

Factors Affecting Large Scale Modular Construction Projects

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Lack of success in traditional logistics strategies employed on large scale modular construction projects highlight the need for strategies that utilize multifunctional approaches focusing on elements of transport and logistics. Such strategies will enable fast track schedule milestones and benefit significantly from lower attendant cost in comparison to current methods. From content analysis of available data found in scholarly documents and industry publications addressing modular construction projects and related logistics strategies, inferences indicate an overrun of time and money for the project. Detailed cost and schedule risk analyses can provide improvement in result to next-generation transportation and logistics planning for large scale modular construction projects. The primary focus of this paper is to identify the factors attributing toward the success/failure of large projects globally. The study identified multiple factors from literature which when holistically integrated in a project can potentially result in on-time delivery in support of the optimal construction installation sequence. This will help ensure project and commercial expectations are met. Alternative logistics and transport strategies and associated detailed planning is a requirement that must be part of the overall plan in order to ensure project success.

Keywords: Schedule slippage, modular construction for large infrastructure projects, transportation and logistics

Introduction and Background

Multiple reports have been published on the Canadian Oil Sands Project which endured a significant schedule slippage and cost overruns of $US 2 Billion resulting from "issues transporting Korean-made modules to the … site in northern Alberta" (Healing, 2013; Krugel, 2013; Tait, 2013). The affected project was initially estimated at $8.9 Billion and was completed at $12.9 Billion with $2 Billion of the overrun assessed to be due to the impact of an unsuccessful logistics and transportation strategy (CBC News, 2013). Some of the other projects which observed similar problems with regard to transportation are Chevron's Gorgon LNG Project in Australia with $US 15 Billion increased costs from $US 37 Billion to $US 52 Billion in part due to "logistical challenges" (Chevron Corp., 2012). Table 1 in the next section lists projects with the causes of failure and the magnitude of the overruns. One of the commonalities which can be observed in the matrix is the failure to meet the established schedule for the delivery of modules. Thus the major financial impact of failing to meet schedule commitments can be significant henceforth demanding further inquiry for improving logistics and transportation planning methodology to ensure scheduled module delivery milestones are met. Closer examination and assessment of lessons learned as well as pinpointing enhancements that can be made to future logistic plans for similar construction efforts is justifiable when a lack of adequate planning is the primary cause for an overrun, such as the US $2 Billion on the Canadian Oil Sands Project (CBC News, 2013).

Background

The use of modular construction has increased on large construction projects that are located in geographically remote areas such as Kazakhstan, or northern Canada, where conventional construction techniques are unfeasible (DeLaTorre, 1994; Haidar et al., 2010). Gassel (2006) citing Modular Building Institute (MBI) refers Modular construction as units (or modules) that are fabricated in the factory and then transported to the site. And modules for this study has been defined as "transportable unit/component of a facility that are assembled away from the job-site" (Azhar et al., 2012). As observed by reviewing the definitions for both modules and modular construction, transportation plays a key role in its successful installation. And the importance on effective transportation of modules is enhanced considerably when either the site is geographically located in remote locations or the project is big/complex in nature. Advantages of using modular construction may include improved schedule, and effective risk management capabilities (Brookfield & Cooke, 2011). At the same time disadvantages of using modular construction include increased engineering cost, increased cost of off-site supervision including field engineering, quality assurance and project management, increased steel costs due to module structure required, and increased complexity of logistics and material tracking (West, 2011). Typically large projects can be defined as projects where construction costs exceed one Billion US Dollars (Merrow, 2012). Such large projects are complex and are composed of sub-activities which need to be managed effectively. And such projects, especially ones located in remote locations can have serious economic repercussions if not planned properly. Table 1 lists the big projects that suffered huge economic losses. Accordingly, it is difficult to isolate specific reasons for project delays associated with specific costs impacts; however, "logistics challenges" is consistently mentioned as a primary reason for cost overruns. For example, the Papua New Guinea LNG project referenced in Table 1 referred to the following as reasons for delays and cost increases, "Delays from work stoppages and land access issues have added $1.2 billion to the cost estimate, and the adverse logistics and weather conditions have added $700 million" (Platts, 2012). Likewise, on the Vogtle Nuclear Power Plant Project it has been reported that "the project's ... schedule is largely threatened by delays in the delivery and manufacturing of sub-modules…; and the sub-module issues would require revising the construction schedule and could add $200 million to the project's costs" (Crumbo, 2013).

Table 1

Listing of Projects Using Modular Construction that have been Impacted by Logistical Challenges that have Contributed to Significant Project Cost Overruns

Project	Reasons for using Modular Construction	Cost Impact of Logistics Related Delays	Causes of failure related to Logistics Protocol
Kearl Oil Sands Project – Canada	Remote location; labor availability	$US 2 Billion	Inability to convince state governments to allow transport over state highways
Gorgon LNG Project - Australia	Remote location; labor availability	$US 15 Billion*	Logistical challenges
Vogtle Nuclear Project – Georgia, U.S.A.	Labor availability	$US 200 Million	Delays in delivery of sub-modules
Papua New Guinea LNG Project – Papua New Guinea	Remote location; labor availability	$US 3.3 Billion**	Extraordinary logistics challenges
Kashagan Project – Kazakhstan	Remote location; labor availability	$US 79 Billion***	Logistics-related reasons included in bases for cost overruns

* - Cost overrun explained, in part, by "logistical challenges" (Chevron, 2012).
** - Cost overrun explained, in part, by "extraordinary logistics challenges" (Platts, 2012).
*** - Cost overrun from $US 57 to $US 136 Billion. "Shell decided to use a huge swamp; barge from Nigeria to drill oil. It was taken to Louisiana and refitted for frigid conditions, then chopped into pieces and sent halfway around the world to landlocked Kazakhstan. The barge had to be towed across the Atlantic, through the Black Sea and up Russia's Volga-Don canal to the Caspian port of Astrakhan. There it was reassembled and extended with pontoon-like structures until it was the size of a football field. It all took months longer than planned. In Astrakhan, fires destroyed equipment and tools were stolen." (Chazan, 2007).

Note: The logistics protocol is a complement to the commercial contract established between a supplier and a customer. It defines the logistics rules, which have to be respected to insure the correct realization of the various processes (in terms of cost, quality and time).

The literature review indicates the lack of specific research regarding the use of modular construction in project logistics and transportation studies targeted at optimal planning approaches. Thus this study aims to identify factors with regard to transportation of modules that are identified in literature as critical for the success/failure of large projects, where large modular construction was utilized

Research question

What critical factors, with regard to transportation of modules, are identified in literature as critical for the success/failure of large projects, where large modular construction was utilized? The success of large projects for this study was based on the timely delivery of the modules from the factory to the construction site. This study only accounted for factors that were true for all projects, irrespective of their geographical location. Regional factors which vary from one geographic location to another were not part for this study. Additionally, the study was accounted for projects completed globally.

Methodology

This study utilized content analysis method, to answer the established research question, starting with identifying relevant studies published in the field. The reason for the selection of the research method was because the authors were able to perceive the problem associated with logistics of large projects but were unable to find scientific solutions that could specifically explain the reasons for the failure of mega projects. Hence content analysis of the existing publications was the first step in addressing these questions.

The keywords utilized for the search were: construction module logistics and transportation, mega-projects logistics, cost, and schedule overrun problems and reasons, logistics contingency planning, construction module supply chain, individual oil company module transport problems, mega-project. A total of 70 academic and industry studies were identified and reviewed in this process. Upon identification and initial review of these studies, filter of terms such as schedule slippage, modular construction for large infrastructure projects, transportation and logistics was applied to sort the studies further. The studies pertaining directly to the problem of transportation of construction modules for large projects were selected further.

During the course of analysis, overlaps were determined across the studies to identify the factors which were critical for success of the large projects where modular construction was used. In course of the analysis, regional and global factors were identified which affected the success of the projects. For this study factors which were applicable globally were shortlisted and then validated by an expert industry professional. This expert has been associated with mega projects for the past twenty years. Currently, the expert is a director for a division in one of the top fortune 500 companies. Thus upon the completion of the study, derived from this analysis, were factors that were formulated into key elements for consideration and assessment of the research question posited in the preceding section.

Results

Consideration of the many factors involving significant complexity in making decisions leading to the failed results that were the genesis of this study can be given in hindsight and critiqued accordingly. However, the positive approach to this lesson-learned is to review applicable and relevant data that will result in a new approach in a broader perspective with regard to large scale modular construction projects in general.

This would necessarily relate to the logistics and transportation aspect to drive a strategy for future use that can be employed to succeed where others have not done so. The traditional procurement strategy must be revisited and an integrated contemporary approach employed that achieves a seamless information flow and clear delineation of responsibilities defining what the path forward and continuous focus by management must be. The factors for consideration and assessment include:

- Modular Construction Decision Factors
- Technology
- Cost/schedule risk analysis
- Integrated Planning Approach
- Project-Specific Logistics and Transportation Strategy

The subsequent section discusses each of these factors in detail.

Modular Construction Decision Factors

It involves consideration of numerous decision-making factors including: owner's acceptance of modular construction; project schedule criticality; management participation during front end engineering development (FEED); suitability of design for modularization; project participants familiarity with modular design and construction; project budget and degree of scope definition; degree of integration of project team; structurally sound module designs; well defined engineering and material and equipment requirements available for consideration ahead of decision-making; and, site accessibility (Azhar, 2012). After dutiful consideration and thorough analysis of pertinent factors outlined above, the decision to select modular construction can be made with a meaningful basis.

Technology

Technology such as 3D CAD (or building information modeling), internet, robotics, and automated design software interacting with fluctuating labor conditions and supply chain configurations has enabled modular construction to provide cost effective options including prefabrication, preassembly, modularization and offsite fabrication (MBI, 2010). The Construction Industry Institute – CII has developed a software tool for providing a decision framework for evaluating projected cost impact of modular decisions (CII, 2012). Due to the availability of such technologies and changes in the Construction business environment, the tool provides structure in decision making if adopted and integrated properly, since implementation requires systematic analysis and forces proper focus on key issues (CII, 2012). In addition technologies like route engineering software help determine routes that minimize travel time, do not have excessive gradients, minimizes traffic disruptions, requires that relatively few traffic signals be used, avoids densely populated areas, and others. (Berry & Luhan, 2012). This in-turn helps effective implementation of plans to ensure modules are delivered as per schedule.

Integrated Planning Approach

Development of the integrated detailed plan that will allow overall visibility to the detailed level in order to manage and control the project and, specifically, the logistics and transportation aspect. The plan will identify the required components and their predecessor and successor activities that must be included to formulate a comprehensive integrated modular construction and delivery plan.

According to Slootman (2007), the integrated plan must include developing:

- A functionally integrated logic network identifying the sequence of individual modules;
- Module fabrication durations to determine the number of modules that are in the fabrication and assembly;
- Definitive modular stowage plans for transport including ocean transport;
- Criteria for selection of potential module fabrication contractors and storage area requirements;
- Schedule for material and equipment and engineering deliveries required to support module fabrication schedules;
- Implementing procurement plans and processes that will support modular construction; and,
- Integrating and resource loading and leveling individual schedules for consolidation and optimal planning in support of project milestones.

Further to integrating all functional aspects, procurement planning includes logistics and transportation planning for actual module deliveries. Where complex, involved logistics are integral to module deliveries, various detailed planning subsystems will be required including a transportation logistics system containing heavy-haul transportation logistics information and routing capability, along with route engineering software applications that assist in determining one or more optimal routes for module transportation including identification of and plans to obtain required permits (Berry & Luhan, 2012).

Cost/schedule risk analysis

According to Haridar & Ellis (2010) planning for large projects, due to complexity and project size, should not be limited to or strictly follow the typical construction planning steps. Rather, planning should be more well-defined in areas such as design, long lead procurement scheduling, and detailed construction scheduling efforts. Effectively, production integration is the product to be achieved through detailed and defined planning and scheduling due to the complex nature of very large projects (Haidar & Ellis, 2010). One published study proposed a quantitative methodology which combines resource-constrained scheduling and Monte Carlo simulation-based risk analysis. This methodology could potentially improve overall project management for owner companies through streamlining decision-making and planning processes, most notably for the modular construction of large projects (Wu & Lu, 2013). As large projects become more costly and complex there needs to be more focus on the management of non-technical risks, notably relating to key environmental and social issues, issues that have notably impacted module transport on the Kearl project addressed above. In this respect, forward planning, well integrated project teams and timely interventions are all essential to avoid some of the hugely expensive project delays that are pervasive in the sector (ERM Foundation, 2010).

Project-Specific Logistics and Transportation Strategy

Once the decision has been made to utilize modular construction, a project-specific logistics and transportation strategy requires careful consideration to determine the most appropriate course of action. Ultimately, the dilemma faced by the genesis of this logistic analysis "reveals many challenges shippers and logistics providers encounter when transporting heavy equipment and oversized loads through communities, between states, across borders, and around the world. Every project move is unique and companies routinely find themselves in a trial-and-error cycle as they plan for the unexpected, learn from experience, and continue to perfect the process" (O'Reilly, 2012). Moving large loads is complex, especially with the permitting and planning which stands true to transport modules across state and national boundaries. In addition, working with government officials and coordinating transporting units on public roads can potentially alter plans. The strategy required to overcome these possibilities includes developing alternative strategies to alleviate the risks associated with a singular course of action.

According to Bradford (2009) key elements of the Logistics and Transportation Plan include route identification, constraints, transportation envelope, and schedule availability. Furthermore, the responsibility for logistics contingency planning is the key to being prepared. Designating an entity as sole point of contact responsible for coordination and transportation including logistics contingency planning is important. Appropriate authority must be given to coincide with designated responsibility (Bradford, 2009). Various considerations are necessary to take into account in planning alternate strategies. According to Red Prairie (2007) these may include:

- Total delivered cost management:
  "Ability to analyze and predict the total supply chain costs from the source to the point of distribution. It includes the capability to roll up both international and domestic logistics costs by product and delivery route, plus the ability to accurately calculate all the applicable duty, tariffs and other customs-related costs while factoring in any preferential trade agreements. More advanced capabilities would include the ability to model and estimate inventory levels and total carrying costs" (RedPrairie, 2007).

- Global logistics process automation:
  "Transitioning from manual intensive processes and adopting such things as internet-based transaction automation technology" (Aberdeen, 2006).

- End-to-end visibility:
  "Increased visibility of logistics process steps creates control" (AberdeenGroup, 2006).

- Supplier portals and Advance Ship notice capability:
  "Web portals that provide some level of visibility, the ability to generate ASNs, and print bar code labels. Shippers post freight movement requests and/or detail ASN notices delivered" (RedPrarie, 2007).

- Total product identification and regulatory compliance:
  "Systemized approach to identify products and ensure conformance to regulatory and export rules" (RedPrairie, 2007).

- Dynamic routing:
  "System modeled rates/lanes give realistic view of cost/service advantages between shipping alternatives" (RedPrairie, 2007).

- Variability management:
  "Ability to manage in-transit exceptions more effectively" (RedPrairie, 2007).

- Integrated international and domestic workflow:
  "Reduction in total logistics costs through a more holistic approach to process and carrier/mode coordination across international and domestic moves" (RedPrairie, 2007).

- Integrated planning and execution platform:
  "End-to-end, optimized global logistics control and cost minimization" (RedPrairie, 2007).

- Financial supply chain management:
  "Financial Supply Chain Management is about looking at how to optimize working capital of a company "(Kristofik, et al, 2012).

Discussion

Notwithstanding the apparent comprehensive approach outlined above, the product of the effort described has proven in the oil sand project that encountered a $2 Billion overrun to be insufficient to ensure module deliveries that will support project milestones and detailed schedules as evidenced by the problems associated with the lack of alternative route planning. Alternative route planning is required based on a history of unanticipated problems associated with public relations and governmental roadblocks based on community interests, environmental interests, and political will, or lack thereof. In addition legal action taken by project obstructionists with differing agendas can also complicate matters and impede project progress. Therefore, it is essential to have alternate strategies in place, i.e. Plan B, C, and D, to the extent necessary to ensure success.

Additionally, in due course of the research, one of the biggest constraints for this study is the hesitation by large corporations to release details of losses encountered by a lack of logistics planning, due to privacy concerns.
Due to the lack of specific research into this area, the aim of the paper was to serve as a starting point for an exploration of critical factors associated with mega projects. The factors identified in this study do not operate in isolation and each one of them together helps form an integral component of the general logistics associated with mega-projects. Identifying these factors is just the beginning to better understand the bigger picture associated with the general logistics of mega projects. Each of these areas is a specialization and merits a detailed study in order to investigate the impact of each identified factor on the overall success or failure of the mega projects.

Benefits and future research

If the identified factors are addressed during the planning stage of the projects, the probable occurrence of the incidents as observed in the preceding sections will be reduced. Thereby impacting the overall success of the project for all the stakeholders associated.

Regarding future research, selective study of individual elements of logistics and transportation plans identified herein would be worthwhile for application to the collective knowledge of enhancements that can improve schedule and reduce costs to ensure project milestones are achieved and budgets are under control. In addition, another prospective study would aim at combining the regional and global factors and then reviewing them by industry experts for their comprehensiveness.

In-depth research needs to be conducted on all aspects of logistics planning for large scale construction projects in order to gain a better understanding of the intricate details of these factors that affect the outcome of such projects for the potential immediate benefit of companies involved, as well as to better educate and equip future workforce with necessary skills to navigate issues like these involved in mega projects.

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