

01 Mar 2024

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Recommended Citation

M. Abdul Nabi et al., "Modeling And Understanding Dispute Causation In The US Public-Private Partnership Projects," *Journal of Infrastructure Systems*, vol. 30, no. 1, article no. 04023035, American Society of Civil Engineers, Mar 2024.

The definitive version is available at <https://doi.org/10.1061/JITSE4.ISENG-2328>

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Modeling and Understanding Dispute Causation in the US Public–Private Partnership Projects

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Abstract: The partnership between the public and private sectors has led to a new and innovative way of delivering infrastructure projects that is referred to as public–private partnership (PPP). There are various benefits associated with PPP delivery methods including risk sharing, access to private funding, innovation, and flexibility, among others. Despite the proved benefits, contract conflicts and disputes are very common in PPP projects. While previous research studies examined the risks and the potential causes of conflicts in PPP projects, little-to-no research efforts were directed to study and model the interconnectivities between the different causes of conflicts in PPP agreements. To this end, the aim of this paper is to fill the gap in knowledge by providing a deeper understanding of the causalities or relationships between the different factors that cause disputes in PPP projects in the United States. The authors used a comprehensive analytical approach that involved three primary steps. First, 37 PPP case studies of infrastructure and construction projects were collected and analyzed using manual content analysis. Second, social network analysis was conducted to study the interdependencies between the different causal factors leading to disputes in PPP in general and in relation to Execution, Investment and Operation, and Third-Party Claims, in particular. Third, association rule analysis was conducted to identify key associations between the different causal factors that may trigger the three different types of PPP disputes. The findings showed that the key causes of disputes in PPP projects are related to (1) legal and regulatory, (2) payment and financial, and (3) poor management. While Execution-related disputes were found to be caused by complex interactions of causal factors, dispute causation of Investment and Operation–related and Third-Party Claims–related disputes seemed to be less simplistic. As such, the outcomes of this paper highlighted the important aspects required to avoid dispute occurrence in PPP projects. Ultimately, this paper contributes to the body of knowledge by providing directions for scholars and practitioners toward the aspects and interdependencies that require optimization and/or thorough consideration to avoid dispute occurrence and subsequently ensure successful implementation of PPPs. DOI: [10.1061/JITSE4.ISENG-2328](https://doi.org/10.1061/JITSE4.ISENG-2328). © 2023 American Society of Civil Engineers.

Introduction

The traditional model of delivering infrastructure projects entails that the public sector (e.g., the government) is the primarily party responsible for the public services. Nevertheless, it is well documented that the public sector alone cannot bear the investments needed for a prosperous infrastructure development (Mahalingam 2010). For instance, the recent ASCE (2021) infrastructure report card shows that the total investment gap has gone from \$2.1 trillion to nearly \$2.59 trillion. Due to the tremendous capital investments needed for maintaining, renewing, and expanding the crumbling

infrastructure assets, it was necessary for the public sector to think of innovative ways for financing infrastructure and construction projects. To this end, the partnership between the public and private sectors has led to a new and innovative way of delivering infrastructure projects, formerly referred to as public–private partnership (PPP).

The United States Government Accountability Office (1999) defines a PPP as “a contractual arrangement that is formed between public and private-sector partners . . . to renovate, construct, operate, maintain, and/or manage a facility or system, in whole or in part, that provides a public service. Under these arrangements, the agency may retain ownership of the public facility or system, but the private party generally invests its own capital to design and develop the properties. Typically, each partner shares in income resulting from the partnership.” According to the World Bank PPI Report (Saha et al. 2022), the private sector contribution to public infrastructure increased by 49% in 2022 when compared to 2021. Such increased reliance on PPP delivery methods is associated with various benefits including: (1) high capability to deliver value-for-money public services and infrastructure; (2) the introduction of the private sector’s sources and expertise (i.e., financial, technical, and managerial innovation); (3) reduced life-cycle cost, improved service, and performance quality; and (4) promoted public management, among others (Zheng and Tiong 2010).

Despite the documented and proved benefits, contract conflicts and disputes are very common in PPP projects (Owolabi et al. 2018). In fact, PPP projects are prone to complex disputes because they involve complex contractual arrangements, multiple stakeholders (Ahatty et al. 2021), and long-term commitments (Siddiquee 2011). Furthermore, disputes can arise at any stage of the PPP project life cycle, including contract negotiation, construction, and operations (Caldwell et al. 2009). Thus, analyzing PPP disputes is crucial

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Note. This manuscript was submitted on March 21, 2023; approved on September 13, 2023; published online on November 2, 2023. Discussion period open until April 2, 2024; separate discussions must be submitted for individual papers. This paper is part of the *Journal of Infrastructure Systems*, © ASCE, ISSN 1076-0342.

to ensure successful implementation that protects the public interest, achieves project objectives, identifies underlying problems, facilitates communication, and enhances accountability among project stakeholders. Based on the aforementioned, there is a dire need to analyze and understand the underlying problems and issues leading to disputes in PPP projects.

Generally, disputes in construction projects are usually caused by multiple events or factors contributing to problems between stakeholders. Therefore, it is important to investigate the relationships among the various causal factors in order to control and minimize the sources of disputes. This is supported by Woodley (2019), who argued that the complex interplay among multiple factors is responsible for claims and disputes, and that simple procedures to avoid disputes are unlikely to be effective. Love et al. (2008) proposed that in order to decrease the occurrence of conflicts in construction, it is crucial not only to pinpoint the primary factors that cause them, but also to investigate their intricate relationships and connections. In relation to PPP disputes, Zhang et al. (2021) argues that the causes of conflicts are considered to be one of the most important risks on PPP projects because they do not only directly affect the project goals, but also have a substantial indirect impact on the project through their interaction with other causes. Hence, to minimize the occurrence of disputes in PPP projects, it is vital to comprehend not only the primary factors that cause them but also the relationships and interconnections between those factors.

Knowledge Gap and Research Goal

Many studies were directed to solve different issues encountered in PPP schemes as well as provide great addition to the PPP body of knowledge. While some studies focused on the payment-, financial-, and incentive-related aspects associated with PPP projects (Carmichael et al. 2019; Li et al. 2020; Wang and Zhang 2019; Dai et al. 2021; Swanson and Sakhrani 2020; Owolabi et al. 2020; Osei-Kyei and Chan 2015), others have directed their efforts toward social (Wang et al. 2021), behavioral (Lv et al. 2021; Guevara et al. 2020), and stakeholders' relationship-related issues (Salazar et al. 2021). Furthermore, there are studies that focused on (1) studying the knowledge structure related to PPP, (2) examining procurement strategies (Dolla and Laishram 2020), and (3) contract management and governance models (Neto et al. 2020). Finally, some studies focused on the causes of failures associated with PPP projects in general, or in relation to specific regions, countries, or infrastructure sectors, including comparing the root causes of conflicts in PPP agreements between different counties (e.g., China and Ghana) (Osei-Kyei et al. 2019) and presenting theoretical "causal-predictive" models of the root causes and preventive measures for interorganization disputes in PPP projects in Iran (Mirzaee et al. 2022). Table 1 summarizes the studies that examined PPP-related issues along with the scope and their achieved objectives in relation to this paper.

As presented in Table 1, various studies have identified factors leading to failures in PPP projects. Generally, potential causes of conflicts and disputes among project stakeholders—as well as failure of PPP—may also be associated with inefficiencies such as poor management, delays, and cost overruns, among others (Zhang and Tariq 2020; Tariq and Zhang 2021a, b). Despite the latter, not all factors triggering disputes may also lead to the failure of the entire PPP agreement but rather only cause inefficiencies and suboptimal performance. To this end, a research study focusing on actual disputes rather than PPP failures in general is needed to ensure that only factors leading to disputes are examined. However, as previously stated, the most efficient method to decrease the likelihood of disputes in construction projects, including PPP projects,

is not only to pinpoint the primary factors that cause them but also to investigate their intricate relationships and connections (Love et al. 2008; Woodley 2019; Zhang et al. 2021). Despite the latter, the literature falls short in addressing the direct causes leading to PPP disputes and their interconnectivities in general and in the United States, in particular. Therefore, while few previous studies have identified some of the causes of conflicts in PPPs projects (such as Osei-Kyei et al. 2019; Mirzaee et al. 2022), there exists a gap in the body of knowledge in relation to understanding and modeling the interconnectivities and causal relationships between the different causes of disputes in PPP agreements. Hence, this paper contributes to the existing literature by providing a deeper understanding of the interdependencies between the different causes of disputes in PPP projects, which will assist project parties to better determine how the occurrence of one (or more) dispute(s) might impact or affect the likelihood of another (or other) dispute(s). This will ultimately help the contracting parties to draw proper inferences about dispute causalities in their PPP projects and, consequently, identify actions or mitigation measures that could be taken in order to avoid critical disputes between them and improve the performance of their PPP projects.

Research Methodology

For the analysis of this paper, the authors adopted an integrated analytical approach consisting of three primary steps, as illustrated in Fig. 1 where the subsequent subsections provide a detailed explanation of each step.

To ensure the reliability, validity, and accuracy of the followed case study analysis process in this paper, the authors followed a methodology that adheres to the guiding principles provided by Yin (2018) in relation to conducting case study research. More specifically, Yin (2018) recommends that the following general tasks be followed when conducting case study research: plan, design, prepare, collect, analyze, and share. In relation to that, the authors "planned" the case study process by determining the context, scope, and focus of the intended analysis and identifying the research goal (i.e., which is providing a deeper understanding of the factors that may cause disputes in the US PPP projects). As for the "design" phase, the authors have identified potentially relevant case studies by specifying that the following criteria have to be met by the considered case studies: (1) PPP projects executed in the United States, (2) projects with disputes between the project parties, and (3) projects in the infrastructure and construction sector rather in other sectors. Thus, multiple case studies were considered rather than a single case study. As for the "preparation" task, the authors have developed a case study protocol to guide the actual data collection process by screening candidate cases and conducting a pilot case study in order to reduce any potential biases. Afterward, the authors have "collected" the relevant case studies through the Case Law Google Scholar search engine that includes documentations and archival records of the reasons of disputes between the parties in PPP projects. Next, the authors "analyzed" the collected information from the case studies using a combination of analysis procedures, mainly content analysis, social network analysis, and association rule analysis, as subsequently detailed in the paper. Finally, the authors have "shared" the obtained insights or conclusions from the case studies through visual (e.g., the figures presented in this paper) and textual (i.e., discussing the obtained findings as subsequently provided in the paper) means.

Step 1: Data Collection

The first step of the methodology comprises of (1) collecting actual case studies of litigations related to PPP projects; and

Table 1. PPP-related research work

Papers	Scope	Causes of PPP failures	Causes of disputes	Interconnectivities
Sinha and Jha (2019)	Analysis of the impact of judicial overreach on PPP construction projects.	Yes	No	No
Zhang and Tariq (2020)	Categorization of the types of water PPP failures, and identify failure drivers occurring in different stages of the PPP life cycle.	Yes	No	No
Wang et al. (2021)	Incorporation of social benefits into an evaluation model to balance the protection of public and private interests in transportation PPP projects.	No	No	No
Carmichael et al. (2019)	Analysis of PPP toll road options based on discounted probabilistic cash flows.	No	No	No
Li et al. (2020)	Development of a dynamic reputation incentive mechanism for urban water environment treatment PPP projects.	No	No	No
Wang and Zhang (2019)	Development of a model to determine the value of the standby letter of credit in the transfer stage of a PPP project.	No	No	No
Song et al. (2022)	Identification of the intellectual structure and knowledge domains of PPP research.	No	No	No
Neto et al. (2020)	A comparative analysis of Brazilian PPP units in terms of governance models, infrastructure growth, and contract management.	No	No	No
Tariq and Zhang (2020)	Study of the failure drivers in international water PPP projects and categorizing them.	Yes	No	No
Salazar et al. (2021)	Examination of the mechanisms associated with the way PPP sponsors establish relationships among themselves.	No	No	No
Tariq and Zhang (2021a)	Identification of the factors associated with the private sectors leading to the failure of water PPPs.	Yes	No	No
Tariq and Zhang (2021b)	Exploration of the socioeconomic, macroeconomic, and social-political failure drivers leading to the failure of international water PPPs.	Yes	No	No
Dai et al. (2021)	Investigation of the relationships between the characteristics of eldercare PPP facility projects and payment mechanisms.	No	No	No
Lv et al. (2021)	Examination of how PPP renegotiation behaviors evolve with traffic changes.	No	No	No
Swanson and Sakhrani (2020)	Development of an approach to appropriating the value of flexibility in PPP megaproject design.	No	No	No
Zhang et al. (2021)	Establishment of a legal framework for international PPP projects to evaluate the legal risks of the entire project life cycle.	Yes	No	No
Owolabi et al. (2020)	Investigation of the project financiers' perspectives on the critical success factors for bankable completion risk in private finance initiative and PPP megaprojects.	No	No	No
Guevara et al. (2020)	Examination of the behavior associated with special purpose vehicles equity investors participating in PPP tendering processes.	No	No	No
Dolla and Laishram (2020)	Assessment of the impact of procurement strategies on the local governments' service delivery in the context of India.	No	No	No
Tariq and Zhang (2021c)	Critical analysis of the failure causes of PPP water projects in sub-Saharan Africa.	Yes	No	No
Alcazar et al. (2000)	Analyzing the Buenos Aires water concession.	No	No	No
Bayliss et al. (2001)	Investigating the benefits and challenges of water privatization in Africa.	No	No	No
Casarin et al. (2007)	Analyzing lessons learned and failure of water privatization from the Buenos Aires's concession.	Yes	No	No
Hall et al. (2005)	Investigating the role of public resistance to failure of privatization in water and energy.	Yes	No	No
Nickson and Vargas (2002)	Examining the impact of governmental capacity on the failure of private participation in water sector.	Yes	No	No
Osei-Kyei et al. (2019)	Exploring and comparing the root causes of conflicts and conflict resolution mechanisms in PPPs between Ghana and China.	No	Yes	No
Mirzaee et al. (2022)	Presenting a causal-predictive model of the root causes and preventive measures for interorganization disputes in PPP projects in Iran.	No	Yes	No

(2) subsequently documenting the main causes that led to litigations and disputes.

Collection of Legal Case Studies

To achieve the goal of this paper, there is a need to identify the main causes leading to disputes in PPP projects. Different resources could be adopted for the identification process of disputes causes including: literature review, documentations of alternative dispute resolution methods (i.e., arbitration, mediation, etc.), and/or litigations. However, for the analysis of this paper, there is a need to investigate the causes and their interconnectivities rather than individually.

Thus, the authors opted for utilizing actual case studies rather than the literature because the latter may not provide adequate insights on the cooccurrence of the causes in PPP disputes. Furthermore, because it is hard to access PPP disputes handled using alternative dispute resolution methods due their confidential nature, the authors collected case studies of actual litigations related to PPP infrastructure and construction projects in the United States.

The legal case studies were collected using the Case Law Google Scholar search engine due to (1) its efficient accessibility, (2) availability of legal case studies across all US state and federal courts, and (3) its frequent use by previous published studies to

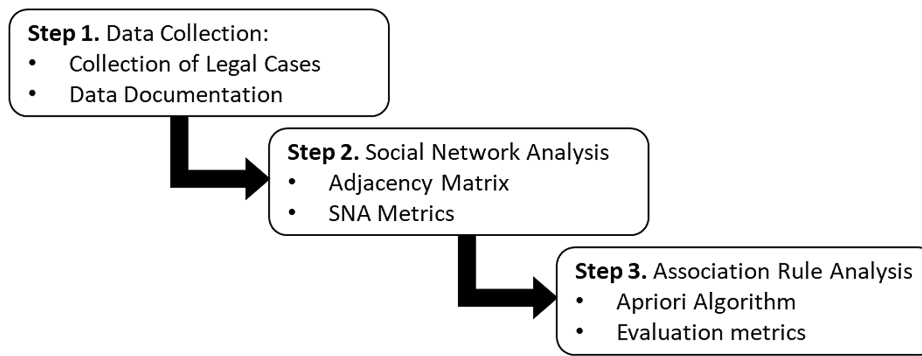


Fig. 1. Research methodology.

investigate various contractual and legal aspects (Abdul Nabi and El-adaway 2022; Ali et al. 2021; Sexton et al. 2020). The database search process included the use of predefined keywords including: “Public-Private Partnerships,” “PPP,” and “Construction.” The database search led to the collection of 241 case studies of litigations in various US federal and state courts. Afterward, the authors made sure that only relevant case studies of litigations are included in the analysis of this paper. To this end, a preliminary screening was performed as to only include the case studies reflecting (1) disputes in projects related to the infrastructure and construction sector rather than to other sectors, (2) disputed projects are delivered using PPP, and (3) the factual context surrounding the disputes among the stakeholders involved in the project. It is important to note that most legal case studies stipulate the facts needed for the court to resolve the litigated disputes among the parties. Thus, the authors made sure to include only those possessing clear examination of the facts that led to litigations among the PPP stakeholders.

Furthermore, in case the same PPP project had multiple court reviews and reports, the authors considered them as a single case study to avoid duplications and ensure optimal results. Based on the aforementioned criteria, a total of 51 court reviews and reports pertaining to 37 different legal case studies of litigations were considered for analysis in this paper.

Data Documentation

Upon data collection, the authors analyzed the case studies by documenting (1) all the relevant causes that led to disputes among the PPP stakeholders, (2) the type of court assigned to rule for the dispute (i.e., state versus federal courts), and (3) the project type (i.e., horizontal versus vertical). Furthermore, PPP agreements can have different modes (i.e., Build-Operate-Transfer, Transfer-Operate-Transfer, among others) and functions (i.e., leasing, loan, development, construction execution, etc.) (Yang et al. 2020). To accommodate for the different PPP modes and functions, the legal case studies were categorized into the following three types: (1) Execution, (2) Investment and Operation, and (3) Third-Party Claims. This categorization is based on prior studies that highlighted that disputes could occur during the execution or construction phase of PPP projects (Okudan and Çevikbaş 2022; Cherkos et al. 2020; Sharafi et al. 2018), or during the Investment and Operation phase of PPP projects (i.e., disputes associated with sponsors, investors, and operators of the project) (Chou and Lin 2013; Ramsey and Asmar 2020), or due to third-party claims (i.e., disputes) between parties having no contractual privity (such as public organizations, community, etc.) and PPP stakeholders (Chew and Kolivos 2011; Currie and Teague 2015; Ivanov 2015).

The identification of the causes of disputes and the analysis of the case studies was performed using content analysis, which was

carried out in accordance with the guidelines provided by Creswell (2009) for qualitative research methods. More specifically, the procedure followed in this paper is known as “inductive manual content analysis” (Kyngäs 2020) and it was chosen because it ensures better accuracy and documentation of the identified dispute causes and case study attributes (Abdul Nabi and El-adaway 2022). As for the considered criteria, the documentation process (i.e., the content analysis) mainly focused only on the causes that were mentioned in the court review and the factual background associated with the litigated disputes as to avoid any subjectivity and biasness throughout the process. During the review and analysis process, the authors constructed a reference matrix R such that the identified causes are presented as rows and the reviewed litigation as columns. Whenever a cause is referred to in any of the reviewed case studies, its corresponding cell is assigned a value of 1; otherwise, the corresponding cell value is set to 0. Following the aforementioned procedure, the authors were able to construct a c by l binary matrix R where c represents the number of identified causes and l represents the number of analyzed litigations (which is 37 for this paper). It is important to note that the transformation into a binary matrix is essential to allow the authors to examine not only the frequency but also the cooccurrence and interconnectivities of the various causes leading to disputes in PPP projects. Furthermore, to understand how causation pattern differs in relation to the different dispute types, the analysis will also be conducted on the legal cases as categorized by their dispute type. Thus, after formulating the reference matrix $R_{c \times l}$, a reference submatrix was derived for each type of dispute and analyzed individually (i.e., a total of three submatrices). It is worth mentioning that all potential causes in the current studies were considered in the content analysis. As for the “coding” process of the causes of disputes, more details are provided in the Appendix, which presents the identified causes, a brief description for each cause, and sample excerpts from the analyzed case studies.

Step 2: Social Network Analysis

Social network analysis (SNA) is important to study the interconnectivity between different causal factors because it provides a way to understand how different factors interact and collectively produce complex outcomes (i.e., disputes for this paper) (Walters and Chinowsky 2016). SNA can be used to map out the connections between different causal factors, revealing how they interact and influence each other (Bahaei and Gallina 2023). By examining the structure of these networks, researchers can identify key factors that play a critical role—as well as the ways in which different factors interact—in relation to the investigated problem (Luo and Zhong 2015). SNA consists of investigating social structures using graph

theory and networks (Otte and Rousseau 2002). Typically, networks are composed of nodes and edges. Nonetheless, the advantages of SNA are derived from its centrality metrics that enable the identification of the most significant nodes based on their frequency and connections to other nodes within the same network (Abdul Nabi et al. 2020). To this end, SNA is an effective tool for investigating interconnectivity and interactions among different elements.

Despite being used originally for social science, SNA was incorporated in various infrastructure and construction engineering and management-related research (Eteifa and El-adaway 2018; Aljassmi et al. 2014; Wambeke et al. 2012; Rubulotta et al. 2013; Abdul Nabi et al. 2020). For instance, Aljassmi et al. (2014) identified the causes of defects in construction projects and ranked them based on SNA centrality metrics. Similarly, Eteifa and El-adaway (2018) examined the central causes of fatalities in construction projects. As for the scope of this paper, analyzing disputes requires not only to recognize the main underlying factors but also to investigate their intricate connections and interdependencies (Love et al. 2008; Abdul Nabi and El-adaway 2022). Based on the aforementioned reasons, the authors adopted SNA to analyze the key causes of disputes in PPP infrastructure and construction projects, while also considering their interconnectivities. SNA was used in this paper in order to study the cooccurrence and the interconnectivities between the different causes of disputes. In other words, the cooccurrence of the different causes of disputes was represented as a binary matrix (i.e., referred to as the “reference matrix” as detailed in the next subsection) based on the causes of disputes that appeared in the same case study; whereas, the interconnectivities between the different causes of disputes was represented as a weighted numerical matrix (i.e., referred to as the “adjacency matrix” as detailed in the next subsection). It is worth mentioning that the foundation behind the use of such representations for the cooccurrence and interconnectivities between the factors has been used by many previous research studies that used SNA to study and model the dependencies between different factors, such as factors leading to disputes in modular construction projects (Abdul Nabi and El-adaway 2022), factors leading to construction business failure (Assaad and El-adaway 2020), factors leading to safety fatalities (Eteifa and El-adaway 2018), and factors influencing bundling strategies of infrastructure projects (Assaf and Assaad 2023), among others.

Construction of the Adjacency Matrix

In order to perform SNA, a weighted adjacency matrix $A_{c \times c}$ should be developed based on the reference matrix $R_{c \times l}$ constructed during data documentation and case study analysis (Hummon and Doreian 1990). The weighted adjacency matrix $A_{c \times c}$ is derived by multiplying the reference matrix $R_{n \times m}$ by its transpose and replacing its diagonal entries with zeros as shown in Eq. (1) (Eteifa and El-adaway 2018)

$$A_{c \times c} = \begin{cases} R_{c \times l} \times R_{l \times c}^T & \text{for } i \neq j \\ 0 & \text{for } i = j \end{cases} \quad (1)$$

where $R_{l \times c}^T$ is the transpose of the reference matrix, c is the total number of causes, and l is the number of case studies.

SNA Metrics

Once the weighted adjacency matrix $A_{c \times c}$ is derived, the authors are able to develop a network graph depicting the causes as nodes and their interconnections as edges. The matrix $A_{c \times c}$ is then utilized for network visualization and analysis using the Gephi software package. There are many centrality measures used in SNA to reflect interconnectivities among the various nodes of the network. However, the authors utilized the most commonly adopted measures to

analyze undirected weighted networks in the infrastructure and construction engineering and management-related field including:

1. **Network Density:** this quantifies overall connectivity among the causes in the network (Park et al. 2011). As such, network density is the proportion of the links that were actualized among the c causes (nodes) of the dispute network (Giuffre 2015). It is calculated using

$$\text{Network Density} = \frac{2 \times \text{Actual connections}}{c \times (c - 1)} \quad (2)$$

2. **Weighted Degree Centrality:** this is the sum of all edges' weights connected to a given node (Freeman 1978). For the scope of this paper, it represents the number of times a cause occurred with other causes in the analyzed litigations and disputes. The degree centrality (DC) of an i th cause is calculated by simply summing the entries of the i th row in the weighted adjacency matrix $A_{c \times c}$ as depicted in Eq. (3)

$$d_i = \sum_{j=1}^n a_{ij} \quad (3)$$

where d_i is the degree centrality of a node (cause of conflict) i , and a_{ij} is the entry at the i th row and j th column of matrix $A_{c \times c}$.

Step 3: Association Rule Analysis

The authors performed association rule analysis (ARA) by adopting the Apriori algorithm to examine the different possible associations. According to Agrawal et al. (1993), ARA is a well-known method for identifying associations among different factors in a database. The Apriori algorithm has numerous advantageous features such as its ability to uncover hidden patterns and combinations, and its user-friendliness (Verma et al. 2014). Htet (2019) asserts that this algorithm is a prominent technique for discovering knowledge in data mining. Thus, various studies, such as Xu et al. (2018), Assaad and El-adaway (2021), and Liao and Perng (2008), have used the Apriori algorithm to investigate interconnections between different variables related to construction management and engineering field. Following the same approach, the authors adopted ARA to identify and quantify the key associations between the causes that trigger PPP disputes in relation to relation to the different dispute types.

An association rule is a relationship between two or more items that occurs frequently in the data set. An association rule is typically expressed in the form $\{X \sim Y\}$ where X and Y are sets of items. The strength of an association rule is measured using three metrics: support, confidence, and lift (Shi et al. 2019). Support measures the frequency with which the rule occurs in the data set, while confidence measures the proportion of times that the rule is true for the items in the data set (Liu et al. 2018). The Apriori algorithm calculates the support and confidence of each association rule, and then filters out rules that do not meet the minimum support and confidence thresholds. While the considered data set of 37 case studies in this paper might be perceived to be relatively small for ARA, it is, however, considered to be sufficient for the aim of this paper. In fact, previous studies that conducted ARA on case studies in the construction and infrastructure management area included comparable sample sizes (Abdul Nabi and El-adaway 2022; Assaad and El-adaway 2021; Khalef and El-adaway 2023; Ahmed and El-adaway 2023). Nevertheless, to overcome potential biases that might occur due to the considered sample size in this paper, the authors have specified threshold values for the “support” and “confidence” measures in order to make sure that only reliable and robust associations are identified (Navale and Mali 2019).

More specifically, the threshold values were specified as percentage values rather than as absolute (or crisp) values in order to avoid any drawbacks that might be caused by the considered sample size. In relation to that, the authors used a threshold equal to 30% for the “support” measure and a threshold of 75% for the “confidence” measure as recommended by previous studies for comparable sample sizes (Ye et al. 2019; Azamouh et al. 2013). Finally, the lift is a measure of the strength of association between two items (Chen et al. 2020). Generally, a lift value greater than 1 indicates that the two items are positively associated with each other (Ayub et al. 2017). To this end, key associations of causes are those possessing a lift greater than 1, while satisfying the previously mentioned support and confidence thresholds.

In order to apply the Apriori algorithm, the authors used the reference submatrices reflecting the legal cases for the three different dispute types. For each reference submatrix, the Apriori algorithm is performed to generate associations and interconnectivities. The Apriori algorithm works in two phases. In the first phase, it scans the data set to identify frequent itemsets. An itemset is considered frequent if it occurs in the data set with evaluation metrics that exceed a predefined minimum support and confidence threshold (Shi et al. 2019). In the second phase, the Apriori algorithm uses the frequent itemsets generated in the first phase to generate association rules, and subsequently calculate their evaluation metrics (Abdul Nabi and El-adaway 2022).

Results and Analysis

Collected Case Studies

A total of 51 legal case studies were collected. These case studies belong to 37 different PPP projects. The collected legal case studies are presented along with their references and citations in Table 2.

The collected legal case studies reflect litigations as follows: (1) spanning the period between 2002 and 2021, (2) from the various US federal and state courts, (3) pertaining to PPP horizontal and vertical construction and development projects, and (4) for different dispute types.

Fig. 2 shows the distribution of the cases across different project types, court types, and dispute types. As shown in Fig. 2, 56.8% of the collected legal case studies were litigated in state courts, while the remaining 43.2% were litigated in federal courts. Furthermore, 59.5% of the case studies were vertical projects, while 40.5% were horizontal projects. While horizontal projects included highways, bridges, and runways, vertical projects included telecommunication towers, water treatment facilities, and public buildings, among others. Furthermore, Fig. 2 shows that 37.8% of the collected PPP legal case studies included Execution-related disputes, 29.7% included Investment and Operation-related disputes; and 32.4% included Third-Party Claims-related disputes. Therefore, different dispute types in PPP projects may be triggered by different causes. The latter explains the motivation behind analyzing the causes of disputes at the aggregate level (overall network) and at the dispute-type level.

Identified Causes of Disputes

Based on the conducted manual content analysis of the collected cases, a total of 15 causes were identified ranging from payment and financial aspects, bidding-related issues, design, work progress, to legal and regulatory. After identifying the causes of disputes, the reference matrix R was constructed. More specifically, the binary matrix R was constructed comprising of 15 rows representing the identified causes and 37 columns representing the analyzed cases. Fig. 3 shows the constructed reference matrix R where a shaded cell

indicates that the corresponding cause was mentioned in the case study (i.e., having a value of 1).

Social Network Analysis

To perform SNA, the reference matrix $R_{15 \times 37}$ was transformed into a weighted adjacency matrix $A_{15 \times 15}$ to visualize the dispute causation network. Fig. 4 shows the aggregate network (i.e., the one including all legal cases) comprising of 15 nodes representing the identified causes of disputes and 98 edges representing their interconnectivities. The degree centralities of the causal factors are proportional to the size and color intensity of the nodes. In other words, as the degree centrality increases, the size and color intensity of the node increase. Furthermore, the strength of interconnectivities between each pair of causal factors is represented by the thickness and color intensity of edges. Therefore, higher interconnectivity between any pair of factors is associated with thick and dark-colored edges.

Fig. 4 shows that the most eminent causal factors of disputes in PPP projects are (1) payment and financial, (2) legal and regulatory, and (3) poor management. Referring to Eq. (2), the authors were able to compute the density of the aggregate causation network. Given that the actual number of edges is 98, the network density is then equal to $(2 \times 98)/(15 \times 14) = 0.933$. The latter indicates that 93.3% of all potential connections were actualized in the network. Thus, it can be concluded that disputes were triggered by multiple factors rather than a single factor, reemphasizing the importance of understanding the interplay of various causal factors on the occurrence of disputes in PPP projects.

In order to better understand PPP dispute causation, the authors investigated the difference between the interactions of causal factors across the various dispute types. To do that, the authors derived the submatrices for the Execution-, Investment and Operation-, and Third-Party Claims-related disputes $R_{15 \times 14}$, $R_{15 \times 11}$, and $R_{15 \times 12}$, respectively. Subsequently, the submatrices were transformed into adjacency matrices following Eq. (1) and the dispute causation subnetwork for each dispute type was plotted in Fig. 5. Similar to the aggregate network of Fig. 4, the color intensity and size of the nodes and edges are proportional to the degree centralities and interconnectivity weights, respectively.

As shown in Fig. 5(a), the most eminent causal factors of construction execution-related disputes in PPP projects are (1) payment and financial, (2) subcontracting, and (3) work progress and delays. Even though subcontracting was not from the top causal factors in the aggregate dispute causation network, it was found to be more critical in the Execution dispute causation subnetwork. The latter is expected because subcontracting-related issues are mainly associated with the execution and construction phase of the construction projects. Another interesting finding is that Execution-related issues are still mostly triggered by payment and financial issues, as well as legal and regulatory issues. Furthermore, the network density for Execution-related disputes still exhibits high-interconnectivities indicating that these types of disputes also depend on complex interrelated factors and project conditions. As for the causation subnetwork of Investment and Operation-related disputes [Fig. 5(b)], the most eminent causal factors are: (1) payment and financial, (2) legal and regulatory, and (3) poor management. It can be noted that labor issues, site conditions, subcontracting, variations and change orders, as well as quality were barely found to cause disputes in the subnetwork under hand. By checking the subnetwork density, it was found to be 0.654 indicating much lower density than that of the aggregate network and Execution subnetwork. This shows that Investment and Operation-related disputes exhibits a more segregated nature—when compared to construction execution-related disputes—in terms of the interconnectivity among the factors

Table 2. References for the collected legal cases

Case study	References
C1	Airis SFO, LLC v. City & County of San Francisco, No. A121855 (California Court of Appeals 2010).
C2	Augusta Apartments LLC v. Landau Building Company, No. 11-0438 (Supreme Court of Appeals of West Virginia.2011)
C3	Bridgeport Harbour Place I, LLC v. Ganim, 30 A.3d 703, 131 Conn. App. 99 (Appellate Court of Connecticut 2011); and Bridgeport Harbour Place I, LLC v. Ganim, (AC 30549) (Conn. App. Ct. Aug. 30, 2011).
C4	Building 11 Investors LLC v. City of Seattle, 912 F. Supp. 2d 972 (United States District Court, W.D. Washington, at Seattle 2012).
C5	Caribbean Airport Facilities INC. v. Vazquez, Civil No. 12-1032CCC (D.P.R. Apr. 4, 2013).
C6	Clearwater Construction v. County Gen. Purpose Auth., 166 A.3d 513 (Commonwealth Court of Pennsylvania 2017); and Clearwater Construction, INC. v. Northampton County Gen. Purpose Auth., No. 1658 CD 2016 (Commonwealth Court of Pennsylvania 2017).
C7	Community House, Inc. v. City of Boise, Idaho, 623 F.3d 945 (9th Cir. 2010); Community House, Inc. v. City of Boise, Idaho, 654 F. Supp. 2d 1154 (D. Idaho 2009); Community House, Inc. v. City of Boise, Idaho, No. 1: 05-cv-00283-CWD (D. Idaho Mar. 18, 2014); Community House, Inc. v. City of Boise, Idaho, No. 09-35780 (9th Cir. Oct. 6, 2010); and Community House, Inc. v. City of Boise, Idaho, No. CIV 05-283-S-BLW (D. Idaho July 29, 2009).
C8	Crown v. Dept. of Transp., 824 N.E.2d 934, 4 N.Y.3d 159, 791 N.Y.S.2d 494 (2005); and Matter of Crown Communication NY, Inc. v. Department of Transp. of The State of New York, 7 (N.Y. Feb. 10, 2005).
C9	Destiny USA Holdings, LLC v. Citigroup Global Mkts. Really Corp., 2009 N.Y. Slip Op 51550 (NY: Supreme Court, Onondaga 2009); and Destiny USA Holdings, LLC v. Citigroup Global Mkts. Really Corp., 2009 N.Y. Slip Op 31584 (NY: Supreme Court, Onondaga 2009)
C10	Detroit Intern. Bridge Co. v. Government of Canada, 192 F. Supp. 3d 54 (D.C. 2016); and Detroit International Bridge Company v. Government of Canada, Civil Action No. 10-476 (RMC) (D.C. June 21, 2016).
C11	Generali-US Branch v. Lachel & Associates, Inc., No. 4: 17-cv-00168-TWP-DML (S.D. Ind. Feb. 19, 2019).
C12	Hills of Troy v. Parsippany, 921 A.2d 1169, 392 N.J. Super. 593 (Super. Ct. Law Div. 2005).
C13	Hurchalla v. Lake Point Phase I, LLC, 278 So. 3d 58 (Fla. Dist. Ct. App. 2019)
C14	Intellect Corporation v. Celco Partnership GP, 160 F. Supp. 3d 157 (D.C. 2016); and Intellect Corporation v. Celco Partnership GP, Civil Action No. 15-0902 (RC) (D.C. Feb. 5, 2016).
C15	Cutonilli v. Federal Transit Administration, Civil Action No. ELH-13-2373 (D. Md. Mar. 30, 2015).
C16	King County v. Viracon, Inc., Civil Action No. 2: 19-cv-508-BJR (W.D. Wash. Dec. 4, 2019).
C17	LandValue 77, LLC v. Board of Trustees of California State University, No. F058451 (Cal. Ct. App. Mar. 16, 2011).
C18	League to Save Lake Tahoe v. Tahoe Regional Planning Agency, No. 3: 09-cv-478-RCJ-RAM (D. Nev. Aug. 29, 2011).
C19	Mewhinney Centerra Lifestyle Center LLC v. Poag & Mcewen Lifestyle Centers-Centerra LLC, 2021 C.O.A. 2 (Colo. App. 2021).
C20	Long v. City of Burlington, 199 A.3d 542, 2018 V.T. 103 (Vt. 2018).
C21	Montgomery County v. CC Homes Associates, LLC, 2107, September Term, 2019 (Md. Ct. Spec. App. July 13, 2021).
C22	MP Nexlevel of California, Inc. v. CVIN, LLC, No. 1: 14-cv-288-LJO-GSA (E.D. Cal. July 7, 2014); and MP Nexlevel of California, Inc. v. CVIN, LLC, No. 1: 14-cv-288-LJO-GSA (E.D. Cal. Oct. 7, 2014).
C23	National City Bank v. Landau Building Company, No. 11-0437 (W. Va. Oct. 21, 2011).
C24	National Waste & Recycling Association v. Warrick County Solid Waste Management District, No. 3: 15-cv-00158-RLY-MPB (S.D. Ind. Mar. 29, 2016).
C25	Parkridge 6 LLC v. US Department of Transportation, No. 1: 09CV1312 (LMB/IDD) (E.D. Va. Apr. 6, 2010); Parkridge 6 LLC v. US Department of Transportation, Civil Action No. 09-cv-01478 (GK) (Dist. Court Nov. 9, 2009); and Parkridge 6 LLC v. US Department of Transportation, 772 F. Supp. 2d 5 (D.C. 2009).
C26	Professional Engineers in California Government v. Department of Transportation, 198 Cal. App. 4th 17, 129 Cal. Rptr. 3d 255 (Ct. App. 2011).
C27	Reading Blue Mountain & Northern Railroad v. Seda-Cog Joint Rail Authority, No. 1627 CD 2018 (Pa. Commw. Ct. July 6, 2020).
C28	Redondo Beach Waterfront, LLC v. City of Redondo Beach, 51 Cal. App. 5th 982 (Ct. App. 2020); Redondo Beach Waterfront, LLC v. City of Redondo Beach, No. B291111 (Cal. Ct. App. July 9, 2020); Redondo Beach Waterfront, LLC v. City of Redondo Beach, No. B291111 (Cal. Ct. App. June 19, 2020); and Redondo Beach Waterfront, LLC v. City of Redondo Beach, No. B292007 (Cal. Ct. App. Apr. 27, 2020).
C29	Richland/Wilkin Joint Powers Authority v. United States Army Corps of Engineers, Civil No. 13-2262 (JRT/LIB) (D. Minn. Apr. 8, 2019); and Richland/Wilkin Joint Powers Authority v. United States Army Corps of Engineers, Civil No. 13-2262 (JRT/LIB) (D. Minn. Sept. 7, 2017).
C30	Star Operations, INC. v. Dig Tech, INC., No. 03-15-00423-CV (Tex. App. July 27, 2017).
C31	Texas Bay Cherry Hill v. City of Fort Worth, 257 S.W.3d 379 (Tex. App. 2008); and Texas Bay Cherry Hill v. City of Fort Worth, No. 2-06-325-CV (Tex. App. May 29, 2008).
C32	The Port of Corpus Christi, LP v. Port of Corpus Christi Authority of Nueces County, No. 13-19-00378-CV (Tex. App. July 1, 2021).
C33	Tutor Perini Bldg. Corp. v. Port Auth. of NY & NJ, 2019 N.Y. Slip Op 31902 (Sup. Ct. 2019).
C34	In Re George Washington Bridge Bus Station Development Venture LLC, No. 20-cv-1324 (AJN) (S.D.N.Y. Feb. 18, 2020); and In Re George Washington Bridge Bus Station Development Venture LLC, No. 20-cv-7433 (JSR) (S.D.N.Y. Aug. 4, 2021).
C35	Walker v. Metropolitan Board of Parks & Recreation, No. M2007-01701-COA-R3-CV (Tenn. Ct. App. Jan. 9, 2009).
C36	Walsh/Granite JV v. HDR Engineering, INC., Civ. A. No. 17-558 (W.D. Pa. Mar. 27, 2019); and Walsh/Granite JV v. HDR Engineering, INC., No. 2: 17-cv-558 (W.D. Pa. Nov. 7, 2017).
C37	Yancey v. International Fidelity Insurance Co., No. 1: 16-cv-0057 (E.D. Va. May 25, 2016).

triggering disputes. Finally, the causation subnetwork of Third-Party Claims show that the most eminent causal factors include: (1) legal and regulatory, (2) poor management, and (3) payment and financial. Thus, the results show that disputes related to Investment and Operation and Third-Party Claims are mostly triggered by the same causal factors identified in the aggregate dispute causation network. Furthermore, the density of the Third-Party Claims subnetwork

has the lowest value indicating the least complexity and interconnectivity among the causal factors compared to all other types of disputes.

To this effect, the results clearly show that payment and financial, legal and regulatory, and poor management are the main causes driving disputes in PPP projects, in general. However, the interconnectivity and associations among these factors may vary depending on

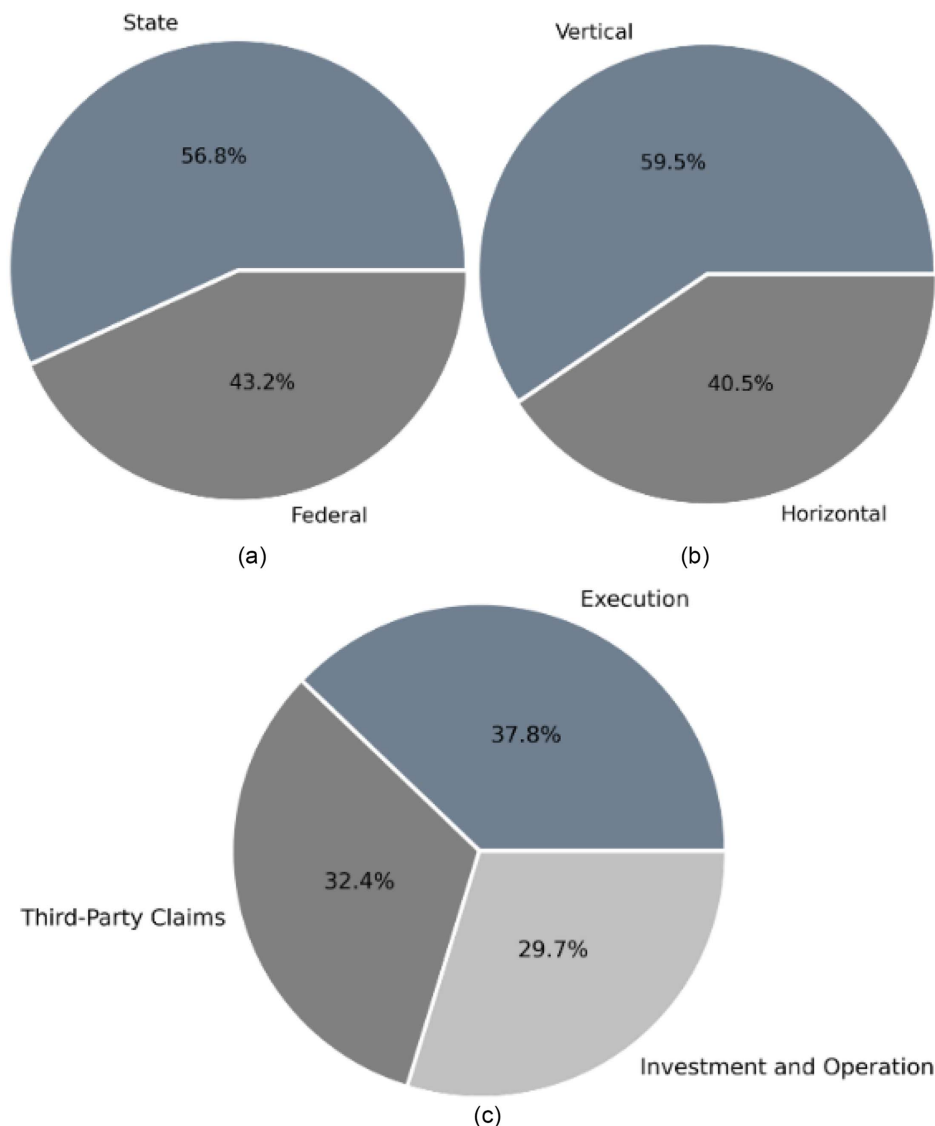


Fig. 2. Distribution of collected cases in terms of: (a) court type; (b) project type; and (c) dispute type.

the dispute type as reflected by different levels of interconnectivities in the various subnetworks. The latter emphasizes the need for more detailed analysis of the interconnectivities in each subnetwork. To achieve that, the Apriori algorithm was performed on each subnetwork. For better understanding of the SNA results, the authors included Table 3 presenting the factors, their DCs in the aggregate network and subnetworks, along with the corresponding network densities.

Association Rule Analysis

This section presents the findings regarding the key associations between the causal factors leading to PPP disputes in relation to Execution, Investment and Operation, and Third-Party Claims.

Key Associations for Execution-Related Disputes

To pinpoint the key associations of factors leading to construction execution-related disputes in PPP projects, all conceivable associations were generated and then sieved using the predetermined thresholds for support, confidence, and lift (0.3, 0.75, and 1, respectively). To this end, four associations met these minimal requirements and are presented along with their evaluation metrics in Table 4.

As shown, all key associations possessed a lift greater than 1. Thus, it can be concluded that there is a correlation between work progress and delays and (1) design errors, (2) legal and regulation, and (3) payment and financial. Furthermore, another key association shows a positive correlation between subcontracting on one hand and payment and financial on the other. Such results align with having payment and financial, subcontracting, work progress and delays, and legal and regulatory as the most central causes of PPP disputes in relation to disputes. However, no key association was found between poor management and any other causal factors. The latter does not indicate that poor management is not an important causal factor but rather no evidence of any positive correlation with any other causes. On the other hand, although design errors are not from the most central causes, it has a strong positive association with work progress and delays. Ultimately, these identified associations when cooccurring are most likely to trigger disputes during the Execution of PPP projects.

Key Associations for Investment and Operation-Related Disputes

To pinpoint the key associations of factors leading to Investment and Operation-related disputes in PPP projects, all conceivable

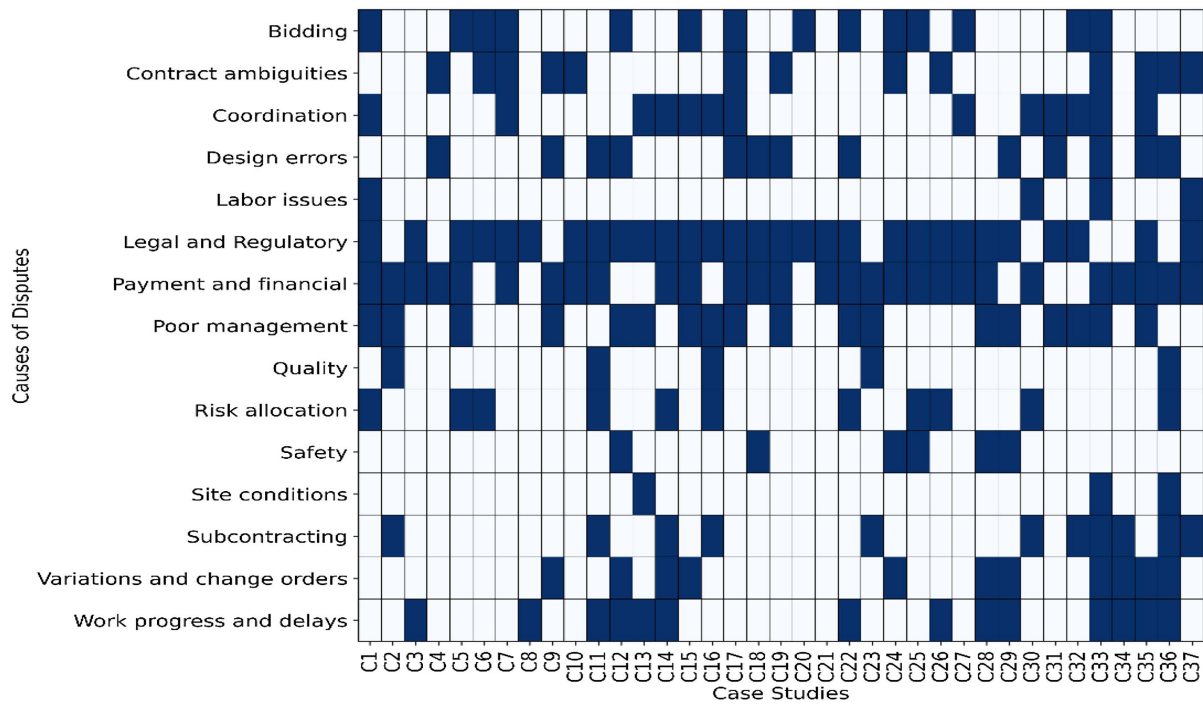


Fig. 3. Constructed reference matrix.

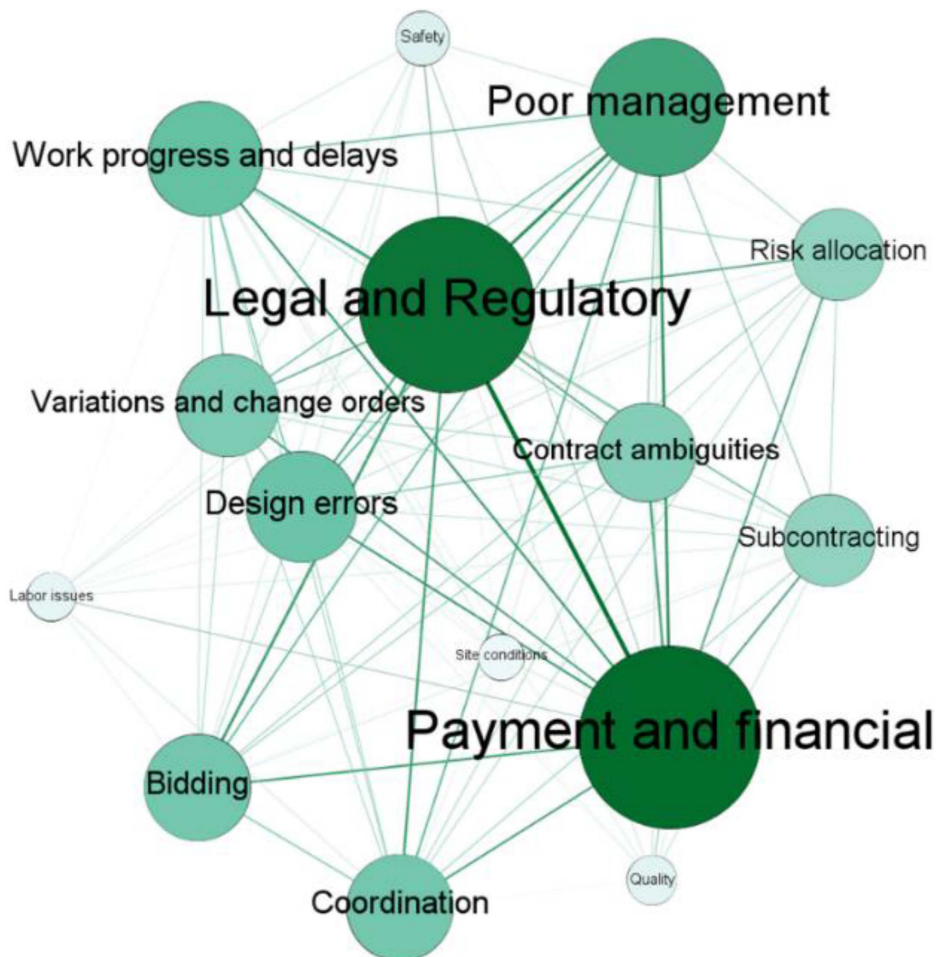


Fig. 4. Aggregate dispute causation network.

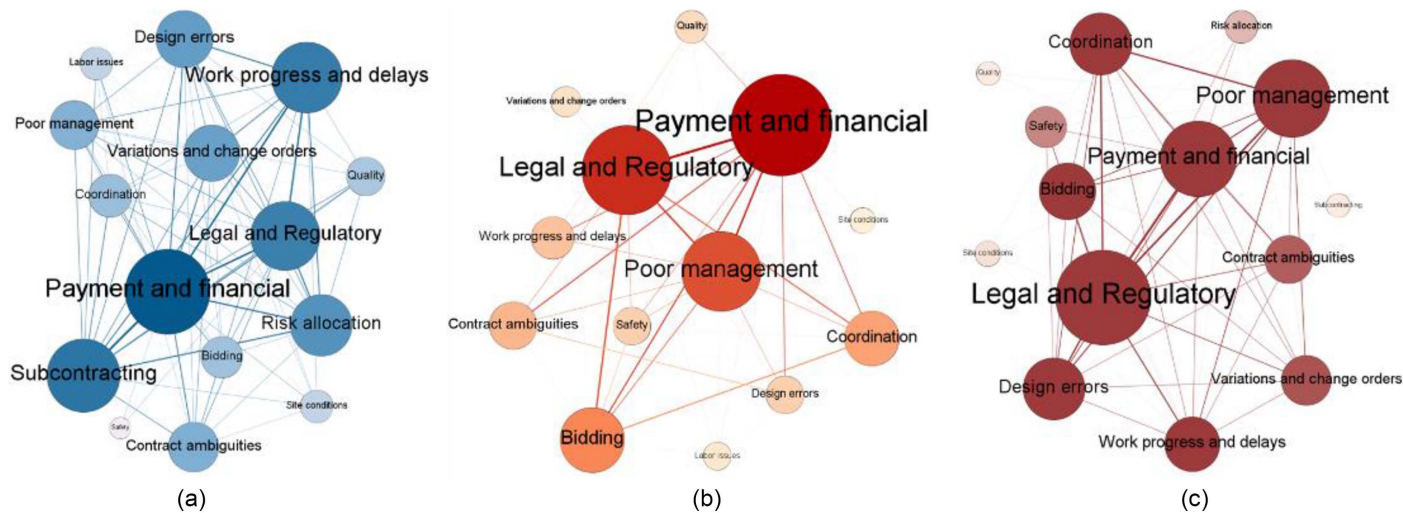


Fig. 5. Dispute causation subnetworks for: (a) Execution-related; (b) Investment and Operation-related; and (c) Third-Party Claims-related disputes.

Table 3. SNA metrics for the aggregate network and subnetworks

Causal factors	All disputes		Execution		Investment and Operation		Third-Party Claims	
	DC	Rank	DC	Rank	DC	Rank	Weighted degree	Rank
Bidding	134	6	48	11	42	4	44	5
Contract ambiguities	122	8	60	8	28	6	34	8
Coordination	134	6	50	10	34	5	50	4
Design errors	140	5	70	6	20	8	50	4
Labor issues	48	12	36	13	12	11	0	13
Legal and regulatory	236	2	86	4	62	2	88	1
Payment and financial	246	1	108	1	72	1	66	3
Poor management	180	3	58	9	54	3	68	2
Risk allocation	112	9	76	5	0	13	16	10
Safety	56	10	20	14	20	8	26	9
Site conditions	44	13	36	13	10	12	8	11
Subcontracting	112	9	92	2	0	14	6	12
Variations and change orders	128	7	68	7	14	10	36	7
Work progress and delays	146	4	88	3	24	7	42	6
Quality	50	11	44	12	16	9	6	12
Network density	0.933		0.914		0.654		0.637	

Table 4. Key associations of causes leading to Execution-related PPP disputes

Associations	Support	Confidence	Lift
Design errors, work progress and delays	0.36	1.00	1.75
Subcontracting, payment and financial	0.50	0.88	1.23
Work progress and delays, legal and regulatory	0.43	0.75	1.05
Work progress and delays, payment and financial	0.423	0.75	1.05

associations were generated and then sieved using the predetermined thresholds for support, confidence, and lift (0.3, 0.75, and 1, respectively). To this end, six associations met these minimal requirements and are presented along with their evaluation metrics in Table 5.

All key associations possessed a lift greater than 1. Thus, it can be concluded that there is a correlation between legal and regulatory-related issues with (1) poor management, (2) coordination, and

Table 5. Key associations of causes leading to Investment and Operation-related PPP disputes

Associations	Support	Confidence	Lift
Coordination, bidding	0.364	1	2.2
Coordination, legal and regulatory	0.367	1	1.375
Bidding, legal and regulatory	0.455	1	1.375
Poor management, legal and regulatory	0.455	0.833	1.15
Contract ambiguities, payment and financial	0.364	1	1.1
Payment and financial	0.909	1	1

(3) bidding. Other key associations showed a positive correlation between (1) coordination and bidding; and (2) contract ambiguities and payment and financial. Furthermore, the results show an interesting finding that payment and financial showed a positive correlation with an empty itemset. This indicates that there is strong evidence that payment and financial could be a single direct cause of PPP disputes related to Investment and Operation. Such results align with having a low-density network for the Investment and

Table 6. Key associations of causes leading Third-Party Claim–related PPP disputes

Associations	Support	Confidence	Lift
Coordination, poor management	0.417	1	1.74
Design errors, poor management	0.333	0.8	1.371
Work progress and delays, legal and regulatory	0.333	1	1.09
Bidding, legal and regulatory	0.417	1	1.09
Design errors, legal and regulatory	0.417	1	1.09
Coordination, legal and regulatory	0.417	1	1.09
Legal and regulatory	0.917	0.917	1.09

Operation network (i.e., indicating less interconnectivity among the causal factors leading to disputes). Ultimately, all the associations, when cooccurring together, are most likely to trigger disputes in relation to Investment and Operation of PPP projects.

Key Associations for Third-Party Claims–Related Disputes

For the Third-Party Claims–related disputes, seven associations met the minimal threshold. All identified associations are presented along with their evaluation metrics in Table 6. Ultimately, all key associations possessed a lift greater than 1. Thus, it can be concluded that there is a correlation between legal and regulatory–related issues with (1) design errors, (2) coordination, (3) bidding, and (4) work progress and delays. Other key associations show a positive correlation between poor management and (1) design errors; and (2) coordination. Furthermore, the results show an interesting finding where legal and regulatory showed a positive correlation with an empty itemset. The latter indicates that there is strong evidence that legal and regulatory could be the single direct cause of PPP disputes related to Third-Party Claims. Such results align with having a low-density network for the third-party subnetwork (i.e., indicating less interconnectivity among the causal factors leading to disputes). Ultimately, all the aforementioned associations, when cooccurring together, are most likely to trigger disputes in relation to Third-Party Claims of PPP projects.

Discussion

The key findings of this paper are discussed in terms of the identified central causes leading to disputes in PPP projects in general as well as in relation to the three different dispute types.

Central Causes of PPP Disputes

The aggregate network analysis revealed three primary causes of disputes in PPP projects: payment and financial–related issues, breach or lack of understanding of applicable legal and regulatory requirements, and poor management. Prior research has already identified payment-related, and poor management as major contributors to disputes in construction projects in general (Assah-Kissiedu et al. 2010; Cakmak and Cakmak 2014). Thus, the findings of this study reiterate the importance of these factors in reducing PPP disputes. However, understanding the applicable legal and regulatory framework is considered a crucial element promoting successful implementation of PPPs (Verhoest et al. 2014). Ultimately, while payment and financial–related issues and poor management could be leading causes of disputes in construction in general, legal and regulatory–related issues are key causal factors of disputes specific to PPP projects. In fact, the legal and regulatory framework used for

PPP integration not only promotes project success but also helps minimize the occurrence of disputes in PPP projects.

By conducting detailed analysis of the case studies, payment and financial challenges causing disputes in PPP projects were related to at least one of the following issues: (1) inadequate financial and budget analysis, (2) payment holds and delays, (3) lack of adequate funds, and (4) unauthorized payments. While lack of adequate funds as well as payment hold and delays are perceived to cause disputes in all construction projects, financial and budget analysis as well as payment authorization processes are more critical to PPP projects. The latter is of high criticality because the complexity of PPP contracts stem from the complex allocation of responsibilities and obligations among project stakeholders in relation to project financing and payment mechanisms (Dabak 2014). In fact, while funding and payment mechanisms in general construction projects are mainly the responsibility of the owner, PPP projects include different and various funding and payment mechanisms that could be allocated to both public and private entities (Colverson and Perera 2012).

As for the legal and regulatory challenges, they were mainly associated to the lack of the parties' understanding of the (1) applicable statutory requirements such as statute of limitations, (2) permitting and zoning requirements, (3) contractual conditions, (4) project feasibility requirements and procedures, (6) bidding requirements, and (7) public meetings and information disclosure requirements. More specifically, project feasibility requirements and procedures as well as public meetings and information disclosure requirements are two of the main causes that could be more critical to PPP projects as compared to other construction projects. In fact, PPP projects should be granted public approval as well as information associated with the project should be disclosed to the public. According to Shekara (2018), there is high complexity in addressing public meetings and guarantying satisfaction in an efficient manner. Furthermore, project feasibility requirements and procedures are considered to be uniquely complex in PPP projects due to the various associated objectives (i.e., technical, social, legal, and political, as well as financial and economic, among others) and the many stakeholders that are involved in the preparation and approval process (Ng et al. 2010). Poor management challenges causing disputes in PPP projects were related to at least one of the following: (1) inadequate/inefficient decision-making, (2) notice and submittals, (3) poor communication, (4) adverse culture, and (5) lack of expertise. Thus, management-related issues causing disputes in PPP projects are similar to those of construction disputes in general.

It is noteworthy that the aggregate network (Fig. 4) has a high density of 93.3%, which implies that the causes of disputes are highly associated within the network. Therefore, disputes in PPP projects are mostly caused by multiple interconnected factors. PPP projects include varying aspects that may trigger different types of disputes including Execution, Investment and Operation, as well as Third-Party Claims. Thus, the following subsections provide detailed discussions in relation to each type of dispute.

Execution-Related Disputes

The conducted SNA showed that the top three causes of PPP disputes in relation to Execution are: (1) payment and financial issues, (2) subcontracting, as well as (3) work progress and delays. Furthermore, a total of four key associations were found to be positively correlated with each other in triggering PPP disputes in relation to construction execution including: (1) “design errors” and “work progress and delays,” (2) “payment and financial” and “subcontracting,” (3) “work progress and delays” and “legal and

regulatory,” and (4) “work progress and delays” and “payment and financial.”

The mechanism of PPP dispute causation in relation to Execution was further analyzed by understanding the reasoning behind the identified central causes and key associations. Generally, many of the analyzed case studies had disputes associated with inadequate engineering and design specifications and plans. To this end, the design-related issues directly led to either the parties’ inability to obtain required permits and approvals, on-site damages, or work suspension. The latter reasons led to project and work progress delays, which are considered one of the proximate causes of disputes. To this end, one of the key associations included a positive correlation between “design errors” and “progress and delays.” Furthermore, the legal case studies showed that all legal and regulatory-related issues in Execution disputes are related to the inadequate alignment of the design plans and specifications with the permitting and zoning requirements, and thus suspension or delays of the work. The latter explains having “legal and regulatory” positively correlated with “work progress and delays.” Nevertheless, most of the case studies experiencing “work progress and delays” led to payment holds and delays as means to compensate for associated damages, thus further triggering conflicts among the stakeholders. The latter aligns with having “work progress and delays” positively correlated with “payment and financial.” Finally, payment and financial-related issues in the Execution subnetwork were associated with holding and delaying payments to the subcontractors due to either (1) contractor’s or developer’s bankruptcy; and/or (2) alleging defects or project delays. To this end, “payment and financial” was found to be positively correlated with “subcontracting.” Fig. 6 shows PPP Execution-related disputes and their associations based on the analysis of the case studies related to Execution disputes.

Ultimately, by referring to Fig. 6 and based on the discussion beforehand, dispute mechanism in relation to PPP Execution is very similar to any other construction projects. This is reasonable because Execution-related disputes are strictly associated with the construction phase rather than investment, operation, or preplanning phases. Ultimately, in order to minimize PPP disputes related to Execution, it is crucial to ensure that public agencies, or the PPP entity, have an adequate qualification and selection program that takes into account the designers’ and subcontractors’ expertise and capabilities on one hand and their familiarity with the applicable legal and regulatory requirements in terms of design and execution on the other. Furthermore, it is important to ensure clear and unambiguous payment terms and conditions in the contract, which help reducing breach of contract claims, and/or opportunistic behaviors by any of the parties.

Investment and Operation-Related Disputes

The conducted SNA showed that the top three causes of PPP disputes in relation to Investment and Operation are: (1) payment and financial, (2) legal and regulatory, and (3) poor management. Furthermore, a total of six key associations were found to be positively correlated with each other in triggering PPP disputes in relation to construction execution including: (1) “coordination” and “bidding,” (2) “coordination” and “legal and regulatory,” (3) “bidding” and “legal and regulatory,” (4) “poor management” and “legal and regulatory,” (5) “contract ambiguities” and “payment and financial,” and (6) “payment and financial.”

The mechanism of PPP dispute causation in relation to Investment and Operation was further analyzed by understanding the reasoning behind the identified central causes and key associations. Generally, many of the analyzed case studies had disputes associated

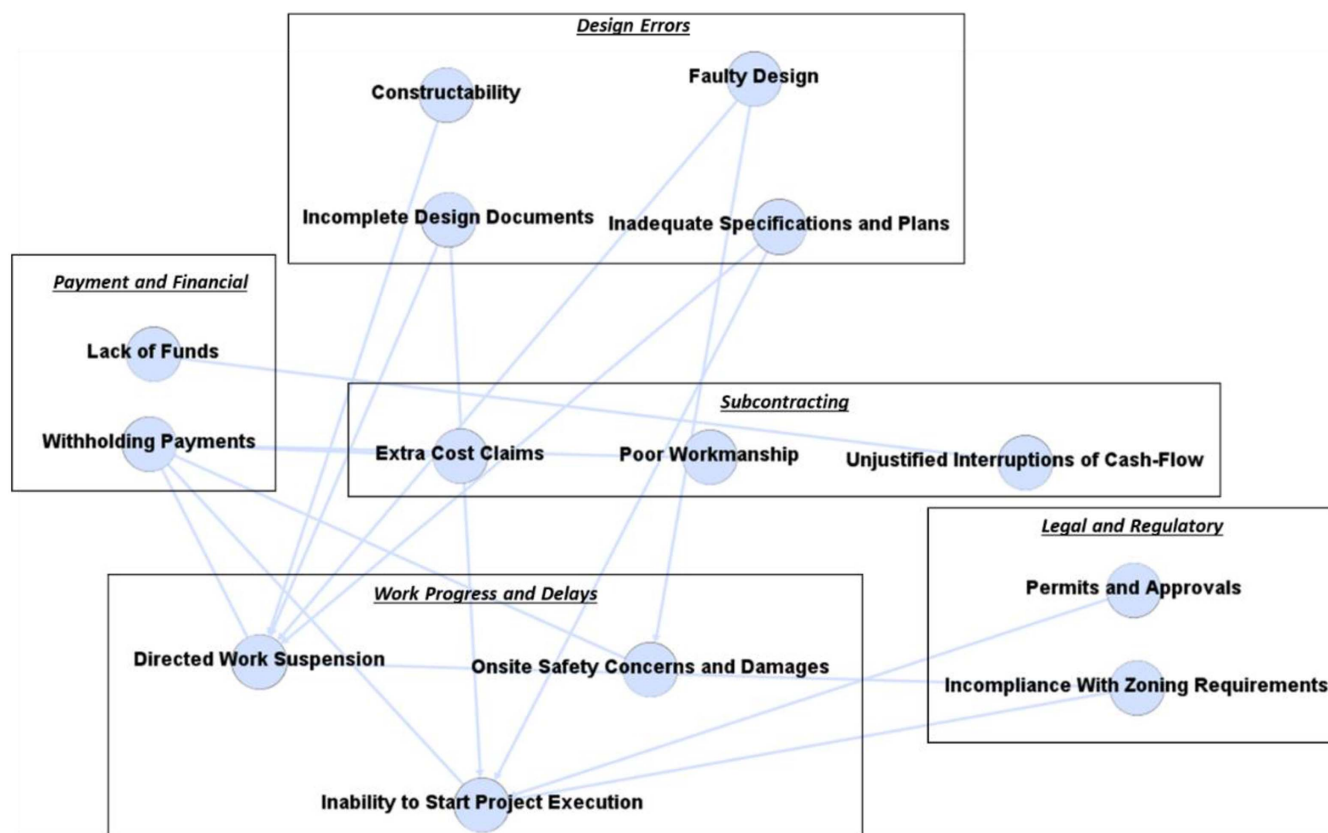


Fig. 6. PPP construction Execution-related disputes.

with “payment and financial.” The main encountered issues were mainly related to (1) inadequate budget and financial analysis/feasibility, (2) lack of funding, and (3) unauthorized/illegal payments. The association rule analysis showed that such issues can be the only cause triggering disputes in relation to Investment and Operation. More specifically, many case studies reflected claims related to unauthorized or illegal payments due to lack of understanding of contract conditions, and/or opportunistic behaviors by the sponsors, investors, or developers. This aligns with having positive correlation between “payment and financial” with “contract ambiguities” and “poor management.” Furthermore, poor management-related issues were exhibited in terms of adverse managerial culture among the stakeholders, lack of communication and sharing of information, and inefficient or poor decision-making. Therefore, all the aforementioned aspects led to claims of breach of contract, breach of applicable legal acts and statutes, and claims of bad faith. This is reflected by having “poor management” associated with “legal and regulatory” issues. Finally, other types of disputes were mainly related to “bidding,” more specifically: (1) lack of adequate coordination and communication of bidding terms, conditions, and processes; (2) inadequate negotiation process; and (3) violation of bidding terms, regulations, and statutes. To this end, “bidding” had a positive correlation with “legal and regulatory,” “coordination,” and “poor management.” Fig. 7 shows PPP Investment and Operation-related disputes and their associations based on the analysis of the case studies related to Investment and Operation disputes.

While many of the causal factors in Fig. 7 can be associated to disputes in all construction projects, legal and regulatory-, payment and financial-, and coordination-related issues are distinct in nature for PPP disputes. More specifically, PPP projects require better understanding of the bidding statutes, public disclosure act, better coordination with the various associated stakeholders including the public, and adequate coordination of project information, as well as efficient and adequate financial and payment schemes. In order to minimize PPP disputes related to Investment and Operation, it is crucial to ensure that:

1. The applicable terms and regulations are clearly stipulated for bidders in terms of bidding submissions, procedures, and selection criteria.
2. Adequate negotiation procedure between public entity and investors/developers/sponsors is adopted promoting the meetings of the minds among the parties.

3. Extensive budget and financial analysis is performed during the early stages of or prior to the contract execution.
4. Trust among the PPP stakeholders is promoted through open communication and coordination.
5. There is clear financing, payment, and funding terms and mechanisms in the contract.

Third-Party Claim-Related Disputes

As shown in Fig. 8, the conducted SNA showed that the top three causes of PPP disputes in relation to Third-Party Claims are: (1) legal and regulatory, (2) poor management, and (3) payment and financial. Furthermore, a total of seven key associations were found to be positively correlated with each other in triggering PPP disputes in relation to construction execution including: (1) “poor management” with “coordination” and “design errors”; (2) “legal and regulatory” with “work progress and delays,” “bidding,” “design errors,” and “coordination”; and (3) “legal and regulatory.”

The mechanism of PPP dispute causation in relation to Third-Party Claims was further analyzed by understanding the reasoning behind the identified central causes and key associations. Generally, many of the analyzed case studies reflected disputes associated with “legal and regulatory.” The main encountered issues were mainly related to Third-Party Claims where the project feasibility, zoning, environmental impact, and financial impact of the development project are challenged by the public. Many of these cases showed either inadequate feasibility analysis, lack of adequate environmental impact reports, and lack of local zoning requirements and regulations reflecting poor management practices, and subsequently leading to work suspension and delays due to delayed public approval. The latter explains having “legal and regulatory” positively associated with “design errors” and “work progress and delays.” Furthermore, the analysis shows that, although these disputes are Third-Party Claims requiring no contractual privity, “coordination” is still considered a potential causal factor. This is because PPP projects involve the public as a key third-party stakeholder and thus requiring adequate coordination with the community to ensure smooth execution and operation. Most of the disputes reflected lack of adequate coordination of the project plans and specifications during public meetings leading to conflicts and claims with third parties to the PPP agreement. Such conflicts arise due to the public rejection of the project plans, zoning, as well as interference with the environment, and public and private properties.

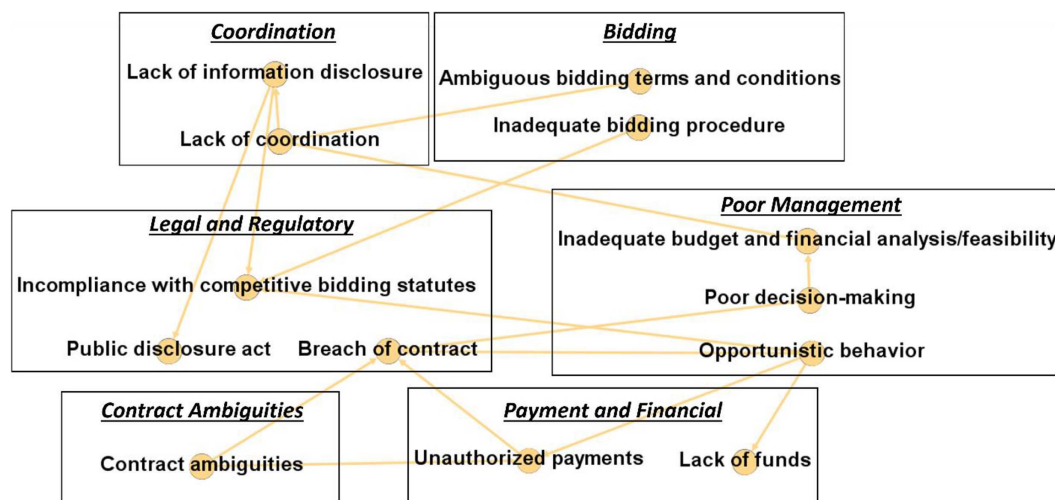


Fig. 7. PPP Investment and Operation-related disputes.

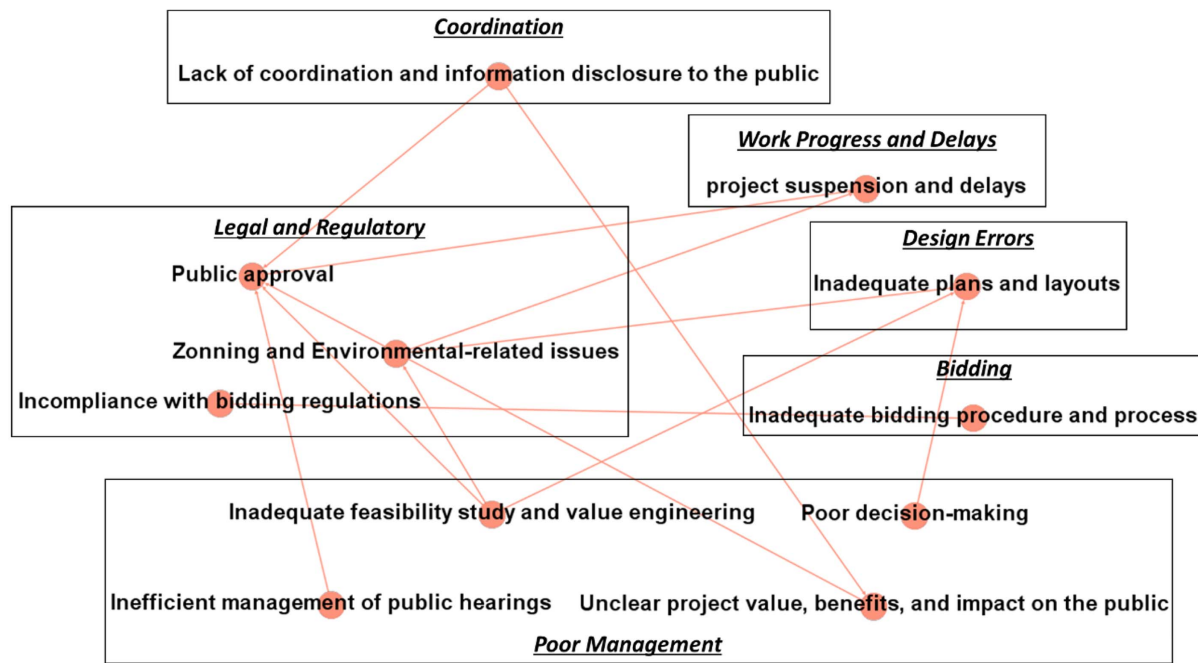


Fig. 8. PPP Third-Party Claims–related disputes.

Generally, Third-Party Claims in construction projects can be mainly associated with safety injuries, damages of adjacent properties, among others (Abdul Nabi et al. 2020). However, Fig. 8 shows that most of the causal factors of third-party disputes are unique to PPP projects including lack of coordination and information disclosure to the public, public approval, inefficient management of public hearings, unclear project value, benefits, and impact on the public, and incompliance with bidding regulations. The latter is because the public is considered a crucial and important stakeholder in PPP projects. Thus, in order to minimize PPP disputes related to Third-Party Claims, it is crucial to ensure that (1) private stakeholders are able to develop, plan, construct, and operate a project that aligns with the public interest and needs; and (2) understand the legal framework that should be adopted to guarantee public approvals through adequate feasibility analysis, environmental impact reports, as well as zoning and permitting requirements.

Research Contributions

This study contributes to the existing body of knowledge by identifying the primary causes of disputes of PPP projects. This is achieved by examining the interconnectivities of these causes. Furthermore, the outcomes of this paper indicated that PPP disputes are mainly triggered by complex associations among different causal factors rather than standalone causes. Furthermore, the findings of this research offer an insight to practitioners and researchers on the types of disputes that require more effort to avoid their occurrence. In fact, Execution-related disputes seemed to reflect higher complexity and interconnectivity when compared to Investment and Operation and Third-Party Claims. Therefore, dispute avoidance in relation to Investment and Operation and Third-Party Claims was shown to be more simplistic because associated disputes are triggered by fewer and less interconnected factors. Ultimately, this paper substantiated the importance of considering the interplay between the various causal factors to avoid dispute occurrence by industry practitioners and researchers. Furthermore, this study investigated causation mechanism associated with the three different types of

disputes by investigating key associations and correlations. The latter shall offer a better understanding on how disputes arise in relation to Execution, Investment and Operation, and Third-Party Claims. Ultimately, this paper highlights the importance of the following aspects in avoiding dispute occurrence in PPP projects:

1. **Execution:** Public agencies and PPP entities shall possess an adequate qualification and selection program that takes into account the designers', contractors', and subcontractors' expertise and capabilities on one hand and their familiarity with the applicable legal and regulatory requirements in terms of zoning, permitting, and feasibility studies on the other. Another aspect is related to the importance of establishing clear and unambiguous payment terms and conditions in the contract, which help reducing breach of contract claims, and/or opportunistic behaviors by any of the parties.
2. **Investment and Operation:** Public agencies and/or PPP entities should ensure that bidding terms and conditions are clearly understood and stipulated in terms of bidding submissions, procedures, and selection criteria. Adequate negotiation procedures that promote the meeting of the minds between public entity and investors/developers/sponsors shall be adopted to ensure smooth execution. Another important factor is the necessity of performing extensive budget and financial analysis during the early stages of or prior to the contract execution. Furthermore, the partnership should be greatly built upon trust among the PPP stakeholders through open communication and coordination. Finally, Investment and Operation–related disputes are highly minimized by ensuring clear financing, payment, and funding terms and mechanisms in the contract.
3. **Third-Party Claims:** Public agencies shall ensure that private stakeholders have the capabilities to develop, plan, construct, and operate public projects that intersects with the public interest and need. In addition, private stakeholders should have thorough understanding of the legal and regulatory framework that allows them to perform adequate feasibility analysis, environmental impact reports, as well as understanding zoning and permitting requirements.

The outcomes of this paper provide practitioners with early warning signs in relation to the causal factors that would most likely trigger conflicts in relation to the three different types of PPP disputes. Furthermore, the outcome of this research provides directions for scholars toward the aspects that require further optimization to avoid dispute occurrence and subsequently ensure successful implementation of PPPs. In conclusion, this paper contributes to the existing knowledge by assisting PPP stakeholders in managing and mitigating the sources of disputes in order to decrease their frequency and maximize the potential benefits of PPPs.

Conclusion, Limitations, and Future Work

Understanding the causes of conflict and dispute in PPP projects and their interconnectivities is essential to mitigate and avoid their occurrence. To this end, this study analyzed 37 actual cases of disputes using SNA and the Apriori algorithm. Accordingly, the results highlighted that the main types of dispute causes in PPP projects are: (1) payment and financial, (2) legal and regulatory, as well as (3) poor management. The outcomes further suggest that all the three aforementioned causal factors are also key triggers to disputes in relation to Investment and Operation and Third-Party Claims. However, disputes related to Execution seems to be further impacted by subcontracting-related issues. Furthermore, the results show that PPP disputes are generally caused by complex interactions of various causal factor. However, Execution-related disputes seem to exhibit higher complex interactions in comparison to Investment and Operation and Third-Party claims. Based on the aforementioned, the findings of this paper highlight the early warning signs in relation to the causal factors that are highly likely to trigger conflicts in relation to the three different types of PPP disputes. In addition, this paper contributes to the existing knowledge by assisting PPP stakeholders in managing and mitigating the sources of disputes in order to decrease their frequency and maximize the potential benefits of PPPs.

In addition, the findings of this paper identified important aspects that should be considered by practitioners and scholars to control dispute occurrence in PPP projects including those related to:

1. Establishment of adequate qualification programs for sponsors, designers, contractors, and subcontractors as to ensure high technical and financial expertise, familiarity with legal and regulatory requirements, and working with public communities.
2. Promoting trust through clear, fair, and unambiguous contract conditions and agreement terms, specifically in relation to payment, financing, and funds.
3. Establishment of clear bidding procedures, terms, and regulations in relation to different types of PPP modes and functions.
4. Developing a negotiation procedure and checklist that ensures meeting of the minds of the various PPP stakeholders prior to contract formation and execution.

5. Establishing an adequate payment and financing mechanisms for the various PPP modes and functions.

Furthermore, the outcome of this research provides directions for scholars toward the aspects that require further optimization to avoid dispute occurrence and subsequently ensure successful implementation of PPPs.

The research conducted in this research has some limitations. First, the representation of interconnectivity between the different causes of disputes was mainly based on their cooccurrence. Therefore, future research studies are recommended to examine different representations of interconnectivities and investigate how they affect the obtained results and the identified key causes of disputes. Second, the considered sample of 37 case studies might be deemed to be relatively small; thus, future research efforts are recommended to collect more case studies and extend the considered case studies so that more insights could be obtained. Third, this paper considered threshold values for the “support” and “confidence” measures when conducting the ARA; hence, future research studies could be directed to study the impacts of different threshold values on the identified relationships and causalities between the different causes of disputes in PPP projects. Another limitation is the inclusion of disputes that were only resolved using litigation. In fact, disputes resolved using alternative dispute resolution methods are hard to access due to confidentiality and privacy terms. However, litigations can provide good insights on dispute causation in general because they reflect the extreme consequences of conflicts that may arise among project stakeholders. Finally, the scope of this paper is limited to the investigation of interconnectivities in general rather than the impact of causal factors on each other. Future research work can utilize the findings of this paper to address the following research questions:

1. What are the quantified impacts of dispute causes on each other? Is there a possibility to model the probability of dispute occurrence based on the causes identified in this paper and their quantified impacts?
2. What are the similarities and differences in the factors leading to disputes between the different PPP modes?
3. What are the best practices that should be adopted to ensure adequate negotiation process among project stakeholders?
4. What are the different financing and payment mechanisms as well as their associated risks and benefits? How can these financing and payment mechanisms be reflected in the contract terms and conditions?
5. What are the building blocks of robust qualification programs that ensure the selection of suitable private entities, developers, sponsors, contractors, designers, and subcontractors?
6. What are the available bidding procedures, regulations, and terms? How are these bidding requirements differing based on the PPP type of agreement or mode? What are the best practices—or risks and benefits—associated with the identified bidding processes?

Appendix. Causes of Disputes

Causes	Descriptions	Sample excerpts
Bidding	It refers to inadequate bidding documents, procedures, evaluation, and selection processes	C1: “. . . the City provides us with a lengthy summary of the competitive bidding process that suggests Airis was unfairly awarded this agreement over a San Francisco-based company.” C6: “. . . Clearwater submitted a bid but was not chosen. Unhappy with the selection made, Clearwater brought a claim under Section 9109(n) of the P3 Act . . .”

Appendix. (Continued.)

Causes	Descriptions	Sample excerpts
Contract ambiguities	It refers to misunderstanding and misinterpretation of the contract conditions and provisions by the stakeholders	C19: "... <i>P&M insists that the drafting of the Agreement before us intended to eliminate its fiduciary duties. We conclude, however, that no such intention is plainly and unambiguously revealed...</i> " C33: "... Plaintiff also alleges that it was reasonable for it to rely upon those details because that was STV's intent, the Construction Documents were being incorporated into plaintiff's contract with the Developer, STV represented the details as accurate, and plaintiff did not have an independent duty, time, access or permission to survey the details set forth by STV in the Construction Documents."
Coordination	It refers to inadequate communication, information sharing, and coordination among project parties	C14: "... <i>Intelect alleges no duty on Defendants' part to affirmatively communicate to Powerwave's subcontractors whether Powerwave had secured, or had failed to secure, the bond...</i> " C16: "... <i>King County concedes that Viracon did not receive its first notification of a filming issue associated with IGUs manufactured with gray PIB-based sealant until after Viracon manufactured and sold the IGUs used on the Chinook Building...</i> "
Design errors	It refers to design deficiencies, inadequate plans, and specifications among others	C11: "... <i>Lachel failed to provide adequate initial support design and contingency plans for the tunnel, and Lachel's inadequate initial support design and contingency plans were the proximate cause of Walsh Vinci JV's loss...</i> " C22: "... <i>CVIN and CENIC "rushed through the process of applying for" the grant funding and, as a result, the "design and engineering of the Project was incomplete, inadequate and materially deficient...</i> "
Labor issues	It refers to inadequate staff, expertise, safety associated with labors	C33: "... <i>PANYNJ's interference allegedly breached the Contract, in the following ways: ... (8) not properly staffing the Project with qualified and available personnel, and (9)...</i> " C11: "... <i>On Friday, September 19, 2014, at 6:30 p.m., normal tunneling activities were taking place when a noise was heard coming from the south tunnel. The workers were evacuated from the tunnel, and then rock from the roof of a portion of the south tunnel collapsed.</i> "
Legal and regulatory	It refers to incompliance with legal and regulatory requirements including competitive bidding regulations, zoning and permitting, among others	C12: "... <i>The matter presents issues on the extent to which a municipality is exempt from its own zoning approval ordinances, the reasonable exercise...</i> " C32: "... <i>POCC's agreements with Carlyle violate the public disclosure and competitive bidding requirements of the Public and Private Facilities Infrastructure Act...</i> "
Payment and financial	It refers to payment and financial issues such as holding or delaying payments, inadequate funding, unauthorized payments, etc...	C2: "... <i>Augusta counterclaimed against Landau for breach of contract alleging construction defects and unauthorized payments...</i> " C30: "... <i>Dig Tech alleged that Star had hired it to perform some of the hole-boring work for the installation of electrical conduit needed for Star to complete its part of the construction project and that Star did not pay Dig Tech for the work it did...</i> "
Poor management	It refers to inadequate stakeholder management including lack of trust, opportunistic behavior, inadequate expertise, among others	C1: "... <i>It was a breach of the duty of good faith and fair dealing for it to undermine a project that it had submitted for approval by withholding information, refusing to correct misinformation, and working behind the scenes to ensure that the City took a course contrary to the for which it was ostensibly seeking approval...</i> " C33: "... <i>PANYNJ's interference allegedly breached the Contract, in the following ways: ... (5) failing to manage the Project design, access to the Project site and other necessary elements, (6) failing to respond to design and other inquiries with accuracy and in a timely manner, (7)...</i> "
Quality	It refers to the quality of design and workmanship in the execution phase of PPP	C2: "... <i>Augusta counterclaimed against Landau for breach of contract alleging construction defects and unauthorized payments...</i> " C16: "... <i>according to King County, Viracon, Quanex I.G. Systems, and Truseal knew that the gray PIB-based sealant was "defective and its performance [] inferior to that of [b]lack PIB" and...</i> "
Risk allocation	It refers to inadequate allocation of risks, responsibilities, and obligations	C25: "... <i>the VDOT is improperly applying the "Virginia Public Private Partnership Act" by engineering a sole-source, noncompetitive contract with a private entity (the MWAA) without requiring the private entity to put up capital or share risks...</i> " C22: "... <i>CVIN's assets of \$1.3 million at the time the Project commenced demonstrate that MP was undercapitalized compared to the risks and obligations inherent in the Project, which was estimated to cost at least \$66 million...</i> "
Safety	It refers to worker safety onsite as well as overall public safety associated with the PPP project	C29: "... <i>The DNR denied the Permit in October 2016 finding the Project did "not adequately protect the public, health, safety and welfare of [Minnesota's] citizens, [did] not represent the minimal impact solution..."</i> " C11: "... <i>normal tunneling activities were taking place when a noise was heard coming from the south tunnel. The workers were evacuated from the tunnel, and then rock from the roof of a portion of the south tunnel collapsed...</i> "

Appendix. (Continued.)

Causes	Descriptions	Sample excerpts
Site conditions	It refers to site-related issues, differing or unanticipated site conditions	C33: "... PANYNJ's interference allegedly breached the Contract, in the following ways: ... (7) subjecting Plaintiff to differing site conditions ..." C36: "... HDR's engagement includes providing professional review of the site investigation, preliminary and final design, construction observation, and other engineering services ..."
Subcontracting	It refers to issues associated with subcontractors such as deficient work, design, and payment delays or issues, among others	C2: "... Petitioner counterclaimed against Landau (subcontractor) for breach of contract, alleging construction defects and unauthorized payments." C36: "... HDR maintains that Walsh/Granite breached their contract by invoking § III.C.3 and withholding payments based on § XII.H for alleged quantity growth for items not listed in the Matrix ..."
Variations and change orders	It refers to excessive changes of the plans, specifications, and designs	C33: "... PANYNJ's interference allegedly breached the Contract, in the following ways: ... (4) making unreasonable design and other changes to the Project, which resulted in hundreds of pending change order requests, request for information and other direction, (5) ..." C14: "... Intellect does state in its opposition that its "consent to [Defendants'] request caused [Intellect] to incur expenses which would have been covered by the Carriers as a change order if the Project had resumed as anticipated ..."
Work progress and delays	It refers to delays and suspension of project execution and/or completion	C3: "... According to the complaint ... This [development] agreement was executed "after more than a year of protracted negotiations and delays ..." C36: "... In this letter, [Walsh/Granite] advised it was withholding \$18,316,125 to offset damages due to schedule delay (\$4,276,872) ..."

Data Availability Statement

All data, models, and code generated or used during the study appear in the published paper.

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