DELAY FACTORS FOR INTERNATIONAL ENGINEER-PROCURE-CONSTRUCT (IEPC) HIGH-SPEED RAIL CONSTRUCTION PROJECTS

Due to complex projects and diverse risks, schedule delay has always been one of the major problems in high-speed rail construction. Chinese infrastructure companies are the main force of the international market after the Chinese government implemented the One Belt and One Road initiative (OBOR). Currently, more than 10 international engineer-procure-construct high-speed rail (IEPCHSR) projects are being considered or undertaken overseas by Chinese companies. However, delay has severe consequences for the progress of most IEPCHSR projects. The aim of this study is to identify the significant delay factors for IEPCHSR projects. This study was conducted as an exploratory study through literature review and semi-structured interview with seven managers from Chinese IEPCHSR related companies. Result reveals that some delay factors concluded from general international infrastructure projects are also applicable in IEPCHSR projects. In the engineering phase, inappropriate management in design management, inefficient land acquisition, design changes and lack of EPC subsidiary contract management for HSR projects are likely to cause delays. In the procurement phase, improper procurement prepared, under-estimated procurement price, unreliable agency, inefficient logistics in equipment and labour are leading causes. In the construction phase, the significant delay factors are improper construction task planning, inexperienced site supervision, ineffective technical standard management and ineffective continuous progress payment. Further study will analyse their interrelationships with Chinese construction companies using a questionnaire survey and structural equation modelling (SEM) technique. The result from this study should enable the Chinese HSR practitioners to gain a better understanding of the inter-relationships between the different potential delay factors.

Keywords: Delay factors; High-speed rail; International EPC projects; Construction; China

INTRODUCTION

High-speed rail (HSR) is currently regarded as one of the most significant technological breakthroughs in passenger transportation development (Campos and De Rus, 2009). Meanwhile, HSR is not only a significant booster of socioeconomic development and the cornerstone of many industries, but also provides a new alternative to flying or driving, reduces national dependence on oil, and fosters urban and rural community development. Due to these features, a growing number of countries regard HSR projects as an important part for promoting economic development. There has been a fast development in the global HSR network over the past two decades, with 34000 km of HSR networks completed and already in service worldwide. As at the end of 2017, the mileage of HSR networks had reached 37300 km, with 15900 km of new line under construction, and China account for almost 60% of HSR operation mileage and almost 90% of HSR plan to build mileage respectively. HSR construction are challenging infrastructure projects globally, and countries such

as France, Germany, Japan, Spain and China (leaders in the core technology of HSR) are intending to apply their HSR knowledge to other countries, causing fierce competition in international market. In addition, the engineering-procure-construct (EPC) approach has become a favoured delivery system that combines the procurement of construction service in one contract for megaproject. Although early study has drawn a substantial attention about HSR, researches related to features like long distance, complex geographical conditions, complex construction technical and infrastructure projects especially international engineering-procurement-construction high-speed rail (IEPCHSR) projects are still unexplored.

China has been leading the HSR technological development worldwide (Shao et al., 2017). After the Chinese government implemented the One Belt and One Road initiative (OBOR), Chinese HSR is popular in international market because demand for high-speed rail has increased in OBOR countries, and Chinese HSR has low construction cost per km. However, technical incompatibility, inexperience operation management system and unfamiliar with overseas market rules were the huge barriers which restrict Chinese HSR exportation. The Chinese government has implemented international HSR projects in Morocco, Saudi Arabia, California in the US, Indonesia, Iran, and Poland. However, owing to ineffective understanding of the EPC delivery approach and inexperience in dealing with a wide range of risks in working in the challenging international environment, many Chinese companies have suffered from delays in the delivering of EPC projects, for example, the Turkish Ankara to Istanbul HSR project, which was constructed within 8 years by a Chinese and Turkish consortium; the Saudi Arabian Haramain HSR project constructed from 2009 to 2017, expected to be operational in 2018; and the Venezuelan HSR project, which was constructed from 2009 with a project duration of 36 months, but which was shut down immediately. Despite current studies identified and classified delay factors with projects in different field and worldwide area, specific delay factors in IEPCHSR project still need to be conducted.

HIGH-SPEED RAIL RESEARCH AND DEVELOPMENT

High-speed rail project

High-speed rail network has been an explosive growth worldwide; Campos and Rus (2009) found that 23 countries are considering HSR project (UIC, 2017). Many scholars investigated HSR project mostly in Asia and Europe, and they concerned about financial and region impact by HSR project. Cheng et al. (2015) explores the development of HSR as an instrument for promoting economic integration both through enhancing competitiveness and achieving greater economic cohesion in China and the European Union. A limited number of HSR studies have explored HSR projects under international market. After China implemented the OBOR initiative, researchers began to investigate HSR implemented under this initiative. Wang et al. (2018) stated that with the advancement of China’s OBOR policy and subsequent development of HSR projects (i.e. Trans-Siberian Railway, Pan-Asian HSR, Central Asia HSR, Eurasian HSR, China-Russia-Canada-USA HSR) have gradually promoted Chinese HSR transportation projects agenda. Shao et al. (2017) proposed a method for the selection of the most urgent need for transnational HSR construction in the OBOR region. However, they only discussed the HSR project from political strategy, and few studies pay attention on construction management of international HSR project. Meanwhile, Wang and Huang (2017) indicated that China has specific expertise in high-speed trains, communication signals, traction power supply, public works,

system integration, security monitoring, operation and management. The above-mentioned expertise and economic development agenda has led to Chinese worldwide expansion of HSR construction and has become a unique case for international HSR construction research.

International EPC project

International projects adopted various delivery methods such as Build-Operate-Transfer (BOT), Design-Build (DB), Public-Private Partnership (PPP) and EPC. Only a few studies investigated HSR project based on those methods, where Chou et al. (2012) compared the use of PPP policy between HSR projects and general infrastructure projects, and the results reveal that most experience learnt from general infrastructure projects is also applicable in HSR projects after some adjustments. However, we could only find out few researches related to IEPCHSR project. An EPC contract typically covers project management, site management and supervision, engineering, materials and equipment, civil works, foundation and site infrastructure works, transport and installation, and commissioning, as well as scheduling and performance guarantees for the entire solutions (Du et al., 2015). Based on those issues, Galloway (2009) stated the high risks of EPC contract, and the study pointed out that owners shift their risks to contractors through this delivery approach. Meanwhile, international infrastructure construction projects are prone to delays. A common characteristic of infrastructure construction is that they are dynamic and complex with various parties' agenda which can be conflicting, comprise many stages of work, entail long periods to completion and have high levels of uncertainties and face complex geological ground conditions (Al-Kharashi and Skitmore, 2009). Hence, there is an urgent need to investigate delay factors in IEPCHSR project.

Construction delay management

Preview studies have been explored the construction delay research from three related fields. Fallahnejad (2013) identified and ranked the cause of delay in long distance project such as pipeline in Iran, which imported materials, unrealistic project duration and client-related materials are the top three factors. Highway and railway are the most similar projects to HSR, and these types of project have a linear character and need long path to be executed. Han et al. (2009) investigated the critical delay causes in Korea Train Express project, and found that lack of owner's abilities, conflict between public agencies and inappropriate delivery system are the main causes. Public infrastructure project had also been explored. Al-Khalil and Al-Ghafly (2010) determined the most important cause of delay in public utility project in Saudi Arabia, which contractor, owner and consultant are three major parties, with important causes of delay like cash flow problem. Despite some literature on construction delay factors, the IEPCHSR project management is still difficult to be fully addressed due to its unique features.

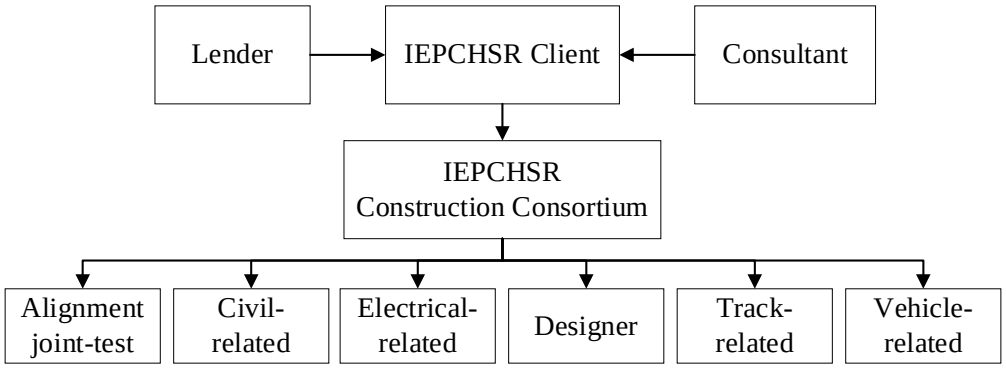
Identifying delay factors can be studied from different aspects. Yang and Wei (2010) analysed delay problem in planning and design phases, which "changes in client's requirement" are the main causes. However, lack of studies concerned about delay factors in IEPCHSR project implementation phase. Meanwhile, previous studies have conducted researches in different countries and different areas. Different conditions may cause a difference in project environment and its context (e.g. economy, politics, culture, weather) and many other characters of a region or country create a unique environment for its project. Arditi et al. (2017) studied the effect of organizational culture on delays in construction companies located in the U.S. and India. From their

findings, they indicated that different causes of delay are experienced regardless of the national cultures in different geographical regions and higher executives of international companies should be prepared for the different organizational cultures.

Furthermore, construction delays adversely impact on project stakeholders including local government, main contractors, financial investors, users amongst others (Faridi and El-Sayegh, 2006). Sage and Dainty (2014) stated that across infrastructure construction project, complex geological ground condition involved vary stakeholders even with wild animals. The problems for IEPC project are due to uncertainties in estimating, contracting, design, procurement of equipment and materials, construction, economic and political circumstances, technology issues, and the use of management techniques (Du et al., 2015). When Chinese companies exported IEPCHSR project, they often set up a construction consortium whose typical structure is presented in Figure 1. A comprehensive review of HSR project exportation for Chinese companies and its significant delay factors have not sufficiently investigated. Due to lack of experience in contract management and inefficient construction delay management, almost all the HSR project suffered huge loss and failed delivery.

Thus, above all mentioned in literature reviews, it seems that there is a research gap in IEPCHSR delay factors, and the research objectives in this study can be summarized, 1. To investigate the management status of IEPCHSR construction projects among Chinese companies; 2. To identify critical delay factors in IEPCHSR project from E, P and C stages.

Figure 1: Structure of IEPCHSR project



METHOD

To achieve the research objectives, a qualitative and exploratory semi-structured interview were conducted in Chinese companies which are the main stakeholders in HSR construction consortium. Of the high number of Chinese companies implementing international projects in overseas markets, only a few companies have ability to undertake HSR projects. Thus, seven companies were finally selected. This study selected one respondents from the middle and top management levels with five to fifteen years of experience in IEPCHSR projects from each company. For this qualitative research, seven respondents (see Table 1 for background and experience) were interviewed, selection based on that suggested by Creswell et al., (2004), who recommended that for a phenomenological study the number of interviewees could range between five and twenty-five. All the respondents were contacted by relying on personal contacts to reach IEPCHSR project professionals. Although the number of interviews was relatively small, they were comprehensive and lengthy, and they covered a wide variety of IEPCHSR projects which were processed by those companies. First, this study scrutinizing two railway projects implemented by Chinese

companies in Africa, which railway project have a linear character and they share a lot of common problem and challenges (Fallahnejad, 2013). Furthermore, the interview consisted of 10 questions, and all questions were developed based on documents scrutinized and previous studies of delay factors in different projects. The respondents were asked to indicate the causes of delay associated with the E, P and C phases of IEPCHSR projects. The author translated all questions from English to Chinese, and interviews were conducted in Chinese. The open-ended interview questions were designed to collect narrative responses, contextualizing the individual perspectives of each respondent, while allowing the expression of individual views. Some of the interviews were conducted face-to-face and others were conducted by telephone, mainly because such respondents could not make time for the interview during the normal working hours. The duration of each interview session was about 40-60 minutes. The interviews were recorded and transcribed and the qualitative data analysed using thematic analysis suggested by Reissman (2008), and this method involves structural analysis and dialogic/performance analysis.

RESULTS AND DISCUSSION

As discussed in former section, respondents in the interviews focus on three themes related to IEPCHSR project: Engineering, Procurement and Construction. Identification as well as what delay factors in these themes critically affecting IEPCHSR project to ensure of the implementation of those projects. The responses from seven interviewees are summarised and presented in the following subsections. Out of seven respondents to answer questions in each stage, only five respondents answered question in Engineering, four respondents answered question in Procurement and Construction, which questions related to their working area.

Table 1: Companies' and Respondents' general background

Respondent selected company	Type of Company	Respondents' Experience
1. China Railway International Co., Ltd., (CRIC)	Client	10 years
2. China Civil Engineering Construction Corporation (CCECC)	Civil-related	12-13 years
3. China Railway Group Limited (CREC)	Contractor	11 years
4. SINOHYDRO Corporation Limited (SINOHYDRO)	Electrical-related	8 years
5. China Railway Design Corporation (CRDC)f	Designer	15 years
6. CRRC Qingdao Sifang Corporation (CRRC)	Vehicle-related	10 years
7. China Railway Signal and Communication (CRSC)	Signal-related	6 years

Engineering Phase

Although there are many delay factors identified in engineering phase by researches in former studies, engineering is still a critical process in which the owner’s requirement including wishes, desires, and needs are identified and designed to be submitted to the main contractors. Out of the seven respondents, five respondents expressed their ideas in this phase.

Respondent from CRIC stated: “IEPCHSR project is usually constructed by a consortium including main contractors and local companies, and the consortium will be in charge of all the management. International HSR line design first relies on preliminary investigation in the target country, however one of the delay factors is that all the survey tasks will be completed by the design company with local support. It means not all the construction company can participate in the pre-design and location selection.”

As mentioned in second section, IEPCHSR project involved different types of companies in construction consortium. Thus, multiple facets of consortium capability directly impact the project schedule and cost. According to respondent from CRIC, it proved that poor consortium capability especially improper information management among all participants with a large volume of information due to complexity of EIPCHSR project which lead strong schedule delay

A respondent from CREC stated: “HSR projects involve many technical standards in engineering phase. However, many countries still follow their own standards with local organizations offering the support documents to design team, which in this situation affects the process of design tasks.”

HSR is a high-tech product, which means complex technical interfaces should be considered. Chinese HSR system has its own standard which reduce various interface link issues. However, implementing different construction and technical standard in international infrastructure market lead to schedule delay. The result proved that it is essential to uniform construction standard among organizations, and it allows active exchange knowledge, skills and technologies (Tang et al. 2006).

A respondent from CCECC stated: “Compared to traditional infrastructure project, when constructing HSR line, it will pass through different types of areas such as highway, existed railway, rivers and private area. This greatly increases the difficulty of land acquisition in a country with private ownership of land, and it also increases the proportion of bridge and tunnel. In addition, HSR projects need huge temporary areas for large precast concrete beams and track laying base for storing track resources all along HSR line.”

A respondent from CRDC stated: “IEPCHSR line is quite a long project, mainly with bridges and tunnels, and the construction usually faces challenging engineering geological condition. So, design teams have extensive design works, often face design changes and on top of that have to obtain permits from owners. However, delays in approving design documents often impact the whole construction schedule.”

Subsequently, complexity of stakeholders along the HSR line lead to massive tasks and high cost about land acquisition not only for local government but also for construction consortium. Ahsan and Gunanwan (2010) stated that international development projects can often take longer due to protracted land acquisition problems which occur as a result of local politics, land law and religious issues. Salim and Negara (2016) drew attention to Indonesia's notoriously lengthy land acquisition process, which argued that the Indonesian government had failed to ensure land provision on time and this what caused the construction delays in Indonesia's HSR project. both of them support the interview results in this study. Furthermore, the result stated variable geological ground conditions often caused design changes during execution phase, which because extra civil investigation, drawing design documents and approving documents from client cause serious delay.

A respondent from CRSSC stated: “International HSR project has many subsidiary contracts based on the general FIDIC (Fédération Internationale Des Ingénieurs-Conseils,1999), Chinese IEPCHSR contractors have no experience in application of standardized forms of the EPC contract and this causes delay in contract negotiation period with owners. Hence, the slow progress negotiation with local government and companies under EPC contract is the main delay factor during the whole project.”

In addition, IEPCHSR project engineering phase include investigation, design, land acquisition, procurement, transportation, construction and alignment joint-test. Hence, when such complex projects are being transferred to global markets, the management of standardised forms of HSR contract mode based on general EPC contract should be particularly restricted by the Chinese government and the associated companies.

Procurement Phase

For IEPCHSR project, the procurement phase is an essential phase the financial forecasting can reach 50% of the total contract amount, especially for those with technically sophisticated equipment. Out of the seven respondents, four respondents expressed their ideas in this phase.

A respondent from CRIC stated: “IEPCHSR often faces massive resource transport tasks, which involve kinds of equipment import and export. HSR core technical equipment mainly relies on import from Chinese companies because most of the targeted countries have low technical production level.”

A respondent from SINOHYDRO stated: “Most Chinese HSR construction companies have no overseas subsidiary especially in some developing countries. Hence, a great number of equipment and materials are imported by local agencies. However, unreliable agency and inefficient logistics seriously affected the construction schedule.”

In IEPCHSR project, the construction materials mainly rely on two parts, general materials from local market and special materials from China. Under the strict EPC contract regulation, general materials can only be procured by construction consortium from local markets, which restricts Chinese companies’ independent procurement plans. Furthermore, lack of overseas subsidiary is another delay factor in procurement for Chinese companies, which means special materials like core technical equipment can only be imported by local suppliers. However, local suppliers especially in developing countries are not expert in large-scale and high-tech machinery supply chain tasks. Hence, recognized technical standard perfection is important, which may cause schedule delay because of law issues. Our result support Pal et al, (2017) who stated EPC projects involve complex procurement contract tasks including equipment delivery and installation, maintenance, labour supply, and engineering training. HSR project procurement plan involves more technology patents and intellectual property issues and has a huge volume of equipment demand.

A respondent from CREC stated: “While Chinese companies have an experienced team not only in management but also in construction labour, the local labours are mostly lack of HSR project construction experiences. Improper labour management is one of the delay factors, because many Chinese managers do not arrange technical training between Chinese technician and local labour forces before the construction.”

As we know from the respondent, improper labour management caused lack of IEPCHSR high technicians in overseas project management and equipment operation

which restrict the project schedule. Chinese companies should develop an expert team for IEPCHSR project, coping with the increasing demand of IEPCHSR projects.

A respondent from CRRC stated: “HSR projects are unimaginable expensive, and HSR project has a massive advance works before the allowance of construction. However, the strict contract regulation from EPC contract and policy limitation from Chinese government are the main obstacle.”

Improper financial planning like lower than estimated price for procurement of goods, services, and contracts are significant factors affecting project schedule delay and cost underrun (Ahsan and Gunawan, 2010). Thus, based on EPC contract, the main contractors have to gain much support from home country in both politics and finance, and main contractor and government awareness of the EPC contract about the extent of responsibility and regulation risk they bear is strongly necessary.

Construction Phase

IEPCHSR construction throughout project starts from commencement at site to alignment joint-test. While HSR construction has a tremendous success focus on construction in China, it still suffers from various delay issues in international markets. Out of the seven respondents, three respondents expressed their ideas in this phase.

A respondent from CRIC stated: “Project consortium charged all the management tasks in IEPCHSR project. However, consortium had an ineffective construction planning between Chinese companies and local companies, which caused cross construction problem and construction delay.”

Having pointed to the influence of consortium capability, during project execution, schedule is also influenced by improper construction tasks implement. IEPCHSR project has various stakeholders including local companies, and those companies undertake many prepared tasks before construction consortium enter the construction site. However, improper tasks planning and delivering lead to cross construction problem. These views support Wang (2013) who stated the importance for owners to deal with the large volume of information contributed by all project participants.

A respondent from CREC stated: “IEPC contract had a strict financial regulation. In international market, delay in progress payment, exchange rate fluctuations, and improper financial procedure always cause construction delay.”

Our results discussed the importance of financial preparation in both engineering and procurement phase. However, due to a long construction period and EPC contract requests a milestone payment method for HSR project, the respondent also perceived that delay payment in project progress has significant impact. This view supports Ahsan and Gunawan (2010) who found financial crisis and loan disbursement in international environment among the construction period caused delay progress payment. This study proved such impact is growing on HSR and such infrastructure project mostly.

A respondent from CCECC stated: “When Chinese consortium construct the IECPHSR project as the main contractor, construction supervision was always conducted by the Chinese company. However, under strict construction requirements, Chinese companies had not met the requirements of international supervision standards. Inexperience site supervision of the construction process and accessing acceptance of construction results in construction quality, HSR technique,

construction information, personnel training often caused construction reworks, which IEPCHSR offer suffered construction delay."

It is highly relevant to our results that consultant plays an essential role in IEPCHSR consortium, and Chinese companies are always pointed as supervising instead of local or individual authorities. However, high technology and domain knowledge are needed in HSR complex construction procedure like track laying, tunnel holing-through, bridge erection, amongst other things. Thus, they made site supervision requires precision and accuracy to insure the high quality and schedule on time, and this require main contractors establish a cooperative partnership management in quality, schedule and environment. Under this mode, it can make clearly relationship between contractor and supervising unit with international law, regulation and environment.

CONCLUSIONS AND FUTURE RESEARCH DIRECTION

Although construction delay management in international market has drawn much attention by researchers, delays in public infrastructure project like HSR projects implemented by international consortium is hard to identify due to its complexity. Compare to previous research more concerned about general project, our study has presented a comprehensive introductory review about the status of Chinese companies which export IEPCHSR project expertise to overseas markets, in particular regarding delay factors in the international infrastructure construction market. Qualitative research was conducted by interviewing top managers from seven Chinese HSR companies. Seven respondents answered questions related to the causes of delays in IEPCHSR projects associated with EPC projects.

First, our result indicate that some delay factors identified from general international infrastructure projects are also applicable to IEPCHSR projects with proper adjustment. Then, specific delay factors were identified by summarizing the conversation from each interview from E, P and C phases. In engineering phase of the IEPCHSR, our results show that construction consortium capability affect schedule most, broadly, without a uniform construction standard in consortium established by main contract in high-tech project can lead serious construction delay. Inefficient land acquisition and design changes are two significant factors because of long and complex geological ground conditions, and a lack of EPC subsidiary contract management for HSR projects are the main delay factors. In procurement phase, compare to previous studies concerned procurement contract, respondents focus delay problem in improper procurement planning, especially financial estimation due to unimaginable expensive HSR project. Under strict international market regulation, unreliable agency and inefficient logistics often lead to lack of core equipment and technician labour which those factors cause serious construction delay. Finally, in the construction phase, we also found that improper construction task planning in the construction consortium, inexperienced site supervision ineffective technical standard management by consultant, and ineffective continuous progress payment are the main delay factors. These key findings if properly addressed, should help enable Chinese companies to identify and minimise construction delays during IEPCHSR projects.

In future research, the study will systematically investigate the interrelationships amongst these delay factor groups identified, before proposing a conceptual framework. This will be followed by a quantitative approach using exploratory factor analysis and structural equation modelling (SEM) technique. A typical case study, Indonesia's Jakarta to Bandung HSR project will be selected to test the theory.

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