

Article

Triggers of Delays in International Projects Using Engineering Procurement and Construction Delivery Methods in the Belt and Road Initiative: Case Study of a High-Speed Railway Projects

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Abstract: Since the Belt and Road Initiative (BRI) has been put in practice by the Chinese government, several High-Speed Railways (HSR) have been built by Chinese Engineering Procurement and Construction (EPC) firms. However, many delays have created severe detrimental consequences on the progress of most HSR projects. This study sought to explore the essence of the recurring triggers of delays in international EPC HSR projects under the BRI, and a structured questionnaire survey approach was applied to compile the first-hand dataset from Chinese EPC firms working for BRI infrastructure projects. The data were evaluated, and the Relative Importance Index (RII) was adopted to assess the magnitude of the important delay triggers. The findings suggest that HSR projects are still susceptible to unavoidable delays in global construction infrastructure projects. In the engineering phase, improper management of the design, unsustainable land acquisition, and insufficient use of EPC joint venture are the salient trigger of delays. In the procurement phase, the leading causes of unsuitable procurement, undervalued procurement cost, inefficient logistics in labor and materials, improper planning, unqualified site supervisors, inefficient technical standard management, and inefficient constant payment terms are likely to trigger delays in the construction phase HSR projects. Five critical groups of delay factors are identified by this study, which has an essential primary contribution to the body of knowledge and is helpful to EPC contractors working for HSR projects under BRI.

Keywords: delay; EPC delivery method; construction projects; high-speed railway; Belt and Road Initiative; China



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1. Introduction

The Chinese government, highlighting the need for further international involvement that is economically advantageous and furthers social development, initiated the Belt and Road Initiative (BRI) to make headway in infrastructure growth. The initiative began getting underway, or completed by moving forward, with other nations and regions in 2013. The BRI contributes to the advancement and expansion of the Silk Road Economic Belt and the 21st Century Maritime Silk Road and thus prolong the practice of wide-ranging opening of new segment of markets to represent the beginning of a new paradigm [1]. BRI infrastructure projects overseas have been a pathway to create strategic interconnectivity between China and other countries, further strengthening interdependence between China and the BRI partner countries [1,2]. Liu and Dunford [3] demonstrate developing particular infrastructure systems and new multilateral funding structures to support poverty

mitigation and sustainable growth. Infrastructure construction is a critical component of the BRI, and it has made a significant contribution in facilitating international integration and advancement in the region, primarily during the initiative's beginning phases [4]. However, most of the BRI partners in underdeveloped countries have insufficient funding for infrastructural development. The BRI's HSR, as a mileage infrastructure project, is not contentious.

For instance, first, the majority of analysts naively consider that HSR or HSR-related infrastructure projects are an essential part of the economies of BRI countries, which encourage enhanced regional and inter-regional mobility and expansion of international trade and economic exchange [1,5]. The associated investment is intended to close the gaps in underdeveloped infrastructure of many BRI countries. In particular, countries that have yet to become part of the global economy are where economies of scope pose challenges. Second, experts were concerned about the detrimental implications of investing in HSR projects as part of transportation network infrastructure. The environmental, social, and corruption issues may be of particular importance in BRI partners regions, which are already recognized for having weak governance frameworks.

The infrastructure investment is helpful in all nations, and it is worth the work it would entail. There are proposals in progress to construct tremendous development schemes under the BRI. However, this study's emphasis is on the EPC HSR project in BRI. HSRs are a massive boost to socio-economic growth and the most significant transport mode, they are cheaper than air transportation, reliable, have standard facilities, create less CO₂ emissions than aviation, and are safe and green [6,7]. Carbon emission significantly impacts human health and the environment [8,9] and should be considered a part of the Sustainable Development Goal (SDG 11) by monitoring or reducing air pollution [10]. HSR projects have substantial implications on passengers and products, foreign commerce, and transport. Therefore, for the BRI implementation, the development of HSR is necessary as other infrastructure projects. HSR projects are dynamic, large-scale, lengthy projects; cross rugged land and longitudinal environments; and require a high degree of expenditure, thus requiring many stakeholders [11]. China has the most extensive HSR network globally with over 60% of trips taken globally; more than 90% of the HSR networks intend to create additional mileage. HSR development is creating building programs across the whole globe. In the foreign sector, countries such as Germany, France, Japan, and Spain want to keep their industries active by striving to expand their markets, and this strategy results in fierce competition in the foreign sector [6].

Moreover, infrastructure projects' construction is an excellent opening for Chinese EPC companies to pursue "going global" activities [12]. According to China's Ministry of Commerce statistics, China has implemented vast infrastructure projects in the BRI countries and regions since 2013 and has brought in USD 500 billion worth of foreign exchange from these projects. The EPC is extensively used to obtain contracts in foreign engineering and has successfully supported and run a thriving business in the construction market. It includes collecting project delivery (PD) stakeholders who have a personal interest in project success [13]. Nevertheless, a limited numbers of firms can accomplish the EPC mission, depending solely on their capabilities due to increased riskiness of EPC projects in the international construction market [14]. The majority of EPC contractors are building and construction firms; for example, Chinese EPC contractors' capacity is mainly in construction [12,15]. Because of the complexities and dynamic processes in the international EPC, many of the essential threats that crop up in EPC projects are outside the reach of the ability of the contractors to handle—for example, HSR infrastructure projects [16,17]. Studies linked to characteristics such as long-distance [18], a wide variety of diverse and challenging geographic circumstances [19], clients' financial constraints [20], customer' lack of expertise [21], sophisticated construction techniques [22], and especially international EPC for infrastructure projects, are still unexplored. Although technological incompatibility was the primary constraint for Chinese HSR exports, other restrictions, such as lack of expertise in overseas legal requirements, significantly affected such exports' performance.

China's government has already implemented international HSR projects globally under the context of BRI. For instance, Kenya's Mombasa–Nairobi railway [23], Ethiopia's Addis Ababa–Djibouti railway [24], and another are critical for a few reasons, such as an unsuccessful EPC approach and lacking expertise operating knowledge working in various changing circumstances and challenging environments. Therefore, the management was unable to use an aggressive defense approach for risk assessment. As their foreign sector expands exponentially, Chinese EPC contractors face several obstacles. According to 2017 surveys undertaken by the Financial Times, a Chinese construction firm completed a total of 18 international HSR projects; the results showed that the total value of canceled and postponed projects was nearly double that of those currently under development. For example, the HSR in Indonesia [25]. The Haramain HSR project in Saudi Arabia was signed from 2009 to 2017 and was planned to be ready for implementation in 2018 [26]. The cost overrun on the Mecca Light Railway (MLR) project is USD 0.676 billion, which is 34.4% of the contract value [27]; the Turkish HSR project from Ankara to Istanbul was contracted within eight years by Chinese and Turkish companies, but was shut down immediately.

While recent research has defined and listed delay factors for projects beyond the fields of research and widely known regions, several small challenges still exist in the infrastructure market that call for a concrete solution. A thorough analysis of HSR projects for Chinese international firms and their primary delay triggers has not been adequately studied in the context of BRI. The inefficient contract administration and lack of expertise in general construction delays led to a tremendous loss of project delivery performance. The result ended up running late and delayed; nearly all HSR projects incurred significant losses and missed completion.

However, limited research has identified and prioritized the triggers of delays in international EPC projects, especially HSR delay factors. Hence, the aim of this study is (1) to identify and categorize critical triggers of delay in the EPC HSR project from engineering, procurement, and construction phases; (2) to investigate the current state of management international EPC HSR construction projects among Chinese companies; and (3) calculate the relative significance triggers of delays and illustrate the rating of variables and related groups in terms of their importance concerning delays.

This research provides a one-of-a-kind contribution and pertinent study of the following three crucial aspects. First, we identify and categorize critical delay factors in the EPC HSR project from engineering, procurement, and construction phases, thus contributing to a deeper comprehension of how EPC is implemented successfully in BRI projects. Second, we explore international EPC HSR construction projects' management status among Chinese companies, thus enriching the prior EPC management studies related to HSR projects and delay-related issues. Third, our study focuses on EPC for HSR projects in the BRI context, which leads to a deeper comprehension of how the BRI projects are implemented successfully. The rest of this paper is structured as follows: Section 2 reviews the relevant literature. Section 3 presents the research methods. Section 4 presents the results and Section 5 is the discussion, followed by the conclusions in Section 6, and limitations and future research direction in Section 7.

2. Review of Relevant Literature

Concerning achieving the paper's goals, we first went conducted a broad search employing a variety of google search engines, such as the Web of Science (WOS), Science Direct (SD), the Wiley online library (WOL), Springer Link (SL), Taylor Francis Online (TFO), and the China National Knowledge Infrastructure (CNKI). In this context, the most prominent phrase and keywords were EPC contract, Belt and Road infrastructure projects, international high-speed railway (HSR) project, overseas infrastructure, delay, and cause of delay. The following secondary keywords and key phrases were also in the results: overseas construction project, delay, international construction project, and construction delay. This study picked 60 primary research papers with a reasonable potential to significantly impact, published between 2005–2020, as the potential for a follow-up review.

For the particular collection, the selection parameters are as follows: first, two sets of primary and secondary core themes, keywords, and phrases appear in the abstract and title, and second, literally, the entire content of the paper is applied to global infrastructure construction activities and delays. The papers collected papers from various high-ranking publications, such as the *International Journal of Project Management (IJPM)*, *International Journal of Construction Management (IJCM)*, *Journal of Construction Engineering and Management (JCEM)*, and *Engineering Construction, and Architectural Management (ECAM)*. These papers pertained to delay triggers and methods of international high-speed railway under BRI infrastructure projects. Research on delays in EPC HSR projects in the international market in the literature mostly concern the following two topics: (1) international EPC contracts under BRI and (2) construction delay management. The specific contributions and limitations in the reviewed articles are discussed in the following sub-sections.

2.1. International EPC Contract under Belt and Road Initiative

The BRI enhances cooperation, infrastructure developments, international exchange, flexibility and equality, shared learning, and knowledge exchange (International Students Scholarship) between partner countries. Huang [4] believes that the construction of a reliable infrastructure that is vitally important to the BRI routes can foster cooperation and growth throughout the region, especially with the funding from international organizations such as the World Bank (WB) and the Asian Development Bank (ADB), as well as Chinese institutions. For example, in the Silk Road Fund (SRF), several international Chinese companies invest heavily in infrastructure implementation projects in partner countries of the BRI, such as HSR development and other infrastructure projects.

The current BRI projects, including some infrastructure construction projects, show the international collaboration between China and other countries. The BRI has delivered many infrastructure projects [12]. The BRI countries' laws are implemented following the partnership arrangement terms between BRI and Chinese firms [28]. In the absence of certain rules or legislation concerning the construction in the domestic laws, international contracting law, such as the FIDIC Conditions of Contract, will be implemented [29]. EPC contracts are typically utilized for large-scale construction and engineering projects and industrial projects, where the customer values efficiency and cost certainty over aesthetics. *The FIDIC Conditions of Contract 1999 (The Silver Book)* [29] illustrates an EPC contract model. Constant recognition of the EPC implementation has steadily received endorsement in global construction markets [30,31]. As a Fast-Track Delivery (FTD) project, the EPC approach is beneficial for a contractor. It gives early involvement, cuts expenses, and reduces the preparation, planning, and contractual arrangements needed, which add insignificant expenses to the construction timeline [32]. As compared to the conventional Design-Bid-Build (DBB) contract mode, wherein the project owners have the technical design and the contractors are exclusively responsible for the building the construction, the major contractors are designated for the operations ranging from design, procurement, and constructing the building based on necessary requirements given under the EPC contract model. In EPC projects, the major contractors must devise and review the increasingly creative design and procurement solutions to strike the ideal combination of profitability and inherent risk and address greater logistical challenges in buying and shipping materials and equipment at a reasonable rate [33–36]. The various participants who adopt the EPC method as a global approach meet their unique social and economic demands seeking a diverse economic and social climate [35–38]. For a project to succeed, anyone from the team, others outside the project, and anyone else who might be engaged with the project must be fully involved [39]. This guideline suggests that, in general, EPC contractors (clients, consulting engineers, vendors, designers, and subcontractors) can work together to execute the project on time and in a collaborative method [37,39]. It is critical for those who receive compensation or assistance from EPC service contractors and municipalities to work together with the central government and other local authorities, such as municipal entities, to access their resources [35].

In line with the BRI in China, several international Chinese construction firms have invested in international infrastructure procurement under the EPC procurement arrangement [38,40]. The dynamic investment conditions associated with overseas ventures are more unpredictable than in domestic construction markets [41]; however, NDRC [42] emphasizes the BRI's target growth sector of service interconnection. The HSR industry is at the forefront of infrastructure interconnection and will perform a key role in the BRI's advancement. In 2016, the first year of HSR's "going out" strategy, China's HSR has matured and its territory has expanded to include the whole planet. Chinese engineering firms have also looked at a more oriented approach to dealing with Japan and other old railway network powers [43]. For instance, the Indonesian HSR [44], the Iran HSR [45], and the Moroccan high-speed rail network [40] are all overseas HSR projects. The popularity of China's HSR can be attributed to its excellence and the political and economic powers also cannot be overlooked. The innovations and concepts of introducing and re-inventing and the possibilities of developing, planning, interconnecting, intellectualization, humanization, and diversification of China's HSR technology all contribute to the integration customization, interconnection, intellectualization, humanization, and diversification of China's HSR technology. The development of the HSR is fueled by creativity.

Consequently, the preceding literature synthesis provided the insights mentioned above about EPC project management research's goals, strategies, and importance in integrating with HSR projects in BRI and the characteristics of EPC project management in construction companies. Therefore, the need to investigate how still remains and EPC entrepreneurs should strive to produce a management model that strikes a balance between cost limits and performance gains, allowing EPC contractors to increase activity in an economically viable manner.

2.2. Construction Delay Management

Project management experts have acknowledged that it is essential to understand and monitor project deadlines, and eliminating delays is key to effective construction project management [46]. The term "construction delays" refers to time spent on a project that extends beyond the contract obligations' delivery that has been settled upon the date of the project [47]. Increased expenditures may cause substantial financial hardships, especially in the long term [21]; delays of time [48,49], due to the inability to satisfy quality efficiency requirements [50]; and serious incidents are notoriously prevalent on the worksite [51]. Similarly, the delays associated with implementing EPC HSR projects under BRI infrastructure projects can trigger delays such as a severe expense overrun, time overruns, a lack of quality, further and absolute risk, and injuries [52]. The majority of current studies focused almost exclusively on delay-triggering factors that have dominated the research over the past decade; for instance, Bhargava et al. [53] expanded their ideas and offered straightforward proof for the concept that time overrun and cost overrun exist and, in fact, correlate. Further, Wambeke et al. [54] noticed that the most crucial reasons for construction issues in America are turnaround time, permission, clear design and sketches, rework, early and late starting, adverse weather, untrained work, and lack of direction. Nine fundamental causes were identified by factor review, accounting for three-quarters of the delay. Pourrostan and Ismail [55] developed a list of the most important issues concerning Iranian construction project development through related literature, accompanied by a structured questionnaire to uncover the delays' origins and consequences from consultants' perspectives of contractors.

Fallahnejad [18] evaluated and prioritized the elements contributing to project delays in long-distance projects, such as pipeline construction in Iran, finding that imported materials, unsustainable timeframe, and client-related materials are the top three causes of project delays. Marzouk and El-Rasas [56] evaluated the main reasons for Egypt's construction project delays. Moreover, Yu et al. [57] have used factor analysis to synthesize forty safety features into four main factors that significantly impact metro safety management in China. To collect data, the authors circulated a specific questionnaire survey to approximately 120

engineers who were taking part in five different metro building ventures in five separate cities in China, asking them to rate the value of each project. Kim et al. [58] investigated the reasons that cause hospital projects to be delayed in Vietnam; hospitals are a kind of advanced industrial construction project. As a case study, factor analysis and survey experts were included. They reported thirty-three variables and ranked them as a part of these categories: the skill of the owner and the manager, the capacity of the planner and contractor, outside consequences, and the ability of planners. Hospital project delays are caused by a variety of variables, including the managerial skill of the manager of and other critical factors. This result revealed hospital project management policies and assisted practitioners in completing effective hospital projects. Each country was selected based on objective evidence from previous studies in order to determine and recommend effective measures, and a questionnaire was administered in each of the case studies. Shah [59] evaluated the most compelling causes behind project delays and cost overruns, as well as potential mitigation steps for construction projects in Australia, Malaysia, and Ghana. The primary goal of choosing case samples is to do a comparison-based examination of delay causes and organize them into several priority levels of impact on project delays across various countries. According to the results of different case samples, planning and timing deficiencies are critical factors in some countries, such as Australia. The traditional way of construction, strong evaluation of projects, and feedforward processing are critical factors in Ghana. Sepasgozar et al. [60] reviewed a set of causes in different projects in various countries and provided a model of delay analysis. However, the most important considerations are late payment certificates, underestimating project costs, project difficulty, and project duration. However, in Malaysia, the most compelling reasons triggering project delay and cost overrun are the contractor's improper preparation, inadequate site control, and insufficient contractor expertise. Durdyev et al. [61] identified that the major concurrent delays in construction projects are resource shortages, inefficient schedule development, inadequate procurement of materials, and delays in scope verification, especially a lack of labor force, which significantly impacts projects. Matthews et al. [62] utilized a case study with the help of the main contractor and some of their subcontractors in determining how best to approach the construction of the iconic Perth Football Stadium, which included obtaining a building information model (BIM) as an asset, in order to handle, identify, estimate, and protect its asset. Further, the owner or/and contractor deferring repayment, as well as a subcontractor's lack of management capacity and quality control, were found to be the primary causes of construction project delays in China by Wang et al. [63]. As the primary data collection procedure, a questionnaire with 20 variables created by Chen et al. [64] investigated the triggers of delays in China's grain bin development projects. The most critical group of triggers was discovered using a structural equation modeling (SEM) method. There were one hundred eight replies to the questionnaire, resulting in five different groups of delays. The major causes of delays, according to their results, were a lack of suitable machinery, inadequate coordination among contracting parties, issues with subcontractors, changes in orders, and the designers' lack of experience. Khatib et al. [65] discussed and evaluated all the multiple triggers of delays that were important to the capacity expansion of reconstruction projects in the Middle East, and he found that the three primary issues influencing the length of the overarching reconstruction project were the constraints and requirements of the location, the configuration of the electrical and mechanical alterations, buildability, and the complexity of the worksite. His findings made it apparent that there were considerable delays in reconstruction projects. Furthermore, this was evident by quantifying certain variables relative to the project's length on the final results. The most critical delay causes, extracted from the reviewed literature, are summarized for the actual questionnaire survey and presented in Table 1.

Table 1. Triggers of delays identified from the literature of EPC BRI and non-BRI EPC projects.

Factor Grouping	Triggers of Delays
Contractor Related (CR)	CR#1-Typically, change of subcontractors [18] CR#2-Inadequate contractor experience [66] CR#3-Ineffective construction approach [67] CR#4-Impotent project team [66] CR#5-Poor coordination and communication [67] CR#6-Impractical technology [68] CR#7-Insufficient scheduling and planning [6] CR#8-Low supervision and site management [68] CR#9-Reworking due to incompetence [6] CR#10-Untrustworthy of subcontractors [18]
Equipment Related (ER)	ER#1-Equipment allocation problem [69] ER#2-Equipment breakdowns on a regularly [70] ER#3-Insufficient equipment [71] ER#4-Insufficient latest equipment [72] ER#5-Inefficiency of the equipment [35] ER#6-Equipment deficit [71] ER#7-Slow deployment of equipment [70]
Design Related (DR)	DR#1-The complexity of project design [73] DR#2-Design changes during construction [74] DR#3-Design errors [14] DR#4-Insufficient survey before the design [75] DR#5-Lack of experience in the design team [73] DR#6-Delays in mistakes producing documents [75] DR#7-Misunderstanding requirements by designer [75] DR#8-Inefficient usage of the software [10] DR#9-Ambiguous descriptions in drawings [74]
Project Related (PR)	PR#1-Project complexity [73] PR#2-Lack of significant execution [75] PR#3-Unsuccessful delay penalties [73] PR#4-Participants' legal disagreements [10] PR#5-Ineffective construction planning [10] PR#6-Delay in payment and improper financial procedure [74]
Materials Related (MR)	MR#1-Shortage of Materials on Site [69] MR#2-Sorting material destroy [7] MR#3-Lag manufacturing of materials [70] MR#4-Material costs are rising [70] MR#5-Materials late delivery [35] MR#6-Delay in transportation materials [7] MR#7-Low grade materials [69] MR#8-Inconsistency of suppliers [35]

3. Research Methodology

3.1. Checklist of EPC HSR Delay Factors

A list of key significant causes of delays of the existing HSR projects was identified from the extant literature before developing a questionnaire study, as shown in Figure 1. Furthermore, leading to the scarcity of bespoke studies on construction project delays, systematic interviews with ten experts were performed. A total of six contractors, two engineers, and two consultants were recruited, who have a combined background of more than fifteen years of implementing EPC HSR projects in the context of BRI. The interviewees were asked to explain and confirm the delay factors on EPC HSR projects through structured interviews. The questionnaire questions formed the interview topic framework, and the respondents were given the opportunity to choose the types of questions for which they were knowledgeable. Following the structured interviews, 40 important delay factors were confirmed and nominated on the core principle of a mean score of 3.0, in reference

to Table 2. The following 40 delays were granted a mean value of 3.0 by the stakeholders involved, demonstrating that they are the potential crucial EPC HSR projects. Nine experts, five academics, and four business experts participated in a pilot study before the actual questionnaire survey to develop the delay factors list and increase the specificity of the queries. After following multiple recommendations, 40 delay factors were chosen as the most likely to have been adequately qualified for the real questionnaire survey (Table 1).

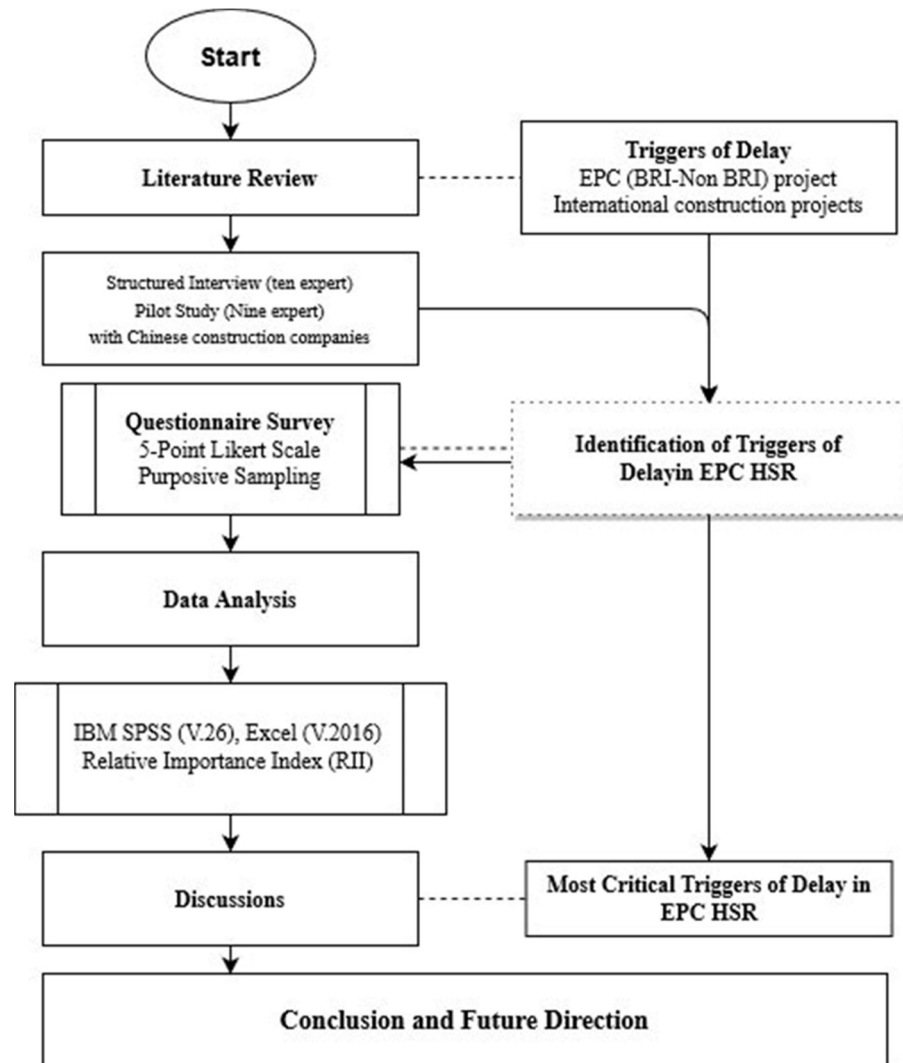


Figure 1. Research methodology.

Table 2. RII and ranks of the triggers of delays in IEPC projects.

Factor Grouping	ID	RII Output						Phase
		RII	SD	Mean	Rank	(<i>p</i> Value) Shapiro–Wilk Test	(<i>p</i> Value) Kruskal–Wallis Test	
Contractor Related (CR)	CR#1	0.742	0.35	3.712	9	0.00 *	0.253	Engineering
	CR#2	0.858	0.36	4.288	1	0.00 *	0.289	
	CR#3	0.745	0.33	3.727	7	0.00 *	0.044	
	CR#4	0.748	0.34	3.742	6	0.00 *	0.203	
	CR#5	0.827	0.34	4.136	1	0.00 *	0.723	
	CR#6	0.618	0.32	3.091	30	0.00 *	0.234	
	CR#7	0.742	0.32	3.712	5	0.00 *	0.023	
	CR#8	0.824	0.32	4.121	1	0.00 *	0.534	
	CR#9	0.739	0.30	3.697	4	0.00 *	0.325	
	CR#10	0.785	0.30	3.924	2	0.00 *	0.654	
Equipment Related (ER)	ER#1	0.664	0.28	3.37	19	0.00 *	0.545	Procurement
	ER#2	0.682	0.29	3.43	14	0.00 *	0.047	
	ER#3	0.700	0.29	3.54	7	0.00 *	0.432	
	ER#4	0.661	0.30	3.32	17	0.00 *	0.543	
	ER#5	0.676	0.30	3.45	13	0.00 *	0.645	
	ER#6	0.685	0.31	3.50	12	0.00 *	0.453	
	ER#7	0.642	0.32	3.25	16	0.00 *	0.213	
Design Related (DR)	DR#1	0.621	0.32	3.106	18	0.00 *	0.324	Engineering
	DR#2	0.794	0.33	3.970	1	0.00 *	0.541	
	DR#3	0.733	0.30	3.667	2	0.00 *	0.143	
	DR#4	0.715	0.30	3.576	4	0.00 *	0.197	
	DR#5	0.724	0.31	3.621	3	0.00 *	0.089	
	DR#6	0.697	0.30	3.485	3	0.00 *	0.345	
	DR#7	0.673	0.31	3.364	9	0.00 *	0.251	
	DR#8	0.555	0.32	2.773	16	0.00 *	0.234	
	DR#9	0.691	0.30	3.455	6	0.00 *	0.218	
Project Related (PR)	PR#1	0.567	0.31	2.833	13	0.00 *	0.435	Construction
	PR#2	0.567	0.29	2.833	13	0.00 *	0.223	
	PR#3	0.633	0.27	3.167	10	0.00 *	0.923	
	PR#4	0.676	0.27	3.379	6	0.00 *	0.984	
	PR#5	0.670	0.29	3.348	5	0.00 *	0.345	
	PR#6	0.664	0.30	3.318	5	0.00 *	0.432	
Materials Related (MR)	MR#1	0.697	0.32	3.485	3	0.00 *	0.234	Procurement
	MR#2	0.639	0.35	3.197	5	0.00 *	0.452	
	MR#3	0.694	0.37	3.470	3	0.00 *	0.234	
	MR#4	0.579	0.41	2.894	5	0.00 *	0.437	
	MR#5	0.785	0.37	3.924	1	0.00 *	0.423	
	MR#6	0.727	0.28	3.636	1	0.00 *	0.190	
	MR#7	0.615	0.13	3.076	2	0.00 *	0.234	
	MR#8	0.655	0.35	3.273	1	0.00 *	0.5432	

Note: * The Shapiro–Wilk test has a *p*-value of 0.05, which means the datasets were not normally distributed.

3.2. The Questionnaire Survey

This study designed a standardized questionnaire survey to gather highly experienced professionals and industry practitioners' perceptions on the significance of the delay variables in EPC HSR projects. The survey questionnaire methodology was adopted because of three main reasons. Firstly, the questionnaire surveys needed less time to address the necessary queries, as they had been left to the respondents. Second, the analysis sought to analyze the delay causes based on the relevant industry practitioners' and experts' opinions. Furthermore, this approach is consistent with quantitative research approaches, facilitating statistical evaluation of the outcomes to obtain precise explanations that aid in better understanding the survey topic [49,76]. Third, comparatively, questionnaires are

quicker to perform, clearer, more commonly recognized in construction and engineering management, and easier to interpret. Furthermore, questionnaires have been commonly utilized in construction delays research [46,77].

A purposive or impartial sampling approach utilizing pre-defined parameters was used to evaluate experts all around the globe. Several academics and experts have been selected based on two pre-defined requirements—comprehensive working experience and EPC contract and EPC projects [78,79].

Between June and August 2020, the questionnaires were distributed to 115 respondents via the Chinese social media platforms WeChat and QQ, via email, and in person. The corresponding author sought out information from the main office of Chinese International EPC companies in China, and then the questionnaires were circulated by the main office to prospective eligible respondents. The questionnaire is divided into two distinct parts. The first part is designed to collect important general information regarding survey participants. In the following part, participants were informed to suggest their impressions of each of the 40 critical delay factors' relative importance evoked by their own experience in delivering EPC HSR projects.

In surveys, the Likert style scale is often used to measure the value of variables, and the suggested scale number ranges from 5 to 7 [80]. The 1–5 point Likert scale is often used in the construction management (CM) context, so this research used a nominal 5-point Likert style scale, where 1 and 5 denoted the lowest and highest priority ranks, respectively. Figure 2 indicates the respondents' background details, including experience, past construction projects, and occupation. The 5-point Likert style scale was used in recent research to examine the Indian construction industry's schedule delays and risks [81] and delays in rail transportation [82]. A total of 106 credible responses were received after multiple reassurances, representing a sample size of 66 percent. The rate of participating respondents is comparable to previous research that showed lower response rates of 60% [81], 59% [49], and 36% [64]. In August 2018, a list of the world's largest 250 enterprise contractors was released by the Engineering News-Record [83]. The rankings were focused on the total income of the projects that each contractor signed, both domestic and overseas contracts. Among the top ten global contractors, the top four were Chinese companies.

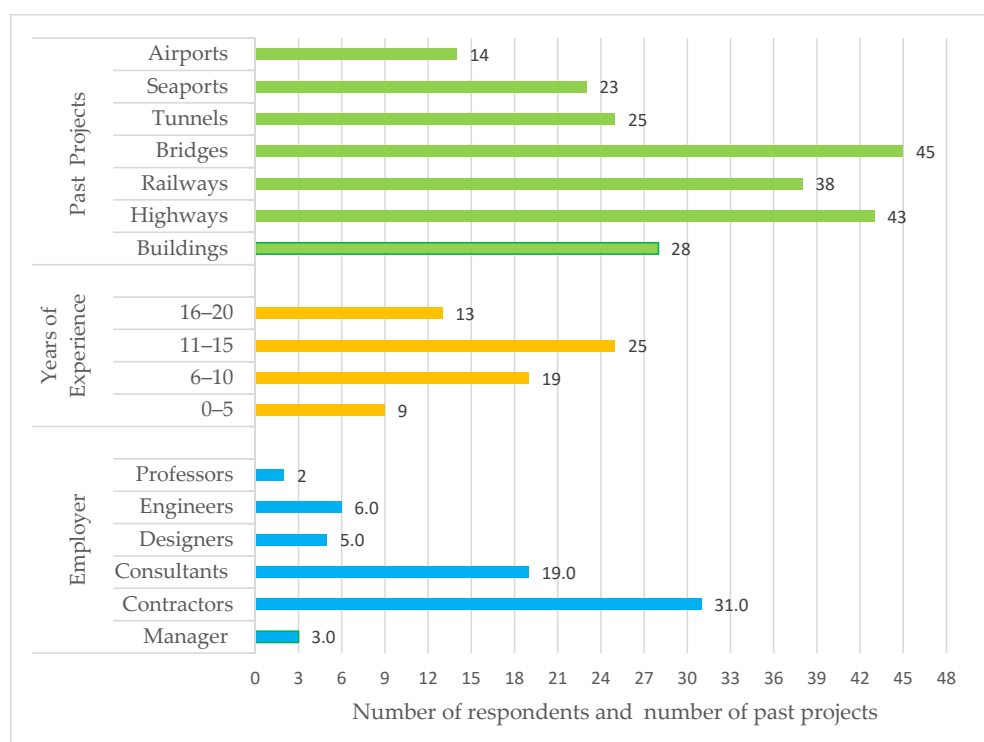


Figure 2. Key information of the industry respondents.

As far as Chinese contractors' out-backed contracts are concerned, new agreements signed with overseas infrastructure projects have risen to USD 265.28 billion, including an average growth rate of 8.7% in 2017. A significant contributor to these latest contract areas is Africa. The value rise was made possible due to Africa's recent developments. They were chosen as questionnaire respondents. Likewise, as a result, broad and divergent perspectives were collected. However, Figure 2 indicates that the respondents comprise managers, contractors, consultants, designers, and engineers who make up the EPC HSR project team's bulk. It implies that their composition is sufficient to determine the crucial factors that may trigger a delay in the EPC HSR project. These participants constitute the most significant sample in previous studies on the EPC projects internationally [12,32,35]. Figure 2 also shows that the proportion of participants who have at minimum ten years of engineering expertise conducting EPC projects, primarily in line with the implementation of HSR projects, and hence were well-positioned to focus on and rate the factors that cause delays in EPC HSR projects.

3.3. Data Analytical Procedure

Data were evaluated via a sequence of predictive research protocols focused on various statistical approaches. The researchers used the IBM SPSS (V.26) to undertake numerous empirical statistical studies. The reliability test was carried out to determine the internal reliability of the survey instrument's response; reliability is characterized as the degree to which an evaluation, questionnaire, or measurement technique produces the same finding on repeated additional tests [84]. The accuracy of a replicated calculation ensures that the exact measurement is applied in the same manner [85]. As a result, it was decided that a Likert-type response was appropriate because this research utilized a 5-point Likert-type of response. To assess internal reliability, Cronbach's alpha test, a commonly used reliability metric, was measured to verify the collected responses' internal reliability. Use Cronbach's α to test the efficiency of the instrument.

$$\alpha = \frac{k}{k-1} \left(1 - \frac{\sum \sigma_i^2}{\sigma^2} \right)$$

σ_i^2 is the variance of ratings on each variable. $\sum \sigma_i^2$ is the overall test rate recorded and k variance are the numbers of variables [86].

From a theoretical perspective, alphas will range from 0 to 1; a higher linear coefficient of the wider spread suggests a more significant internal consistency. In the assumption of the general rule of thumb, if $\alpha > 0.9$ displays great internal consistency as suggested by [87]. The overall mean of the Coefficient alpha for all attributes is 0.949, which was found to be outstanding. This result suggested that a participant who preferred a particular Likert-type scale rating for one of the objects relevant to the trigger of delay EPC HSR projects is expected to have a similar decent rating for the comparable products [88].

In addition, the properties of unifactoriality and to assess whether or not single factors are present on a test were also measured in the design were examined to construct validity [89]. According to the specific suggestions of Chou et al. [90], the Shapiro–Wilk test was used to evaluate if the dataset was normally circulated and to make it easier to apply the suitable statistical (parametric) or non-statistical procedures to the dataset. Additionally, we examined the data to see if it was accurate and if it would be acceptable for factor analysis. Consequently, we ran the Kaiser–Meyer–Olkin (KMO) test and Bartlett's sphericity test. The 40 different delay triggers have KMO coefficient higher than 0.7 (KMO = 0.93), showing adequate inter-correlation. Bartlett's sphericity test results are 7331.143, and the significance level's related degree is minimal ($p=0.000$). Therefore, the correlation matrix is non-singular and non-orthonormal, so the null hypothesis is falsified. Both criteria (KMO testing and sphericity testing by Bartlett) support data collection to ensure that the building's validity is ensured and the variables are suitable for use in potential factor analysis studies. As indicated in Table 2, the Shapiro–Wilk test outcomes reveal that

the dataset does not follow a normal distribution, demonstrating that certain non-statistical (non-parametric) procedures should be performed to investigate further. Continuing to follow Ameyaw's [91] specific suggestions closely, the Kruskal–Wallis test was undertaken to examine whether or not there were statistically significant differences in responses from the experts and professionals such as contractors and clients. The Kruskal–Wallis test is known as a non-parametric statistical procedure that uses ordinal data to assess differences in responses across specific groups or subgroups [91]. Because there are no statistically significant discrepancies in the replies of the various practitioners, as indicated in Table 2, the data may be considered holistically.

Moreover, for each item and the complete items Spearman correlation coefficient was performed. As a result, the p -value (significance) was shown to be lower than 0.01 for all elements, and the similarities at the 0.01 stage are essential such that the 40 triggers of delay are reliable and accurate to maintain external reliability. When the validity construct is examined, it provides a more accurate assessment of whether the survey instruments reach their intended goal [92].

Following the previous tests, the study then conducted the RII technique to assess the importance of delay in each phase of EPC HSR projects based on previous similar studies conducted by Kometa et al. [93] and Sambasivan and Soon [48] to identify construction project delays. The collected data from the survey were evaluated using the RII for each factor, based on Equation (1):

$$RII = \frac{\sum W}{(A * N)} \quad (1)$$

where W = respondents' weightings for each variable (in this study, the number of participants ranged from 1 to 5), N = the total number that responded, and A = most significant value (i.e., 5 in this instance).

The magnitude of the RII ranged between 0 (in this study, 0 not comprised) and 1. After that, the RII is ranked, and the results are presented in Table 2. The RII of the mean groups is calculated by taking the average RII of the factors of each group.

4. Results of Data Analysis

Ranking of the Triggers of Delays in EPC HSR Projects

This study identified, evaluated, and categorized the reasons for the delay of the EPC-HSR project into five influential groups as contractor-related (CR), equipment-related (ER), design-related (DR), projects-related (PR), and materials related (MR). A thorough and accurate RII approach to the 40 EPC HSR project delay triggers is prioritized and ranked to this end. In the survey, the participants were informed about rating the triggers of delay on a 1–5 scale, where one meant the least significant and 5 meant the most important, concerning an EPC HSR project's triggers of delay in Table 2.

The first group of the most critical cause of delay in EPC HSR projects is the CR group (RII = 0.763) based on the classification and ranking (Table 2). The most critical delay factors in the perceptions of the contractors are attributed to lack of contractor expertise (RII = 0.858), inadequate project coordination and preparation (RII = 0.827), and poor site control and monitoring (RII = 0.824). The second group is the DR group (RII = 0.689) delay factors classified and ranked overall as the second more critical delay cause of EPC HSR projects and included vital factors such as design modifications (RII = 0.794) undertaken by the contractor or his representative during development. The design errors (RII = 0.733) created by the designers and the lack of expertise of the design team in full-scale construction projects (RII = 0.724). The third overall ranked group is the MR group (RII = 0.674), codenamed for the MR group including the reality that much of the materials were late and that this attributed to the key determinants (RII = 0.785), delay in transportation materials (RII = 0.727), and materials shortage on-site (RII = 0.697).

In the MR group and the ER group (RII = 0.673) triggers of delay were the fourth most crucial group. The ER group's significant factors were insufficient equipment (RII = 0.700), equipment deficit (RII = 0.685), and inefficient equipment (RII = 0.676). The fifth

most crucial group was the PR group (RII = 0.676). Its prominent factors were delay in participants' legal disagreements (RII = 0.676), ineffective construction planning (RII = 0.670), and delay in payment and improper financial procedure (RII = 0.664). Table 3 shows the most critical triggers of delay.

Table 3. Most critical triggers of delay in EPC phase of HSR.

Factor Grouping	ID	RII	SD	Mean	Rank	EPC Phase
Contractor Related (CR)	CR#2	0.858	0.36	4.28	1	Engineering
	CR#7	0.827	0.34	4.13	5	
	CR#8	0.824	0.32	4.12	1	
Design Related (DR)	DR#2	0.794	0.33	3.97	1	
	DR#3	0.733	0.30	3.66	2	
	DR#5	0.724	0.31	3.62	3	
Materials Related (MR)	MR#1	0.697	0.32	4.48	1	Procurement
	MR#5	0.785	0.37	3.92	1	
	MR#6	0.727	0.28	3.63	1	
Equipment Related (ER)	ER#3	0.700	0.29	3.54	9	
	ER#5	0.676	0.30	3.45	13	
	ER#6	0.685	0.31	3.50	12	
Project Related (PR)	PR#4	0.676	0.27	3.37	6	Construction
	PR#5	0.670	0.29	3.34	6	
	PR#6	0.664	0.30	3.31	4	

To determine the RII score of each group separately, we calculated the mean score of each RIIs of the triggers in every related group presented the RIIs of the mean score groups. The ranking means, scores, and RIIs of all specific groups are shown in Table 4.

Table 4. RII and ranking for factor groups.

Nu	Code/Groups	RII	Rank	Phase
1	CR# Contractor Related	0.763	1	Engineering
2	DR# Design Related	0.689	2	
3	MR# Material Related	0.674	3	Procurement
4	ER# Equipment Related	0.673	4	
5	PR# Project Related	0.629	5	Construction

5. Discussion

In the present section, the crucial trigger of delays in HSR projects during the EPC phases are addressed, which are compiled and listed in five prominent groups, including contractor (CR), equipment (ER), project (PR), and materials (MR). These groups comprise 40 triggers of delay in the EPC HSR project based on RII and mean rating. The complete RII and mean rating for all 40 triggers of delay are substantial, indicating that all variables are significant. When used in conjunction with the RII rankings and mean rating, practitioners and high-speed railway (HSR) construction professionals can meticulously minimize the impacts of avoidable constituents while simultaneously incorporating the existence of non-constituents further into the project planning phase in order to generate straightforward schedules

5.1. Critical Delay Factors in the Engineering Phase

During the engineering phase of EPC, the execution phase plan for an EPC contract was created for EPC contract documents. This includes designs, supervision, acquisition, development, commissioning, and start-up expenses, which are directly connected and borne by the EPC contractor and the charges and expenditures of the contractor. The EPC contractor should be entirely responsible for the scheduled completion of all construction development and activities needed for the project's successful delivery. The required

delivery tasks are the provision of planning, qualified and skilled labor, equipment, tools, consumables, support equipment, specialized equipment, and any other services or facilities that may be required. However, an important portion of EPC contracts is that it permits the proprietor to interact with only one contractor for all other major projects, including HSR, which oversees all connections with subcontractors. A project manager should manage risk better while enabling contractors to allocate and specialize in their tasks. The findings of this study disclosed that the triggers in CR-related groups had relatively high importance in determining the criticality in EPC HSR projects. Due to significant involvement of triggers of delay such as communication, coordination, and lack of managerial skills, EPC HSR projects may face more challenging situations and trigger high cost overrun and schedule delay during the implementation of EPC HSR projects.

The most important cause of delay in EPC HSR projects is contractor-related. This group applies to many contracting concerns in the engineering phase (design phase) of the EPC HSR projects, such as insufficient contractors' expertise, poor communication coordination between parties, poor management skills, and monitoring of the site (supervision).

Inadequate contractor expertise is the most critical case of delay in EPC HSR projects' engineering phase [6,68,70]. The engineering phase identifies owners' requirements and may include surveying numerous parties in the selection phase. As EPC contractors are generally responsible for the design/procurement/construction of projects as a particular individual, the critical difference between EPC and DDB contract strategy is the allocation of the risks of the multiple activities therein focuses on specific client contractors. Thus, multiple critical aspects of contractor ability have an immediate effect on project schedule and cost. It confirmed that poor contract management skills, especially improper information management between all stakeholders with a massive quantity of details due to the nature and sophistication of the EPC HSR project's engineering phase, can lead to an intense schedule delay.

Poor coordination and communication between parties is a critical issue in the engineering phase of EPC HSR projects. An HSR project is implemented globally, as it includes several contracting stakeholders, including the clients, engineers, consultants, designers, and design team. Effective communications among project stakeholders are essential for project success, in line with the findings of King [94] and Ruqaishi and Bashir [95]. The EPC HSR projects have consistently suffered due to poor communication among contracting parties, specifically in the Middle East and Southeast Asia, since each project has an international presence and comprises of Chinese employees and locals [96]. The divergence strategy explains that the operational frameworks beyond the Chinese-made materials suppliers increase their dependence on others. The major portion of the Chinese construction firms operate as a partnership, in which most of them have an uninterrupted line of communication with other contracting firms. This restricts their communication both internally and externally [97]. A lack of communication and coordination eventually leads to problems (e.g., design flaws, repeatedly changed orders, and contract conflicts), potentially triggering considerable delays.

Poor supervision and site management are frequent phenomena that trigger delays in the deployment of infrastructure projects [48]. The results indicate that this analysis demonstrates that contractors have poor site management capability in EPC HSR projects. Almost all site managers and contractors are trained as civil engineers with excellent professional knowledge of specific Chinese construction industries but are limited in their understanding of managerial skills [64]. Furthermore, these general contractors and managers would not lead a successful EPC HSR construction project entirely; thus, this has created significant schedule delays.

This study indicates that design-related groups also contribute to delays. It is possible that the group could drastically impact the delay issue in the EPC HSR projects' engineering phase. This is similar to Yang and Wei [77] findings, as was discussed previously. The designer's success is crucial in keeping construction delays to a minimum. Design-related

groups in this study consist of changing design during construction, design errors, and lack of experience in design team projects.

Design changes during HSR line design construction are the most significant delay since they primarily prolong project delays. The HSR line design changes occur due to insufficient investigation of soil, terrain, and geological and geotechnical characteristics, such as bad rock conditions [7], as well as other unforeseeable ground conditions. Adding new features to the paths, such as bridges, tunnels, or passenger stations, creates structural improvements. Adequate investigation of the soil's geotechnical characteristics during the feasibility study is expected to minimize the design phase's adjustments. The EPC HSR line is a very lengthy project, mainly bridges and tunnels, and construction is generally faced with difficult engineering geological conditions. Project teams, however, have actual design practice, must frequently undergo design revisions, and seek permissions from operators. However, delays in the approval of concept documents often affect the whole construction timeline [6].

Design errors are another critical delay of EPC HSR projects related to the design process. Design failures may occur due to various designers' lack of experience or preliminary investigation of terrain and soil layers, stations, and others' capacity. Moreover, feasibility analysis and risk assessments become viable and relevant at this stage, so an investigation must be undertaken to determine whether the design requires detailed investigation of soil layers' geotechnical conditions and geological characteristics to avoid a design errors feasibility study. The project should be conducted by highly qualified high-speed railway engineers, while the design phase should be expanded.

The design team's lack of expertise is also a critical delay factor in developing design documentation, ambiguity, errors, and contradictions in requirements and sketches. HSR projects require several professional requirements in the engineering phase. However, following their model guidelines, some countries always want to adopt the same model's standards; the design team has made tremendous progress with their local assistance. It enabled them to meet clients, hear their needs, and learn their interests [6].

5.2. Critical Delay Factors in the Procurement Phase

When bidding for an EPC HSR project, the procurement process is the most important. The financial forecasting will surpass 50% of the total contract volume, particularly for those bids which require more sophisticated equipment [6] technically. As a concern, material-related and equipment-related groups are the most critical delay trigger group projects due to role in their procurement phase of the EPC HSR project. These groups cover the material's late delivery, delay in transportation materials, improper equipment, low efficiency of the equipment, and equipment shortage.

On-time delivery of materials is an essential factor in constructing HSR projects. In complicated situations, unanticipated circumstances, such as a lengthy delay in the construction materials distribution, supply chain, and procurement, may increase the complexity of interruptions in HSR projects, thus affecting the projects' ability to reach deadlines. In EPC HSR projects, some construction materials are procured from the local market, while the others are imported from China, due to China's great abundance of natural resources and possible shortage of related materials in the local market. Under the strict EPC contract regulation [29], only construction materials supplied by project consortiums can be obtained from local markets, restricting China-based firms' ability to form autonomous procurement teams and plans. Moreover, overseas subsidiaries' absence is another delaying factor in the procurement phase for Chinese EPC firms, ensuring that local suppliers can only supply unique supplies such as critical technological equipment.

However, local and low-scale suppliers cannot deal with large and specialized equipment procurement activities in developing countries. Consequently, a well-defined quality of innovative technology is expected, which is more likely to trigger scheduling and planning delays due to legalities. This study's findings are consistent with Dachyar [75] and Pal et al. [35], who claimed that large quantities supply contract arrangements that can

be used in EPC projects, including tools, equipment, and material delivery following the installation and repair, which could alleviate the labor force in order to be more readily available and increase familiarity with the engineering planning preparation. The HSR equipment and materials in the procurement phase would entail many invention licenses and intellectual rights concerns and produce many equipment demands.

5.3. Critical Delay Factors in the Construction Phase

During the HSR development process, the contractor will launch the project and build alignment joint tests. When relating to the international markets, the building sector continues its success, but it also struggles with delay issues in other countries. The most important category of delays impacting EPC HSR projects' construction phase is attributable to the project-related group. This group refers to legal disputes between project participants, ineffective construction planning, delay in payment, and improper financial procedures.

Legal disputes between project participants are a critical delay factor caused in the construction phase of EPC HSR projects. The reasons for these delays are of the same type, which primarily relates to the interrelationships between project members. It is primarily addressed by the various forms of contractual partners, though they can or may not be mutual in preferences. At the same period, the above may be due to a set of factors, such as undefined provisions in existing contracts, unpredictable activities and works not specified in current contracts, delays in reimbursement of finished work by customers, and lack of coordination between contracting parties [98]. Settling any disagreements over an EPC HSR project's precise configuration often involves a long-term mechanism that can prolong the HSR development process. This conclusion is also compatible with the results of other research conducted by Ruqaishi and Bashir [95].

Ineffective construction planning is a critical delay trigger caused in the construction phase of EPC HSR projects and project contractors in command of all management activities in the EPC HSR project. However, the contractor did not have good development collaboration between Chinese international firms and local construction firms, which triggered construction development delays and cross-construction challenges, and this is compatible with the earlier studies carried out by the [6,63]. Since starting the construction phase, the contractor in charge assigned to the project will be slowed down by the insufficient quality of construction activities on site they have been given through other contractors. The EPC HSR project involves several stakeholders upstream and downstream, and each of them prepares several construction-related activities before the start of the building construction on the project site. Accordingly, to compensate for this lack of preparation and implementation, a cross-construction dilemma arises. This supports the findings of Wei [17], who stated the types of responsibility of owners coping with a large amount of data given by all project stakeholders.

Delay in payment and improper financial procedure are critical delay factors caused in the construction phase of EPC HSR projects. According to FIDIC [29], Silver Book Art. 4.2, EPC contracts have highly stringent financial oversight. Periodic payments, exchange rate fluctuating, and the preponderance of inadequate financial procedures all trigger delays in construction progress in the international market [6]. In this paper, the critical argument is that both the infrastructure and procurement phases of a project involve financial planning. Owing to the lengthy construction period, it takes longer to develop than the contract. Nevertheless, because of a milestone payout process and the contract demands, a successful payment is made. Additionally, it assumes that the project is slower than it should be. This perspective supports Ahsan and Gunawan [99] and Diallo and Thuillier [100] due to the extreme financial crisis and the company's foreign loan disbursement throughout the construction phase, which causes a delay in the progress payment. The study results show that such an effect is rising on HSR and such other infrastructure projects mainly.

6. Conclusions

Construction delays in infrastructure projects, including HSR, have attracted much interest from researchers and practitioners; delays in HSR projects undertaken by experienced contractors are hard to find since they are complicated. Compared to previous research concerned about the general project, this paper collected, identified, and examined the critical delay factors in the EPC HSR project in all phases by a comprehensive review of the available publications on construction projects delays, as well as formal interviews with experts, a list comprising of 40 triggers of delays was identified. A validated survey was performed to acquire opinions on their effect on the subject and discussed the benefits of the whole company. On the verdict of industry practitioners and technical experts and it was rated by 5-point likability ratings to conclude at a Likert value, and it was graded by employing RII.

The result indicates that the EPC HSR project contractors-related group in the engineering phase applies to many contracting concerns such as insufficient contractors' expertise, poor communication coordination between parties and (supervision), poor management skills, and poor monitoring of the site. Design-related groups consist of design changes during construction, design errors, and the project design team's lack of experience in are critical triggers of delays.

In the EPC HSR project's procurement phase, material-related and equipment-related groups are the most important delay triggers. These groups cover the material's late delivery, delay in transportation of materials, improper equipment, low efficiency of the equipment, and equipment shortage. The most critical group of delays impacting EPC HSR projects in the construction phase is attributable to the project-related group containing legal disputes between project participants, ineffective construction planning, delay in payment, and improper financial procedures.

Apart from these findings, which are specific for delay triggers, there are more intangible triggers such as knowledge management causes, socio-political causes, and natural disasters. Therefore, such factors were substantially impacting the EPC HSR projects related to the BRI. Therefore, it is critically needed for a particular category of intangible causes of delays.

These crucial findings should allow Chinese EPC firms to recognize and reduce the construction delay in EPC HSR projects. This study makes unique contributions to EPC contractors and firms working for HSR projects in the context of BRI.

7. Limitations and Future Research Direction

Given some considerations, the validity of the study's results is limited in the following factors. First, this study's collective comprehension only causes delays from the Chinese construction firms' viewpoint for international EPC HSR projects. Second, this study's theories nevertheless draw perceptions from other regions of the world and various approaches to project execution through the literature and may extend from project to project in domestic and international markets.

More research should be conducted given this study's results and conclusions. We suggest investigating any of the following directions in the future: How the scope of EPC projects can be defined for BRI or non-BRI. The suggested analysis method can be used for particular kinds of EPCs, including road projects as well as in different phases of BRI projects such as pipelines, dams, hydropower infrastructure, etc. Other than the five critical groups identified in this study, there are more delay triggers affecting the EPC HSR project in BRI project or non-BRI projects, such as knowledge management causes, socio-political causes, and natural disasters, which need further investigations in the future. In EPC projects, the role of project managers, stakeholder involvement and project management requirements, or customer acquisition, should also be further investigated in the future.

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