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**Article**

## Schedule overruns as a barrier for liquefied natural gas projects: A review of the literature and research agenda

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## Review article

# Schedule overruns as a barrier for liquefied natural gas projects: A review of the literature and research agenda

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## HIGHLIGHTS

- Natural gas is a strategically important transition fuel en route to lower carbon future.
- Liquefied natural gas projects are frequently plagued by significant overruns in scheduling and cost.
- These overruns could impede the adoption of natural gas in both the short-term and long-term.

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## ABSTRACT

With only half of the carbon footprint of coal, natural gas is widely considered to be an important transition fuel as the world economy shifts away from more carbon-intensive energy sources towards lower-carbon alternatives. Liquefied natural gas (LNG) has accordingly grown as a solution for connecting producers and consumers of this valuable resource that are geographically separated by large distances or barriers that make pipelines infeasible. Many construction projects are underway or being planned around the world to bring onstream the vast amounts of infrastructure required for this strategically important energy source. Despite the importance of these projects, however, they are frequently plagued by significant overruns in both scheduling and cost that could impede the progress of the adoption of natural gas in both the short- and long-term. Towards understanding these impediments, this paper puts forward a systematic literature review that synthesizes project management research and prior contributions in the LNG domain to identify risk factors that are most important to schedule and cost overruns in LNG projects. We then put forward a series of research questions that highlight the most fruitful areas for future investigations in this area, thereby helping to lay the groundwork for research that would potentially speed up the rate at which new natural gas supplies can supplant more carbon-intensive fuel sources around the world.

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## 1. Introduction

Natural gas has only half of the carbon footprint of coal (Rotman, 2009), can be used as a versatile fuel source in a broad range of

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contexts and products (e.g., [Osorio-Tejada et al., 2017](#); [Sharafian et al., 2017](#)), and is increasingly abundant ([Smil, 2015](#); [Economides and Wood, 2009](#); [Leather et al., 2013](#); [Weijermars, 2012](#)). These features have contributed to natural gas' relative attractiveness and its role as an important transition fuel ([Rotman, 2009](#)) as the world economy shifts away from more carbon-intensive energy sources in favor of lower-carbon alternatives. Large and steadily growing natural gas reserves in the U.S. and elsewhere have also carried with them significant political benefits ([Kaplan, 2017](#); [Medlock et al., 2014](#); [Moryadee et al., 2014](#)). As a result of these advantages, the U.S.'s Energy Information Administration (EIA) ([EIA, 2016](#)) forecasts that the consumption of natural gas around the world will increase from 120 trillion cubic feet (Tcf) in 2012 to 203 Tcf in 2040.

Despite its relative attractiveness as a fuel, however, natural gas is frequently produced in parts of the world that are far removed from the customers who want to use it. Liquefied natural gas (LNG) has accordingly grown as a solution for connecting producers and consumers of this valuable resource that are geographically separated by large distances or barriers that make pipelines infeasible. The liquefaction of natural gas essentially involves cooling the gas down to  $-162\text{ }^{\circ}\text{C}$  and reducing its volume to nearly 1/600th of what it was in its gaseous state so that, as shown in [Fig. 1](#), it can be transported in specialized tankers to receiving terminals around the world, and then returned to its gaseous state before being distributed to customers ([Smil, 2015](#)). The World Energy Council (WEC) ([WEC, 2013](#)) projects that the global LNG trade will increase from 300 billion cubic meters (bcm) in 2010 to 660 bcm by 2030—that is, it is predicted to more than double in 20 years. It therefore follows that a large number of construction projects are underway or being planned around the world to bring onstream the vast amounts of infrastructure required for this aggressive increase in the world's capacity to produce, liquify, transport, and re-gasify LNG.

But this considerable number of LNG-related construction projects has been plagued by significant overruns in both cost and scheduling that could impede the progress of the transition to this lower-carbon fuel source. Construction projects in the upstream oil & gas industry<sup>1</sup> are usually complex, and are exposed to greater risks than many other sectors due to the relatively high levels of capital investment involved, environmental and social issues, and conflicting interests among stakeholders ([Van Thuyet et al., 2007](#); [Zou et al., 2007](#)). As a result, these risks can negatively influence project performance measures like schedule, cost, and quality ([Van Thuyet et al., 2007](#); [Charoengam and Yeh, 1999](#)).

These significant schedule overruns have become increasingly commonplace within LNG projects, contributing to severe cost blowouts that have in turn resulted in a more than doubling of the upstream capital cost index of LNG developments around the world from 2003–2013 ([Smil, 2015](#), p. 208). Various risk factors that influence delays are associated with most large-scale projects but, as noted by [Merrow \(2012\)](#), upstream oil & gas megaprojects

are often more vulnerable to these risks than their non-oil & gas counterparts, and consequently face schedule and budget overruns quite often. [Clews \(2016\)](#) explains that the upstream part of the oil & gas industry is the most complex and critical part of the sector from a projects point of view, and therefore has a significant impact on the industry's overall performance in delivering LNG supplies. Upstream productivity therefore requires more serious attention ([PwC, 2014](#)), as development in this part of the industry is expected to underpin the substantial increases in LNG exports in the coming decades ([BREE, 2012](#)). The upstream part of the sector encounters challenging and complex geological risks, as well as facing volatility in oil prices, geopolitical and political challenges, and environmental and internal risks that all pose serious threats ([Clews, 2016](#)).

However, even though risks in construction projects can never be entirely removed, they can be minimized if the root causes are properly identified and managed at an early stage ([Smith et al., 2006](#)). The identification, assessment, and management of risks—particularly in the upstream dimensions of gas projects—are imperative for delivering these kinds of capital-intensive projects in a way that preserves their economic viability and strategic usefulness.

Despite the clear importance of the size and ubiquity of the upstream oil & gas industry, however, there has been very little significant research identifying and examining the causes of overruns in schedule or budgets in this sector. The literature offers a few insights into the trials and tribulations of project-related difficulties more broadly within the hydrocarbon sector (e.g., [Olaniran et al., 2015](#)), but these contributions have so far failed to usefully tailor their lines of inquiry specifically to the LNG domain, or have focused mostly on cost blowouts without paying much attention to the equally important issue of schedule overruns. Therein lay the overarching contributions of this research: to provide a critical review and synthesis of the literature related to schedule overruns in LNG construction projects, to shed light on patterns and themes emerging within the literature in these areas, and to put forward a series of research questions that highlight the most fruitful areas for future investigations in this area. In doing so, this paper will help to lay the groundwork for research that would potentially accelerate the rate at which new natural gas supplies can supplant more carbon-intensive fuel sources around the world.

The paper is structured as follows. We will begin by outlining the methodology used to systematically review the relevant literature. Next, we will explain the scope of the review and explain the types of relevant literature included in it. The paper then presents an analysis and synthesis of the literature, and highlights the risk factors that most significantly contribute to barriers that impede the delivery of LNG projects. Finally, we will present conclusions and their implications, and recommend directions for further research.

## 2. Methodology

Following the five-point framework for conducting literature reviews put forward by vom Brocke, Simons ([vom Brocke et al., 2009](#)), a conceptual map ([Fig. 2](#)) was constructed to identify the relevant subtopics that are connected or that could be potentially connected to the research area being reviewed. Textbooks and other kinds of integrative literature were used to map the connectedness of these subtopics ([Baker, 2000](#)).

The elements of the concept map were then comprehensively searched via all four of the approaches prescribed by [vom Brocke et al. \(2009\)](#)—specifically, by searching journals, databases, keywords, and backward/forward searches.

The review was confined to papers published in English (cf. [de Araújo et al., 2017](#)), in peer-reviewed journals (cf. [Rowley and](#)

<sup>1</sup> As noted by the United Nations ([Sigam and Garcia, 2012](#), p. 3), a traditional breakdown of the oil & gas industry divides the sector into three main parts: the upstream (typically covering the exploration, development, and production aspects), midstream (transportation and storage), and downstream (processing, refining, and marketing). LNG megaprojects frequently do not neatly fall within any of these three silos, however, and can sometimes include elements from all of them. But we argue that LNG projects are most appropriately connected to the upstream part of the sector. This perspective is bolstered by the oil & gas industry itself. The Society of Petroleum Engineers, an organization with over 120,000 members around the world that focuses principally on the upstream dimensions of the industry, has included hundreds of articles about LNG over the years in its flagship publication, the *Journal of Petroleum Technology*. Thus, we do agree that project-related trends in the upstream part of the industry are not always perfectly true for all LNG projects, but they are sufficiently connected that including LNG in a discussion about upstream projects and vice-versa is more helpful than not.

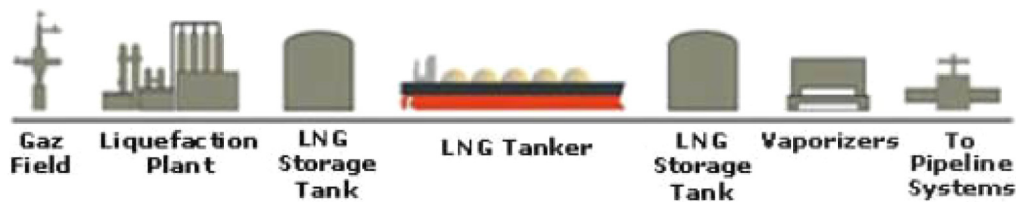


Fig. 1. Conceptual Diagram of LNG Value Chain (Natural Resources Canada, 2017).

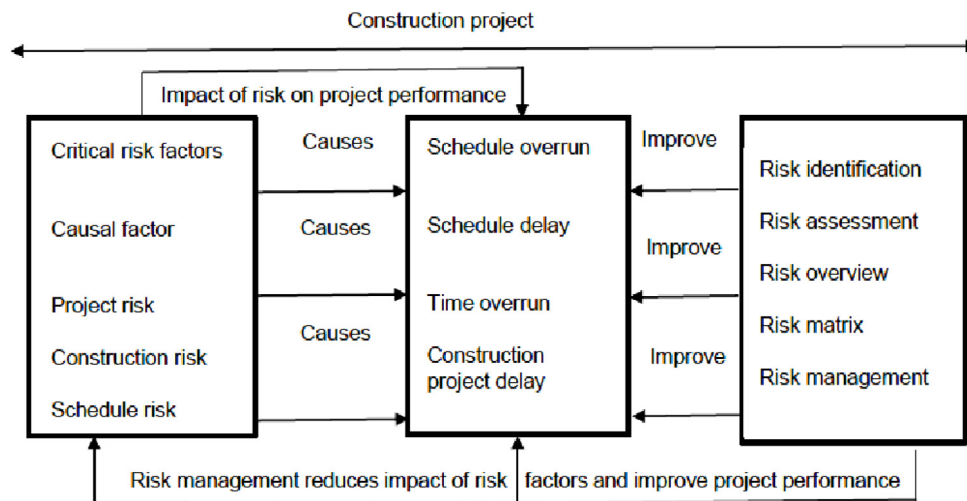


Fig. 2. Conceptual map of risk and construction schedule overrun.

Slack, 2004), in proceedings of reputable conferences (cf. Webster and Watson, 2002), or in scholarly databases (along with searchable keywords) from 1985 until the present day. The beginning of this targeted timeframe, 1985, was selected because the earliest foundational contributions pertaining to the topic of delays in construction projects (e.g., Arditi et al., 1985; Sullivan and Harris, 1986) emerged at that time.

To compare the relative profile of different contributions, the academic journals in which they were published were categorized according to their impact rating in the Scimago Journal ranking database (cf. Mok et al., 2015). Relevant literature items were identified using keywords via five databases: Emerald, ASCE Library, Science Direct, ProQuest, and Taylor & Francis Online. Backward searches – that is, reviewing literature that was cited in the articles obtained from the keyword search – were also applied (cf. vom Brocke et al., 2009) to ensure that any relevant articles pertaining to the topic were not overlooked.

Content analysis was used to analyze and synthesize the literature items included in the review. This analytical method is essentially a systematic and structured way for reducing a large amount of textual data to facilitate analysis (Krippendorff, 2004; Weber, 1990). Laplume et al. (2008) note that content analysis “can be used both quantitatively (e.g., frequency counts, correlations, trends, and differences over time) and qualitatively (e.g., theme identification, theory elaboration)” (p. 1156). In this review, the content of the selected literature items was quantitatively analyzed under codes that were adapted from the standardized codebook developed by Laplume et al. (2008). Specifically, the content was broadly classified according to: year of publication, author(s), article title, journal, number of risk factors and categories (independent variables), project sector, country, methodology, data source, and sample dimension (Mok et al., 2015; Tesfaye et al., 2016; Sartor et al., 2014).

### 3. Literature analysis and synthesis

Risks are essentially specific events or activities which represent a threat to the performance of a project in terms of cost, time, quality, or safety (Perry and Hayes, 1985; Flyvbjerg et al., 2003; Tah and Carr, 2001; Choudhry et al., 2014; Sajid et al., 2018). Categorizing and classifying the different types of risk that can impact a project is useful inasmuch as it helps prospective researchers and practitioners alike to understand the scope and breadth of the uncertainties that they face, as well as how different risks are related to each other (Zou et al., 2007; Tah and Carr, 2001; Alsharif and Karatas, 2016; Khodeir and Mohamed, 2014). Various approaches have been used to classify risks, such as the ownership of concerned parties involved in the project (Perry and Hayes, 1985), the origin of risks and their impact on projects (Tah and Carr, 2001; Tah et al., 1993), and the nature and magnitude of risks (Cooper and Chapman, 1987). Table 1 summarizes the common risk sources identified in the project management literature.

Previous contributions in the project management domain have typically tended to categorize risk as coming from external sources (e.g., economic, social, political, legal, public, logistical and environmental) or internal sources (e.g., financial, design, contractual, construction, personal, involved parties and operational) (Van Thuyet et al., 2007; PMI, 2008; Christian and Mulholland, 1999). However, upon applying the content analysis methodology outlined in the previous section and taking into consideration the specific contextual factors from the LNG sector, some slightly different themes and priorities emerge, including the geographical region of the project, the industry-specific nature of the risk, the global structure of the sector, the heightened importance of non-technical risks, and the increasing complexity of LNG systems. Each of these will be explained in the sections that follow, and are anchored in the appropriate literature from the review.

**Table 1**  
Common risk sources from project management literature.

Risk sources	Selected literature																		
	Assaf et al. (1995)	Kumaraswamy and Chan (1998)	Mezher and Tawil (1998)	Christian and Mulholland (1999)	Odeh and Battaineh (2002)	Assaf and Al-Hejji (2006)	Faridi and El-Sayegh (2006)	Sambasivan and Soon (2007)	Abd El-Razek et al. (2008)	Al-Kharashi and Skitmore (2009)	Enshassi et al. (2009)	Mahamid et al. (2012)	Aziz (2013)	Fallahnejad (2013)	Choudhry et al. (2014)	Marzouk and El-Rasas (2014)	McCord et al. (2015)	Ruqaishi and Bashir (2015)	Aziz and Abdel-Hakam (2016)
Client/Owner		x			x	x	x	x		x	x	x	x	x		x	x	x	x
Consultant/designer					x	x	x	x		x	x	x	x	x		x	x	x	x
Contractor		x			x	x	x	x		x	x	x	x	x		x	x	x	x
Project/construction		x	x	x		x					x	x	x		x	x	x	x	x
Contract					x			x		x				x	x			x	x
Design		x		x		x				x	x	x	x				x	x	x
Material	x	x	x		x	x		x	x	x		x	x			x	x	x	x
Equipment	x	x	x			x			x			x	x				x	x	x
Labor/manpower	x	x	x			x			x			x	x				x	x	x
Site/HSE			x	x					x						x				x
Procurement				x															
Management																			
External		x			x	x		x		x	x	x	x	x	x	x	x	x	x
Financing	x		x				x		x						x				x
Changes	x		x						x										
Environment	x		x						x										
Contractual relationship	x		x		x		x	x	x	x								x	x
Governmental relations	x		x				x												
Scheduling and controlling	x								x										x
Labor and equipment					x			x			x			x		x		x	
Planning and scheduling							x												
Unforeseen condition							x												
Rules and regulation									x										x
Execution										x									
Material/equipment											x								
Interface														x					
Communication													x						
Non-technical risks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Total risk sources as per literature</b>	<b>9</b>	<b>8</b>	<b>10</b>	<b>4</b>	<b>8</b>	<b>9</b>	<b>8</b>	<b>8</b>	<b>9</b>	<b>7</b>	<b>12</b>	<b>8</b>	<b>9</b>	<b>9</b>	<b>7</b>	<b>7</b>	<b>10</b>	<b>8</b>	<b>15</b>

### 3.1. Geographical region

The uncommonly international nature of the LNG industry when compared to most other sectors (Smil, 2015; Yergin, 2011) causes geographical issues to rise in relative importance within the category of external sources. Fig. 3 shows the geographical origin of literature concerning schedule overruns. Malaysia and India stand out at the top of the list with 10 articles, followed by Saudi Arabia with seven articles. Literature pertaining to Asian/African/European/Middle Eastern countries other than those mentioned in the diagram are considered within the four “other” categories. More than three quarters of the survey project literature focused on schedule overrun problems in developing countries<sup>2</sup>. By stark contrast, less than one quarter of the literature included in the survey discuss project delay issues in developed countries.

Despite this heavy emphasis in the literature on developing countries, however, these kinds of problems have frequently been observed more evenly in the practitioner domain. For example, a recent study conducted by EYGM Limited (2014) evaluating the performance of 365 oil & gas megaprojects around the world

reveals that 55% of projects in North America, 74% of projects in Europe, and 80% of projects in Oceania and the Asia-Pacific region were suffering from pronounced project delays. This lack of agreement between the academic literature in this area and what is actually happening within LNG project environments leads to:

**Research question 1:** How is the problem of schedule overrun in LNG projects different in developed nations than in developing ones?

### 3.2. Industry-specific nature of project risks

Construction projects in most sectors are complex and dynamic in nature. They involve numerous risks (McCord et al., 2015; Jarkas and Haupt, 2015), including delays (Odeh and Battaineh, 2002; Assaf and Al-Hejji, 2006; Faridi and El-Sayegh, 2006; Sweis et al., 2008; Enshassi and Mosa, 2008; Aibinu and Jagboro, 2002; Kaliba et al., 2009; Frimpong et al., 2003), finance-related difficulties (Assaf et al., 1995; Alaghbari et al., 2007) and, in some cases, political factors (Mahamid et al., 2012). In many ways, oil & gas projects fit very well within the generic literature about project risks (Mohammad and Price, 2005) inasmuch as they, too, are inherently complex and risky (Butler, 2015; Salama et al., 2008). As a result, their success is often strongly connected to whether or not they are delivered within the allocated schedule and budget.

<sup>2</sup> Our definitions of “developed” and “developing” countries were based on classifications used by the United Nations in UNCTAD STAT 2017 <http://unctadstat.unctad.org/EN/> and World Economic Situation and Prospects (WESP) 2014 [http://www.un.org/en/development/desa/policy/wesp/wesp\\_current/wesp2014.pdf](http://www.un.org/en/development/desa/policy/wesp/wesp_current/wesp2014.pdf), which is prepared by the United Nations Secretariat Department of Economic and Social Affairs (UN/DESA).



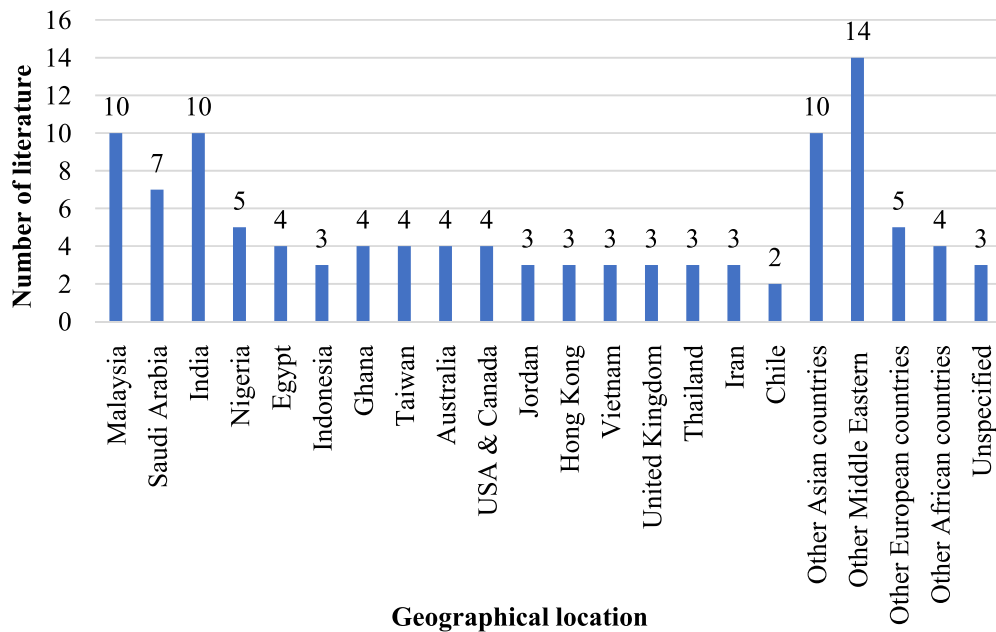


Fig. 3. Number of literature items per geographical region.

Today's oil & gas projects are generally regarded as being mega-projects<sup>3</sup> (Olaniran et al., 2015), which are much larger in size, involve longer timeframes, and typically require significantly more capital investment than is considered normal in many other industries (Salama et al., 2008; Dey, 1999). Ruqaishi and Bashir (2015) observe that delays in the construction of oil & gas processing facilities in Oman not only cost trillions of dollars to the owner companies in lost investment, but also frequently impede the economic development of the host country—which, in the case of Oman, is highly reliant on that sector for income and jobs. In an oil & gas environment, delays in the commissioning of projects necessarily carry with them a loss in production and revenue (Khan, 2015). Nonetheless, despite these harsh consequences, a very large number of oil & gas construction projects are suffering from schedule overruns (Naimi et al., 2008).

While these contributions from oil & gas projects offer helpful industry-specific perspectives about schedule overruns, however, a large fraction of them (e.g., Van Thuyet et al., 2007; Fallahnejad, 2013; Jergeas and Ruwanpura, 2010; Pham and Hadikusumo, 2014) are more focused on midstream and downstream parts of the business, and may therefore fail to capture many of the nuances and idiosyncrasies that are specific to the upstream parts of the industry (Perrons, 2014) which, as noted earlier, frequently plays a vital role in LNG. It therefore follows that the most important risk drivers in LNG projects might be slightly different from those discussed in literature based on those other parts of the oil & gas sector. This leads to:

**Research question 2a:** *What are the most important risk drivers and causes behind schedule overruns in LNG projects?*

**Research question 2b:** *How are the risk drivers and causes behind schedule overruns in LNG projects different from those in other industries?*

### 3.3. Global structure of the industry

Internal risks are related to the management of internal resources, and therefore tend to be more controllable than many other sources of risks in the project domain (Tah and Carr, 2001; Tah et al., 1993). Table 2 summarizes the internal risk drivers explored in the 111 items of project management literature exclusively highlighting the issue of schedule overrun in various construction projects (including oil and gas projects). As mentioned earlier, the review has applied content analysis which, as noted by Laplume et al. (2008), can be used for frequency counts, correlation, and trends. Therefore, to identify the internal risk drivers that contribute the most to schedule overruns, this review has applied a risk ranking calculated by counting the frequency of each risk driver appearing in the 111 literature items pertaining to schedule overruns (Srdic and Selih, 2015; Pall et al., 2016). As shown in Table 2, the risk drivers with the higher frequencies are considered to be most critical to schedule overruns within the literature.

But here, too, the extremely international nature of the LNG industry sets it apart from many others. LNG projects frequently bring together large numbers of consultants and contractors from around the world (Wood, 2012), and involve supply chains and construction materials that span the globe (Hawk et al., 2013). This important feature of the sector therefore significantly impacts internal risk sources such as procurement, contractors, and managing consultants. The technical consequences of this global scope have received a healthy amount of attention within the scholarly literature (e.g., Grønhaug and Christiansen, 2009; Agarwal et al., 2017), but far less focus has been given to the management dimensions of this. And while there are significant contributions in the literature looking at the challenges of managing projects across international borders (e.g., Lientz and Rea, 2012; Köster, 2009; Aleshin, 2001), little effort has been devoted to capturing the myriad ways in which the LNG sector's internal risks are very likely different from other parts of the market. For example, the extremely capital-intensive nature of the industry and the strategic importance of energy supplies to nations are such that the industry frequently contends with political sensitivities (Yergin, 2011; Hofmeister, 2010) that would quite likely impact supply chain

<sup>3</sup> By definition, a "mega-project" is one that has a budget of over US\$1 billion (Rostand, 2012; Westney, 2008) without including development costs that have been incurred before the project was approved (Jergeas, 2008).

**Table 2**  
Internal risk drivers causing schedule overruns in project management literature.

Internal risk sources	Internal risk drivers	References	Risk ranking		
			Frequency count	Overall rank	Rank within sources
Client/Owner related risks	Slow inspection and decision-making process	Assaf et al. (1995), Jarkas and Haupt (2015), Sambasivan and Soon (2007), Assaf and Al-Hejji (2006), Sweis et al. (2008), Doloi et al. (2012b), Odeh and Battaineh (2002), Fallahnejad (2013), Mezher and Tawil (1998), Van Thuyet et al. (2007), Enshassi et al. (2009), Marzouk and El-Rasas (2014) and Abd El-Razek et al. (2008)	71	5	2
	Poor organizational structure and multi-level decision-making bodies		27	32	4
	Delay in progress payment to the contractor		74	4	1
	Owner interference and work suspension		35	18	3
	Absence of financial incentives or delay penalty for contractor to finish ahead/ behind schedule		20	34	5
	Long period between design and time of bidding and lowest bidder selection		20	34	5
	Improper project feasibility study and imbalance in the risk allocation		16	36	6
Consultant-related risks	Delay in approving major changes in scope of work	Arditi et al. (1985), Al-Momani (2000), Kazaz et al. (2012), Sambasivan and Soon (2007), Assaf and Al-Hejji (2006), Sweis et al. (2008), Abd El-Razek et al. (2008), Fallahnejad (2013) and Chan and Kumaraswamy (1997)	25	33	3
	Lack of knowledge, skills and inadequate experience of design team		32	19	2
	Ineffective and lack of supervision and control		13	38	4
	Fail to understand client's specific requirement		11	39	5
	Slow response from consultant for testing and inspection		47	13	1
Contractor-related risks	Lack of experience, motivation, skills, competence of contractor personnel	Arditi et al. (1985), Frimpong et al. (2003), Faridi and El-Sayegh (2006), Sambasivan and Soon (2007), Al-Kharashi and Skitmore (2009), Marzouk and El-Rasas (2014), Mahamid et al. (2012), Fallahnejad (2013), Assaf and Al-Hejji (2006), Sweis et al. (2008) and Pham and Hadikusumo (2014)	57	9	2
	Delay in subcontractor's work, conflict and lack of control leading to frequent change of subcontractor		65	7	1
	Delay in resource mobilization at site and lack of technical experts required for commissioning/start-up		30	20	5
	Lack of operation, quality and control procedure, poor construction methods		47	13	4
	Financial failure of the contractor		55	10	3
	Improper technical study by contractor during bidding stage		8	41	6
Site-related risks	Poor site management and supervision issue	Choudhry et al. (2014), Doloi et al. (2012b), Mezher and Tawil (1998), Van Thuyet et al. (2007) and Perera et al. (2009)	57	9	2
	Site accidents and fatalities due to lack of safety measures and rules		40	15	3
	Unforeseen site ground conditions and poor subsurface conditions		70	6	1
	Delay in handing over of site to contractor		35	18	4
Procurement (material, equipment, labor) related risks	Congestion, overcrowding, and interference among people at site		10	40	5
	Delay in material procurement and delivery, long lead time on imported items and poor quality of material	Christian and Mulholland (1999), Assaf and Al-Hejji (2006), Sambasivan and Soon (2007), Sweis et al. (2008), Odeh and Battaineh (2002), Fallahnejad (2013), Van Thuyet et al. (2007), Enshassi et al. (2009) and Al-Kharashi and Skitmore (2009)	79	3	1
	Changes in material types and specification during construction and shortage of material and utilities at site		70	6	2
	Improper storage of materials leading to damage at site		19	35	6
	Lack of skilled operators for specialized equipment		20	34	5
	Low equipment productivity, shortage of modern equipment		63	8	3
	Equipment breakdowns due to unplanned maintenance of equipment		40	15	4
Nationality of the laborers and personal conflict/disputes		15	37	7	
Management-related risks	Poor coordination and inadequate integration between project interfaces	McCord et al. (2015), Mahamid (2011), Kazaz et al. (2012), Assaf and Al-Hejji (2006), Alaghbari et al. (2007), Sambasivan and Soon (2007), Faridi and El-Sayegh (2006) and Frimpong et al. (2003)	63	8	3
	Lack of communication and exchange of required data between parties		65	7	2
	Lack of resources, shortage of skilled labors		57	9	4
	Improper planning and scheduling deficiencies		71	5	1
	Lack of training, competency check and management support for personnel		10	40	5

(continued on next page)

decisions—like, say, selecting the country of origin for construction materials. Thus:

**Research question 3:** How do the heightened political sensitivities surrounding LNG projects impact internal risks?

### 3.4. Non-technical risks

External risks arise from a company's external business environment and, because they are often perceived as being relatively uncontrollable, have historically been managed via a range

Table 2 (continued).

Internal risk sources	Internal risk drivers	References	Risk ranking		
			Frequency count	Overall rank	Rank within sources
Contract related risks	Unrealistic time schedules imposed on contract or change in schedules	Sambasivan and Soon (2007), Choudhry et al. (2014), Doloi et al. (2012b), Odeh and Battaineh (2002), Fallahnejad (2013), Mezher and Tawil (1998) and Van Thuyet et al. (2007)	57	9	2
	Disputes and claims due to contractual anomalies/conflicts in contract		52	11	3
	Poor contract management, errors, and omissions in contract document		46	14	4
	Frequent change/variation orders issued by client, contract modification		81	1	1
	Excessive contract and sub-contract		3	43	5
Design related risks	Change in design due to design complexities, error or omission	Sullivan and Harris (1986), Assaf et al. (1995), Kaming et al. (1997), Abd El-Razek et al. (2008), Kazaz et al. (2012), Mahamid et al. (2012), Assaf and Al-Hejji (2006), Choudhry et al. (2014), Aziz (2013) and Enshassi et al. (2009)	80	2	1
	Non-compliant design with govt. regulations, standards		8	41	5
	Inadequate site investigations and collection of data required for design		30	20	4
	Rework due to changes in design, specification		37	16	2
	Unavailability of drawing/design on time and delay in approval for drawing		35	18	3
Construction/project related risks	Poor labor productivity, defective work, and quality issues	Al Zubaidi and Al Otaibi (2008), Assaf and Al-Hejji (2006), Choudhry et al. (2014), Doloi et al. (2012b), Pham and Hadikusumo (2014), Van Thuyet et al. (2007), Mezher and Tawil (1998), Aziz (2013), Enshassi et al. (2009) and Al-Kharashi and Skitmore (2009)	48	12	2
	Increasing complexities of mega projects		10	40	6
	Construction delay due to work interruptions, absenteeism, strikes		29	31	4
	Rework due to error in execution, poor workmanship		63	8	1
	Selection of improper project delivery system (Design-build/turnkey)		19	35	5
	Poor project management practices and lack of effective project control		36	17	3
	Delay in commissioning and start-up due to delay of other parties work		7	42	7

of outward-looking activities such as scanning, forecasting, and strategic thinking (Tah and Carr, 2001; Tah et al., 1993). The literature concerning non-technical risks (NTRs) has over the years included a diverse array of factors such as environmental risks and restrictions (Chen et al., 2011; Lo et al., 2006), social factors (Wagner and Armstrong, 2010), weather and economic conditions (Al-Momani, 2000), difficulty in obtaining permits from regulatory authorities, government regulations and procedures (Fallahnejad, 2013; Ahsan and Gunawan, 2010), and land acquisition and leasing issues (Fallahnejad, 2013; Pham and Hadikusumo, 2014). Over time, however, the NTR literature has for the most part coalesced into four themes according to the underlying nature of the risks: economic/financial, political and regulatory, social, and environmental (Chen et al., 2011; Lo et al., 2006; Boateng et al., 2015; Wan Ahmad et al., 2016; Mansfield et al., 1994; Adekoya and Ekpenyong, 2016). A detailed review of non-technical risk drivers along with their ranking (based on the frequency count of their appearance in the literature) in contributing to schedule overrun is shown in Table 3.

It is also worth noting, however, that there have been significant changes in one particular aspect of the NTR literature in an impressively short time span: environmental stewardship and safety. High-profile disasters like the *Piper Alpha* incident in 1988 (Paté-Cornell, 1993), the *Exxon Valdez* oil spill in 1989 (Coll, 2012; Plater, 2011), Shell's *Brent Spar* incident in 1995 (Sluyterman, 2007; Frynas, 2003; Sluyterman, 2010), and the *Deepwater Horizon* accident in 2010 (Flournoy, 2011; Perrons, 2013) have brought about a marked change in the expectations placed upon oil & gas companies with regards to environmental stewardship, safety, and human welfare (Perrons, 2014; Hofmeister, 2010; Mirvis, 2000; Managi et al., 2005)—and these disasters have therefore raised public awareness on this front for LNG projects, too (e.g., Zhang and Tan, 2018).

While the increasing magnitude of these reactions from society are easy enough to spot in hindsight, however, the literature

frequently seems to be at a loss as to why these stories unfold in the way that they do until well after the event. This hints at a rather pronounced failure to understand the underlying mechanisms that cause these reactions. Case study and more qualitative methodological approaches in future investigations might therefore reveal much about these situations inasmuch as they frequently add the “more complete, holistic, and contextual portrayal” (Jick, 1979, p. 603) that these research methods can provide. Although qualitative investigations are notoriously difficult to replicate (Jick, 1979; Eisenhardt, 1989), Yin (1994) points out that “case studies are the preferred strategy when ‘how’ or ‘why’ questions are being posed... and when the focus is on a contemporary phenomenon within some real-life context” (p. 1). As shown in Table 4, however, case study and qualitative methodologies account for only a small fraction of the literature in this area. We accordingly put forward:

**Research question 4:** How can case study and qualitative methodologies improve our understanding of “how” and “why” types of questions connected to the non-technical risks of LNG projects?

### 3.5. Increasing complexity of LNG systems

Table 4 also reveals another important trend in the literature. A large number of the quantitatively based contributions assess the frequency of risk factors by using tools such as Relative Importance Index (RII), mean score, and Importance Index. Other analytical tools like Spearman's rank correlation, ANOVA, and factor analysis have also appeared, but in only a small proportion of the literature. While these tools have laid a solid foundation by ranking the main factors causing project delay, however, they are unable to provide a meaningful understanding of the clustering effects of similar attributes (Doloi et al., 2012b). Moreover, these methods are incapable of representing the real complexity of the interdependencies among risk drivers (Fang and Marle, 2012). A useful next step



**Table 3**  
External/NTR drivers causing project delay in project management literature.

External/NTR sources	S/N	NTR drivers	Selected reference source	Risk ranking	
				Frequency count	Rank
Political and regulatory risks	1	Political instability, political opposition, and interference		19	6
	2	Unstable government policies—changes in wages and taxation by government	Wan Ahmad et al. (2016), Boateng et al. (2015), Khodeir and Mohamed (2014), Sambasivan and Soon (2007), Assaf and Al-Hejji (2006), Sweis et al. (2008), Doloi et al. (2012b), Chan and Kumaraswamy (1997), Fallahnejad (2013), Van Thuyet et al. (2007), Enshassi et al. (2009), Al-Kharashi and Skitmore (2009), Marzouk and El-Rasas (2014), Abd El-Razek et al. (2008), Jarkas and Haupt (2015), Frimpong et al. (2003), Faridi and El-Sayegh (2006), Choudhry et al. (2014), Aziz (2013), Mansfield et al. (1994), Aziz and Abdel-Hakam (2016), Kazaz et al. (2012) and Mahamid (2011)	23	5
	3	Delay in approval/permission from regulatory bodies or local authorities		17	7
	4	Difficulty in obtaining licenses, permits and patent rights		42	3
	5	Regulatory and legislative changes, changes in compliance mechanism		37	4
Economic/financial risks	6	Dependence on foreign funds and inadequate liquidity		7	12
	7	Economic disaster, recession, volatile economic conditions and financial crisis		23	5
	8	Inflation, change in foreign exchange, interest, material, and energy rates		45	2
	9	Fluctuation or changes in oil prices or market		1	15
	10	Changes in government funding policy		4	13
	11	Joint venture or ownership problems and shareholder's pressure		12	9
	12	Competition within the energy industry and from alternative energy sources		2	14
Social risks	13	Imposition of fiscal, taxation and other measures to promote low carbon emission economy		1	15
	14	Socio-cultural issues (such as cultural heritage, community development)		17	7
	15	Difficulty in obtaining land and access rights from landowners		13	8
	16	Vandalism, theft, terrorism, and damage of equipment and property		8	11
Environmental risks	17	Extreme weather/climate conditions, natural disasters		84	1
	18	Environmental protection pressure due to adverse environmental impact		10	10

**Table 4**  
Research methods used in analyzing project schedule overrun.

Main analytical method	Literature in which it was applied
Ranking of factors using <ul style="list-style-type: none"> <li>• Relative Importance Index (RII)</li> <li>• Mean score</li> <li>• Importance index score</li> <li>• Frequency and severity indices</li> <li>• Weighted average</li> </ul>	Chan and Kumaraswamy (1997), Abd El-Razek et al. (2008), Sambasivan and Soon (2007), Doloi et al. (2012b), Alaghbari et al. (2007), Assaf and Al-Hejji (2006) and Fallahnejad (2013)
Spearman rank correlation coefficient	Abd El-Razek et al. (2008), Assaf and Al-Hejji (2006) and Le-Hoai et al. (2008)
Analysis of variance (ANOVA)	Sweis et al. (2008) and Al Zubaidi and Al Otaibi (2008);
Factor analysis	Doloi et al. (2012b), Yang and Ou (2008) and Le-Hoai et al. (2008)
Case study (single/multiple)	Pham and Hadikusumo (2014), Alinaitwe et al. (2013) and Alsharif and Karatas (2016)
Regression analysis (simple/multiple)	Doloi et al. (2012b) and Al-Momani (2000)
Structural equation modeling (SEM)	Yang and Ou (2008) and Doloi et al. (2012a)
t-test (significance test)	Meeampol and Ogunlan (2006) and Hampton et al. (2012)
Cronbach's alpha coefficient	Ruqaishi and Bashir (2015) and Jarkas and Younes (2014)
Kruskal–Wallis Test	Ruqaishi and Bashir (2015) and Islam et al. (2015)
Chi-square test	Aibinu and Odeyinka (2006) and Love et al. (2013);
Kendall coefficient of concordance	Braimah and Ndekugri (2009)
Probability distribution	Love et al. (2013)
PERT technique	Christian and Mulholland (1999)

for the literature in this area, therefore, would be to apply more advanced statistical methods that are capable of showing complex interactions and interdependencies between and among the risk attributes that impact schedule and cost overruns. Structural Equation Modeling (SEM), which is a multivariate analysis capable of estimating the interrelated complex dependent relationship between variables, was found in only a small fraction of the literature pertaining to these topics. This lack of understanding with regards to these more complex interactions and interdependencies needs to be addressed with more sophisticated analytical tools that can reveal them. Thus:

**Research question 4:** How important are the interactions and interdependencies between the risk sources in impacting schedule overrun in LNG projects?

#### 4. Conclusion and recommendations

This paper set out to provide a critical review and synthesis of the literature related to schedule overruns in LNG construction projects, and to shed light on patterns and themes emerging within the literature in these areas. We then put forward a series of research questions that highlight the most fruitful areas for future investigations in this area, thereby helping to lay the groundwork

for research that would potentially accelerate the rate at which new natural gas supplies can supplant more carbon-intensive fuel sources around the world.

We do believe, however, that this literature review was underpinned by a few assumptions that, although reasonable today, might seem less so as the years roll on. Specifically, we conceded that project-related trends in the upstream part of the oil & gas industry are not always perfectly true for all LNG projects, but they are sufficiently connected that including LNG in a discussion about upstream projects and vice-versa is more helpful than not. However, the LNG market is still evolving and changing (Smil, 2015), and it is therefore quite reasonable to wonder if the two industries may start to behave more and more differently in the future as a result.

The paper's methodology section also confined the literature review to previous contributions published in English. In light of the uncommonly international nature of the LNG industry when compared to other sectors, however, this methodological decision might be creating blind spots insofar as valuable perspectives might be emerging in the non-English speaking world that are underrepresented or overlooked entirely because of this choice. A different methodological approach to future literature reviews in this area that is more inclusive of non-English literature may therefore capture dynamics and issues to which we were oblivious here.

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