

EXPLORING THE CAUSES OF CONTRACT DISPUTES AND THEIR SOCIAL NETWORK RELATIONSHIPS IN THE MEGAPROJECTS: A CASE OF JINAN AIRPORT PROJECT

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Abstract. Contract disputes hinder the successful delivery of megaprojects. This study aims to identify crucial contract disputes and causes for dealing with contract disputes problems and improving megaproject performance. 107 contract dispute-related documents were collected and analyzed using a mixed method of text mining and social network analysis. Text mining was used to sort out emerging contract disputes and causes. Social network analysis was used to identify crucial contract disputes and causes by analyzing their network relationships. Our study obtained 12 contract disputes and 10 corresponding causes in the megaproject context. The results show that payment dispute is the most prevalent contract dispute in megaprojects. Our study also found that payment dispute and settlement dispute have high degree of centrality; incomplete survey and design content and unclear contract terms are critical causes as the bridging roles in the relationship network of causes in megaprojects. This study expands the literature on the identification of contract disputes and corresponding causes in megaprojects. Meanwhile, it provides practical guidance for project managers on designing contract items and dealing with contract disputes in megaprojects.

Keywords: megaproject, contract dispute, contract cause, social network analysis, text mining.

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1. Introduction

A megaproject is defined as an extensive public infrastructure endeavor surpassing the 1.0 billion US dollars investment threshold or significantly impacting public scrutiny, environmental concerns, and government budgetary allocations (Flyvbjerg et al., 2010), which are critical for people's quality of life and driving regional economic growth (Agénor, 2010). Compared to general projects, megaprojects are large in scale and long in duration, and they face multiple uncertain events, revealing great complexity and uncertainties. These uncertainties always result in numerous extra-contract works, which induce contract disputes (Locatelli et al., 2017) and reduce project performance. For example, the Edinburgh Tram Project has frequent contract disputes, leading to excellent schedule delays and significant cost overruns (Currie & Teague, 2015). International Transport Forum shows that contract renegotiation and contract disputes occurred in 50% of French highways,

40% of a sample of highways in the United States, and 22% of projects in the United Kingdom, approximately, indicating that contract disputes are a common phenomenon in megaprojects (Makovsek et al., 2014). Contract dispute is defined as a contract question or controversy that must be settled beyond the job site management staff, which may come from financial plans, permits, regulations, scope definition, realistic obligations, risk identification/allocation, technical plans/specifications, dispute resolution process, etc. (Diekmann & Girard, 1995). Compared with contract conflicts and conflict disputes, contract disputes focus on these issues arising from disagreements on the contract goals, interests, and strategies, such as ambiguous provisions at the contract preparation stage (Shen et al., 2017), schedule delays at the implementation stage (Iyer et al., 2008), and deteriorating relationships at the resolution stage (Harmon, 2003). These contract disputes

were related to cost overruns, schedule delays, and interest conflicts, which hinder the successful delivery of megaprojects (Li et al., 2012). Thus, it is crucial to identify contract disputes and corresponding inducements to solve in megaprojects.

Previous studies have explored the typologies of contract disputes and their causes. Several contract disputes are identified in different construction projects, including payment and financial related, delay related, design and scope related, contract related, bidding related, project management related, client's administration related, quality related, risk related, claim and dispute management related, behavioral and professional related, and external factors related contract disputes (Cakmak, 2022; Francis et al., 2022; Mirzaee et al., 2024; Senaratne & Farhan, 2023; Shabana & Gad, 2023; Titus & Ali, 2023; Wang et al., 2023). Besides, causes have been identified for contract disputes, such as payment delays by client, scope of work changes, ambiguities/contradictions in contractual documents, not meeting the required quality of work, progress delay by the contractor, design errors/design failure, misinterpretation of contractual terms and conditions, lack of communication, differing physical site conditions, delay in completion of project, uncontrolled factors (weather, disasters), late decision making by the client, unfair risk allocation, owner transfer risk to contractor, unrealistic performance expectation, price escalation and material shortage (Nabi & El-adaway, 2022; Elhag et al., 2020; Hansen et al., 2023; Rahnamayiezekavat et al., 2022; Senaratne & Farhan, 2023; Tanriverdi et al., 2021). Although existing studies have identified contract disputes and causes in different project contexts, the disputes and causes are still unclear in the megaproject context. Besides, the relationships between contract disputes and causes were stressed in the linear rather than the network ed. E. Cakmak and P. I. Cakmak (2014) used the ANP to rank the factors influencing contract disputes in general construction projects through expert interviews. Nabi et al. (2023) identified three key causes of contract disputes – payment and financial, legal and regulatory, poor management – in PPP projects from the network perspective; Nabi and El-adaway (2022) explored holds and delays, delay in project completion, poor communication among the project stakeholders, lack of collaboration between various trades are the four causes in modular projects.

Current studies show that the typologies and significance of contract disputes and causes vary in different project contexts (e.g., PPP and modular construction projects). Still, few have identified the contract disputes and the causes in the megaproject context. Compared to conventional projects, megaprojects have more contract disputes co-occurring. For example, land acquisition delays, frequent design changes, and late payment in high-speed railway projects often occur at one time. These disputes are not independent but interconnected through schedule delays and cost overruns, forming an interrelated network of contractual disputes. Meanwhile, contract disputes

in megaprojects are driven by multiple and interwoven causes. For instance, in Beijing airport projects, causes such as policy changes, design defects, site condition variations, and conflicts often co-occur. Thus, it requires megaproject managers to systematically identify contract disputes and corresponding causes from the network perspective. To fill the gap, this study aims to identify the contract disputes and causes in the megaproject context and to explore the relationships from the network perspective. Three detailed objectives are: (1) Identifying the main contract disputes and causes in the megaproject context. (2) Identifying the crucial contract disputes by analyzing the co-occurrence relations. (3) Identifying the crucial causes of contract disputes by analyzing the co-occurrence relations. Our study enriches the literature of contract disputes in the megaproject context. Meanwhile, it can help project managers resolve megaproject contract disputes by providing information on contract disputes and their causes.

2. Theoretical foundations and literature reviews

2.1. Social network analysis in project management

Social network analysis (SNA) is used to identify the actors and network attributes by analyzing the network relationships between actors. In previous studies, SNA was used to pinpoint bottlenecks of project team performance (Solis et al., 2013), identify the core risk sources, and test the significance of the general contractor (Nabi & El-adaway, 2022; Aljassmi et al., 2014; Eissa et al., 2021). In megaprojects, numerous contract disputes often co-occur due to their incredible complexity and vagueness. Contract disputes affect or are affected by other contract disputes, forming a contract dispute network where each dispute is a node, and their co-occurrence in a dispute event serve as a link. Roles of nodes are different due to their network attributes (Hu et al., 2016). In the contract dispute causes network, the causes of contract disputes are viewed as nodes. There is a link when two causes simultaneously lead to the same contract dispute. SNA is a practical tool for identifying key nodes through the analysis of node attributes like degree centrality (E. Cakmak & P. I. Cakmak, 2014). This approach helps our study identify crucial contract disputes and their causes by analyzing both contract dispute and cause networks in the megaproject context.

2.2. Literature on contract disputes in megaprojects

Megaprojects' contract disputes have been explored in previous studies (Lee et al., 2021; Silva et al., 2023). For example, Iyer et al. (2008) identified time delay disputes, site handover delays, advance payment delays, and drawing delays in construction projects. Cheung and Pang (2013) found contract disputes and opportunistic disputes to be key types of contract disputes. Ilter and Bakioglu (2018)

divided the contract disputes into contract disputes (e.g., risk allocation, payment terms) and speculative disputes (e.g., construction plans, management conditions). Current studies have explored contract disputes in different construction contexts, but few focus on contract disputes and their relationships in the megaproject context.

2.3. Literature on causes of contract disputes in megaprojects

Existing studies have found that the causes of contract disputes vary in different project types (see Table 1). For example, some contract disputes come from payment and financial-related factors, such as payment delays by the client, the project exceeding budget, contractor's cash flow difficulties, client's cash flow difficulties, consultant delaying payment certification, delay in evaluation of completed works (Francis et al., 2022; Alrasheed et al., 2023; Rahnamayiezekavat et al., 2022; Cakmak, 2022; Nabi & El-adaway, 2022). In megaprojects, contract disputes stem from standardized contracts (Serpell & Torres, 2023) and project participants' behaviors, such as design changes, payment changes, and schedule changes (Love et al., 2011), which are not executed by the formulated contract items (Shalaby & Khalafallah, 2018). Besides, contract disputes

causes interact because there are close connections between different megaproject tasks, which build a network relationships. Prior studies have identified multiple causes for contract disputes in project contexts, but few further explored the causes in megaproject contexts. Moreover, current studies such as Viswanathan et al. (2020) and Love et al. (2011) stressed linear relationships between causes, ignoring network ones.

3. Research methodology

A mixed method of text mining and SNA was used in our study. First, text mining was used to identify contract disputes, causes, and their co-occurrence frequency using Rost-CM6 software. Data for text mining were collected from 107 contract dispute-related documents, which provide detailed information on contract disputes, such as the types, project participants, specific content, meeting minutes, causes, solutions, etc. Rost-CM6 software was chosen because of its functionality, accessibility, and fitness. (1) Rost-CM6 software streamlines the process of text content analysis by offering functions such as word frequency statistics, co-word analysis, cluster analysis, and semantic network analysis, which support the quantitative text analysis. (2) Rost-CM6 software is readily available,

Table 1. Literature on the causes of contract disputes in construction projects

Cause	Specific causes	References
Payment and financial related	Payment delays by the client, project exceeds the budget, contractor's cash flow difficulties, client's cash flow difficulties, consultant delaying payment certification, delay in evaluation of completed works	Francis et al. (2022), Alrasheed et al. (2023), Rahnamayiezekavat et al. (2022), Cakmak (2022), Nabi and El-adaway (2022)
Delay related	Progress delay by contractor, late decision making/response by client, engineer delays issuing design drawing, suspension of work	Senaratne and Farhan (2023), Alrasheed et al. (2023), Francis et al. (2022), Hansen et al. (2023), Cakmak (2022)
Design and scope related	Scope of work changes (owner initiated), design errors, incomplete design, inconsistencies of design documentations	Francis et al. (2022), Tanriverdi et al. (2021), El-Sayegh et al. (2020)
Contract related	Ambiguities in contractual documents, misinterpretation of contractual terms, unfair risk allocation, breach of contract	El-Sayegh et al. (2020), Cakmak (2022), Titus and Ali (2023), Rahnamayiezekavat et al. (2022)
Bidding related	Inaccurate project cost estimation, inadequate site investigation, selection of contractors by low bid	Ahmed and El-adaway (2023), Elhag et al. (2020), Nabi and El-adaway (2022)
Project management related	Poor supervision and site management, incompetent contractors, weak schedule practices by contractors, poor coordination between construction activities	Illankoon et al. (2022), El-Sayegh et al. (2020), Hansen et al. (2023)
Clients' administration related	Client requesting unrealistic performance expectations, client as layman/inexperienced, client failing to comply with contractual obligations	Francis et al. (2022), Tanriverdi et al. (2021)
Quality related	Poor quality of work, defects in completed work, poor quality material	Rahnamayiezekavat et al. (2022), Silva et al. (2023), Ilter (2012), Odenigbo et al. (2020)
Risk related	Differing physical site conditions, force majeure events	Shabana and Gad (2023), Nabi and El-adaway (2022)
Claim and dispute management related	Lack of dispute resolution methods, unattended claims	Cheung and Pang (2013), Vo et al. (2020)
Behavioral and professional issues	Lack of communication, lack of trust, negligence/lack of professionalism	El-Sayegh et al. (2020), Titus and Ali (2023), Gamil and Abd Rahman (2023)
External factors	Uncontrolled weather, material shortage, changes in government regulations	Ballesteros-Pérez et al. (2017), El-Sayegh et al. (2020), Liu et al. (2019)

with easy installation and configuration and a low learning curve. (3) Rost-CM6 software can fit with SNA software, ensuring the completeness of our research methodology (Shamshiri et al., 2024). Then, SNA was used to identify the key contract disputes and causes using UCINT 4.0 software. In previous studies, agent-based modeling, system dynamics, and SNA have been standard methods for identifying key factors. Agent-based modeling explores the interaction mechanisms, path dependencies, and emergent behaviors. System dynamics is used for variable feedback and time series trajectory exploration. In contrast, SNA was used to identify the key contract disputes and causes by calculating the network node attributes (i.e., degree centrality, closeness centrality, betweenness centrality, and core degree) (Freeman, 1978). Three reasons are provided for choosing SNA as follows. (1) SNA can directly identify key nodes through calculating node's centrality instead of ABM/SD's complexity. (2) It aligns with our co-occurrence data with SNA's relational matrices rather than ABM's micro-rules or SD's equations. (3) SNA offers mature, efficient tools with high transparency for replication in contrast to ABM/SD's complex coding and sensitive parameter tuning.

3.1. Data collection

3.1.1. Case selection

Considering the unique nature of megaprojects and the details of the research questions, this study adopted a single-case study approach. Yin (2018) noted that analyzing a single case can uncover the essence of many general phenomena and provide insights for addressing similar issues by focusing on the problem and highlighting the differences between theory and practice. Case selection was based on information-driven sampling (Flyvbjerg, 2006). Two primary criteria guided the selection process. First, the selected case was a large-scale project with significant social, economic, and environmental impacts that could provide a wealth of accessible data for in-depth analysis without making data collection difficult. Second, the selected case involved many contract dispute incidents and had a good contract dispute management track record.

The Jinan Airport Project is a typical example of a megaproject. Its total investment is 43.9 billion RMB, with an estimated construction cost of 33.2 billion RMB. Its construction period spanned from 2019 to 2023. The client is Jinan International Airport Construction Co., Ltd., jointly established by Jinan Urban Construction Group Co., Ltd. and Shandong Airport Management Group Co., Ltd., which has entered into 323 contract documents with its partners (including contractors, design firms, survey companies, project management companies, and testing firms). The client adopted the general contract with main contractors by dividing the project into nine packages. Each package is undertaken by a consortium of three or more contractors acting as the main contractors. Due to the complex external environment and large scale, this project has seen

frequent contract disputes, which may provide insightful and valuable reference information for contract dispute management.

Jinan Airport Project has multiple project participants, including 90 contractors, 21 project management companies, 24 designers/survey companies, and 16 testing firms. Due to the tight project schedule, multiple stakeholders require extensive coordination in inter-organizational interfaces, which results in numerous contract disputes, such as blurred work boundaries and frequent task changes. Project participants observed that different types of contract disputes often emerged in the same period, and that a dispute event resulted from concurrent causes. The large amount of interface coordination work indicates that issues related to contract disputes in the Jinan Airport project may be complex, and suit for further discussion.

3.1.2. Data collection

Data were collected from the secondary contract dispute-related documents and semi-structured interviews. (1) First, 200 contract dispute-related documents were obtained from the contract negotiation records and meeting minutes from 2019 to 2023. We screened the data to ensure the validity and representativeness of the sample as follows: 1) The documents needed to contain detailed descriptions of dispute events, stakeholders involved, causes, and resolution processes; 2) The number of contract disputes or causes involved in the documents had to be more than one; 3) The sources of contract dispute-related documents had to be reliable. We prioritized formal official records, arbitration/mediation reports, court judgments, or formally documented project reports. (2) Finally, 107 contract dispute-related documents were obtained with detailed information on contract disputes, such as the titles, dispute events, stakeholders involved, causes, and resolution processes.

Two rounds of semi-structured interviews were conducted. The first semi-structured interview aimed to review and refine the contract disputes and causes identified by text mining. To ensure the quantity and quality of the interviews, theoretical sampling was used to select respondents. The quality of respondents refers to their comprehensive understanding of the research topic. All respondents in this study were key managers of the Jinan Airport project and had worked on the project for at least three years. Each expert interview lasted 45–60 minutes, covering the expert's basic information, a review of contract disputes they had handled, and verifying contract disputes and causes obtained from the text mining. Saturation was achieved after the ninth interview when no new concepts or categories could be derived. We interviewed the 10th expert to finish the first-round semi-structured interviews (see Table 2). The second semi-structured interview requires the same 10 experts to evaluate the relationships between contract disputes and underlying causes. Each expert interview lasted 45–60 minutes, including assessing the relationships between contract disputes, between

Table 2. Information on the 10 experts

Code	Company	Position	Years of experience	Years of experience in Jinan Airport project
Expert 1	Jinan International Airport Construction Co.	Deputy General Manager, Bidding and Legal Affairs Department	18	5
Expert 2	Jinan International Airport Construction Co.	Section Chief of Contract Management Section of the Bidding and Legal Affairs Department	13	5
Expert 3	Jinan International Airport Construction Co.	Employee of the Contract Management Section of the Bidding and Legal Affairs Department	6	4
Expert 4	Jinan International Airport Construction Co.	Employee of Tender and Legal Affairs Department, Project Costing Section	11	4
Expert 5	Jinan International Airport Construction Co.	Section Chief, Installation Section, Engineering Department, Work Area	13	5
Expert 6	Jinan International Airport Construction Co.	Employee of the Planning and Design Section, Main Engineering Office	12	5
Expert 7	China Eighth Construction Co.	Contract Department Manager	15	4
Expert 8	China Construction Eighth Development and Construction Co.	Procurement Department Manager	21	4
Expert 9	Shandong Puhua Project Management Co.	Cost Department Manager	8	4
Expert 10	Yingte International Project Management Co.	Cost Department Manager	9	4

causes, and between contract disputes and causes using a 10-point scale (0 = no relations, 10 = the closest relations). The Kendall consistency coefficient (W) value was 0.76 ($p < 0.01$), indicating a high degree of consistency among the 10 experts. Finally, the arithmetic mean of the 10 experts' ratings was calculated to supplement the relationship matrix of contract dispute-dispute, cause-cause, and contract dispute-causes.

3.2. Data preconditioning

Text mining was used to identify prevalent contract disputes and causes by counting the frequency of contract disputes and contract dispute causes in 107 documents related to contract disputes. Text mining was also used to identify co-occurrence relationships between contract disputes, between causes, and between contract disputes and causes. The more the co-occurrence of two nodes (i.e., contract disputes or causes), the greater the value in their relationship matrix, indicating a closer relationship between two nodes. Furthermore, our study supplemented the relationship matrix by interviewing 10 experts. Given the different numerical scales, our study normalized the initial matrix obtained from text mining and the supplementary matrix obtained from expert interviews (Patro & Sahu, 2015) (see Eqn (1)). Here, x is the original element value in the matrix; $\min(x)$ and $\max(x)$ are the minimum and maximum values of all elements in the matrix. Our study chose ($a = 0$) and ($b = 10$) to normalize values to map them into the interval [0, 10].

$$x' = \frac{x - \min(x)(b - a)}{\max(x) - \min(x)} \quad (1)$$

3.3. Analytical strategy

Three steps were conducted to obtain the key contract disputes and causes (see Figure 1).

- (1) First, this study identified the emerging contract disputes, causes, and relationships using text mining. 1) 107 contract dispute-related documents were obtained as a text database for text mining. Rost-cm6 software was used to segment text files and extract word stems for contract dispute topics; clean the words by removing words unrelated to contract disputes and causes such as standardized texts, conjunctions, etc.; extract features and reduce dimensionality of the obtained topic words. Each theme word was composed of multiple words with similar meanings. For example, 'quality standards' and 'quality of engineering' were merged into 'quality', and 'on-site survey' and 'worksite' were incorporated into 'site'. 2) Ten experts who were key participants in 107 contract dispute events were selected to verify the contract disputes and their causes based on text mining results. Each expert was asked to review the contract dispute-related documents, provide contract disputes and corresponding causes, and explain the proposed solutions. For example, several questions were provided to the experts: In this contract dispute event, what contract disputes have arisen? What were the causes of this contract dispute? What kind of solutions have been adopted to resolve these contract disputes? 3) 12 contract disputes and 10 causes were obtained from the text mining and semi-structured interviews.
- (2) Three primary relationship matrices were obtained from the co-occurrence relationships between con-

tract disputes, between causes, and between contract disputes and causes through text mining using Rostcm6 software. Co-occurrence represented the relationships between two nodes (i.e., contract dispute, causes) when two nodes appear in the same context. The coexistence of multiple types of contract disputes within the same contract dispute event indicates a co-occurrence relationship between the contract disputes. When contract disputes with different causes occur within the same contract dispute event, it indicates co-occurrence between the causes. When contract disputes and their causes arise within the same contract dispute event, it suggests a co-occurrence relationship between the contract disputes and their

causes. The co-occurrence frequency of contract disputes is used to measure the closeness of their relationships, and the co-occurrence frequency is used as the contract dispute matrix value. A similar approach was used to obtain a relationship matrix between the causes of contract disputes and a relationship matrix between contract disputes and their causes. Subsequently, semi-structured interviews were conducted to validate the relationship network. Based on the relationship matrix obtained through text mining, 10 experts reviewed the relationships between contract disputes, the relationships between the causes, and the relationships between each contract dispute and its cause, providing supplementary matrices.

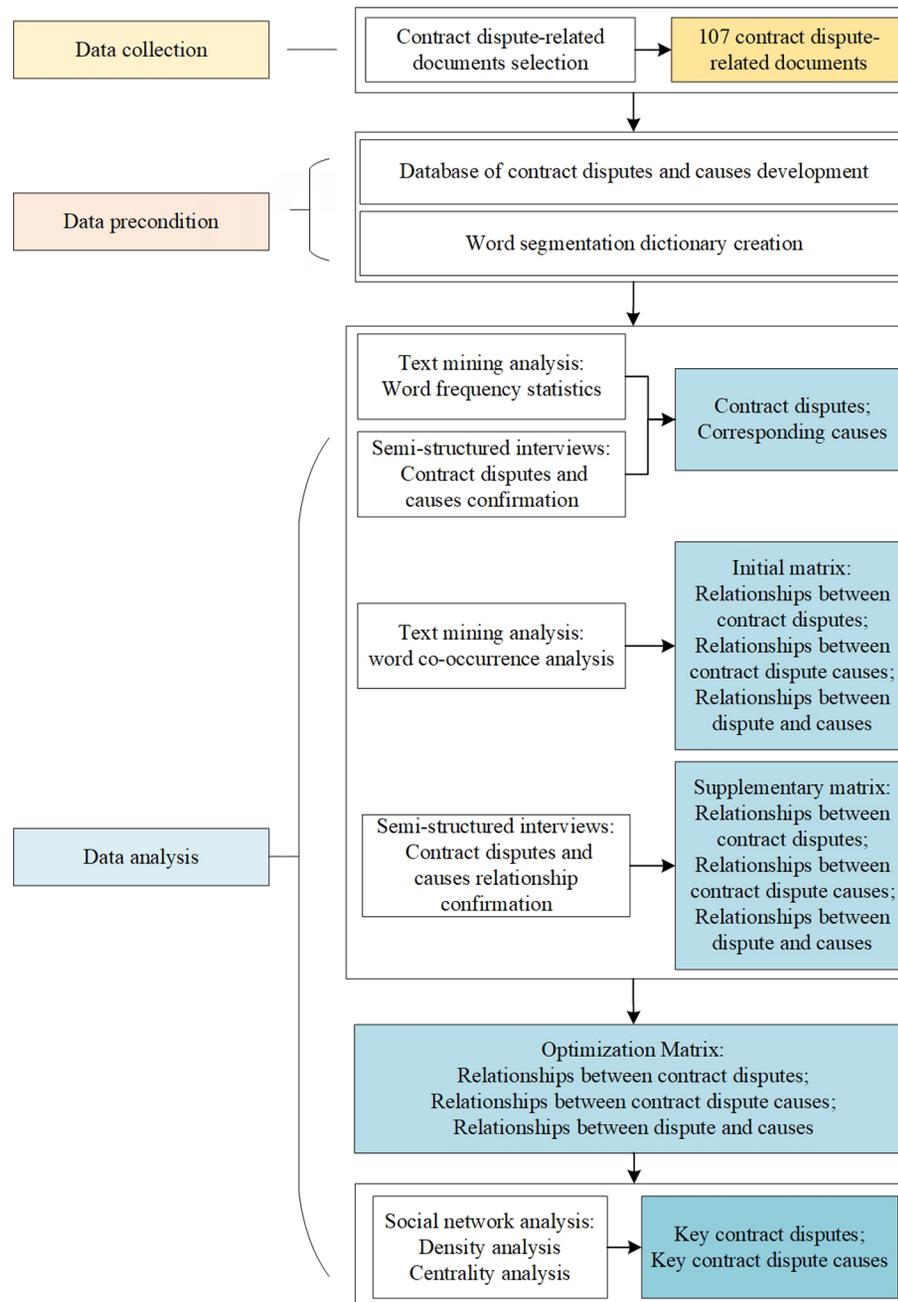


Figure 1. Process for text mining and social network analysis

(3) Third, SNA was conducted to identify the crucial contract disputes and contract dispute causes by calculating the attributes of nodes and networks (i.e., network density, centrality, and core-periphery analysis). Network density refers to the extent to which the links that could potentially exist between nodes do exist. It is evaluated by quantifying the ratio of extant edges to potential edges within a network, offering insights into its structural composition, and serves as a pivotal metric for small networks (Jamali & Abolhassani, 2006). In Eqn (2), m means the number of relationships within the network, n means the count of nodes in the bipartite network, and D indicates the network density with values of [0, 1]. Network density attains a value of 1 in the scenario of complete connectivity – when each node is interconnected, the value of network density is 1; when nodes exist in isolation, the value of network density is 0.

$$D = \frac{m}{n * n - 1}. \quad (2)$$

The multi-valued matrix was converted to a binary 0-1 matrix when a density value exceeds 1.0, considering that network density does not account for the intensity of relationships. The bipartite network has two types of nodes: actors and events. In Eqn (3), m denotes the tally of connections interlinking actors with events, while a and b signify the respective counts of actors and events.

$$D = \frac{m}{a * b}. \quad (3)$$

Centrality is a pivotal metric that reveals critical nodes of the undirected social network, encompassing degree centrality, closeness centrality, and betweenness centrality (Freeman, 1978). Degree centrality is a node's interconnectedness with the remainder of the network. The greater a node's power or influence, the more nodes it is connected to. Degree centrality is a function encapsulating all relationships about a node (Stephenson & Zelen, 1989). The degree of centrality of node i is articulated by formula 4. w_{ij} signifies the weight of the connection between node i and its related node j .

$$C_d n_i = \sum_i w_{ij}. \quad (4)$$

Closeness centrality is a centrality metric that measures the proximity of a node to all other nodes in a network and is defined as the reciprocal of the sum of the distances from a node to all other nodes (Freeman, 1978), which expresses centrality as its reciprocal. The smaller the sum of distances, the higher the centrality (Stephenson & Zelen, 1989). In formula 5, n is the total number of nodes in the network, d_{ij} is the shortest path length from node i to node j .

$$C_c n_i = \frac{N-1}{\sum_{j=1}^N d_{ij}}. \quad (5)$$

Betweenness centrality indicates the degree of a node's linkage role in a social network, encapsulating its level of participation in the relational fabric interlinking other nodes (Freeman, 1977). Betweenness centrality is evaluated by assessing the shortest distance between two nodes' geodesic distances between node pairs (see Eqn (6)). The w_{jk} is the tally of shortest paths interconnecting nodes j and k . The $w_{jk(i)}$ is the count of pathways passing through node i in the paths of node j and node k linking nodes j and k , with node i lying on route.

$$C_b n_i = \sum_{i \neq j, j \neq k} \frac{w_{jk(i)}}{w_{jk}}. \quad (6)$$

Core-periphery analysis is an approach to examine network structures' varying roles and positional hierarchies, which is used to verify the core nodes and peripheral nodes. It can be conducted by using the core algorithm of the UCINET 6.0 software. Core-periphery analysis facilitates the identification of structural equivalence, comprehension of the underlying power dynamics, and social stratification of a social network (Wasserman & Faust, 1994). A core node exerts a significant influence on the network's overall configuration.

3.4. Characteristics of the sample

107 contract dispute-related documents were collected from the Jinan Airport megaproject. These documents came from on-site construction, survey and design, supervision, consultant, procurement, and testing contracts. Text documents were obtained by removing extraction errors and meaningless characters, and 62920 words were gained via an ANSI-encoded text file (txt) analysis to develop the corpus. Considering the size of the text mining corpus, this study opted for the top 100 high-frequency words for text analysis. Table 3 shows that the high-frequency words are contractor, engineering project, project sponsor, construction operation, payment transaction, contract agreement, financial expenditure, stipulated requirement, construction materials, and equipment assets, with the frequency exceeding 200 times. Quantitative measurement, professional training, quality, and results appear less frequently, with the values being fewer than 20 times.

A word cloud diagram is obtained using Rost-cm6 software (see Figure 2). It reveals that "engineering", "contractor", "technology", "quality", and "responsibility" are pivotal in underscoring the focal points of project execution, adherence to technical standards, and the delineation of duties. Words such as "risk", "guarantee", and "schedule" denote a pronounced focus on the realms of risk mitigation and quality assurance. Economic elements refer to "market prices", "costs", and "losses". Words such as "civilized construction" and "government" reflect the relevant content of construction requirements.

Table 3. The frequency statistics of the top 100 words

Words	Frequency	Word	Frequency	Word	Frequency	Word	Frequency
Contractor	732	Quality assurance	104	Scope	52	Audit	36
Engineering project	503	Safety protocols	98	Impact assessment	51	Operational execution	35
Project sponsor	494	Contractual timeframe	83	Project progress	51	Tender documentation	35
Construction operation	361	Acceptance inspection	81	Entrustment	49	Site location	34
Payment transaction	325	Content	81	Supervisor	48	Procurement process	33
Contractual agreement	321	Design	71	Personnel	48	Scheduling plan	32
Financial expenditure	270	Loss	71	Construction period	48	Regulatory approval	31
Stipulated requirement	242	Standard	69	Comprehensive consideration	46	Transportation infrastructure	30
Construction materials	218	Qualified /Complaint	68	Amount	46	Occupational accident	28
Equipment assets	215	Checklist /Inventory	68	Information	45	Project progress imagery	28
Contractual payment	198	Documentation	66	Maintenance	43	Manual labor	27
Accountability	179	All/Everything	65	Infrastructure development	43	Advanced design	27
Provision of services	177	Regulation /Stipulation	65	Market price volatility	43	Legal framework	27
Adjustment mechanism	164	Obligation	64	Testing	43	Roadway construction	27
Performance bond	160	Cause	64	Installation	43	Compensation for damages	26
Contractual provision	154	Generate /Produce	63	Temporary facilities	40	Quality inspection	24
Project initiative	141	Facilities	61	Quality security deposit	40	Mechanical equipment	23
Financial settlement	139	Confirmation	60	Blueprints	39	Gross output value	22
Legal liability	138	Timely	59	Conditions	39	Governmental authority	22
Project completion	137	Implementation	58	Performance execution	39	Payment cycle	21
Project management	137	Temporary	58	Regulatory standards	39	Project supervision	21
Pricing structure	131	Protection	57	Risk assessment	37	Professional training	19
Construction site	130	Project plan	54	Any	37	Quality	19
Breach of contractual terms	118	Mitigative strategies	53	Civilized construction practice	37	Results	18
Technological expertise	112	Auditing process	52	Warranty period	36	Quantitative measurement	18



Figure 2. Word cloud diagram

4. The results of text mining

4.1. The framework of contract disputes and causes in megaprojects

A total of 12 contract disputes are obtained via text mining in the megaproject context, including payment dispute, quality dispute, construction tasks dispute, temporary work dispute, brand dispute (i.e., equipment and materials), order change dispute, material price dispute, breach of contract dispute, guarantee dispute, settlement dispute, site safety and housekeeping dispute, construction coordination dispute (see Table 4). A total of 10 contract dispute causes are obtained via text mining in the megaproject context (see Table 5), including inconsistencies between contract and tender documents, the imperfect clients' management system, unforeseen on-site environment changes, incomplete survey and design content, contractor's bidding and quotation strategies, unclear

contract terms, special construction requirements, policy-related factors, third-party factors, relevance of government audit.

4.2. Co-occurrence relationships between contract disputes and causes

The co-occurrence relationships among contract disputes and causes were identified through text mining, with the co-occurrence frequency defining the values in the initial social network matrix (see Appendix, Table A1). This matrix was then combined with a supplementary matrix derived from interview data to receive the final social network matrix of contract disputes and causes for social network analysis (see Appendix, Table A2).

Table 6 shows that there are non-linear relationships between contract disputes, manifesting as different links and degrees. For example, ZY1 and the remaining 10 contract disputes were involved in the same dispute event but not with the ZY7 (the value being 0.00). Amongst these, ZY1 interacted with ZY2 and ZY10 in the same dispute events, with values of 10.93 and 17.80. Besides, our results show that the degree of contract dispute relationship varies. For example, ZY10 has relations with nine contract disputes, while ZY7 is related to ZY6 and ZY10.

Table 7 shows that there are non-linear network relationships between causes of contract disputes, manifesting as relationships between them vary. For example, C6 connects with the other nine causes with different degrees, such as C3, C4, and C7 being 7.22, 7.04, and 5.95, respectively. Besides, our results show differences in the relationships between causes. For example, C2 co-occurs with C1, C3, C4, C5, C6, C9, and C10, while C10 co-occurs with C4, C6, and C8.

Table 4. Main contract disputes in megaprojects

Code	Contract dispute	Corresponding synonyms
ZY1	Payment dispute	Payment Methods, Payment Ratios, Payment Terms, Payment Cycles, Payment Ratios Based on Project Progress Requirements, and Payment Conditions
ZY2	Quality dispute	Quality Objectives, High Quality and Reasonable Prices, Luban Award, Qualified, Zhan Tianyou Award, Gold Award, High Quality
ZY3	Construction tasks dispute	Construction Task Scope, Construction Task Content, Task Scope, Task Scope of Tender
ZY4	Temporary work dispute	Temporary Water Supply, Temporary Electricity Supply, Temporary Facilities, Temporary Roads, Temporary Water Supply, Temporary Roads, Temporary Electricity Supply, Connection Points
ZY5	Brand dispute (i.e., equipment and materials)	Brand Names of Materials and Equipment, Specifications of Materials and Equipment
ZY6	Order change dispute	Change, Change Order, Variation Order, Work Approval, Construction Change Authorization, Design Variation, Change Estimate
ZY7	Material price dispute	Market Price Fluctuations, Price Adjustment, Material Prices, Price Variations, Contract Material Price Variations
ZY8	Breach of contract dispute	Breach of Contract, Liquidated Damages, Penalty Clause, Remedies
ZY9	Guarantee dispute	Retention, Defects Liability Period, Guarantee, Advance Payment Guarantee, Warranty (Maintenance) Guarantee, Retention Bond/Guarantee, Insurance, Security, Bank Guarantee
ZY10	Settlement dispute	Settled on an Actual's Basis, Detailed Design, Basis for Settlement
ZY11	Site safety and housekeeping dispute	Site Safety and Housekeeping, Site Safety and Housekeeping Costs / Allowance, Site Fencing, Health and Safety, HSE and Housekeeping
ZY12	Construction coordination dispute	Civilization, Safety, and Civilization Construction Fee, Enclosure, Safety

Table 5. Main causes of contract disputes in megaprojects

Code	Cause of the contract dispute	Corresponding synonyms
C1	Inconsistencies between the contract and tender documents	Bidding Documents
C2	The imperfect clients' management system	System, Process
C3	Unforeseen on-site environment changes	Treading, Site, Survey
C4	Incomplete survey and design content	Drawings, Design, Design Institute, Survey, Mapping
C5	Contractor's bidding and quotation strategy	Quotation, Tender Offer
C6	Unclear contract terms	Based on the Principle(s) of, Shall Have Regard to, Including but Not Limited to
C7	Special construction requirements	Clearance, Electromagnetic, Non-stop, Airport Operation, Non-stop Construction
C8	Policy-related factors	Intelligent Site, Migrant Workers' Wages, Jinan City, Shandong Province
C9	Third-party factors	Expansion Project Headquarters, User Department, Inspection and Testing, Agency Construction
C10	Relevance of government audit	Government

Table 6. Network relationship matrix of contract disputes

Code	ZY1	ZY2	ZY3	ZY4	ZY5	ZY6	ZY7	ZY8	ZY9	ZY10	ZY11	ZY12
ZY1	0.00	10.93	3.64	5.03	7.50	4.43	0.00	6.40	6.11	17.80	8.80	3.47
ZY2	10.93	0.00	0.20	0.00	0.41	0.20	0.00	4.01	3.67	3.12	1.22	0.00
ZY3	3.64	0.20	0.00	0.00	0.41	3.22	0.00	1.22	0.41	1.22	1.22	3.74
ZY4	5.03	0.00	0.00	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.61	7.02
ZY5	7.50	0.41	0.41	0.00	0.00	4.00	0.00	0.41	0.00	2.80	0.00	0.00
ZY6	4.43	0.20	3.22	3.10	4.00	0.00	2.40	0.41	0.00	4.02	0.41	0.61
ZY7	0.00	0.00	0.00	0.00	0.00	2.40	0.00	0.00	0.00	5.80	0.00	0.00
ZY8	6.40	4.01	1.22	0.00	0.41	0.41	0.00	0.00	1.40	4.24	2.45	1.62
ZY9	6.11	3.67	0.41	0.00	0.00	0.00	0.00	1.40	0.00	2.84	1.22	0.20
ZY10	17.80	3.12	1.22	0.00	2.80	4.02	5.80	4.24	2.84	0.00	0.61	0.61
ZY11	8.80	1.22	1.22	0.61	0.00	0.41	0.00	2.45	1.22	0.61	0.00	5.95
ZY12	3.47	0.00	3.74	7.02	0.00	0.61	0.00	1.62	0.20	0.61	5.95	0.00

Table 7. Network relationship matrix of causes

Code	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	0.00	2.10	6.42	5.81	0.41	5.52	1.91	0.40	0.80	0.00
C2	2.10	0.00	2.50	0.40	1.50	8.10	0.00	0.00	2.60	0.00
C3	6.42	2.50	0.00	5.54	1.81	7.22	4.52	1.02	2.82	0.00
C4	5.81	0.40	5.54	0.00	6.22	7.04	1.84	0.20	0.20	2.50
C5	0.41	1.50	1.81	6.22	0.00	4.22	0.61	2.00	0.20	0.00
C6	5.52	8.10	7.22	7.04	4.22	0.00	5.95	5.00	5.43	1.60
C7	1.91	0.00	4.52	1.84	0.61	5.95	0.00	2.10	3.91	0.00
C8	0.40	0.00	1.02	0.20	2.00	5.00	2.10	0.00	0.00	3.20
C9	0.80	2.60	2.82	0.20	0.20	5.43	3.91	0.00	0.00	0.00
C10	0.00	0.00	0.00	2.50	0.00	1.60	0.00	3.20	0.00	0.00

Table 8. Network relationship matrix of contract disputes and causes

Code	ZY1	ZY2	ZY3	ZY4	ZY5	ZY6	ZY7	ZY8	ZY9	ZY10	ZY11	ZY12
C1	1.63	7.22	8.82	5.00	8.00	1.20	4.80	0.41	9.82	3.72	4.02	2.41
C2	5.31	0.00	0.20	0.00	0.00	7.70	6.30	0.41	6.80	6.41	1.51	4.41
C3	2.65	1.22	6.23	8.42	0.00	0.82	0.00	1.43	2.61	1.51	8.77	5.35
C4	2.65	0.00	7.03	1.43	0.00	0.61	0.00	1.22	0.61	10.65	1.02	0.82
C5	0.61	0.00	3.61	1.40	5.00	0.20	7.20	0.41	0.00	7.02	3.41	0.61
C6	8.35	3.70	4.61	10.34	7.00	6.30	2.24	6.73	0.00	7.81	4.43	8.22
C7	3.02	0.50	0.41	5.72	1.10	0.00	0.00	2.11	0.00	0.20	6.84	4.01
C8	4.24	4.43	0.41	0.61	0.00	0.20	0.61	0.00	1.84	0.82	2.65	1.00
C9	1.84	0.61	1.61	3.31	0.00	0.00	0.00	0.00	0.20	0.82	0.41	4.10
C10	7.12	0.00	0.00	0.00	0.00	0.00	1.80	1.20	1.70	5.22	0.20	0.00

Table 8 shows the relationship between contract disputes and their causes. The relationships between C4 and ZY10, C6 and ZY4 are closer, with the values being 10.65 and 10.34. C6 exhibits significant associations with contract disputes, notably with ZY1, ZY4, and ZY12. In comparison, C10 has a less critical relationship with all disputes.

5. The results of social network analysis

5.1. Crucial contract disputes in megaprojects

The network density of the contract dispute network is 0.697, indicating that contract disputes are closely connected in the Jinan Airport megaproject. In the social network, the node attributes can be explained using the nodes' size scale and the lines' thickness scale. The larger the node icon, the greater its degree centrality, indicating that it is connected to many lines. The thicker the line, the higher the co-occurrence frequency. As Figure 3 shows, payment dispute (ZY1), settlement dispute (ZY10), and order change dispute (ZY6) are the key contract disputes because of their larger icons. In contrast, temporary work dispute (ZY4) and material price dispute (ZY7) have smaller icons than others. The two lines (i.e., ZY1 and ZY10,

ZY1 and ZY2) are thicker than the other lines, indicating a high degree of co-occurrence. Table 9 shows that payment dispute (ZY1) and settlement dispute (ZY10) have a great centrality degree, with values of 74.11 and 43.06. The closeness centrality of material price dispute (ZY7) and temporary work dispute (ZY4) are high, with values being 20 and 18. Order change dispute (ZY6) possesses the highest betweenness centrality, with a value of 6.593. In contrast, temporary work dispute (ZY4) and brand dispute (i.e., equipment and materials) (ZY5) have lower betweenness centrality, with the value being 0.00.

5.2. Crucial contract dispute causes in megaprojects

Figure 4 shows the network relationships between contract dispute causes. Table 10 shows that the network of contract dispute causes has a high density, with a value of 0.8. Unclear contract terms (C6) and incomplete survey and design content (C4) are the larger nodes in the contract dispute causes network, showing they have many links with others. In contrast, the relevance of government audit (C10) is a small node, revealing it has fewer links with other causes. The thick lines between C6 and other nodes indicate a high frequency of co-occurrence relationships with

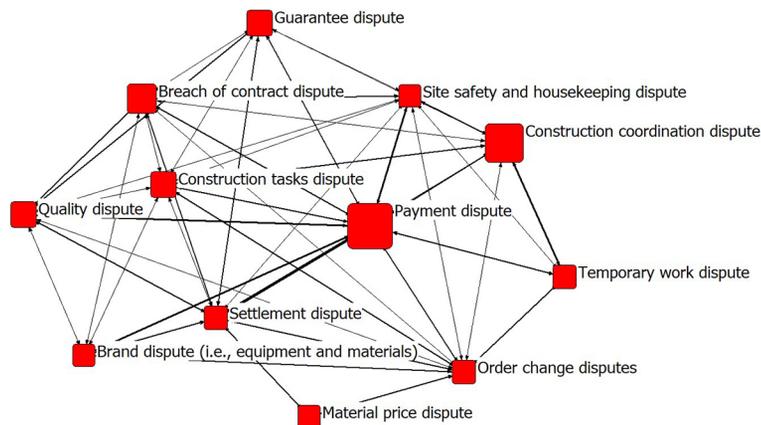


Figure 3. Relationship network of contract disputes

Table 9. Network analysis results of contract disputes

No.	Cause content	Degree centrality	Closeness centrality	Betweenness centrality	Core
ZY1	Payment dispute	74.11	12	2.769	0.961
ZY2	Quality dispute	23.76	14	0.510	0.114
ZY3	Construction tasks dispute	15.28	13	0.852	0.028
ZY4	Temporary work dispute	15.76	18	0.000	0.040
ZY5	Brand dispute (i.e., equipment and materials)	15.53	16	0.000	0.071
ZY6	Order change dispute	22.80	12	6.593	0.045
ZY7	Material price dispute	8.20	20	0.000	0.000
ZY8	Breach of contract dispute	22.16	13	0.852	0.069
ZY9	Guarantee dispute	15.85	15	0.143	0.060
ZY10	Settlement dispute	43.06	12	5.352	0.194
ZY11	Site safety and housekeeping dispute	22.49	13	1.702	0.085
ZY12	Construction coordination dispute	23.22	14	1.226	0.031

other factors. Table 10 shows that unclear contract terms (C6) have the highest centrality degree, with a value of 79.02. Unforeseen on-site environment changes (C3) and incomplete survey and design content (C4) have a high degree of centrality, with the values being 54.5 and 54.29. The difference in closeness centrality of these ten causes is not significant because the values of closeness centrality range from 9 to 15. For example, the closeness centrality of the relevance of government audit (C10) is 15.0. In contrast, the closeness centrality of incomplete survey and

design content (C4) and unclear contract terms (C6) is 9.0. Incomplete survey and design content (C4) and unclear contract terms (C6) have the highest betweenness centrality, with the values being 2.867 and 2.867.

The contract dispute-cause network is a two-mode network that cannot undergo centrality analysis before being converted. The density was calculated as 0.783 using the "network, 2-mode networks, 2-mode cohesion" function in UCINET 6.0 software. Figure 5 shows that the inconsistencies between contract and tender documents

Table 10. Contract dispute causes network analysis results

No.	Cause content	Degree centrality	Closeness Centrality	Betweenness Centrality	Core
C1	Inconsistencies between contract and tender documents	33.43	10	0.533	0.273
C2	The imperfect clients' management system	17.20	12	0.000	0.175
C3	Unforeseen on-site environment changes	54.50	10	0.533	0.391
C4	Incomplete survey and design content	54.29	9	2.867	0.406
C5	Contractor's bidding and quotation strategy	28.94	10	0.533	0.244
C6	Unclear contract terms	79.02	9	2.867	0.560
C7	Special construction requirements	41.61	11	0.167	0.336
C8	Policy-related factors	18.96	11	1.333	0.171
C9	Third-party factors	25.39	11	0.167	0.220
C10	Relevance of government audit	7.30	15	0.000	0.106

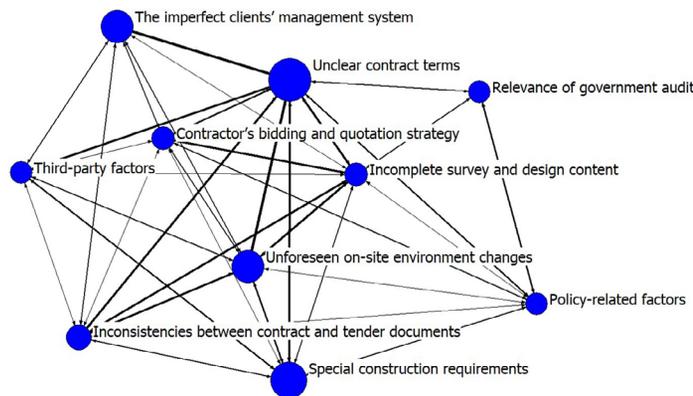


Figure 4. Relationship network of contract dispute causes

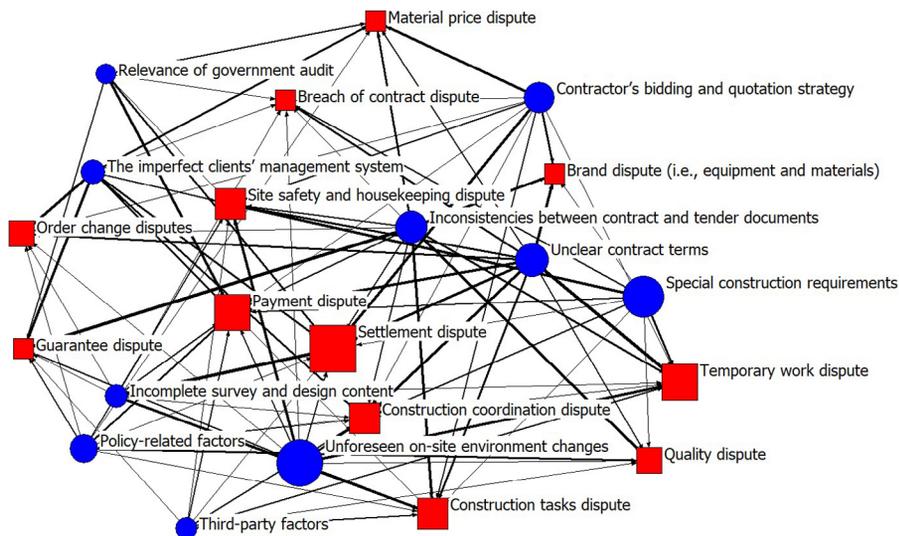


Figure 5. Relationship network of contract disputes and causes

(C1) exhibit the highest degree centrality with the largest node. In contrast, the relevance of government audit (C10) presents the lowest degree centrality with the smallest node. For contract disputes, payment dispute (ZY1) displays the highest centrality degree, while brand dispute (i.e., equipment and materials) (ZY5) exhibits the lowest one. The linkages between C3 and ZY11, C4 and ZY10 demonstrate the most robust linkages in the contract dispute–cause network.

6. Discussion

Our study systematically identified 12 types of contract disputes in megaprojects, among which payment dispute (ZY1), settlement dispute (ZY10), and order change dispute (ZY6) occur with high frequency and occupy central positions in the network of contract disputes. Some contract dispute types, such as temporary work dispute (ZY4), brand dispute (i.e., equipment and materials) (ZY5), and construction coordination dispute (ZY12) are rarely mentioned in current studies but show high contextual importance in megaprojects, reflecting the temporary nature, coordination demands, and multi-stakeholder complexity unique to large-scale projects. Our findings are consistent with existing studies, which pointed out that payment disputes and quality disputes are common disputes in construction projects (Serpell & Torres, 2023), particularly regarding the prevalence of payment disputes across different contexts. However, unlike previous research that has focused chiefly on a single type of dispute, our study reveals that financial disputes (ZY1, ZY10) occupy a core role in the contract dispute network and exhibit a high degree of interconnectivity. Our findings provide a new perspective for understanding the relationships between contract disputes in the megaproject context.

Our study identified 10 key causes of contract disputes in megaprojects, among which unclear contract terms (C6) and incomplete survey and design content (C4) exhibit the highest degree centrality and betweenness centrality in the relationship network of contract dispute causes, indicating the bridging roles in linking multiple contract dispute causes. The core causes can be directly attributed to the clients' unclear task definitions, including inconsistencies between contract and tender documents (C1), imperfect clients' management system (C2), and incomplete survey and design content (C4). Because megaprojects are typically initiated by local governments that often lack extensive megaproject management experience, this exacerbates the ambiguity of project plans. In addition, special construction requirements (C7) and policy-related factors (C8), as context-specific causes unique to megaprojects, are important causes of contract disputes, yet have received limited attention in the existing literature focusing on general project contexts (Illankoon et al., 2022; Serpell & Torres, 2023). For example, Silva et al.'s (2023) systematic review of dispute causes did not mention technical specificity or policy volatility because standard construc-

tion projects face less stringent technical requirements and operate in stable policy environments. In contrast, megaprojects are frequently subject to policy adjustments and changes in technical standards, making them the main disputes in megaproject contexts. Furthermore, prior studies have examined dispute causes from a linear cause–effect perspective (Naji et al., 2020; Viswanathan et al., 2020), overlooking interactions among the causes. Our study found that unclear contract terms (C6) and incomplete survey and design content (C4) are high-frequency causes and bridging nodes linking multiple dispute causes, supporting dispute generation's networked and systemic nature. This finding resonates with Tanriverdi et al. (2021) emphasis on contractual ambiguity but further reveals its cross-causal linking role in megaprojects.

Although our study uses the Jinan Airport megaproject as one case study, its findings offer valuable implications for understanding megaprojects. Key contract disputes and underlying causes identified herein are tested in prior studies to some degree, revealing their specificity and universality. For instance, the high correlation between payment dispute (ZY1) and settlement dispute (ZY10) emerges in transportation projects such as high-speed rail and metro systems (Shabana & Gad, 2023). Quality dispute (ZY2) and construction tasks dispute (ZY3) are consistent with Hussain et al. (2025). Prior studies proved our findings regarding the causes of contract disputes, such as unclear contract terms (C6) acting as a key link connecting special construction requirements for megaprojects (C7) and incomplete survey and design content (C4). For example, in urban complex projects, ambiguous clauses (a manifestation of unclear contract terms) lead to disputes over decoration standards and missing items in drawings (Abdul-Malak et al., 2019; Francis et al., 2022); the imperfect clients' management system (C2) in government-led projects is prevalent in municipal, water conservancy, and other public projects (Naji et al., 2020). Thus, our findings have substantial value for contract disputes in the megaproject context.

7. Theoretical implementation and practical implementation

7.1. Theoretical implementation

(1) Our study extends contract dispute typology literature by identifying 12 types of contract disputes specific to the megaproject context. Beyond the discussed payment and settlement-related disputes, our results highlight the contextual salience of temporary work dispute, brand dispute (i.e., equipment and materials), and construction coordination dispute issues that are rarely mentioned in conventional construction dispute studies (Serpell & Torres, 2023; Silva et al., 2023) but are prominent in megaprojects. This study supplements current typologies by revealing the importance of these underexplored dispute types (Cheung & Pang, 2013; Iyer et al., 2008) with context-dependent

categories that are particularly relevant for complex, multi-stakeholder environments. The findings provide new perspectives for designing contract governance to address contract disputes in megaprojects.

- (2) Our study expands the relevant literature on the antecedent identification of contract disputes by providing ten causes. Prior studies have recognized the significance of ambiguous contract terms or incomplete design (Viswanathan et al., 2020; Tanriverdi et al., 2021) but have not examined their detailed role. Our findings enrich the understanding of dispute causation by revealing that unclear contract terms (C6) and incomplete survey and design content (C4) are bridging nodes linking multiple dispute causes. It confirms that disputes are interactions rather than isolated, which adds a network perspective to dispute causation research. Besides, identifying megaproject specific causes, such as special construction requirements (C7) and policy-related factors (C8), adds contextual nuance to contract dispute. These factors are often absent from general construction dispute's theoretical frameworks (Illankoon et al., 2022) but are essential in policy-sensitive, technically demanding projects like megaprojects. By explicitly incorporating these context specific elements, this study advances the theoretical frameworks of dispute causation, bridging the gap between generic frameworks (Silva et al., 2023) and the realities of governance in megaprojects.
- (3) Our study advances methodological approaches for identifying and analyzing contract disputes and their causes by integrating text mining with SNA. Prior studies have typically relied on surveys or qualitative coding to classify disputes and causes (e.g., E. Cakmak & P. I. Cakmak, 2014; Naji et al., 2020), which capture frequency but often overlook interdependencies. In contrast, the combined use of text mining and SNA in this study enables the simultaneous identification of the most frequent disputes and causes and their network attributes, revealing key disputes and causes that connect multiple conflict pathways. Compared with previous studies that applied SNA to risk or stakeholder network studies (Nabi & El-adaway, 2022; Aljassmi et al., 2014), this study applies SNA to contract management, offering a new analytical scope for understanding what disputes emerge in megaprojects.

7.2. Practical implementation

- (1) This study provides practical guidance to project managers of megaprojects on designing contract items. Our findings suggest that the identification of payment dispute (ZY1), settlement dispute (ZY10), and order change dispute (ZY6) as contract disputes indicates that targeted resolution of these disputes can have an outsized effect on reducing overall dispute incidence. Project clients and contractors should prioritize the clear specification of payment schedules, settlement principles, and change management procedures in the contract drafting stage to minimize am-

biguity and reduce potential conflict. The findings help contract managers consider potential points of dispute to deal with in advance, thus reducing the occurrence of contract disputes.

- (2) This study offers guidance for contract dispute solutions by providing the common causes of contract disputes in megaprojects. The bridging role of unclear contract terms (C6) and incomplete survey and design content (C4) suggests that addressing these issues early can prevent the spread of disputes across multiple domains. Clients should ensure that contract clauses are specific, unambiguous, and operationally enforceable, while survey and design deliverables should be complete and accurate before contract execution. Establishing independent review and verification mechanisms for these documents can further reduce risks. Besides, recognizing megaproject specific causes such as special construction requirements (C7) and policy related factors (C8) underscores the need for adaptive contracts and project management strategies. For projects subject to stringent technical standards or regulatory volatility, stakeholders should incorporate flexible contractual provisions that allow for technical adjustments and policy driven modifications without automatically triggering disputes.
- (3) This study offers guidance for the network based analytical approach, which can be applied as a practical contract dispute monitoring tool. By continuously mapping the relationships between contract disputes and their causes, project managers can detect emerging central disputes or bridging causes and intervene before conflicts escalate. Our study complements existing project monitoring practices discussed in Hu et al. (2016) and Galvin et al. (2021), and adds an analytical dimension that shifts monitoring from passive tracking to proactive network-informed intervention, which is particularly valuable in the dynamic environment of megaproject delivery.

7.3. Limitations

Despite our best efforts, this study is not without limitations. First, due to the limitation of data collection, the data were gathered from one megaproject, although our study collected data over four years. Future studies can conduct multiple case studies or surveys by collecting data from many megaprojects. Second, megaproject contract management processes did not consider temporal effects such as dynamism and turbulence. Future studies can assess the impact of temporal dynamics on contract disputes and their causes by collecting longitudinal information about these evolving trajectories and taking project phases into account to track the dynamic relationships. Third, social network relationships of contract disputes and their causes may exhibit different characteristics at different megaproject stages. Future studies can deepen the understanding of the multi-level nature of social networks, exploring the formation and development of other core network layers.

8. Conclusions

Contract disputes have become a hot issue in megaprojects. Prior studies explored contract disputes in conventional construction projects, modular projects, and the PPP project contexts, but few focused on the megaprojects that face serious contract dispute challenges. Our study addresses this gap by proposing a framework of contract disputes and corresponding causes using text mining and SNA. The findings provide 12 contract disputes and 10 causes in the megaproject context. Our findings found that the payment dispute (ZY1) and settlement dispute (ZY10) have a high centrality degree; material price dispute (ZY7) and temporary work dispute (ZY4) have high closeness centrality; the order change dispute (ZY6) possesses the high betweenness centrality. Meanwhile, unclear contract terms (C6), unforeseen on-site environment changes (C3) and incomplete survey and design content (C4) have the high centrality degree; incomplete survey and design content (C4), and unclear contract terms (C6) have great closeness centrality; incomplete survey and design content (C4) and unclear contract terms (C6) have the great betweenness centrality. Our study enriches the literature on contract disputes by identifying main disputes and corresponding causes, and advances research on contract governance in megaprojects by exploring relationships between contract disputes and causes. Meanwhile, it provides practical guidance for megaprojects in contract management and dispute solutions.

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Author contributions

Hong Xue led the design and implementation of empirical study, including hypothesis formulation, experimental framework construction, data collection and statistical analysis, and wrote the first draft of the paper. Chao Ye assisted in the empirical operation, responsible for data cleaning, model validation and result visualization, and participated in the revision of the paper. Cheng Zhang provided research tools, participated in data analysis and literature review. Zezhou Wu proposed the research di-

rection, supervised the research process, coordinated the inter-institutional resources, and finalized and submitted the paper.

Disclosure statement

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.

References

- Abdul-Malak, M.-A. U., Hanano, H. F., & Turman, H. M. (2019). Administration impairments resulting from imbalanced contract conditions: Owner payment default. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 11(4), Article 05019003. [https://doi.org/10.1061/\(ASCE\)LA.1943-4170.0000321](https://doi.org/10.1061/(ASCE)LA.1943-4170.0000321)
- Agénor, P.-R. (2010). A theory of infrastructure-led development. *Journal of Economic Dynamics and Control*, 34(5), 932–950. <https://doi.org/10.1016/j.jedc.2010.01.009>
- Ahmed, M. O., & El-adaway, I. H. (2023). Data-driven analysis of construction bidding stage-related causes of disputes. *Journal of Management in Engineering*, 39(5), Article 4023026. <https://doi.org/10.1061/JMENEAE.MEENG-5426>
- Aljassmi, H., Han, S., & Davis, S. (2014). Project pathogens network: New approach to analyzing construction-defects-generation mechanisms. *Journal of Construction Engineering and Management*, 140(1), Article 04013028. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0000774](https://doi.org/10.1061/(ASCE)CO.1943-7862.0000774)
- Alrasheed, K. A., Soliman, E., & AlMesbah, F. E. (2023). Dispute classification in construction projects based on litigation cases. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 15(3), Article 4523013. <https://doi.org/10.1061/JLADAH.LADR-910>
- Ballesteros-Pérez, P., Rojas-Céspedes, Y. A., Hughes, W., Kabiri, S., Pellicer, E., Mora-Melià, D., & del Campo-Hitschfeld, M. L. (2017). Weather-wise: A weather-aware planning tool for improving construction productivity and dealing with claims. *Automation in Construction*, 84, 81–95. <https://doi.org/10.1016/j.autcon.2017.08.022>
- Cakmak, E., & Cakmak, P. I. (2014). An analysis of causes of disputes in the construction industry using analytical network process. *Procedia - Social and Behavioral Sciences*, 109, 183–187. <https://doi.org/10.1016/j.sbspro.2013.12.441>
- Cakmak, P. I. (2022). The stakeholders' perspective on the factors contributing to construction disputes. *International Journal of Building Pathology and Adaptation*, 40(5), 712–727. <https://doi.org/10.1108/IJBPA-06-2020-0050>
- Cheung, S. O., & Pang, K. H. Y. (2013). Anatomy of construction disputes. *Journal of Construction Engineering and Management*, 139(1), 15–23. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0000532](https://doi.org/10.1061/(ASCE)CO.1943-7862.0000532)
- Currie, D., & Teague, P. (2015). Conflict management in public-private partnerships: The case of the London underground. *Negotiation Journal*, 31(3), 237–266. <https://doi.org/10.1111/nej.12093>
- Diekmann, J. E., & Girard, M. J. (1995). Are contract disputes predictable?. *Journal of Construction Engineering and Management*, 121(4), 355–363. [https://doi.org/10.1061/\(ASCE\)0733-9364\(1995\)121:4\(355\)](https://doi.org/10.1061/(ASCE)0733-9364(1995)121:4(355))
- Eissa, R., Eid, M. S., & Elbeltagi, E. (2021). Current applications of game theory in construction engineering and management re-

- search: A social network analysis approach. *Journal of Construction Engineering and Management*, 147(7), Article 04021066. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002085](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002085)
- Elhag, T., Eapen, S., & Ballal, T. (2020). Moderating claims and disputes through collaborative procurement. *Construction Innovation*, 20(1), 79–95. <https://doi.org/10.1108/CI-02-2019-0020>
- El-Sayegh, S., Ahmad, I., Aljanabi, M., Herzallah, R., Metry, S., & El-Ashwal, O. (2020). Construction disputes in the UAE: Causes and resolution methods. *Buildings*, 10(10), Article 171. <https://doi.org/10.3390/buildings10100171>
- Flyvbjerg, B. (2006). Five misunderstandings about case study research. *Qualitative Inquiry*, 12(2), 219–245. <https://doi.org/10.1177/1077800405284363>
- Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2010). *Megaprojects and risk: An anatomy of ambition* (8th ed.). Cambridge University Press.
- Francis, M., Ramachandra, T., & Perera, S. (2022). Disputes in construction projects: A perspective of project characteristics. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 14(2), Article 04522007. [https://doi.org/10.1061/\(ASCE\)LA.1943-4170.0000535](https://doi.org/10.1061/(ASCE)LA.1943-4170.0000535)
- Freeman, L. C. (1977). A set of measures of centrality based on betweenness. *Sociometry*, 40(1), Article 35. <https://doi.org/10.2307/3033543>
- Freeman, L. C. (1978). Centrality in social networks conceptual clarification. *Social Networks*, 1(3), 215–239. [https://doi.org/10.1016/0378-8733\(78\)90021-7](https://doi.org/10.1016/0378-8733(78)90021-7)
- Galvin, P., Tywoniak, S., & Sutherland, J. (2021). Collaboration and opportunism in megaproject alliance contracts: The interplay between governance, trust and culture. *International Journal of Project Management*, 39(4), 394–405. <https://doi.org/10.1016/j.ijproman.2021.02.007>
- Gamil, Y., & Abd Rahman, I. (2023). Impact of poor communication on dispute occurrence in the construction industry: A preliminary exploratory study of Yemen construction industry. *International Journal of Construction Management*, 23(16), 2729–2735. <https://doi.org/10.1080/15623599.2022.2092388>
- Hansen, S., Fassa, F., & Wijaya, S. (2023). Factors influencing scheduling activities of construction projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 15(1), Article 6522004. [https://doi.org/10.1061/\(ASCE\)LA.1943-4170.0000594](https://doi.org/10.1061/(ASCE)LA.1943-4170.0000594)
- Harmon, K. M. J. (2003). Resolution of construction disputes: A review of current methodologies. *Leadership and Management in Engineering*, 3(4), 187–201. [https://doi.org/10.1061/\(ASCE\)1532-6748\(2003\)3:4\(187\)](https://doi.org/10.1061/(ASCE)1532-6748(2003)3:4(187))
- Hu, Y., Chan, A. P. C., Le, Y., Xu, Y., & Shan, M. (2016). Developing a program organization performance index for delivering construction megaprojects in China: Fuzzy synthetic evaluation analysis. *Journal of Management in Engineering*, 32(4), Article 05016007. [https://doi.org/10.1061/\(ASCE\)ME.1943-5479.0000432](https://doi.org/10.1061/(ASCE)ME.1943-5479.0000432)
- Hussain, S., Baig, T., Beg, S., & Ali, A. (2025). Linking government support, and quality management with sustainable energy project success: Mediating role of community participation and moderating role of project governance. *Innovative Infrastructure Solutions*, 10(7), Article 300. <https://doi.org/10.1007/s41062-025-02096-6>
- Illankoon, I. M. C. S., Tam, V. W. Y., Le, K. N., & Ranadewa, K. A. T. O. (2022). Causes of disputes, factors affecting dispute resolution and effective alternative dispute resolution for Sri Lankan construction industry. *International Journal of Construction Management*, 22(2), 218–228. <https://doi.org/10.1080/15623599.2019.1616415>
- Ilter, D. (2012). Identification of the relations between dispute factors and dispute categories in construction projects. *International Journal of Law in the Built Environment*, 4(1), 45–59. <https://doi.org/10.1108/17561451211211732>
- Ilter, A. D., & Bakioglu, G. (2018). Modeling the relationship between risk and dispute in subcontractor contracts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 10(1), Article 04517022. [https://doi.org/10.1061/\(ASCE\)LA.1943-4170.0000246](https://doi.org/10.1061/(ASCE)LA.1943-4170.0000246)
- Iyer, K. C., Chaphalkar, N. B., & Joshi, G. A. (2008). Understanding time delay disputes in construction contracts. *International Journal of Project Management*, 26(2), 174–184. <https://doi.org/10.1016/j.ijproman.2007.05.002>
- Jamali, M., & Abolhassani, H. (2006). Different aspects of social network analysis. In *2006 IEEE/WIC/ACM International Conference on Web Intelligence (WI 2006 Main Conference Proceedings) (WI'06)* (pp. 66–72), Hong Kong, China. IEEE. <https://doi.org/10.1109/WI.2006.61>
- Lee, J., Ham, Y., & Yi, J.-S. (2021). Construction disputes and associated contractual knowledge discovery using unstructured text-heavy data: legal cases in the United Kingdom. *Sustainability*, 13(16), Article 9403. <https://doi.org/10.3390/su13169403>
- Li, T. H. Y., Ng, S. T., & Skitmore, M. (2012). Conflict or consensus: An investigation of stakeholder concerns during the participation process of major infrastructure and construction projects in Hong Kong. *Habitat International*, 36(2), 333–342. <https://doi.org/10.1016/j.habitatint.2011.10.012>
- Liu, J., Li, H., Skitmore, M., & Zhang, Y. (2019). Experience mining based on case-based reasoning for dispute settlement of international construction projects. *Automation in Construction*, 97, 181–191. <https://doi.org/10.1016/j.autcon.2018.11.006>
- Locatelli, G., Invernizzi, D. C., & Brookes, N. J. (2017). Project characteristics and performance in Europe: An empirical analysis for large transport infrastructure projects. *Transportation Research Part A: Policy and Practice*, 98, 108–122. <https://doi.org/10.1016/j.tra.2017.01.024>
- Love, P. E. D., Davis, P. R., Sai On Cheung, & Irani, Z. (2011). Causal discovery and inference of project disputes. *IEEE Transactions on Engineering Management*, 58(3), 400–411. <https://doi.org/10.1109/TEM.2010.2048907>
- Makovsek, D., Perkins, S., & Hasselgren, B. (2014). *Public private partnerships for transport infrastructure: Renegotiations, how to approach them and economic outcomes. Roundtable summary and conclusions* (International Transport Forum Discussion Papers No. 2014-25). <https://doi.org/10.1787/5jrw1kn72gs0-en>
- Mirzaee, A. M., Pourrostam, T., Majrouhi Sardroud, J., Hosseini, M. R., Rahnamayiezekavat, P., & Edwards, D. (2024). Dispute root causes and prevention in Iranian public-private partnership projects: A causal-predictive model. *Engineering, Construction and Architectural Management*, 31(1), 405–431. <https://doi.org/10.1108/ecam-02-2022-0108>
- Nabi, M. A., & El-adaway, I. H. (2022). Understanding Disputes in modular construction projects: key common causes and their associations. *Journal of Construction Engineering and Management*, 148(1), Article 04021184. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002208](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002208)
- Nabi, M. A., Assaad, R. H., & El-adaway, I. H. (2023). Analyzing causes of disputes in public–private partnership construction projects. In S. Desjardins, G. J. Poiras, & M. Nik-Bakht (Eds.), *Lecture notes in civil engineering: Vol 497. Proceedings of the Canadian Society of Civil Engineering Annual Conference* (pp. 17–29). Springer, Cham. https://doi.org/10.1007/978-3-031-62170-3_2

- Naji, K. K., Mansour, M. M., & Gunduz, M. (2020). Methods for modeling and evaluating construction disputes: A critical review. *IEEE Access*, 8, 45641–45652. <https://doi.org/10.1109/ACCESS.2020.2976109>
- Odenigbo, O. G., Odusami, K. T., Okolie, K. C., & Okafor, V. C. (2020). Causes of delayed payment in construction project in Nigeria. *European Journal of Engineering and Technology Research*, 5(9), 1049–1053. <https://doi.org/10.24018/ejeng.2020.5.9.2066>
- Patro, S. G. K., & Sahu, K. K. (2015). Normalization: A preprocessing stage. *International Advanced Research Journal in Science, Engineering and Technology*, 2(3), 20–22. <https://doi.org/10.17148/IARJSET.2015.2305>
- Rahnamayiezekavat, P., Sorooshnia, E., Rashidi, M., Faraji, A., Mostafa, S., & Moon, S. (2022). Forensic analysis of the disputes typology of the NSW construction industry using PLS-SEM and prospective trend analysis. *Buildings*, 12(10), Article 1571. <https://doi.org/10.3390/buildings12101571>
- Senaratne, S., & Farhan, S. (2023). Role of standard contracts in mitigating disputes in construction. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 15(1), Article 4522045. [https://doi.org/10.1061/\(ASCE\)LA.1943-4170.0000593](https://doi.org/10.1061/(ASCE)LA.1943-4170.0000593)
- Serpell, A., & Torres, I. (2023). Causes of contractual disputes in construction projects in Chile. *Proceedings of International Structural Engineering and Construction*, 10(1), LDR-05-1–LDR-05-7. [https://doi.org/10.14455/ISEC.2023.10\(1\).LDR-05](https://doi.org/10.14455/ISEC.2023.10(1).LDR-05)
- Shabana, O., & Gad, G. M. (2023). Mitigating claims and disputes for public–private–partnership transportation projects in the United States. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 15(3), Article 4523012. <https://doi.org/10.1061/JLADAH.LADR-827>
- Shalaby, Y., & Khalafallah, A. (2018). Change order disputes: technical causes and negative effects in Kuwait. In *Proceedings of Construction Research Congress* (pp. 315–325), New Orleans, Louisiana, USA. ASCE. <https://doi.org/10.1061/9780784481271.031>
- Shamshiri, A., Ryu, K. R., & Park, J. Y. (2024). Text mining and natural language processing in construction. *Automation in Construction*, 158, Article 105200. <https://doi.org/10.1016/j.autcon.2023.105200>
- Shen, W., Tang, W., Yu, W., Duffield, C. F., Hui, F. K. P., Wei, Y., & Fang, J. (2017). Causes of contractors' claims in international engineering-procurement-construction projects. *Journal of Civil Engineering and Management*, 23(6), 727–739. <https://doi.org/10.3846/13923730.2017.1281839>
- Silva, P. M., Domingo, N., & Ameer Ali, N. A. N. (2023). Causes of disputes in the construction industry – a systematic literature review. *Journal of Financial Management of Property and Construction*, 29(2), 193–210. <https://doi.org/10.1108/JFMPC-03-2023-0012>
- Solis, F., Sinfield, J. V., & Abraham, D. M. (2013). Hybrid approach to the study of inter-organization high performance teams. *Journal of Construction Engineering and Management*, 139(4), 379–392. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0000589](https://doi.org/10.1061/(ASCE)CO.1943-7862.0000589)
- Stephenson, K., & Zelen, M. (1989). Rethinking centrality: Methods and examples. *Social Networks*, 11(1), 1–37. [https://doi.org/10.1016/0378-8733\(89\)90016-6](https://doi.org/10.1016/0378-8733(89)90016-6)
- Tanriverdi, C., Atasoy, G., Dikmen, I., & Birgonul, M. T. (2021). Causal mapping to explore emergence of construction disputes. *Journal of Civil Engineering and Management*, 27(5), 288–302. <https://doi.org/10.3846/jcem.2021.14900>
- Titus, O. O., & Ali, K. N. (2023). Construction dispute and contract incompleteness in Nigeria construction industry. *Ain Shams Engineering Journal*, 14(10), Article 102153. <https://doi.org/10.1016/j.asej.2023.102153>
- Viswanathan, S. K., Panwar, A., Kar, S., Lavingiya, R., & Jha, K. N. (2020). Causal modeling of disputes in construction projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 12(4), Article 04520035. [https://doi.org/10.1061/\(ASCE\)LA.1943-4170.0000432](https://doi.org/10.1061/(ASCE)LA.1943-4170.0000432)
- Vo, K. D., Nguyen, P. T., & Nguyen, Q. L. H. T. T. (2020). Disputes in managing projects: A case study of construction industry in Vietnam. *The Journal of Asian Finance, Economics and Business*, 7(8), 635–644. <https://doi.org/10.13106/jafeb.2020.vol7.no8.635>
- Wang, J., Zhang, S., Jin, R., Fenn, P., Yu, D., & Zhao, L. (2023). Identifying critical dispute causes in the construction industry: A cross-regional comparative study between China and the UK. *Journal of Management in Engineering*, 39(2), Article 4022072. <https://doi.org/10.1061/JMENEA.MEENG-4943>
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511815478>
- Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage.

APPENDIX

Table A1. Initial matrix of social network for contract disputes and causes

	ZY1	ZY2	ZY3	ZY4	ZY5	ZY6	ZY7	ZY8	ZY9	ZY10	ZY11	ZY12	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
ZY1	0	33	11	7	0	7	0	24	27	49	25	17	8	2	13	13	3	12	6	10	9	5
ZY2	33	0	1	0	2	1	0	2	18	5	6	0	4	0	6	0	0	1	0	7	2	0
ZY3	11	1	0	0	2	6	0	6	2	6	6	9	4	1	8	7	2	3	2	2	3	0
ZY4	7	0	0	0	0	0	0	0	0	0	3	5	0	0	6	7	1	11	5	3	2	0
ZY5	0	2	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZY6	7	1	6	0	0	0	0	2	0	6	2	3	1	0	4	3	1	1	0	1	0	0
ZY7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	11	0	3	0	0
ZY8	24	2	6	0	2	2	0	0	1	9	12	6	2	2	7	6	2	7	2	0	0	0
ZY9	27	18	2	0	0	0	0	1	0	10	6	1	4	0	2	3	0	0	0	9	1	0
ZY10	49	5	6	0	0	6	1	9	10	0	3	3	5	3	3	12	4	3	1	4	4	6
ZY11	25	6	6	3	0	2	0	12	6	3	0	12	5	2	18	4	2	8	10	13	2	0
ZY12	17	0	9	5	0	3	0	6	1	3	12	0	3	2	13	4	3	6	2	0	0	0
C1	8	4	4	0	0	1	0	2	4	5	5	3	0	0	4	3	2	4	2	1	0	0
C2	2	0	1	0	0	0	0	2	0	3	2	2	0	0	0	0	0	0	0	0	0	0
C3	13	6	8	6	0	4	0	7	2	3	18	13	4	0	0	10	2	6	5	5	4	0
C4	13	0	7	7	0	3	0	6	3	12	4	4	3	0	10	0	5	10	9	1	1	0
C5	3	0	2	1	0	1	0	2	0	4	2	3	2	0	2	5	0	6	3	0	1	0
C6	12	1	3	11	0	1	11	7	0	3	8	6	4	0	6	10	6	0	12	1	7	0
C7	6	0	2	5	0	0	0	2	0	1	10	2	2	0	5	9	3	12	0	0	2	0
C8	10	7	2	3	0	1	3	0	9	4	13	0	1	0	5	1	0	1	0	0	0	0
C9	9	2	3	2	0	0	0	0	1	4	2	0	0	0	4	1	1	7	2	0	0	0
C10	5	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0

Table A2. Supplementary matrix of social network for contract disputes and causes

	ZY1	ZY2	ZY3	ZY4	ZY5	ZY6	ZY7	ZY8	ZY9	ZY10	ZY11	ZY12	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
ZY1	0	4.2	1.4	3.6	7.5	3	0	1.5	0.6	7.8	3.7	0	0	4.9	0	0	0	5.9	1.8	2.2	0	6.1
ZY2	4.2	0	0	0	0	0	0	3.6	0	2.1	0	0	6.4	0	0	0	0	3.5	0.5	3	0.2	0
ZY3	1.4	0	0	0	0	2	0	0	0	0	0	1.9	8	0	4.6	5.6	3.2	4	0	0	1	0
ZY4	3.6	0	0	0	0	3.1	0	0	0	0	0	6	5	0	7.2	0	1.2	8.1	4.7	0	2.9	0
ZY5	7.5	0	0	0	0	4	0	0	0	2.8	0	0	8	0	0	0	5	7	1.1	0	0	0
ZY6	3	0	2	3.1	4	0	2.4	0	0	2.8	0	0	1	7.7	0	0	0	6.1	0	0	0	0
ZY7	0	0	0	0	0	2.4	0	0	0	5.6	0	0	4.8	6.3	0	0	7.2	0	0	0	0	1.8
ZY8	1.5	3.6	0	0	0	0	0	0	1.2	2.4	0	0.4	0	0	0	0	0	5.3	1.7	0	0	1.2
ZY9	0.6	0	0	0	0	0	0	1.2	0	0.8	0	0	9	6.8	2.2	0	0	0	0	0	0	1.7
ZY10	7.8	2.1	0	0	2.8	2.8	5.6	2.4	0.8	0	0	0	2.7	5.8	0.9	8.2	6.2	7.2	0	0	0	4
ZY11	3.7	0	0	0	0	0	0	0	0	0	0	3.5	3	1.1	5.1	0.2	3	2.8	4.8	0	0	0.2
ZY12	0	0	1.9	6	0	0	0	0.4	0	0	3.5	0	1.8	4	2.7	0	0	7	3.6	0	4.1	0
C1	0	6.4	8	5	8	1	4.8	0	9	2.7	3	1.8	0	2.1	5.6	5.2	0	4.7	1.5	0.2	0.8	0
C2	4.9	0	0	0	0	7.7	6.3	0	6.8	5.8	1.1	4	2.1	0	2.5	0.4	1.5	8.1	0	0	2.6	0
C3	0	0	4.6	7.2	0	0	0	0	2.2	0.9	5.1	2.7	5.6	2.5	0	3.5	1.4	6	3.5	0	2	0
C4	0	0	5.6	0	0	0	0	0	0	8.2	0.2	0	5.2	0.4	3.5	0	5.2	5	0	0	0	2.5
C5	0	0	3.2	1.2	5	0	7.2	0	0	6.2	3	0	0	1.5	1.4	5.2	0	3	0	2	0	0
C6	5.9	3.5	4	8.1	7	6.1	0	5.3	0	7.2	2.8	7	4.7	8.1	6	5	3	0	3.5	4.8	4	1.6
C7	1.8	0.5	0	4.7	1.1	0	0	1.7	0	0	4.8	3.6	1.5	0	3.5	0	0	3.5	0	2.1	3.5	0
C8	2.2	3	0	0	0	0	0	0	0	0	0	1	0.2	0	0	0	2	4.8	2.1	0	0	3.2
C9	0	0.2	1	2.9	0	0	0	0	0	0	0	4.1	0.8	2.6	2	0	0	4	3.5	0	0	0
C10	6.1	0	0	0	0	0	1.8	1.2	1.7	4	0.2	0	0	0	0	2.5	0	1.6	0	3.2	0	0