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ARE LNG LIQUEFACTION PROJECTS TAKING LONGER TO CONSTRUCT?

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LNG liquefaction projects have always had relatively long execution timelines. For most of the LNG industry's history, grassroots projects have taken about 3-4 years to reach first LNG. In general, this schedule range has proven relatively impervious to differences in location, ownership, liquefaction technology, scale, and contractor.

Yet a review of executed and planned projects in recent years shows a discernible increase in project execution times. During this period, we have seen the time taken to reach first LNG on a grassroots project creep up from as little as 3 to over 5 years in some cases. While some of these projects indeed face unique siting and climatic challenges, others are in physically benign settings, yet are still showing execution schedules beyond historical expectations. LNG projects have never been easy to execute, but are they really taking longer to construct?

In this paper, the author will consider the key drivers of project schedule and review their influence on execution times for recent projects worldwide. Drawing on Merlin Advisors' experience and historical liquefaction project database, the paper will evaluate factors that might be driving the schedule trends seen on recent projects and assess whether LNG liquefaction projects really are taking longer to build.

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1. Background

Merlin Advisors (“Merlin”) was formed through the merger of Merlin Associates into Poten & Partners’ (“Poten”) engineering and technical due diligence group. Both Merlin and Poten have advised clients in the LNG industry for more than thirty years. These range from oil and gas companies to banks and investors and include independent oil and gas companies (IOCs), national oil companies (NOCs), utilities, multi-laterals, export credit agencies, commercial lenders, pension funds, and governments.

Merlin’s focus is on technical due diligence assignments for lenders and investors. Merlin was the lenders’ independent technical consultant (ITC) for the very first LNG project financing at Australia’s North West Shelf in the 1980s and today the team is continuing to support the financing of projects including those in East Africa, the US, the Arctic Circle, and Canada. The considerable LNG project experience that Merlin possesses makes us highly knowledgeable of the evolving trends in the industry – and it is this experience on which this paper is drawn.

2. Introduction

LNG liquefaction projects are some of the largest and most complex infrastructure projects undertaken in the world, with total project costs that can run into tens of billions of US dollars. Liquefaction projects, particularly those that involve integrated upstream and midstream facilities, typically involve multiple work scopes, and therefore several contractors are customarily engaged to execute a project. It is normal practice for contractors to be initially screened for selection based on criteria including their proven project experience and track record in delivering similar scopes. Screened contractors will then undergo a competitive tender process, or in some cases be selected “sole-source”, to deliver the relevant scope of the project.

The LNG plant engineering, procurement and construction (EPC) contract is typically the largest contract awarded by an LNG liquefaction project developer. The archetypal LNG plant EPC contract scope encompasses the EPC for the onshore facilities for the project including the LNG trains, inlet facilities, LNG storage facilities, marine terminal, utilities and any support facilities. However, some project developers may choose to extract certain scope items and award them under different EPC or separate engineering, procurement and construction contracts for reasons that could include risk mitigation, cost and schedule.




Given the large quantity of work in the scope of an LNG plant EPC contract, and the associated resource and financial commitment required, most contracts are executed under joint ventures (JVs) between major EPC contractors, with an integrated contractor organization established to manage the execution of a project. Executing projects within a JV consortium is beneficial to EPC contractors as it enables risk to be shared between the JV parties and allows an individual contractor to manage workloads across its various projects. Bechtel is a notable exception to this practice within the industry, having only to-date executed LNG projects as the sole EPC contractor. This has been largely due to its global collaboration agreement to pursue LNG liquefaction projects with ConocoPhillips utilizing its Optimized Cascade[®] technology, which prevented other EPC contractors competing for projects using this technology. However, this agreement was mutually terminated in 2016, with Bechtel continuing

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to seek LNG projects based on other technologies on the same sole-source basis as before. The size and revenue strength of the Bechtel Corporation can be considered as another factor.

The major LNG plant EPC contractors to have led the execution of multiple liquefaction projects during the past 10 years are shown in Table 1 below.

Table 1: List of major LNG plant EPC Contractors

Logo	Contractor	Headquarters	Works alone or as a JV participant during the past 10 years	No. LNG projects participated in during the past 10 years
	Bechtel	Houston, US (Oil & Gas)	Alone	10
	JGC	Yokohama, Japan	Alone & JV participant	10
	TechnipFMC	Paris, France	JV participant	10
	Chiyoda	Yokohama, Japan	JV participant	9
	McDermott (having acquired CB&I)	Houston, US	Alone & JV participant	5
	KBR	Houston, US	JV participant	4

Note: Projects have been counted more than once for different JV participants. Expansion trains have been treated as separate projects if a separate FID was taken after the original FID. Other EPC contractors seen regularly in the LNG industry include Saipem, IHI, and Fluor.

Under LNG plant EPC contracts, the main contractor typically takes overall responsibility for the design and engineering of the plant, the procurement of equipment and materials, the construction and on-site execution, certain commissioning activities, and the overall management of the Project. Subcontracts are used widely and awarded to other approved subcontractors, for example providing certain technology packages, equipment items, or construction scopes, within the EPC contractor's responsibility. Thus, the main LNG plant EPC contractor takes responsibility for the cost and schedule of the project under the terms of its EPC contract.

The objective of this paper is to explore project schedules and whether there has been a trend for increased execution timelines within LNG plant EPC contracts, and if so, the reasons for the expected longer project durations. This paper will also explore delays experienced on LNG liquefaction projects in relation to their contractual schedules and opine on the general types of issues affecting the execution of these projects.

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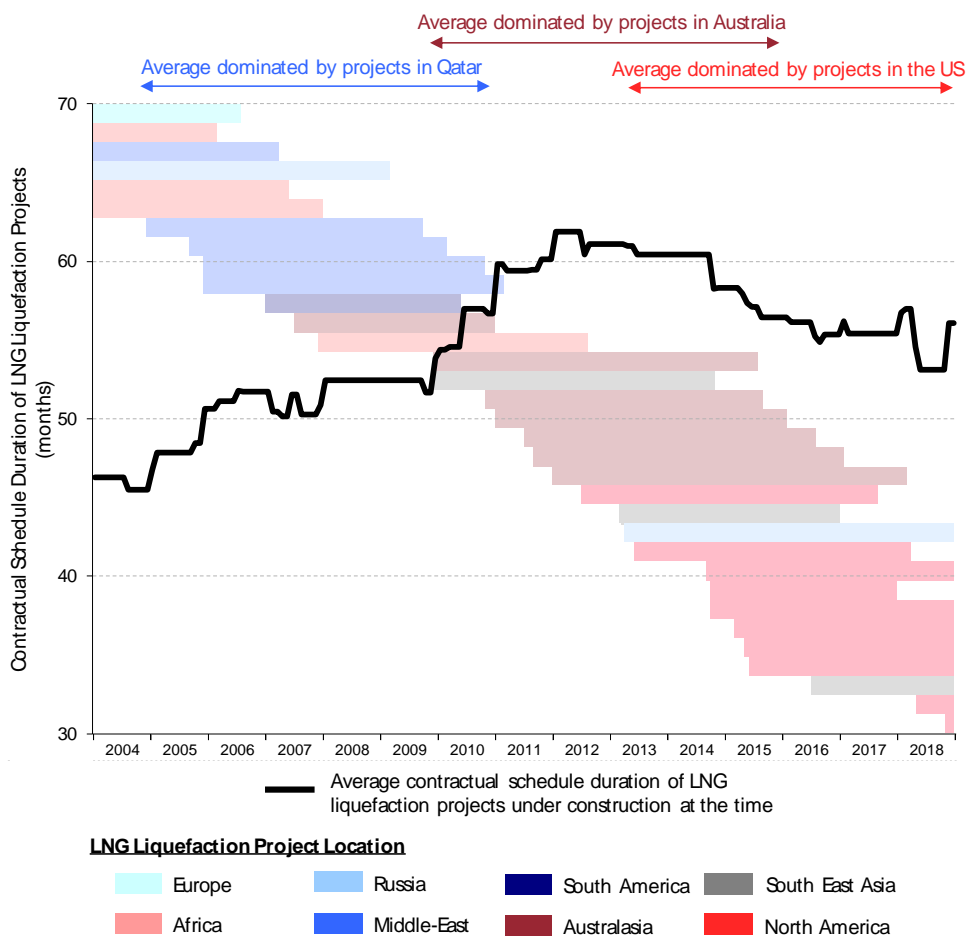
Throughout this paper Merlin has used the Final Investment Decision (FID) date as the publicly available reference for commencement of a project, and first cargo as the reference for project completion. These milestones provide a reasonably accurate reference to compare the schedule durations of LNG liquefaction projects.

3. LNG Liquefaction Project Contractual Schedules

LNG liquefaction projects have always had relatively long execution timelines with projects historically taking around 3-4 years to construct, with only a handful of exceptions. In the past, the critical path for an LNG liquefaction project schedule typically went through the LNG tanks, with this determining the overall contractual duration for the project. However, over the past 10-15 years, the trend has been for longer project execution times, with the critical path no longer being set by the LNG tank EPC schedule due to tank construction becoming increasingly efficient, or tank construction simply no longer dominating the critical path.

Based on data sourced from news articles in the public domain, Figure 1 presents the contractual schedule duration of LNG liquefaction projects from FID to first cargo and shows how the average contractual schedule duration of projects under construction at any specific point of time has increased between 2004 and 2018.

Figure 1: Contractual Schedule Duration of LNG Liquefaction Projects



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Note: Data only includes onshore LNG liquefaction projects only, both greenfield and expansion projects. The contractual schedule duration reflects the entire project. Data is based on public available information for projects that have taken FID since 2000 and reflects the expected schedule at FID to first cargo. Any actual delays experienced on the project are not included.

In general, as shown in Figure 1, major projects in three distinct locations dominate the effect on the average contractual schedule duration at any specific point in time: (i) the mega-train LNG projects in Qatar that took FID around 2004-05; (ii) projects in Australia on both the north-west and east coasts that took FID around 2010-11; and (iii) US liquefaction projects the bulk of which took FID between 2013-15.

The Qatari mega-train projects were the first to be constructed using Air Products' AP-X® liquefaction technology with four trains each of a capacity of 7.8 MMt/y being constructed in the period between 2005-10. Although the Middle-East is a relatively good environment for the major construction activities, the fact that multiple mega-trains were being constructed simultaneously was a key factor in the general increase to around 52 months of the average contractual schedule duration experienced during this time.

The general increase in contractual schedule duration became larger after 2010 as positive FIDs started to be made on Australian LNG projects, with the average rising above 60 months (or 5 years) between 2011-14. Australia was recognized by EPC contractors as being a more difficult construction environment, with labour availability and expected worker productivity considered critical constraints that drove several projects such as those on Curtis Island in Queensland, Wheatstone LNG, and Gorgon LNG to use modularized construction strategies.

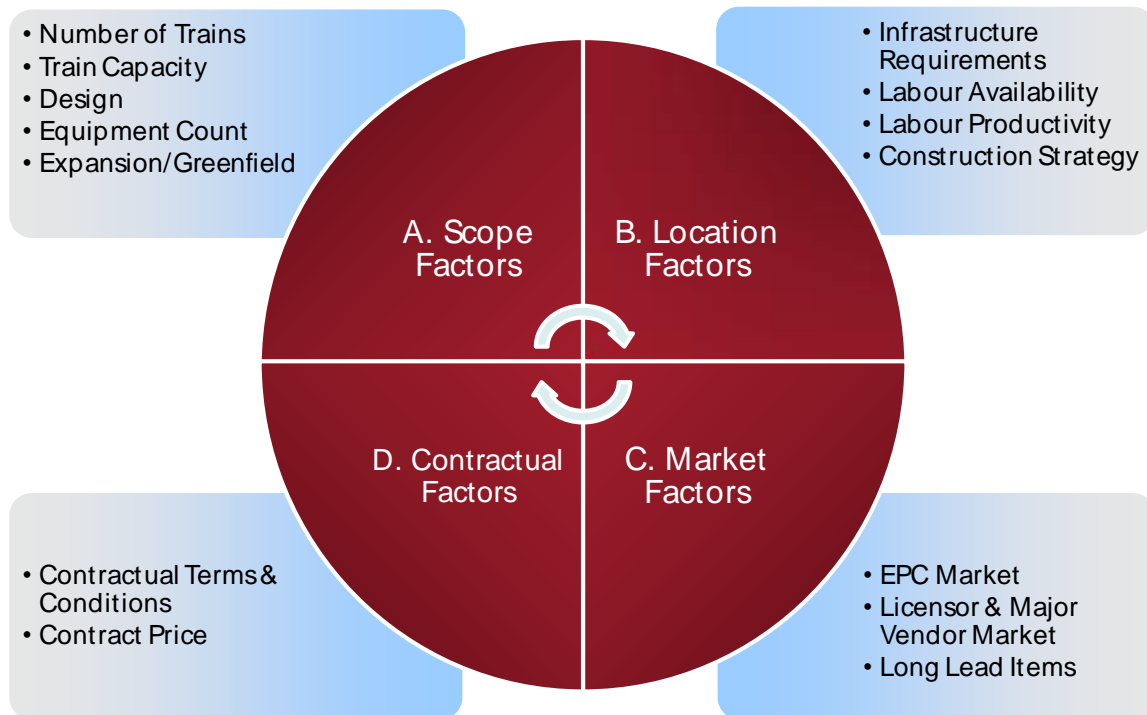
After 2014, following a surge of FIDs on US LNG liquefaction projects and the completion, or scheduled completion, of several Australian LNG projects, the average contractual schedule duration decreased to around 55 months. Prior to this surge in development, the US was generally considered a relatively straightforward construction location, particularly on the US Gulf Coast, and therefore contractors believed that they could take a less conservative approach to their schedule commitments.

4. Analysis of the Key Factors in the LNG Liquefaction Project Contractual Schedule Increase

The factors that affect the contractual schedule of an LNG project broadly fall into four inter-related categories: scope, location, market and contractual. The key aspect that should be recognized is that the contractual schedule for an LNG liquefaction project is the outcome of a negotiation between the project developer and the EPC contractor and will be specific to the scope and design of the project, its location, the market conditions at the time, and the contract terms under which the contractor is required to perform the work.

Figure 2 shows a representation of the different categories and more specific factors within each.

Figure 2: Key Factors influencing an LNG Liquefaction Project's Contractual Schedule

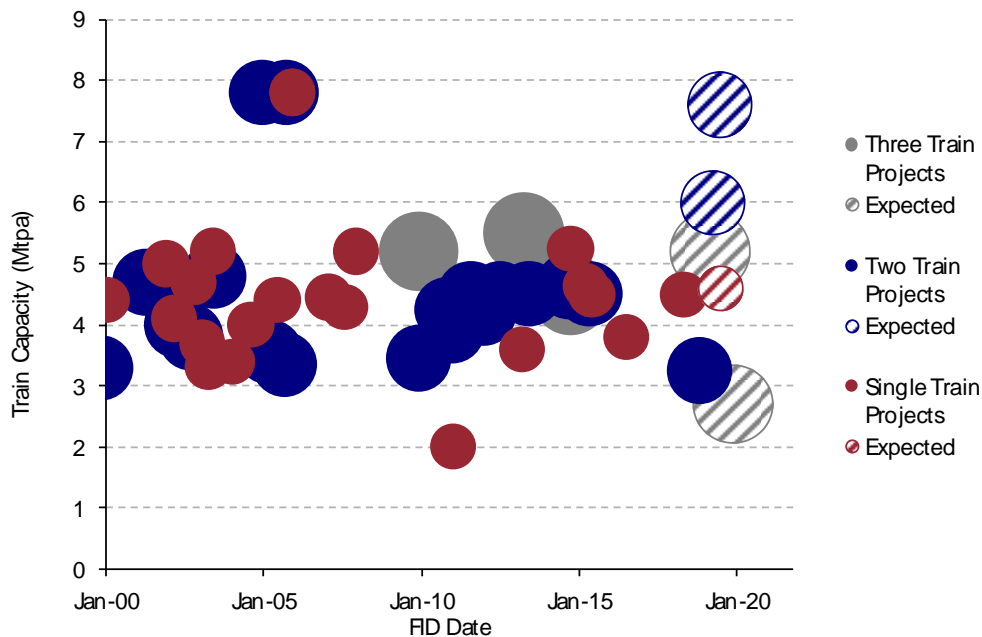


Factors in these categories are discussed in more detail below.

4.1 Design Factors

Larger projects, and projects with more complex scopes, are associated with greater costs, and in general, have longer schedule durations. A two-train LNG project will also obviously have a longer schedule than an equivalent single-train project as the engineering effort, materials and equipment procurement demands, and the construction hours are all increased. However, more importantly, the critical path of a project can be impacted by increased scope, lengthening it as the resources available to execute the scope become constrained. Based on analyzing data for projects since 2000, the average contractual schedule duration of a single-train LNG project to Train 1 is 45 months, whereas for a multiple-train LNG project to Train 1 it is 51 months.

Prior to 2010, most LNG liquefaction projects involved only a single train. However, since 2010, two-train projects have become more prevalent as project developers sought scale to maximize the economic feasibility of various developments. In general, only expansion projects where some project infrastructure is already in place are planned as single train developments, although some exceptions exist. Figure 3 illustrates the trend for larger, multiple-train LNG projects.

Figure 3: The Trend for Larger, Multiple-Train LNG Projects

Note: The size of the bubbles reflect the number of trains constructed as part of the project.

4.2 Location Factors

The location of an LNG liquefaction project, and factors associated with a specific location, are major determinants of a project's schedule. Projects in remote or inaccessible locations can be expected to have longer schedules as execution becomes more complex and challenging. Projects in remote settings typically require more supporting infrastructure and logistics, including extensive site preparation activities, airports, material offloading facilities and camps. Although construction of this early infrastructure is not typically on a project's critical path as it can be designed and constructed concurrently during the main engineering phase, for some projects it is a factor.

Moreover, the most significant factor associated with location is labour availability and worker productivity, which can vary greatly by country and even region. Some projects, for example those in Qatar and the Middle-East, benefitted from widely available labour resources from the subcontinent, with labour easily imported. Another example is Russia where labour is in strong supply, and a large construction workforce can be mobilized to execute a project.

Worker productivity can also vary greatly by location, with some projects requiring more manhours than others. Several projects in Australia experienced challenges during execution, having to contend with more restrictive labour laws and working practices, and having to re-negotiate labour agreements with strong unions to provide more generous conditions and more favourable working rosters to construction

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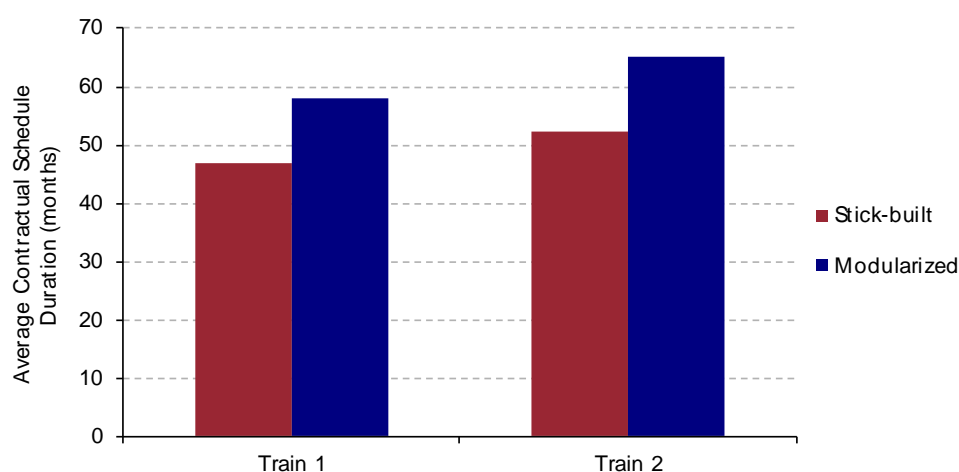
employees. This impacted labour productivity, increasing the number of manhours required, and driving up the costs and the schedule length of several Australian projects.

One construction strategy that projects have used to mitigate against labour availability and productivity concerns is modularization. Modularization enables fabrication and construction hours to be relocated from site to a construction yard, typically in Asia, where labour is relatively plentiful and cheap, and productivity is high. This construction strategy was used on most Australian LNG projects, where modularization reduced the number of manhours at site at the expense of additional engineering and structural design, and the more complex logistics of transporting multiple modules, each weighing thousands of tonnes or more, by sea. Nonetheless, construction activities at site can never be entirely mitigated against, and significant labour was still required to prepare the site and foundations, stick-build some facilities, and connect and install modules upon their arrival.

Modularization can provide cost and schedule benefits to a project in a specific location for the reasons described. The strategy was successfully used on Yamal LNG, which also modularized due to the added challenge of construction in the harsh Arctic environment. Modularization is also planned for the LNG Canada project in British Columbia, where JGC, who have partnered with Fluor to execute the EPC contract, is expected to leverage their experience from Yamal LNG in modular construction using Asian yards.

As shown in Figure 4, a comparison of projects in the LNG industry shows that modularized projects have a contractual construction period 10-12 months longer on average than stick-built projects. However, it should be noted that stick-building projects in certain locations may neither be feasible nor the most economic option and could result in longer schedule durations and/or additional costs.

Figure 4: Average Contractual Schedule Duration comparing Stick-built and Modularized LNG Projects



Note: Data includes onshore liquefaction projects that have taken FID since 2004 only. No comparison undertaken for Train 3 due to an insufficient number of projects.

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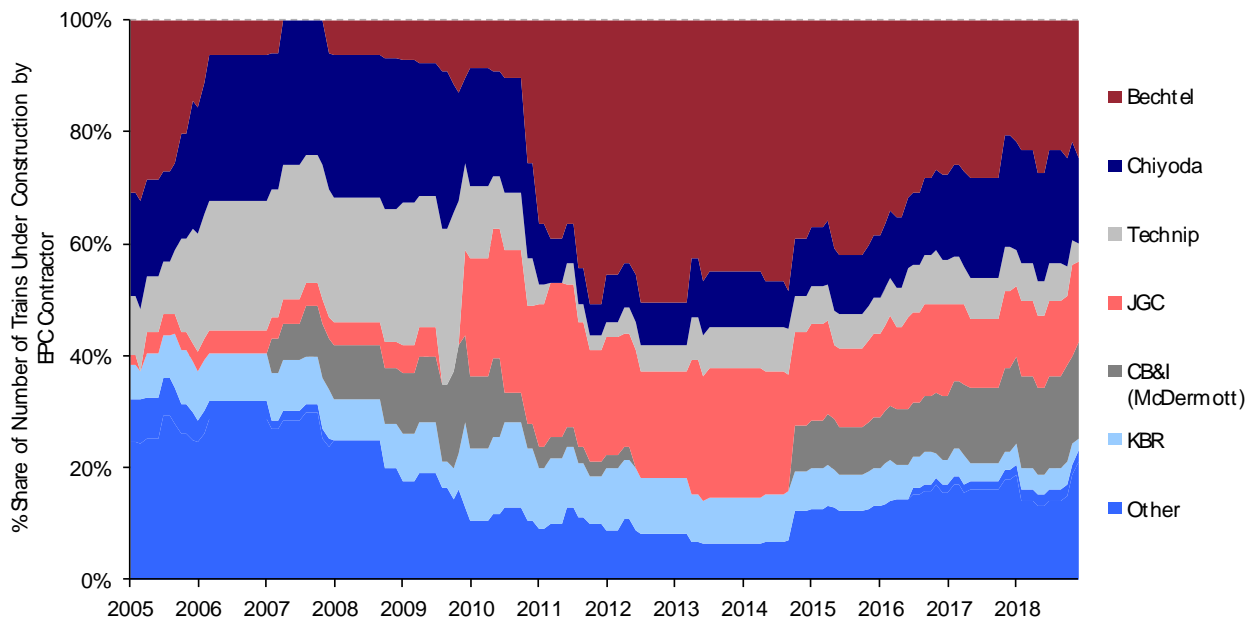
4.3 Market Factors

There are a limited number of contractors that lead and participate in the execution of LNG liquefaction projects. These are large contractors chosen due to their historic experience and track record in executing projects, and this provides project developers, and those financing developments, comfort that they will be successfully completed. Consequently, the workload and availability of EPC contractors and the competition between them, and indeed even major vendors and long lead item manufacturers, can all affect the schedule to which a contractor is prepared to commit.

As the LNG EPC industry is a competitive space, with only a certain number of projects under construction at any time, EPC contractors have the challenging task of trying to gauge their potential future workloads by understanding how the market will evolve so that they can position themselves to win future assignments. Depending on a project developer’s tendering strategy, EPC contractors can put themselves in an advantageous position to win future EPC work by leading early design and FEED studies, though this is by no means proven to be assured.

Figure 5 below shows the estimated percentage share of the number of trains under construction at any one time by the main EPC contractors, with the number of trains being executed under a joint venture being split equally between JV participants.

Figure 5: Estimated EPC Contractor Percentage Share of the Number of Trains Under Construction



Note: The number of trains being executed under a joint venture have been split equally between JV participants for simplicity.

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At times when there have been few projects and competition has been rife, EPC contractors have in some cases committed to unrealistic baselines schedules or underbid projects to secure assignments – although in some of these cases other contractual protections, such as a non-punitive liquidated damages regime or certain cost-reimbursable activities, have mitigated the risk and have been priced into the contract.

4.4 Contractual Factors

Ultimately, a project's schedule is determined through EPC contract negotiation between the project developer and the EPC contractor, and the agreed schedule and associated payment milestones will reflect the scope of work and execution plans. To this end, the agreed contractual project schedule should be looked at in terms of the wider EPC contract conditions, especially the agreed contract price which is an interdependent factor.

Whether a contract is lump sum and/or reimbursable can influence the overall agreed schedule. For lump sum contracts, the EPC contractor needs to be comfortable that it can complete the schedule on time without penalty. Therefore, the EPC contractor is likely to be more conservative in the agreed schedule for a wholly lump-sum contract.

For contracts with certain reimbursable elements, such as construction at site for example, the EPC contractor can be less conservative as, subject to an appropriate mechanism being in place to agree change orders in the eventuality that delays are experienced, it could potentially increase resources to meet the schedule with additional costs passed on to the project.

Schedule liquidated damages and schedule performance bonuses are other tools that can be used as incentives by project developers for EPC contractors to either complete work on time to avoid paying schedule liquidated damages, or to complete work early to achieve a schedule performance bonus. These schemes work by rewarding or penalizing an EPC contractor a certain amount per day early or late subject to a certain payment regime and other limitations.

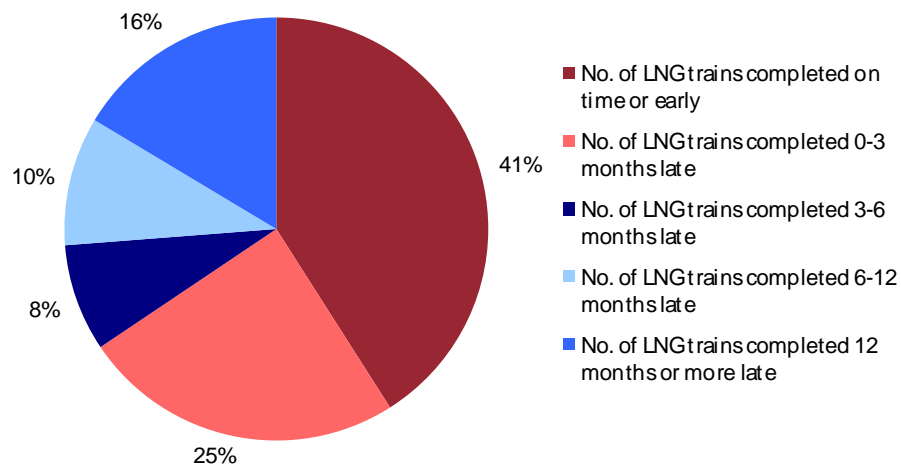
In general, less severe schedule liquidated damages are associated with more challenging project schedules, as the schedule risk being undertaken by the EPC contractor is higher, therefore increasing the likelihood that liquidated damages are triggered. For schedule performance bonuses, the opposite is generally true, with larger bonuses associated with more challenging project schedules as a real incentive for the EPC contractor to deliver a project on schedule.

5. Actual Performance of LNG Liquefaction Projects against their Contractual Schedules

LNG liquefaction projects can face both internal and external challenges during the execution phase that can potentially lead to schedule delays. Project developers and EPC contractors will of course endeavor to mitigate against these factors to the extent possible prior to and during the execution phase; however, many of the challenges faced come from unknown and unforeseen events. Internal factors can include poor contractor execution, unrealistic baseline schedules, design changes and issues, procurement and vendor delays, material and construction quality issues, safety issues, and start-up and commissioning challenges, while external factors encountered have included labour availability and productivity issues, natural disaster events, and events of Force Majeure. All these factors can contrive to push out the expected completion date for a project.

Based on data for LNG liquefaction projects under construction since 2000, the historic schedule performance of projects completing LNG train construction in accordance with their planned schedules is shown in Figure 6. It is estimated that roughly 41% of liquefaction trains have been completed either on time or early, and 25% have been completed with a delay of less than 3 months. As this represents roughly two-thirds of trains constructed, the industry has a fair record of completing projects according to schedule. However, there are some significant outliers – it is estimated that 16% of trains constructed have been completed with a delay of 12 months or more and 10% completed with a delay of 6-12 months. A further 8% of liquefaction trains are estimated to have been completed with a delay of 3-6 months.

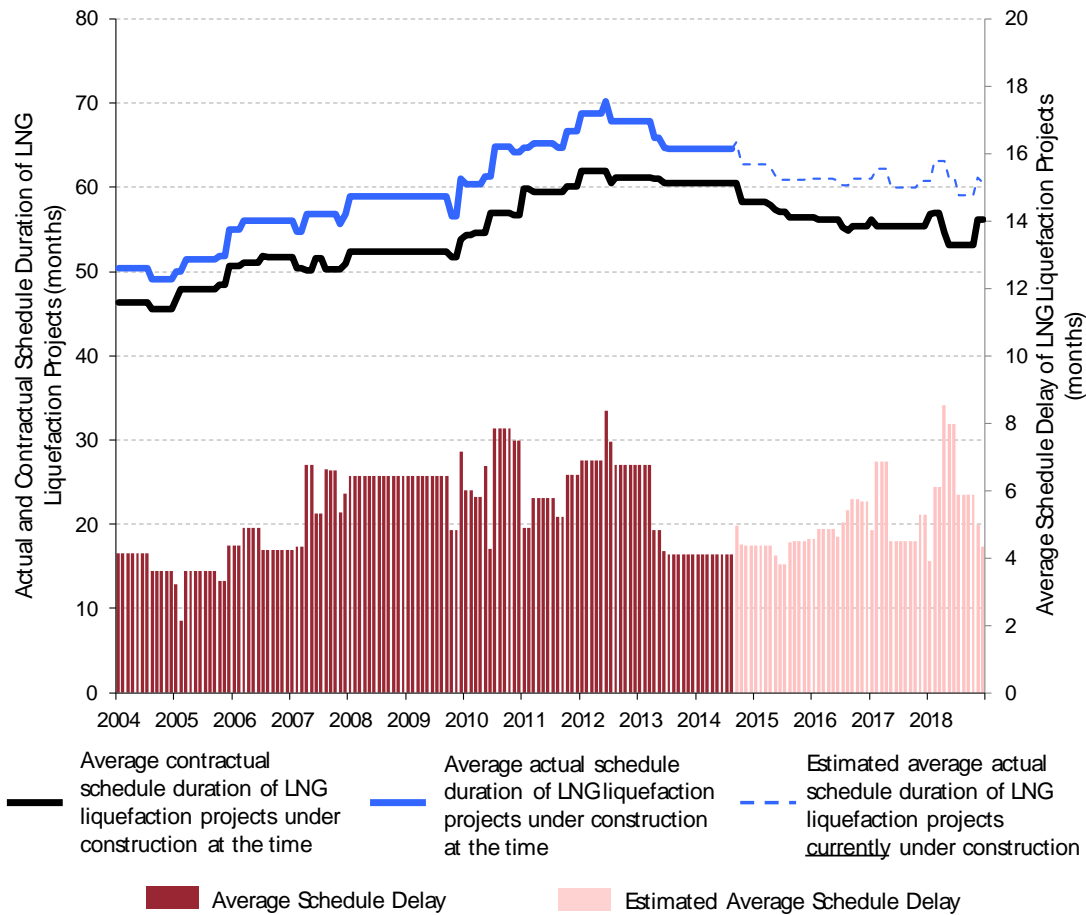
Figure 6: Schedule Track Record of Constructed LNG Liquefaction Trains



Note: The figure is based on data for the construction of LNG liquefaction trains since 2000.

A comparison between the actual average schedule duration and contractual schedule duration of LNG liquefaction projects is shown in Figure 7.

Figure 7: Estimated Average Schedule Delay of LNG Liquefaction Projects



Note: Data only includes onshore LNG liquefaction projects only, both greenfield and expansion projects. The contractual schedule duration reflects the entire project. Data is based on public available information for projects that have taken FID since 2000 and reflects the expected schedule at FID to first cargo.

Figure 7 indicates that the average schedule delay on LNG liquefaction projects has typically varied between 4 and 8 months since 2004, although there are some periods when it has been at the upper end or beyond this range. Notably, however, there is no real trend towards worsening schedule performance over time – however there are distinct periods where more LNG projects in the industry have clearly faced schedule challenges, specifically some of those in Australia and more recently some US liquefaction projects.

Projects that face schedule delays incur additional costs due to longer mobilization times for the contractor, with responsibility for the additional costs borne by either the project developer or the EPC contractor. The division of responsibility will depend on the terms of the EPC contract and the cause and reasons for the schedule delays. EPC contractors will propose change orders to recover additional costs in accordance with the EPC contract terms, and discussions and negotiations will take place to resolve any issues or disputes. EPC contractors take into account schedule risk in the EPC contract pricing, however any additional costs that have to be borne reduce the profit margin on the project.

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In practice, developers tend to place greater emphasis on getting their project completed and revenue streams up and running as quickly as possible as opposed to wrangling over change orders, although this will depend on the total value and number of change orders, and developers will have contingency amounts to cover unexpected costs. Ultimately, division of responsibility depends on the initial contract terms, the relationship between the developer and the contractor, and the willingness of both parties to negotiate any issues in good faith.

6. Conclusions

Over the past 10-15 years, the trend has been for longer LNG liquefaction project execution times, with the average contractual schedule duration of projects under construction at any specific point of time increasing from around 46 months in 2004 to 55 months as of 2018.

Ultimately, the contractual schedule is the outcome of a negotiation between the project developer and EPC contractor and is specific to each project. Scope, location, market, and contractual factors can all affect the agreed schedule for an LNG liquefaction project, although it is difficult to specifically assess the influence of any individual factor. However, location is clearly particularly influential as associated factors such as labour availability and worker productivity vary greatly and can fundamentally affect the execution strategy and schedule for a project.

The execution strategy selected and agreed schedule for an LNG liquefaction project is a trade-off between cost, schedule and risk. The LNG industry has seen a number of projects turn to modularization to overcome some of the associated issues with construction in certain locations. A general comparison of projects in the LNG industry shows that modularized projects tend to have longer construction periods when compared with stick-built projects, however stick-building projects in certain locations may neither be feasible nor the most economic option and could result in longer schedule durations and/or higher costs.

Due to unforeseen events, all projects can face challenges during execution that can potentially lead to schedule delays. Based on data for LNG liquefaction projects under construction since 2000, it is estimated that roughly 41% of liquefaction trains have been completed either on time or early, and 25% have been completed with a delay of less than 3 months. This can be considered a fair record for the LNG industry considering the size and complexity of LNG liquefaction projects. Nevertheless, there are some significant outliers – it is estimated that 16% of trains constructed have been completed with a delay of 12 months or more – showing that some projects face real challenges meeting their required schedules.

From the analysis, it was found that the average schedule delay on LNG liquefaction projects has typically varied between 4 and 8 months since 2004, although there have been some periods when delays have been at or beyond the upper end of this range. However, there is no real trend towards worsening schedule performance over time, just specific periods where clusters of LNG projects have clearly faced schedule challenges, mostly associated with location-specific factors.