra consortium counterparty risk	Lee et al. (2022)
	Investors lack of commitment	Ahmadabadi & Heravi (2019a)
	Lack of consortium expertise	Chou et al. (2012)
	Private investor change	Ahmadabadi & Heravi (2019a), Chou et al. (2012)
	Risk of operating and maintenance costs overruns not attributable to public sector	Lee et al. (2022)
	Third party reliability	Chou et al. (2012)
Project	Project complexity	Ahmadabadi & Heravi (2019a)
	Project default risk (combination of risks)	Cabrera et al. (2015)

(*continued on next page*)

Table A.1 (*continued*)

Risk grouping	Risk	Reference
	Project default risk (project bankruptcy from any/all of the factors above)	Guasch et al. (2016)
	Project delays, changes in law/policy affecting revenue	Ortega et al. (2016)
Quality standards	Quality standards	Ahmadabadi & Heravi (2019a)
Regulation	Administrative/regulatory risk with costly, lenghtly environmental clearance	Wang (2015)
	Change in tax regulation	Ahmadabadi & Heravi (2019a)
	Changes in tariff regulation and quotas	Hamzah et al. (2014)
	Failure to obtain or renew approvals	Ahmadabadi & Heravi (2019a)
	Fee change	Wang et al., 2020)
	Imperfect legal and regulatory system	Chou et al. (2012), Wang et al. (2020)
	Regulatory risk	Cabrera et al. (2015), Carbonara et al. (2015), Cruz & Marques (2011), Freestone et al. (2011), Šeba (2015), Guasch et al. (2016), Wang (2015), Zembri-Mary (2017)
	Tarrif change	Chou et al. (2012)
	Tax regulation changes	Chou et al. (2012)
Revenue	Deficient revenue due to low traffic volume or lower price due to demand elasticity	Ortega et al. (2016)
	Insufficient revenue in the market	Wang et al. (2020)
	Revenue risk	Cabrera et al. (2015), Carbonara et al. (2015), Guasch et al. (2016), Pedro & Macário (2016), Rouhani et al. (2018), Wang (2015)
Safety	Health and safety risks	Lee et al. (2022)
	Road safety audits	Akbiyikli (2013)
Social	Cultural and social impacts	Ahmadabadi & Heravi (2019a)
	Loss due to resistance to pay	Babatunde & Perera (2017)
	Public contestation	Cruz & Marques (2011)
	Public misperception	Chung et al. (2010)
	Public objection	Wang et al. (2020)
	Public/political opposition	Chou et al. (2012)
	Social risk	Zembri-Mary (2017)
	Vandalism	Akbiyikli (2013)
Delay in supply	Delay in supply	Chou et al. (2012)
Technical	Technical risk	Cabrera et al. (2015), Zembri-Mary (2017)
Technology	Technological risk	Ahmadabadi & Heravi (2019a), Albornoz et al. (2021), Chou et al. (2012), Cruz & Marques (2011), Cruz & Marques (2012)
	Untested technology risk	Lee et al. (2022)
Toll-related	Alteration in toll structure	Babatunde & Perera (2017)
	Expectations of undue favour not entertained	Babatunde & Perera (2017)
	Inadequate government supports for toll enforcement	Babatunde & Perera (2017)
	Inadequate toll acts provisions	Babatunde & Perera (2017)
	Increase in income tax	Babatunde & Perera (2017)
	Inefficient toll collection/accounting system	Babatunde & Perera (2017)
	Loss due to poor toll enforceability	Babatunde & Perera (2017)
	Loss of toll revenue	Iseki & Houtman (2012)
	Malpractice in tolling	Babatunde & Perera (2017)
	Unacceptably high toll rate	Babatunde & Perera (2017)
Tourism business prosperity	Tourism business prosperity	Hamzah et al. (2014)
Traffic	Loss due to decline in traffic demand	Babatunde & Perera (2017)
	Traffic risk	Akbiyikli (2013), Albornoz et al. (2021), Carpintero et al. (2015), Chung et al. (2010), Iseki & Houtman (2012), Zembri-Mary (2017)
Uncompetitive tender	Uncompetitive tender	Ahmadabadi & Heravi (2019a), Chou et al. (2012)
Utilities	Accessibility	Cruz & Marques (2012)
	Aging and deterioration	Yuan & Li (2018)
	Utilities access	Akbiyikli (2013)
Weather	Ground/weather conditions	Chou et al. (2012)
	Weather	Akbiyikli (2013)

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trip.2024.101031.

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