A Conceptual Cost Comparison Study between Alberta and Overseas Module Assembly Strategies for Industrial Construction Projects

by

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Abstract

In recent years, the lower cost of construction resources in overseas countries (e.g. China and Korea) and advancements in transportation have increased the interest in offshore fabrication and assembly of industrial modules as an alternative to local assembly in Alberta, Canada. Many research studies have addressed the differences between modular and conventional methods of construction and developed decision support tools to assist the management team in selecting the best construction method. However, no study has investigated the effect of overseas fabrication and assembly on the cost of modular construction projects. This research study attempts to facilitate the performance of cost comparison at the conceptual stage between the local and foreign fabrication and assembly of industrial modules. In this study, the cost items required for conducting conceptual cost comparisons between the Alberta and overseas module fabrication and assembly are identified by interviewing experts in modular industrial construction. Moreover, a new method is proposed to investigate the differences between the Alberta and overseas fabrication and assembly of modules in terms of module quantity and required material. Furthermore, a statistical simulation model is developed to perform a cost comparison study between Alberta and overseas module assembly that can be used in future conceptual cost estimations of similar projects. This research assists project managers in comparing alternative assembly locations in industrial modular projects by providing a list of cost items, conducting a comparison between local and overseas module construction on two industrial projects, and developing a simulation tool for performing cost comparison studies on such projects.

To my dear parents

And my loving husband, Arash,

Without whom none of my success would be possible.

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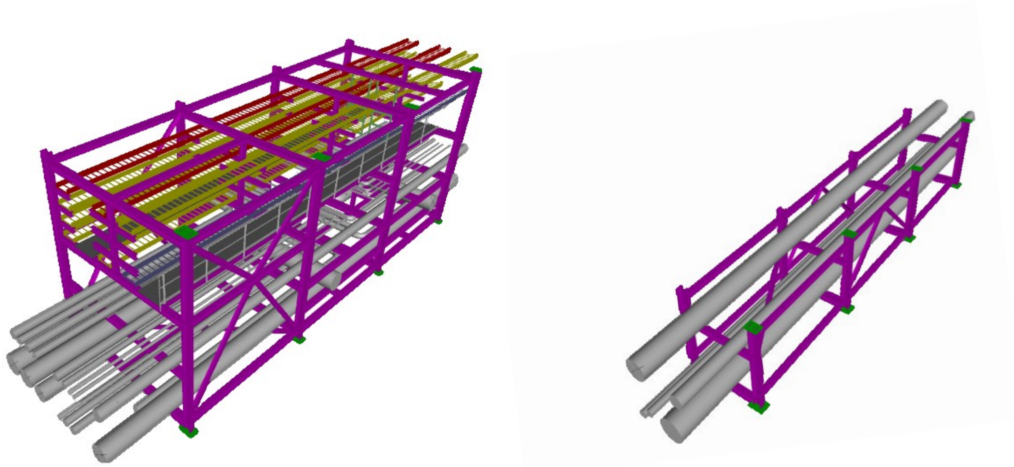
Introduction

1.1 Background

A study conducted by the US Energy Information Administration in 2013 predicts a 56% growth in the world's energy consumption between 2010 and 2040 (EIA 2013). This dramatic increase in the need for energy supplies requires an expansion of energy assets worldwide, as well as in North America (Business Wire 2011). *Industrial Construction* is a common term used in the construction of energy supply facilities such as oil and gas production facilities, nuclear power plants, and petrochemical plants (Sadeghi & Robinson Fayek 2008). Due to the large concentration of oil sands in northern Alberta, Canada, a significant number of industrial construction projects take place in this region every year. The vast majority of the oil sands can be found in the Athabasca sands surrounding the town of Fort McMurray, the Cold Lake sands to the southeast, and the Peace River sands to the west. 315 billion barrels of potentially recoverable oil are stored in these deposits. Mining procedures can be used to recover oil sands located within 75 m of the surface, while deeper deposits require in situ technologies. Only 20% of the oil sands in Alberta is recoverable by mining procedures and the rest is recoverable through in situ production (Jergeas & Van der Put 2001; Jergeas 2008; Bedair 2013).

Modularization is one of the popular methods used in industrial construction in Alberta due to the associated benefits, which include enhanced cost savings and schedule and improvements to safety and productivity in the harsh weather conditions of this region. Numerous industrial modules are fabricated and assembled in fabrication shops and assembly yards located in Edmonton, Alberta every year and are transported by highway to the construction sites in northern Alberta. Due to limitations in highway transportation regulations, the size of these modules is restricted to 24 ft. wide x 25 ft. high x 120 ft. long. This limitation is identified from experts in industrial modular construction (R. Hermann, personal communication, 2015). The limitation in size results in these modules being dubbed *Alberta-Sized Modules*, which are referred to as AB-modules in this thesis.

In recent years, several industrial projects have been carried out with modules fabricated and assembled overseas, in countries such as China and Korea, and transported to Alberta through ocean, railway, and highway transit. The primary motivation behind this decision is the lower labor rates and construction costs overseas compared to Canada. However, due to the particular type of transportation used for transferring these modules, extra considerations are required for this modularization scenario. Since these modules are shipped over the ocean, their size is restricted to ocean transportation regulations, limiting the modules to 13 ft. 5 in. wide x 13 ft. 5 in. high x 80 ft. long. This limitation is also identified from experts in industrial modular construction (R. Hermann, personal communication, 2015). Due to the smaller size of these modules, they are named *Mini Module*s and are referred to as M-modules in this thesis. Figure 1.1 illustrates the size difference between AB- and M-modules.



a. AB-module: maximum size 24 ft. wide x 25 ft. high x 120 ft. long

b. M-module: maximum size 13 ft. 5 in. wide x 13 ft. 5 in. high x 80 ft. long

Figure 1.1: Illustration of the size of an (a) AB-module and (b) M-module

The smaller size of the M-modules leads to several differences between Alberta and overseas module fabrication scenarios. For instance, AB-modules are more flexible in size and spacing for pipe spools and equipment, but they contain larger and heavier components that make them harder to handle. On the other hand, M-modules have smaller and lighter elements that are easier to handle. However, larger quantities of M-modules are required for a particular project when compared to the required quantity of AB-modules. This increase in the quantity of modules impacts the cost of fabrication, assembly, and site operations. Moreover, the shipment cost of M-modules is different from AB-modules due to the intermodal transportation required for transferring M-modules to the construction site. These differences lead to a cost trade-off between the lower construction rate of modules overseas and the additional costs related to the installation of a higher quantity of M-modules. Therefore, a comprehensive comparison at the conceptual stage is required between AB- and M-modules to identify the most cost-effective scenario. Furthermore, additional risks and considerations associated with overseas fabrication and assembly should be identified to prevent rework, schedule delay, and cost overruns.

A familiar example of the importance of conceptual studies and identification of potential risks in this type of project can be illustrated by the Kearl Oil Sands Project. This project, which was recently launched in the Athabasca Oil Sands region, has suffered from several problems, including schedule delays and cost overruns, during first-phase construction. In this project, modules were fabricated and assembled in South Korea and shipped to the construction site in Canada. The initial plan was to ship modules across the Pacific Ocean to the United States and from Idaho and Montana to the construction site in Alberta by river barge and truck. However, due to the Korean-made modules being larger than the regulation limits, transportation permits could not be obtained. Therefore, after spending months in an Idaho port, the modules were disassembled and transported to Alberta in smaller pieces and reassembled in module yards in Edmonton. This process not only caused schedule delays and cost overruns for the owners, but also decreased the construction performance, as a result of disassembling and reassembling the modules (Lewis 2014; Krugel 2013; Tait 2012).

The above example demonstrates the importance of performing conceptual studies to avoid schedule delays and budget overruns in modular construction projects. Due to the immense complexity of these types of projects, a comprehensive conceptual study is mandatory to compare the cost and duration of all possible choices of onshore and offshore fabrication and assembly by considering the limitations and risks in different phases of the project. In this way, the best construction method, with respect to both cost and schedule, can be selected for the project. This conceptual study should include consideration of several options of fabricating and assembling modules in Alberta versus overseas, which are outlined below:

- Option 1: Perform fabrication and assembly in Alberta shops and transfer assembled modules to the construction site.
- Option 2: Perform fabrication overseas, ship fabricated components to Alberta, perform assembly in Alberta assembly yards, and transport assembled modules to construction sites.
- Option 3: Perform fabrication and assembly overseas and ship assembled modules to construction sites.

The decision on the assembly location should be made as early as possible in the conceptual studies, as it significantly affects the final size of the modules. Based on the conditions explained above, performing fabrication and assembly overseas can be a new approach to modularization. However, due to added complications, risks, and uncertainties, the feasibility and cost implications of this scenario should be carefully investigated and compared to other options to determine the best solution.

1.2 Problem Statement

In order to perform a thorough conceptual study, management requires certain parameters and cost items to decide between the different possible options of fabrication and assembly of modules. A review of the literature shows adequate research on developing decision-making tools and guidelines to assist the management in identifying the best construction method between modular and conventional design (Fisher & Skibniewski 1992; Murtaza et al. 1993; Hass et al. 2000; Cigolini & Casteliano 2002). Since the decision is typically made based on the cost advantages of each technique, several cost items have been identified for performing cost comparison studies between modular and stick-built design. In spite of this, no study has been done on the differences between various scenarios of local and offshore module construction. Moreover, additional cost items that should be considered in cost comparison studies between the different modularization scenarios have not been identified. Last, but not least, no decision support tool or guideline has been developed to compare feasible options involving modular construction to identify the most effective one. Therefore, a research study is required to bridge the gap in the existing body of knowledge and determine the effect of overseas fabrication and assembly of industrial modules on construction projects, and identify the required cost parameters and risk factors.

1.3 Objectives

This thesis work aims to facilitate conceptual studies and cost estimations for modular industrial projects involving Alberta-sized or mini-sized modules. The following outlines the objectives of this thesis:

1) Identify the factors affecting project cost that must be considered during the conceptual stage of the project. The total cost is the main decision criteria in many industrial modular construction projects. Therefore, this research investigates the effects of overseas assembly on cost, rather than on project duration.

2) Propose a new method to investigate the differences between the Alberta and overseas fabrication and assembly of modules in terms of module quantity and required material. The scope of this research has been defined to study structural steel as the required material for the modules.

3) Devise an elegant method for converting AB-modules to M-modules and compare these two scenarios in terms of module quantity and required materials, to be used the conceptual studies.

4) Develop two statistical models (i.e. frequency distributions) for the structure weight of AB-modules and M-modules. These statistical models would serve as decision support tools for estimating the module structure weight for future projects.

5) Develop separate regression models for the cost of module fabrication and erection in Alberta with the module structure weight as the input variable.

6) Develop a statistical simulation model to assist planners in conducting conceptual cost estimations and performing cost comparison studies between different scenarios of fabrication and assembly in Alberta and overseas. This simulation model focuses on the estimation of the fabrication and erection cost of the module structure.

1.4 Methodology

The objectives outlined above will be achieved using the following methodology:

a) To achieve the first objective, interviews were conducted with experts and professionals in general management, engineering, and cost estimation in heavy industrial construction. The results of the interviews were analyzed and categorized for multiple cost items.

b) The second and third objectives were achieved by analyzing the 3D models and module drawings of two industrial modular projects designed to meet Alberta size requirements. By reviewing the industrial module design guidelines and interviewing module design experts, a method was developed to convert AB-modules into M-modules to develop a scenario of overseas assembly for the two projects. Another method was also developed to identify the differences between Alberta and overseas fabrication and assembly of modules. Using these two methods, the differences in module quantity and the required structural steel between AB-modules and M-modules was investigated for the industrial projects.

c) To achieve the fourth objective, frequency distributions of module structure weights were developed for the two industrial projects based on the previously determined structural steel requirements for AB-modules and M-modules.

d) The fifth objective was accomplished by applying fabrication and erection cost data in Alberta to AB-modules. This cost data is gathered by conducting interviews with cost estimation experts for industrial modular projects.

e) In order to fulfill the sixth objective, a statistical simulation model was developed using the General Purpose Template in Simphony, a platform used for developing complex simulation models developed in the Department of Civil and Environmental Engineering at the University of Alberta.

1.5 Thesis Organization

The remainder of this thesis is organized as outlined below:

Chapter 2 provides a thorough literature review on the modularization method and its applications in the construction industry. The studies conducted on decision-making tools for modular construction projects are investigated and knowledge gaps are identified. Moreover, a comprehensive review is carried out on the design process of the structure of industrial modules.

Chapter 3 describes important cost items in heavy industrial modular projects, with a focus on the projects including overseas modules. These cost items should be considered when performing cost comparison studies between Alberta and overseas assembly during the conceptual stage of the project.

In **Chapter 4**, a new method is presented that investigates differences between Alberta and overseas fabrication and assembly of modules. Additionally, a straightforward method is developed to convert the AB-modules into M-modules. These methods are applied to two heavy industrial modular projects, using Alberta-sized modules, to demonstrate their application in the construction industry by converting the AB-modules into M-modules and performing a comparison of the module quantities and required structural steel for each construction option. Furthermore, two statistical models (i.e. frequency distributions) are developed for the structure weight of AB-modules and M-modules.

Chapter 5 provides two separate regression models for the fabrication and erection cost of AB-modules. In addition, a simulation model is presented to estimate the cost of fabrication and erection based on the structure weight of the modules. A hypothetical case study is also provided to demonstrate the use of the simulation model in performing cost comparison studies for forthcoming projects.

Chapter 6 recapitulates the academic and industrial contributions of this study, provides the conclusions of the current thesis, and offers recommendations for future research.

Appendices A-C provide additional detailed information regarding the AB- and M-modules studied in this thesis.

Chapter 2: Literature Review

The first section of this chapter provides a review of the literature on the modularization technique, the decision-support tools used in modular projects, and the cost items to be considered in modular projects. Moreover, the research studies conducted on the cost estimation of construction projects at the conceptual phase are reviewed and presented. This section demonstrates the gap of knowledge that exists in the conceptual cost estimation of modular industrial projects and demonstrates the necessity of this study. The second section of this chapter focuses on the structure of industrial modules, provides a review of the characteristics of these structures, and elaborates upon module design steps and considerations. An overview of the current practice in module structure design is provided and is the basis of the module design in Chapter 4.

2.1 Identification of the Knowledge Gap in Conceptual Cost Estimation of Modular Construction Projects

2.1.1 Modularization

The concept of modularization has been used in the construction industry since the late 1950s when skid-mounted gas processing plants and compressor stations were widely used. The initial reason for implementing this method was to decrease the construction cost at the site. However, this technique was later used for construction in remote and sparsely populated areas, including off-shore and arctic regions (Kliewer 1983). O'Connor et al. (2014) have collected the following definitions of terms used in this method from previous research studies. These are given below:

> **Modularization:** "The pre-construction of a complete system away from the job site that is then transported to the site. The modules are large and possibly may need to be broken down into several smaller pieces for transport." (Hass et al. 2000)
>
> **Module:** "A major section of a plant resulting from a series of remote assembly operations and may include portions of many systems; usually the largest transportable unit or component of a facility." (Tatum et al. 1987)
>
> **Pre-fabrication:** "A manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation." (Tatum et al. 1987)
>
> **Pre-assembly:** "A process by which various material, pre-fabricated components and/or equipment are joined together at a remote location for subsequent installation as a unit. It is generally focused on a system." (Tatum et al. 1987)
>
> **Offsite fabrication:** "The practice of pre-assembly or fabrication of components both off the site and onsite at a location other than at the final installation location." (Construction Industry Institute (CII) 2002)

Modularization is often used in construction projects to improve project performance. This technique is usually implemented in harsh project environments, such as severe weather conditions and inaccessible site locations (Murtaza, Fisher, and Skibniewski 1993). Transferring fabrication and assembly of industrial structures to safer places, namely fabrication shops and assembly yards, not only increases productivity, but also enhances quality control and quality assurance by transferring work to a more controlled area. In addition, by performing on-site work in parallel with assembly work, project schedules improve substantially. Another important benefit of this method, which makes it popular amongst construction managers, is the decrease in overall project cost. Due to lower local labor rates, increased work efficiency and productivity, and reduced need for large on-site camp facilities, overall project costs are decreased. Moreover, modularization results in a more cost-effective selection of fabricators and expands this selection to offshore options. In addition, transferring the module assembly job to fabrication shops leads to more automated performance compared to the construction site (Perkowski 1988; Glaser & Kramer 1983).

In spite of these advantages, the modularization technique has several drawbacks compared to conventional design. The modularization method requires more engineering for designing modules, more material and additional work for assembly, and additional transportation and lifting operations (Murtaza et al. 1993; O'Connor et al. 2016). Although these disadvantages result in additional costs when compared to stick-built methods, overall project cost can still be lower as a result of the cost reductions associated with the implementation of modularization techniques. An early study on modular projects demonstrated an 8% to 10% decrease in capital cost of modular plants compared to conventional, stick-built plants (Kliewer 1983). In this case study, project schedule was reduced by 3 to 4 months compared to a stick-built project, with project duration reduced from 36 to 32 months. This timeline reduction resulted in a decrease of an additional 2% to 3% of the installed cost by saving interest.

2.1.2 Decision-Support Tools in Modularized Projects

Over the past decades, several research studies have been conducted to provide decision support tools and frameworks that assist construction managers in making the final decision of whether or not to apply modularization in a project (Song et al. 2005). Fisher and Skibniewski (1992) developed a DOS-based expert system, called MODEX, which enabled users to determine the feasibility of applying modularization to a particular power or process plant project. This research identified several factors that influence the decision between modular or stick-built construction. The MODEX system performed a feasibility analysis considering five categories of influencing factors and determined the feasibility of using modularization techniques. MODEX could also be used for performing an economic analysis to determine the approximate increase or reduction in cost as a result of applying modularization to the project (Murtaza et al. 1993).

A modified version of MODEX, called Neuromodex, was later developed by implementing a neural network to consider uncertainties and incomplete data (Murtaza & Fisher 1994). The inputs of this new system were the same factors previously identified for MODEX and the output was the selection of a construction method. Comparing the results of this system with the opinions of construction professionals validated the accuracy of the system.

A later study done by Cigolini & Casteliano (2002) proposed a quantitative model to fill the gap between the predicted economic results of MODEX and the actual project estimates by determining the cost difference between modular and stick-built methods. In this model, the cost items related to modular construction (e.g. the facility cost, transportation costs, and the cost of consumable resources, such as electric power and water) were identified in the first step. These cost items were then classified based on the criteria of the project location (e.g. module yard or final site) and quantified based on basic module characteristics (e.g. module weight and size, pipe material, equipment, and required labour hours). The resulting costs of the modular and stick-built approaches were subsequently determined and compared for each category (Cigolini & Casteliano 2002).

While several studies have developed decision-support tools that assist management in choosing between conventional and modular construction methods, no studies have examined the effect of module assembly location on project cost. Consequently, no decision-support tools have been developed to allow comparison between the costs associated with local and overseas module fabrication and assembly.

2.1.3 Required Cost Items and Parameters in Modular Projects

In 2007, Jameson conducted a case study of a modularized gas oil hydrotreater (GOHT) project and identified factors and parameters that should be considered when performing a cost comparison between conventional and modular construction methods (Jameson 2007). The factors and parameters identified in this study included module size, specific design criteria at the engineering phase, schedule, labor requirements, labor productivity, amount of structural steel required, shop versus field assembly hours, insulation and fire proofing, schedule extension and indirect field costs, foundation design and installation costs, and transportation and crane costs.

O'Connor et al. (2015) summarized several studies, ranging from academic studies to industry practices, and classified the differences between conventional and stick-built methods into seven categories. These included organization and staffing differences; planning, communication, and alignment differences; early decision differences; cost analysis differences; design differences; shipping limitation considerations; and detailed design deliverables differences (O'Connor et al. 2016).

These previous studies provide an important groundwork for understanding the factors that must be considered in modular industrial projects. However, a review of the current literature identifies a lack of research studies in cost comparison between local and overseas fabrication and assembly, as well as the identification of the parameters required for conceptual cost estimations of such projects.

2.1.4 Conceptual Cost Estimation

Numerous studies have been conducted on conceptual cost estimation in construction projects. In 1998, Powell and Federle developed a computer program to construct conceptual cost models of building projects (Powell & Federle 1998). This program provided accurate ranges of building costs based on statistically calculated price ranges. In 2002, a study was conducted to evaluate the accuracy of cost estimates at different levels of design maturity (e.g. concept, preliminary, detailed, and award) in municipal government construction projects (AbouRizk et al. 2002). This study concluded that estimates are not as accurate as commonly believed. Sonmez (2004) presented the advantages and disadvantages of various conceptual cost estimation methods and developed regression and neural network models to estimate the conceptual cost of a case project, concluding that both modeling techniques provided reasonably precise cost estimates. A new model for conceptual cost estimation, called the Principal Item Ratios Estimating Method (PIREM), was proposed in 2006. This model integrated several conceptual estimating methods (e.g. ratios estimating, parametric estimating) with advanced nonlinear mapping techniques (Yu 2006). By applying this method to two case studies, it was concluded that accurate estimates can be provided using PIREM, with incorporation of advanced mapping technologies. An et al. (2007) proposed a support vector machine (SVM) model for assessing the quality of conceptual cost estimates. The results of the study showed that the SVM model can be used in construction to evaluate quality of the estimated cost and probability of exceeding target cost. Jrade and Alkass (2007) proposed a methodology to perform an integrated conceptual cost estimation and life-cycle cost analysis for construction projects during the initial phase. In 2010, Cheng et al. proposed an artificial intelligence approach to improve conceptual cost estimate precision called the Evolutionary Fuzzy Hybrid Neural Network (EFHNN). The results of this study indicated that EFHNN can be utilized as an accurate cost estimator during the early stages of construction projects. Ji et al. (2010) suggested a statistical methodology for data preprocessing and developed a statistically preprocessed data–based parametric (SPBP) cost model to be used during the conceptual phase. This model was utilized in case studies of building construction and showed accuracy and reliability in the cost estimation results (Ji et al. 2010). Kim and Shim (2013) proposed a hybrid genetic algorithm (GA) case-based reasoning (CBR) system that integrated the CBR approach with GA to predict the preliminary construction cost of high-rise buildings. Hyari et al. (2015) presented an artificial neural network model for the conceptual cost estimation of engineering services in public construction projects. This model complements existing models that focus on construction cost estimation by factoring in the cost of engineering services (Hyari et al. 2015).

The review of the related literature demonstrates a lack of studies on conceptual cost estimation requirements in modular industrial projects. Although several methodologies have been used to estimate project costs at the conceptual phase, no application was found in the literature regarding the performance of conceptual cost estimation for industrial or modular construction projects.

2.1.5 Summary of the Literature Review

The reviewed literature demonstrated an adequate amount of research on modularization techniques, the advantages and disadvantages of the modularization method, and the appropriate application of this method. Moreover, several decision-support tools and methodologies have been developed to assist management in selecting between modular and conventional methods of construction. However, no research studies have been done that include overseas module assembly as a possible option during the decision-making phase.

Further review of the literature identified project cost as a determinant factor in the choice of construction method. Several cost items were identified in the literature that should be considered in the cost comparison of conventional and modular design. However, no cost items were found related to overseas assembly of industrial modules. As the decision on the construction method (between modular and conventional or between overseas and local assembly) should be made at the conceptual phase, a literature review of conceptual cost estimation in construction projects was conducted. This review demonstrated the application of various methods (e.g. linear regression, neural network, genetic algorithm, and fuzzy logic) in estimating project cost at the conceptual phase. In these studies, conceptual cost estimation was performed on different types of construction projects, including buildings and infrastructure projects. However, no studies were found on conceptual cost estimation of industrial modular projects. Therefore, a study is required to investigate cost differences between industrial fabrication and assembly of modules in Alberta and overseas. This study should also identify the required cost items for conceptual cost estimation for such projects. These cost items can subsequently be used to perform cost comparison studies between Alberta and overseas module fabrication and assembly to identify the most cost-effective construction method.

2.2 Structure of Industrial Modules

In general, the main structure of a module is constructed of steel, reinforced concrete, or a combination of both (Dehghan et al. 2008). As casting and curing concrete is a time-consuming process and is not practical in severe weather conditions this material is unsuitable when modularization is used. On the other hand, steel elements do not require a curing process and are instantly at full strength. They also have more strength compared to a concrete component of similar weight, show uniform quality, and have low life-cycle costs. The numerous advantages of steel over other materials make it the first choice of designers and construction managers in heavy modular projects.

Although applying the modularization technique to a construction project considerably reduces the total project cost, a substantial increase in steel quantity is expected. The required steel quantity in heavy modular projects increases by almost 30% compared to stick-built designs and additional costs are necessary for assembly and transportation. However, substantial repairing and rework costs will be eliminated (Bedair 2015). To minimize construction errors, Bedair (2015) advocated for detailed structural drawings of all modules to consider assembly and erection processes..

The following section describes modular elements, the design process, and other considerations regarding the structure of industrial modules.

2.2.1 Module Elements

Module size (length, width, and height) is constrained by limitations of transportation regulations. All modules, including pipe rack, cable tray, equipment, and stair modules, must be designed with consideration of these constraints. In the case of a module that is larger than the limitations (multilevel module), it should be divided into smaller modules, which are then assembled at the construction site (Hua 2014).

The structural system of a module comprises several frame grids, including transverse beams and columns, known as bents, which are attached by longitudinal beams, known as struts. Adequate space beneath the module is required to allow maintenance access and road crossings (Bedair 2015). To improve accessibility, bents are generally moment-resisting frames that support both gravity loads and transverse lateral loads. Instead, vertical bracings are placed in the longitudinal plane to make a braced frame and to resist longitudinal lateral loads (Drake & Walter 2010). Unlike vertical bracings, horizontal bracings are not mandatory in module design. These bracings are occasionally used to secure the structure by restricting lateral displacement during lifting and transport. Vertical pipes and large equipment inside modules should be considered during the design of horizontal bracings to identify the appropriate bay to place them (Bedair 2015).

Service platforms are another essential part of the modules and are incorporated in the design at various elevations to provide maintenance access during operational or shutdown periods. These platforms can be designed either internally or externally—that is, connected to the transverse beams or connected to the sides of the module. The live load on service platforms during operation time should be considered in the module design (Bedair 2015).

Multilevel modules are modules with greater height than the transportation regulation limits. These modules must be divided into smaller modules, which are lifted and stacked at the construction sites. To facilitate this process, base plates are welded to the module columns. By aligning these base plates during the lifting operation, different sub-modules of the main multilevel module can be stacked on top of each other. Horizontal bracings stabilize and align modules during this process. Typically, modules need four to eight lifting points, which should be specified by the design engineer on the drawings, along with the load distributions at each lifting point. Moreover, the module structure should be designed with consideration of the impact condition resulting from the installation process. The weight and centre of gravity of each module, including all components, must be indicated on the structural drawings (Bedair 2015).

2.2.2 Load Conditions

A review of steel design codes demonstrates the lack of a comprehensive design code for steel structures in heavy industrial applications. A considerable number of the current design criteria used by practicing engineers are established by private EPC companies. However, as technical justifications are ignored in some design philosophies, these specifications have limited applications and are not valid for all design conditions. In some cases, the loading pattern applied to some modules differs from the standard patterns defined by engineering codes, requiring greater knowledge and experience of the designers (Bedair 2015).

Load types and load paths of modules are different from stick-built conditions; additional operations required for modules such as lifting, transportation, and installation are the source of these differences (Hua 2014). The following is a brief description of the load types applied to industrial modules (Drake & Walter 2010; Bedair 2015):

- **Dead loads** include the weight of all materials, such as steel structures, piping, valves, fitting equipment, insulation, and fireproofing.
- **Live loads** are produced by operation and occupation of the modules, including temporary loads during construction, operational loads, and maintenance loads.
- **Thermal loads** are self-restraining forces caused by contraction or expansion of members resulting from ambient temperature changes.
- **Anchor loads** arise from the reactive forces on attached steel members resulting from restraints on pipe displacement or rotation during operation conditions.
- **Friction loads** “arise from the sliding of pipes due to the thermal expansion during the operating conditions” (Bedair 2015). These forces act on the attached steel member horizontally.

- **Wind loads** are determined based on the National Building Code (NBC) Section 4.1.7, Division B in the process of designing modules for oil sands projects.
- **Snow loads** are determined based on NBC Section 4.1.7, Division B in the process of designing modules for oil sands projects.
- **Impact loads** arise during the transport and should be applied at the centre of gravity of modules. Unfortunately, no design code in North America provides information regarding this load type.

2.2.3 Connection Types

Several connection types can be used to attach module bents and struts in fabrication shops. In general, an end plate connection is used to bolt the transverse beams to the columns. Shear tab connections are commonly used in oil sands projects, as the fabrication of these connections is simpler than welded connections. Also, welded connections have an increased fabrication cost and are not appropriate for such projects. Since the loads on struts are smaller than those of the transverse beams, it is possible to release the moments at the beam to the column connections in the structural model analysis. Therefore, pinned connections are normally used to attach longitudinal beams to the columns (Bedair 2015).

The connections of the industrial modules are generally designed by the steel fabricators. However, these connections should be consistent with the design assumptions in the structural analysis model generated by the structure designers.

Loading diagrams presenting the critical connections should also be provided by the designers in the structure drawings (Bedair 2015).

2.2.4 Coating and Fireproofing

A coating is applied to the steel structure of the modules to protect the structure against corrosion. The coating type is usually indicated by the client to be compatible with the rest of the facility. Different types of coating are available for module structures, as follows (Drake & Walter 2010):

- **Paint** has a high life-cycle cost compared to other coating types. It can be applied at either a fabrication shop or construction field.
- **Hot dip galvanizing** is the most common coating in oil sands projects as a result of its low life-cycle cost. However, due to the safety issues associated with welding galvanized material, field welding is excluded in this case.
- **Hot dip galvanizing and painting** is a combination of both coating types and is applied in extremely corrosive environments.

Fire protection systems can be either passive or active systems. Active systems, such as water spray systems are less common in oil sands projects, whereas passive systems, such as spray-on cementitious coatings, intumescent coatings, normal-weight concrete, and light-weight concrete, are more common in such projects. Notably, the stiffness of fire-proofing materials should not be considered for load resistance and member size changes can be neglected in the structural analysis model. However, the additional dead load and wind load, due to the increase in member size, should be included in initial module design (Drake & Walter 2010; Bedair 2015).

Coatings and fire protection are two separate systems and are used for different purposes. Fire protection materials should not be considered for use as coatings, since they will accelerate corrosion if applied inadequately (Drake & Walter 2010).

2.2.5 Fabrication and Erection of Industrial Modules

In the systematic process of fabrication, steel items, such as beams, columns, and plates, are produced in a controlled shop environment. The fabrication shop consists of various sections, such as the cutting station, fitting/welding station, and painting/sandblasting station. Different types of cutting machines are used to divide different elements (e.g. beams, angles, and plates). After completing the fitting and welding activities, all products are inspected for quality control purposes and the elements that require painting or sandblasting are transferred to the related stations. Each fabrication shop may be equipped for a special type of procedure, such as light or heavy products (Azimi et al. 2011). The erection process includes connecting fabricated pieces together at the assembly yard or construction site. A common problem during erection is that the centerlines of columns do not line up with the centerline of the anchor bolts. This problem can be prevented by the fabricator by insisting on a survey of the anchor bolt locations prior to fabricating the frames (Azimi et al. 2011).

Chapter 3: Cost Items

The difference in size between AB-modules and M-modules causes a change in both the quantity and weight of required components and modules, which directly affects the total project cost. The decision on the fabrication and assembly location should be made in the initial phases of the project, as it greatly influences the module design, as well as the project cost and schedule. There are several possible options for fabrication and assembly locations that should be studied carefully in the conceptual phase, including fabrication and assembly in Alberta, fabrication overseas and assembly in Alberta, and fabrication and assembly overseas. A combination of these options is also possible; for example, with steel fabrication done overseas and pipe spool fabrication and assembly in Alberta or the reverse. All feasible options should be considered at the conceptual stage and studied carefully to conduct a valid and comprehensive cost comparison study. This chapter outlines the cost items that should be considered in conceptual cost studies for industrial modular projects, including overseas fabrication and assembly. These cost items were identified by interviewing experts with high experience in industrial modular construction (R. Hermann, G. Trigg, A. Gare, R. Kukkola, S. Hemmati, P. Tawfik, N. Koo, personal comminucation, 2015). By interviewing each expert, new factors were identified and previously determined factors were validated. The following is a description of the cost items required for such cost comparison studies.

3.1 Fabrication

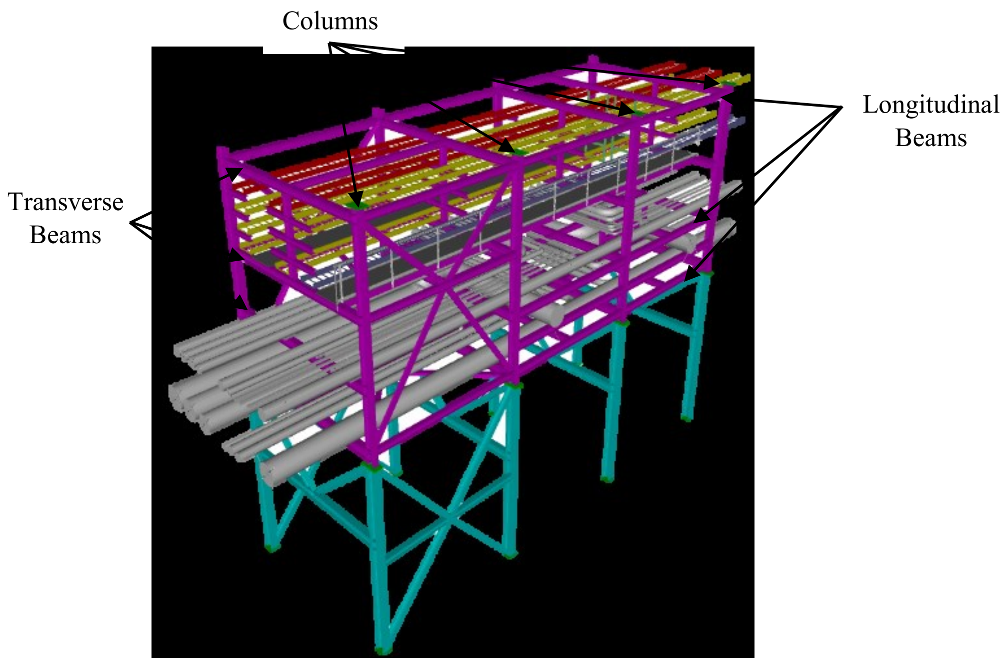
In industrial modular construction, the fabrication of structural steel and pipe spools is the dominant part of construction procedure in terms of cost and schedule. The fabrication operation consists of various activities that transform raw material into steel and pipe spool components. These components are later assembled in assembly yards and used to construct final modules.Additional considerations must be taken into account when performing fabrication overseas, for both steel components and pipe spools. Although the major fabrication activities are similar in steel and pipe spool fabrication shops, each has its own characteristics.

3.1.1. Steel Fabrication

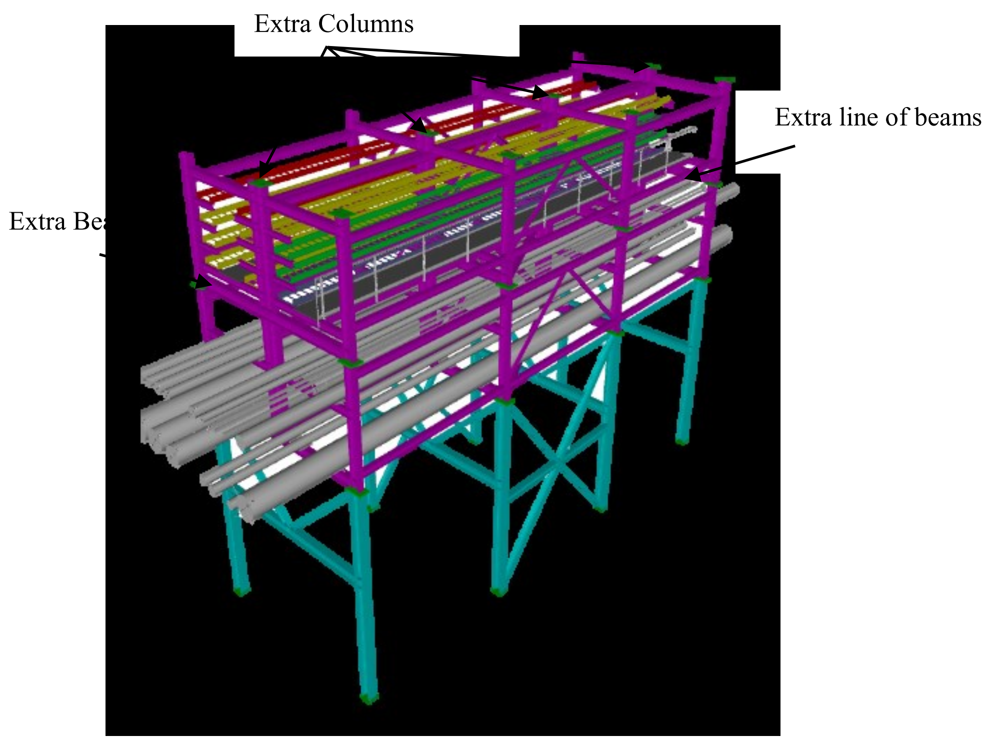
The process of fabricating steel items such as beams, columns, plates, and horizontal and vertical bracings includes various steps. First, steel pieces are cut to desired measures at cutting stations and the required parts are then connected at fitting/welding stations, based on shop drawings. Normally, there are several fitting/welding stations at fabrication shops, as this is the most time-consuming part of fabrication. Final pieces are painted and sandblasted at the last station and after completing inspection, they are transferred to the assembly yard (Azimi et al. 2011).

Due to the size limitation for overseas assembly, the pipe layout must be divided into smaller modules, resulting in a larger quantity of modules (dubbed mini-modules or M-modules) for a particular project. Therefore, smaller steel items in greater quantities are required for the M-module structure. To assure the stability of the structure, additional beams and columns are required for M-modules. Figure 3.1 displays two different module sizes satisfying identical design requirements. The AB-module in Figure 3.1a can be replaced with a set of four M-modules demonstrated in Figure 3.1b. The stability of the AB-module is provided by using three levels of longitudinal beams, four transverse beams in each frame, and eight columns. However, the M-module set requires four levels of longitudinal beams and five transverse beams in each frame, two extra sets of longitudinal beams, and two additional lines of columns. The extra beams in M-modules are required to add stability to the structure and prevent lateral movement during transportation and lifting operations. Although the weight of each steel item in the M-module is lower compared to the AB-module, the greater quantity of elements may result in a greater overall structure weight.

Due to the limited height of M-modules, additional splice connections are required to connect the columns in the module. Extra cross-bracing and moment connections may be required for M-modules, as they have fewer layers to stiffen the structure. The greater quantity of elements in M-modules results in a higher number of connections and welding. Since the connections are designed in fabrication shops, in the case of overseas-fabricated steel components, special attention should be given to the designated bolt sizes to ensure that they are compatible with the standards of Alberta, Canada.



a. AB-module



b. Four M-modules replacing the AB-module in Figure (a)

Figure 3.1: AB- and the equivalent M-module scenarios for identical design requirements

3.1.2 Pipe Spool Fabrication

Pipe spools consist of several items including pipes, flanges, reducers, valves, and fittings. These items are assembled in small segments, called spools, at fabrication shops. The fabrication process begins with cutting raw pipes into the required shapes and sizes. The cut pieces are then grinded at the end surfaces to prepare them for welding. At the fitting/welding stations, all required components are fitted based on the shop drawings and welded together using roll and/or position welding. Then, several tests and operations are conducted on the completed spools, such as a hydro test, heat treatment, and painting, as indicated in shop drawings. (Mosayebi et al. 2012).

There are several possible scenarios for pipe spool fabrication for AB- and M-modules, which are demonstrated in Figure 3.2. If AB-sized modules are required, the spools can be fabricated either in Alberta or overseas. The spools fabricated in Alberta are subject to two different size limits: 18 ft. × 18 ft. × 120 ft. for spools that are placed inside modules at the assembly yard and 8 ft. × 12 ft. × 54 ft. for spools shipped loose. These spools are outside the module envelopes and are added to the module at the construction site. If pipe spools are fabricated overseas and shipped to Alberta to be assembled into AB-modules, they are limited to the container size (7.5 ft. × 7.5 ft. × 35 ft.). For M-modules, the spools are fabricated overseas and then assembled inside the modules before shipment. In this case, the spools are limited to the M-module envelope size (13 ft. 5 in. × 13 ft. 5 in. × 80 ft.).

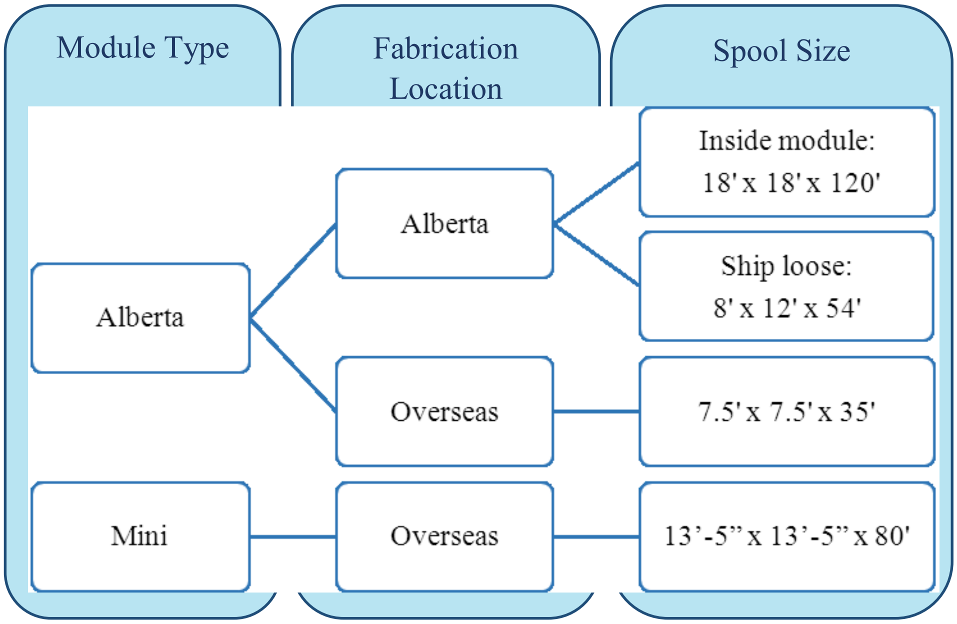
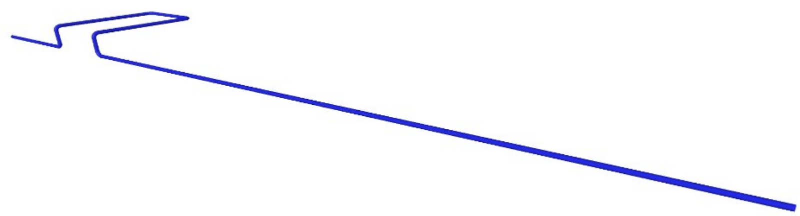
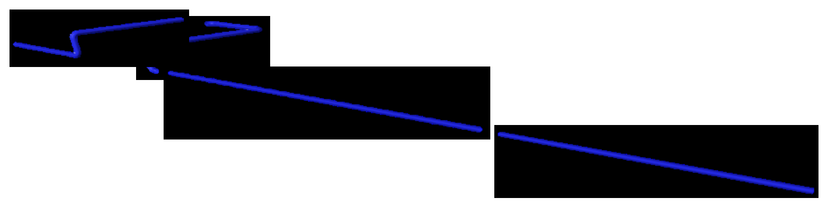


Figure 3.2: Pipe spool fabrication scenarios

As mentioned above, the pipe spools are limited to tighter envelope restrictions when fabrication is completed overseas. Therefore, more cuts are required in the pipe layout, leading to a higher quantity of spools. Figure 3.3 illustrates a series of connected pipes and elbow components cut according to two different envelope constraints, resulting in different quantities of spools for each scenario. As presented in this figure, the one spool in Figure 3.3a is divided into four spools with small dimensions shown in Figure 3.3b, due to the tighter size constraints of M-modules. These spools have less weight, but require more handling operations. They may also require additional hydro testing at the destination fabrication shop or assembly yard. Moreover, the increased number of cuts in the pipe layout requires additional welding.



a. Alberta-size pipe spool



b. Mini-size pipe spool

Figure 3.3: Pipe spools based on different envelope size limitations

If the spools are fabricated overseas for AB-modules, it is feasible to assemble small spools into 120 ft. lengths at Alberta fabrication shops after delivery and then transfer the Alberta-size spools (120 ft.) to the assembly yard for module assembly. All possible scenarios for pipe spool fabrication location should be studied in the decision-making process, as they highly affect the total cost and schedule of the project.

3.2 Assembly

The assembly procedure usually begins when a specific percentage of steel and pipe spool fabrication is completed or, in the case of overseas fabrication, when a percentage of the fabricated steel components and spools is delivered to the assembly yard. This process involves assembling fabricated steel pieces to build the module structure and placing pipe spools and other required equipment in that structure. Steel structures and pipe spools are the main components in this operation, as explained below.

3.2.1 Steel Structure Assembly

The fabricated beams, columns, and bracings are put together at the assembly yard by using simple connections for longitudinal beams and moment connections for transverse beams. Although the assembly process is almost identical for AB- and M-modules, the difference in size and quantities of components affects this procedure. AB-modules are higher in height, leading to a complicated assembly process and crane operation at the assembly yard. However, the lower quantity of components results in fewer man-hours, welding, and handling operations. Moreover, less connection fireproofing is required for the AB-modules as consequence of a lower quantity of connections. Since M-modules are subject to salt attack during ocean transport, it is also necessary to clean salt from connections prior to fireproofing at the construction site. In addition, due to the higher quantity of M-modules, they require more space at the assembly yard for the assembly process. Also, more coordination for both the module yard layout and shipping sequence is required for M-modules, due to greater quantity of these modules.

3.2.2 Pipe Spool Assembly

The fabricated spools are usually placed in the assembled structure of modules after completion of the structure assembly. However, in some instances the structure and spool assembly are done simultaneously to fit massive pipe spools inside the module. The pipe spools are lifted using cranes, placed at the proper position and welded together. If the spools are fabricated overseas, more lifting, handling, and welding operations are required at the assembly yard due to the greater quantity of spools. The difference in quantity between Alberta-sized and mini-sized spools significantly affects the cost of the required non-destructive examinations (NDE), post-weld heat treatment (PWHT), electric heat tracing (EHT), and painting requirements of the pipe spools. Furthermore, spools fabricated overseas require additional coatings and wrappings for protection from sea salt during ocean transportation, which impacts the project cost. It is also possible that the pipe insulations are exposed to moisture during ocean transportation and require replacement.

3.3 Handling and Shipment of Modules

Handling and shipment are significant items to consider for cost comparison studies of different scenarios of module fabrication and assembly. The difference in size and quantity of both fabricated components and final modules affects the load quantity and number of shipments. Besides, a different transportation type is required for each scenario, which not only affects the cost and schedule, but also adds extra risks to the project, such as schedule delay and reworks. If both fabrication and assembly are completed in Alberta, highway transportation would be the primary method used to transfer fabricated components from fabrication shops to assembly yards and modules from assembly yards to construction sites in the Fort McMurray oil-sands area. The existing infrastructure in Alberta is highly suitable for the transportation of large and heavy loads. However, fabricated and/or assembled pieces transferred from overseas are limited to ocean travel, highway, and railway limitations and have limited feasible routes to reach the Fort McMurray area. Also, it is more difficult to adjust the logistics of ocean shipping if the module assembly is delayed. Consequently, it is necessary to conduct a detailed study on the effect of transportation type and its limitations on the transportation cost and schedule. The following subsections explain important cost items and parameters related to handling and shipment in industrial modular construction projects.

3.3.1 Handling and Shipment of Fabricated Steel Components and Pipe Spools

Beams, columns, bracings, and pipe spools of M-modules are fabricated overseas and are assembled into the final structure at the same location. Therefore, no shipment is required for these items. Also, when performing fabrication in local steel and pipe spool fabrication shops, there shipment of the fabricated components is not required. However, if the steel components and/or pipe spools of AB-modules are fabricated overseas, they should be shipped to the assembly location using sea containers. A temporary steel frame is used for loading and unloading these items from the containers to facilitate the shipping process. This unique shipment procedure results in additional considerations and cost items for transporting the components fabricated overseas. The loading and unloading process from sea containers is more difficult and time-consuming and carries safety implications. Furthermore, the containers can be shipped out of sequence to maximize shipment size, which results in project delays. This process also adds several extra cost items to the project, as detailed below:

- Purchasing or renting sea containers and steel frames for long durations
- Extra supply and handling costs for the temporary steel frames
- Shipping back the empty sea containers and temporary steel frames to the supplier
- Transportation costs for the transportation of material from the steel fabricator to the shipyard, to North America and finally to the assembly location

3.3.2 Handling and Shipment of Assembled Modules

If the modules are assembled in local assembly yards in Edmonton, Alberta, the completed modules would be transported to the construction site in the Fort McMurray area via highway transit. Alternatively, the assembled M-modules would be shipped by ocean to North America and then transported to the Fort McMurray area using railway and highway transportation. These extra shipment requirements associated with overseas assembly cause differences in the transportation of assembled AB- and M-modules to the construction site. As mentioned before, M-modules have lower weights and are smaller in size, but higher quantities of them are required for a particular project. Therefore, a greater number of shipments are required in this scenario. Furthermore, the M-modules are handled multiple times from the module assembly location to the shipyard: they are offloaded in North America, loaded onto a trailer or rail car, and offloaded again at the construction site. This is in contrast to AB-modules, which have only one load/offload process: modules are loaded onto trailers at the assembly yard and offloaded at the construction site (unless they are stored at the site). The lifting operations of modules, loading them to transporters, and unloading them from transporters involve cranes, riggings, and crews. This process costs more for overseas transportation, due to the greater quantity of M-modules and required transportation types. In addition, shipping from overseas may require extra permits and the use of demurrage or marshalling yards to store modules until they are transported to the site. Also, it is more difficult to match the shipping schedule with the on-site lifting schedule when modules are transported from overseas locations. As a result of all these additional considerations, the transportation cost of M-modules is often greater than the transportation cost of AB-modules, thereby affecting overall project cost.

3.3.3 Module Weighing Operations

Weighing of modules prior to shipment is required to obtain accurate transport weights and center of gravity of the module for lifting operations. Due to the increased number of M-modules compared to the number of AB-modules required for the same project, this procedure would result in more cost and time expenditures for weighing of M-modules.

3.3.4 On-site Storage for Assembled Modules

After delivery of the assembled modules to the construction site, they are stored in storage areas until the installation time. Depending on the schedule and logistics, the larger quantity of M-modules takes up more on-site storage space, as access clearances are required around the stored modules. The additional lay-down area is an expense to the owner for land and ground preparation. Furthermore, more on-site transportation and road closures are required. Moreover, additional shipping beams and module stands would be required for the greater quantity of M-modules for a given project.

3.3.5 Impact Loading during Transportation

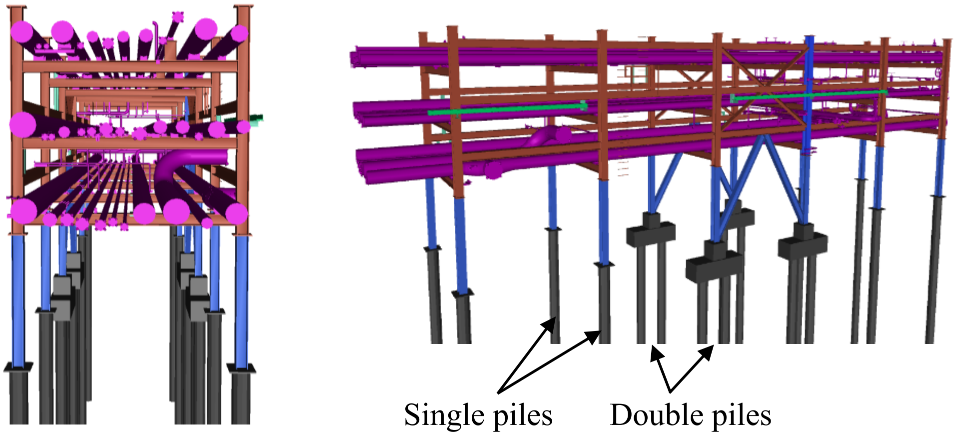
The assembled modules are subject to impact loads during transportation. Evidently, the impact load is different for various types of transportation; therefore, it would differ between AB- and M-modules. Differences in impact load and consequences should be considered during the design phase of the project. Extra beams and bracings may be required to improve the stability of the structure. Also, additional support tools may be required during transportation to maintain module stability.

3.4 Lifting and Crane Schedule

Cranes are the primary equipment used at the construction site for module installation. Specific configurations and riggings, as well as minimum capacity, are key requirements for the cranes on-site. Several activities must take place to prepare a particular crane for lifting a module: the crane is moved to the site, to the location, and then configuration and the rigging of the crane are adjusted. Finally, the ground beneath the crane is prepared by placing mats underneath it (Taghaddos et al. 2010). The difference in the quantity of modules between the Alberta and overseas assembly scenarios greatly impacts the cost of crane operations. Since M-modules have lower weights, the crane may be slightly smaller. However, the greater quantity of M-modules substantially increases the heavy-lifting costs. It also considerably extends the schedule, unless more cranes, rigging, and crews are employed.

3.5 Pile Size and Quantity

As a result of the difference in dimensions between AB- and M-modules, there is a weight difference between these two design schemes that greatly affects the pile design and requirements. Generally, a single or double pile (demonstrated in Figure 3.4b) is placed beneath each column of the module using H-piles or hollow sections (Bedair 2015). Figure 3.4 illustrates an AB-module and its pile system. Double piles are used underneath the columns connected to the bracing system and single piles are used for the remainder of the structure.



a. Front view

b. Isometric view

Figure 3.4: Pile system of an AB-module

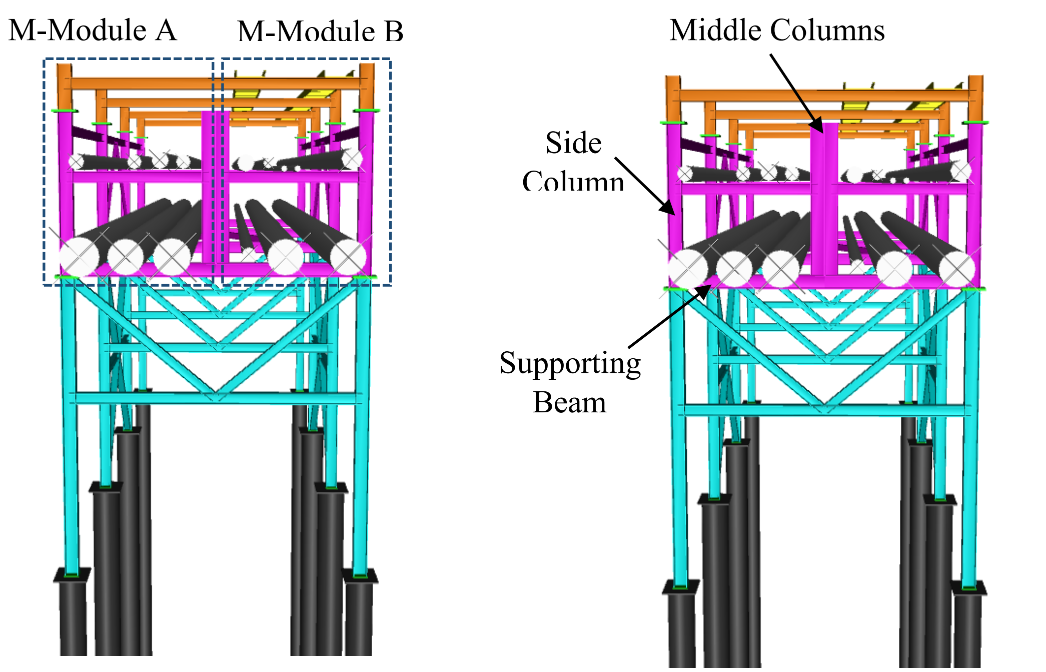
Although the pile system used for M-modules is similar to AB-modules, the design may be different. The AB-modules are almost double in width compared to M-modules, which results in two M-modules instead of one AB-module (considering the limitation in width size, as shown in Figure 3.1). Thus, two extra lines of columns are required in the middle of the AB-modules to create the M-module structure. These additional columns generate two possible scenarios for the pile design of M-modules, as explained below:

- **Scenario 1:** Added piles for the middle columns

  In this case, the middle columns are identical to the side columns. They are extended to the ground level and are connected to a pile beneath them in the ground to transfer the module loads. This scenario creates an extra line of piles for M-modules compared to AB-modules.

- **Scenario 2:** No added piles for the middle columns

  In this scenario, the middle columns are not extended to the ground level. In fact, these columns are connected to a supporting beam at the bottom of the module, (Figure 3.5b). The module loads are transferred from the middle column to the supporting beam and then to the side columns, which transfer the loads to the piles beneath them. Consequently, the pile system used for this scenario is similar to the case involving the AB-modules, as shown in Figure 3.5.



a. Elaboration of M-module envelopes

b. Front view of the M-modules

Figure 3.5: Pile system for a set of two M-modules without piles for the middle columns

The cost difference between these two scenarios should be considered during conceptual estimation, as it considerably affects the module design. Although the first scenario requires an extra line of columns, which results in a larger quantity of piles, the pile sizes for this scenario are smaller and the length can be shorter. However, the second scenario requires a smaller quantity of larger piles. This trade-off should be studied carefully to determine the most cost-effective design.

3.6 Productivity

Productivity differences are a major concern associated with overseas construction projects. China, as one of the biggest manufacturers in the world, has recently experienced fundamental changes in their construction industry, which has led to considerable progress in this industry. This improvement, along with lower material and labor rates, has attracted many international construction firms to this country. However, several studies conducted to compare the construction productivity of China and the U.S. have indicated a considerable gap in the construction industry between these two countries. The lack of advanced construction technologies, educated and trained workers, appropriate experience and knowledge in engineering and project management, and the slow adoption of computer software in construction are major factors related to this gap. Poor performance in these areas also leads to many issues at the site related to safety and quality (Chui and Bai 2010; Shen et al. 2011).

A benchmarking study done by CII (2009) on the construction industry in Alberta argues that the construction productivity in Alberta, Canada is not substantially different when compared to similar U.S.-based projects. However, the severe weather conditions in Alberta, and specifically in the Fort McMurray area, reduces labor productivity during construction. The productivity differences between overseas countries compared to Alberta, particularly in winter, should be considered and applied to the initial conceptual studies of industrial projects. This difference is further discussed in Section 5.1 of Chapter 5.

3.7 Safety

Safety is a significant consideration in the construction industry, but safety guidelines and procedures are different between Canada and overseas countries. According to recent research studies (Chui and Bai 2010), several safety and quality-related issues have been reported in the construction industry in China. These issues result in reworks, delays, and cost overruns for international projects. One of the important safety hazards in modular industrial projects is related to scaffolding. These temporary structures are used to assemble modules at assembly yards. Due to the lower height of the M-modules, less scaffolding and fall protection safety standards are required overseas than for work on AB-modules locally. However, additional scaffolding and fall protection safety measures are required for field welds and connections during M-module installation at the Alberta construction site.

3.8 Organizational Costs

Material, labor, and equipment costs, as well as the cost of the fabrication and assembly processes have been discussed in detail as important cost items that have a significant contribution to the overall cost of an industrial construction project. However, organizational costs should not be neglected because they can be a determining factor in the final decision. The owner, construction management team, and contractors have different coordination requirements for AB-modules and M-modules. Also, the costs associated with inspection and audits (e.g. travel, accommodation) should be considered. Since more modules are needed for the overseas scenario, extra engineering costs and additional drawings and documents are required compared to AB-modules. Not only should these documents be transmitted to the various suppliers and contractors, but their agreements are also required. Moreover, all documents and drawings should be translated into the different languages used in the overseas fabrication operations. Since more labor is required on-site to install M-modules, the camp requirements in this case would be different than for the installation of AB-modules. It should also be noted that due to local jurisdictional requirements, all steel fabricators as well as overseas suppliers, require CWB certification.

3.9 Other Cost Items and Considerations

In addition to the above-mentioned cost items and parameters, the greater quantity of M-modules increases the number of interconnected locations for piping, electrical, and instrumentation work, compared to the use of AB-modules. The greater number of piping interconnection points requires field splices of heat tracing without placing insulation at connection points before shipment. These extra interconnection points may also require temporary support during transport. The electrical and instrumentation work may also require field splices. These splices would need protection from the elements during transportation. Furthermore, due to the smaller size of M-modules, some large equipment such as vessels and exchangers, cannot fit into the M-module envelopes. This would necessitate either module assembly in Alberta or stick-built steel and equipment on site. Due to the impact loads from sea transportation and salt issues, other in-line devices that could be fit into the M-module envelopes would be trial fit and shipped separately to the site for final installation. It should also be reiterated that using M-modules and overseas assembly would have tremendous influence on project schedule. Module shipments from overseas require, approximately, an additional six weeks for shipping time, which requires advancement of the engineering deliverables. Any revisions during this time would need to be done on-site.

3.10 Chapter Summary

The cost items that should be considered in the conceptual cost estimation of industrial modular projects were identified and explained thoroughly in this chapter. The following is a summarized list of these cost items:

- **Fabrication**
    - **Steel Fabrication**
        - Difference in size and quantity of steel components
        - Additional beams, columns, and bracings are required for M-modules
        - Additional splice connections required for M-modules
        - Extra cross-bracing and moment connections required for M-modules
        - Bolt sizes of M-modules should be compatible with standards of Alberta, Canada
    - **Pipe Spool Fabrication**
        - Difference in size and quantity of pipe spools
        - More handling and loading/unloading operations required for M-modules' pipe spools
- **Assembly**
    - **Steel Structure Assembly**
        - More connection welding required for M-modules
        - More connection fireproofing required for M-modules
        - M-modules are subject to salt attack and require cleaning prior to fireproofing.
        - More handling and crane operations required for M-modules
    - **Pipe Spool Assembly**
        - More connection welding required for M-modules
        - More handling and crane operations required for M-modules

        - More quality tests required for M-modules' pipe spools
        - Additional wrappings and coatings required for overseas fabricated pipe spools

- **Handling and Shipment**
    - Difference in transportation cost due to multimodal transportation required for M-modules
    - Difference in handling and shipment cost due to higher quantity of shipments for M-modules
    - Purchasing or renting sea containers and steel frames for long durations
    - Extra supply and handling costs for the temporary steel frames
    - Shipping back the empty sea containers and temporary steel frames to the supplier
    - More difficult and time-consuming loading and unloading processes from sea containers for overseas shipments
    - More weighing operations required for M-modules due to higher quantity of them
    - More storage space required for M-modules.
    - Difference in impact loads and module design
- **Lifting and Crane Schedule**
    - Difference in capacity, configurations, and riggings
    - Difference in loading and unloading requirements

- **Pile Size and Quantity**
    - Difference in length and quantity of piles required for M-modules based on the module design (i.e. with or without added piles for the middle columns)
- **Productivity Differences between Alberta, Canada and Overseas Countries**
- **Safety**
    - Difference in safety guidelines and procedures
    - Difference in the height of scaffolding required for Ab- and M-modules
- **Organizational Costs**
    - Different coordination requirements for AB-modules and M-modules for owners, construction management teams, and contractors
    - Difference in cost of inspection and audits (e.g. travel, accommodation)
    - Extra engineering costs and additional drawings and documents required for M-modules due to higher quantity
    - Translation of documents and drawings into the different languages used in the overseas fabrication operations.
    - Difference in camp requirements
    - All steel fabricators – as well as overseas suppliers – require CWB certification.
- **Other Cost Items and Considerations**
    - Increased number of interconnected locations for piping, electrical, and instrumentation work for M-modules

- More field splices of heat tracing required for pipe spools of M-modules
- More temporary support required during transport for the extra interconnection points of pipe spools in M-modules
- More field splices of electrical and instrumentation work required for M-modules
- Trial fit and separate shipment required for the in-line devices of M-modules
- Impact of overseas shipment on project duration

Chapter 4: Comparison between Alberta and Overseas Module Fabrication and Assembly

The intention of this chapter is to propose a new method to investigate the differences in module quantity and the amounts of structural steel required between Alberta and overseas fabrication and assembly on a particular project. Moreover, a new method is suggested for converting the AB-modules to M-modules for a previously-designed project. These methods were used on two industrial modular projects designed in Alberta size to illustrate the application of these methods in the construction industry. This chapter also provides structure weight distributions of AB- and M-modules, which are used later in the simulation model developed in Chapter 5 to estimate the cost of the fabrication and erection of industrial modules. In general, the cost of steel fabrication and erection is based on the weight of the steel components. Accordingly, cost estimations in this research will be based on the module structure weight.

Two industrial modular projects designed and constructed for Alberta-size modules were analyzed as a case study using the methods proposed in this chapter. One project is the first phase of a four-phase project covering a total area of approximately 21,496 hectares located near the Athabasca River in Alberta, Canada. This plant is expected to reach a production of 1.7 billion barrels of recoverable bitumen over more than 45 years. The construction phase involves building and installing pipelines carrying air, fuel, process and supply water, utility corridors, and other field facilities. It also includes construction of a central processing facility (CPF) covering an area over six hectares, which is equipped with supportive facilities for makeup water treatment, steam generation, bitumen treatment, water recycling, and vapour recovery and cogeneration. The second project is an expansion of a three-phase oil-sands mine project located in the Athabasca Oil Sands region in Alberta, Canada.

4.1 New Method for Converting AB- to M-modules and Comparing the Quantity of Required Modules

As explained before, there is a difference in the quantity of required modules between projects designed in Alberta size and mini size. The subsequent sub-sections present a proposed converting method along with an illustration of the application of this method on modular projects.

4.1.1 Module Transformation

In order to conduct an appropriate comparison study on different scenarios of modular construction (i.e. Alberta and overseas fabrication and assembly), an investigation should be carried out on the effect of each of these scenarios on a single project. Indeed, a particular project designed in both module sizes is required for this study. This way, all the factors contributing to the total cost, such as facility type, plant conditions, and project requirements, remain constant and the difference in the quantity of modules between these two scenarios is quantified. Due to the increased cost of the design process, projects are rarely designed in detail for two different sizes. To circumvent this limitation, sample projects will be used to produce identical project conditions for each scenario by converting AB-modules to M-modules following the procedure described below.

This process requires a 3D model of the modules that includes all structures, pipe spools, instruments, and equipment. The individual steps involved in this process are outlined below:

1. **Determine module envelope for AB-modules**

   A module envelope is the space occupied by a single module and its components. As mentioned before, modules are transported from the assembly yard to the construction site. Therefore, they are limited in dimensions to the permitted load size of the related transporter along the transportation route. Modules are designed to hold the pipes and equipment of an industrial facility, such as a petrochemical plant. The three modules illustrated in Figure 4.1 are samples of adjacent modules in an industrial plant, covered with blues boxes that represent the envelopes of the modules. As shown in this figure, there is a gap between adjacent modules, which is generally the same size as a module bay. This gap is provided to optimize the use of space and minimize the quantity of modules. In determining the module envelopes, the pipes and cable trays positioned in these gaps are divided in half: each part is placed in one of the neighboring module envelopes.

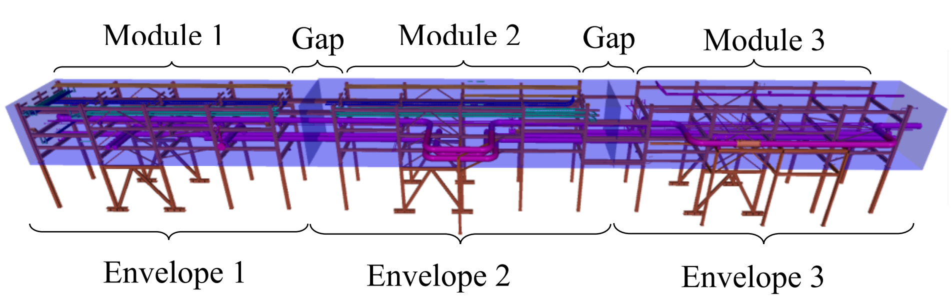
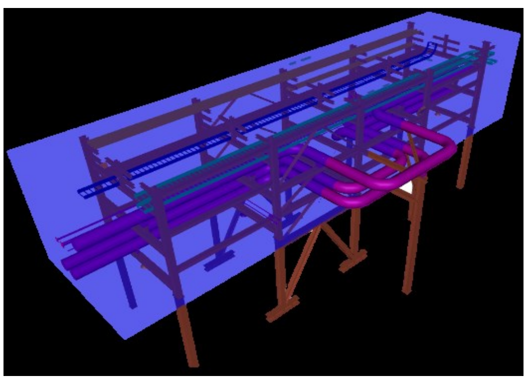
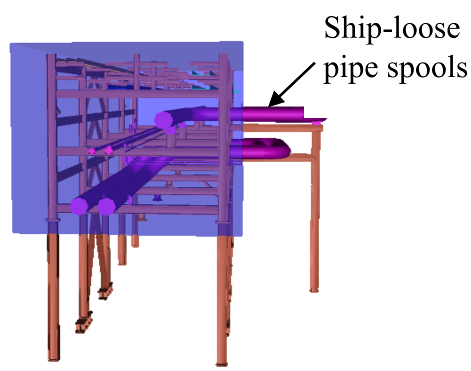


Figure 4.1: Three adjacent industrial modules and their envelopes

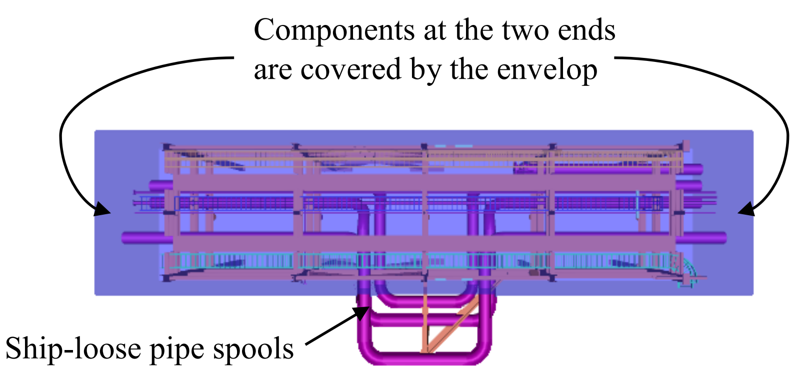
Since pipes and components often hang from the sides of the modules, it is important to precisely specify the module envelope. This way, the components outside the envelope can be prepared for loose shipment. Figure 4.2 demonstrates an AB-module and its envelope in different views. In this case, the envelope covers the hanging pipes from the two ends of the module, but it is not sufficient to entirely include side pipes. Thus, the portion of the pipes outside the envelope should be fabricated as a separate pipe spool, transferred to the construction site as a loose item, and assembled to the module at the field.



a. Isometric view



b. Front view



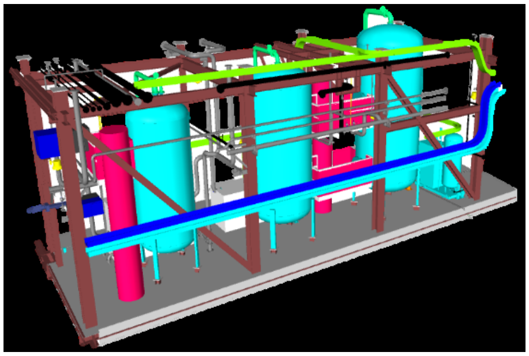
c. Plan view

Figure 4.2: Depiction of an AB-module and the corresponding envelope

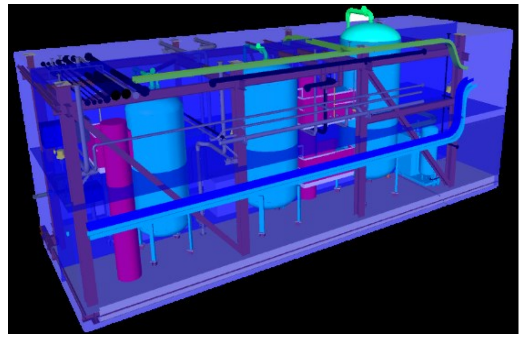
2. **Divide Alberta-envelopes into mini-envelopes**

To define the alternative scenario of M-modules for the sample projects, the Alberta-envelopes determined in Step 1 should be divided into mini-sized envelopes, with consideration given to the following constraints:

- The M-module envelopes are restricted to ocean transport regulations, limiting their size to 13 ft. 5 in × 13 ft. 5 in. × 80 ft. long.
- The AB-modules must be divided in such a way that the columns of the resulting M-modules are in same position as the original AB-module.
- In the process of dividing the Alberta envelopes, no pipe should be cut lengthwise, as they are never cut in that direction in practice.
- In the process of splitting Alberta size envelopes, no instruments or equipment should be divided. Modules containing equipment greater than the mini-sized envelope should not be divided into M-modules. In fact, these modules should be designed and constructed in Alberta size or be stick-built on-site. Figure 4.3a illustrates an AB-module that cannot be divided into M-modules. As shown in Figure 4.3b, splitting this module would truncate the height of the inside tank, which is not possible in practice.



a. Original AB-module



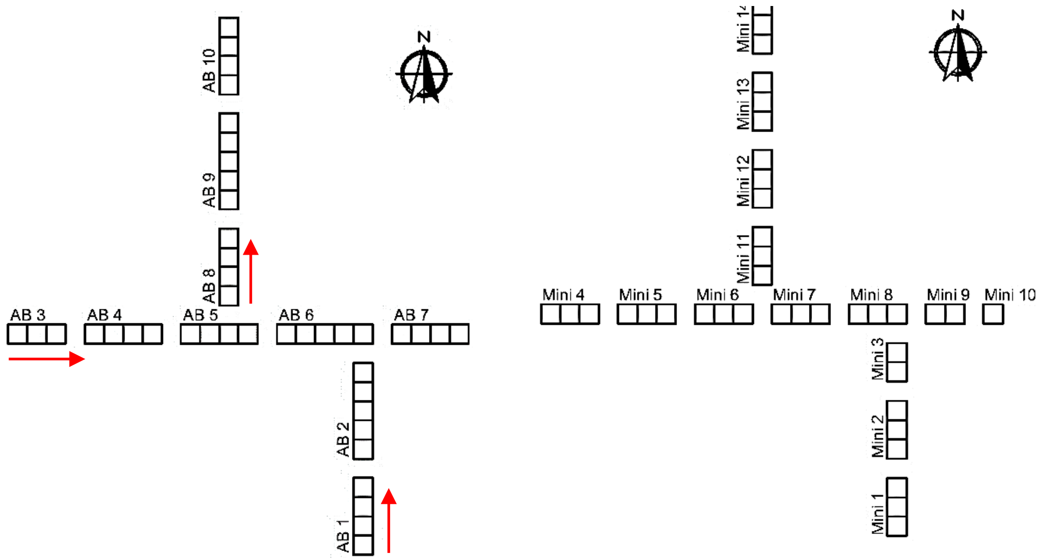
b. Envelopes of the corresponding M-modules

Figure 4.3: Example of an AB-module that cannot be divided into M-modules

3. **Determine size and weight of M-modules**

   The dimensions of the M-modules can be determined from the envelopes developed in Step 2 by subtracting the added amount of the original AB-module from the mini envelope.

This procedure is applied to the two sample projects to discover the quantity of required modules for a hypothetical overseas assembly. These projects include several horizontal and vertical lines of modules covering the industrial plant. Figure 4.4a displays an example of lines of modules shown in the plan view. In this figure, each separate rectangle represents an AB-module which consists of multiple bays. The division process is always started from the south side of the vertical lines and the west side of the horizontal lines and is continued for the rest of the line. The starting point of each line of the sample plant is specified in Figure 4.4a. In this process, each module is divided in length, width, and height with consideration the constraints mentioned above. This procedure is described below, using the sample industrial plant presented in Figure 4.4.



a. AB-modules b. M-modules

Figure 4.4: Plan view of a sample modular industrial plant

Division in length

First, the length of the module envelope is divided into the maximum possible dimensions. In the sample industrial plant presented in Figure 4.4a, the modules consist of 6 m (19.68 ft.) bays and the gap between adjacent modules is the same length. Therefore, considering the allowable length of 80 ft. for the M-module envelope, the maximum possible length for an M-module is 18 m (59 ft.). Considering a 3 m (9.84 ft.) extension from each of the two ends of the module, a 24 m (78.74 ft.) long envelope results, as shown in Figure 4.5. In order to minimize the number of modules, the initial AB-modules should be divided into M-modules with three bays, as much as possible. This process is done continuously down a line of modules, meaning that the whole line is split into M-modules with three bays, leaving a one-bay gap in between. The resulting M-modules are demonstrated in the plan view in Figure 4.4b.

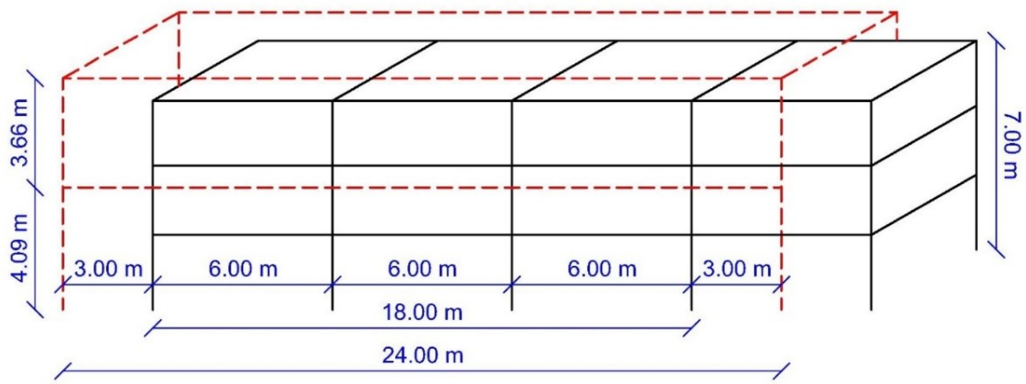


Figure 4.5: AB-module division process in length and height

Division in width

To optimize utilization of space, the ideal way of dividing the width of the module envelope is by splitting it in half. Figure 4.6 demonstrates the division process of an AB-module along its width. In this example, the 7.3 m (23.95 ft.) wide envelope of the AB-module is divided into two 3.65 m (12 ft.) wide mini-envelopes. It should be noted that the contents of the AB-modules should be inspected for any violations against specified constraints. For example, if a pipe or equipment prevents the lengthwise division of the envelope in half, the envelope should be split into two parts, in such a way that the pipe or equipment is not cut.

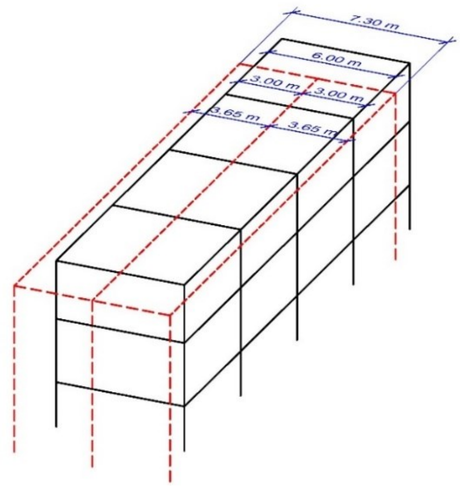


Figure 4.6: AB-module division process splitting the width

Division in height

The final step of this process is the division in height of the AB-module envelope. Similar to Step 1, the original AB-module envelope is divided into the maximum allowable height (13 ft. 5 in. or 4.09 m) to produce a minimum number of M-modules. Therefore, the envelope of the AB-module is divided in height in segments of 4.09 m, beginning from the bottom and going to the top, as shown in Figure 4.6. In most cases, it is not possible to have all divisions at segments of 4.09 m, since a pipe or an instrument is cut lengthwise. Thus, the module is inspected for all possible constraints and the best height for splitting is determined.

The envelopes of the initial modules are divided into M-module envelopes by following these three steps for all AB-modules of the two sample projects. Then, the size of each M-module is determined from its developed envelope. For example, the three-meter extensions of the two ends of the M-module illustrated in Figure 4.6 are removed from the envelope size, resulting in an 18 m length for this M-module. Moreover, the extra 0.65 m in envelope width in Figure 4.6 is deducted to calculate the width of the M-module. Finally, the height of each M-module is determined by considering its position. As represented in Figure 4.5, the height of a bottom or middle M-module is identical to the envelope height, as a set of continuous columns are required for the entire structure. However, the height of the top M-module should be equal to the height of the remaining height of the initial AB-module. The final transformed shape of this module is presented in Figure 4.7. In this case, the AB-module is divided into two sections in all directions, resulting in four M-modules identified as A, B, C and D.

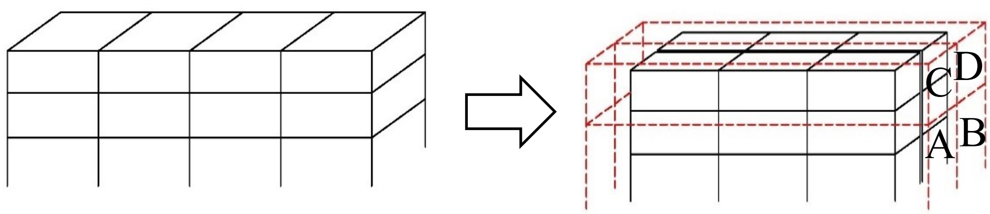


Figure 4.7: An AB-module and the corresponding M-module envelopes

For clarity, one of the module conversion cases is detailed in this part. Figure 4.8 demonstrates one of the AB-modules investigated in this study, as well as the corresponding M-modules and their envelopes. The original module has a size of 36 m long × 6 m wide × 7.35 m high. The goal of the division process is to maximize corresponding M-modules size and to minimize M-module quantity. As shown in Figure 4.8, this particular AB-module is divided into eight M-modules, with the final envelope and module sizes presented in Table 4.1.

Table 4.1: Results of a sample module division

M-Module Name	Envelope Size (m)			Module Size (m)		
	Length	Width	Height	Length	Width	Height
A	24	3.65	4.09	18	3	4.09
B	24	3.65	4.09	18	3	4.09
C	24	3.65	3.36	18	3	3.26
D	24	3.65	3.36	18	3	3.26
E	18	3.65	4.09	12	3	4.09
F	18	3.65	4.09	12	3	4.09
G	18	3.65	3.36	12	3	3.26
H	18	3.65	3.36	12	3	3.26

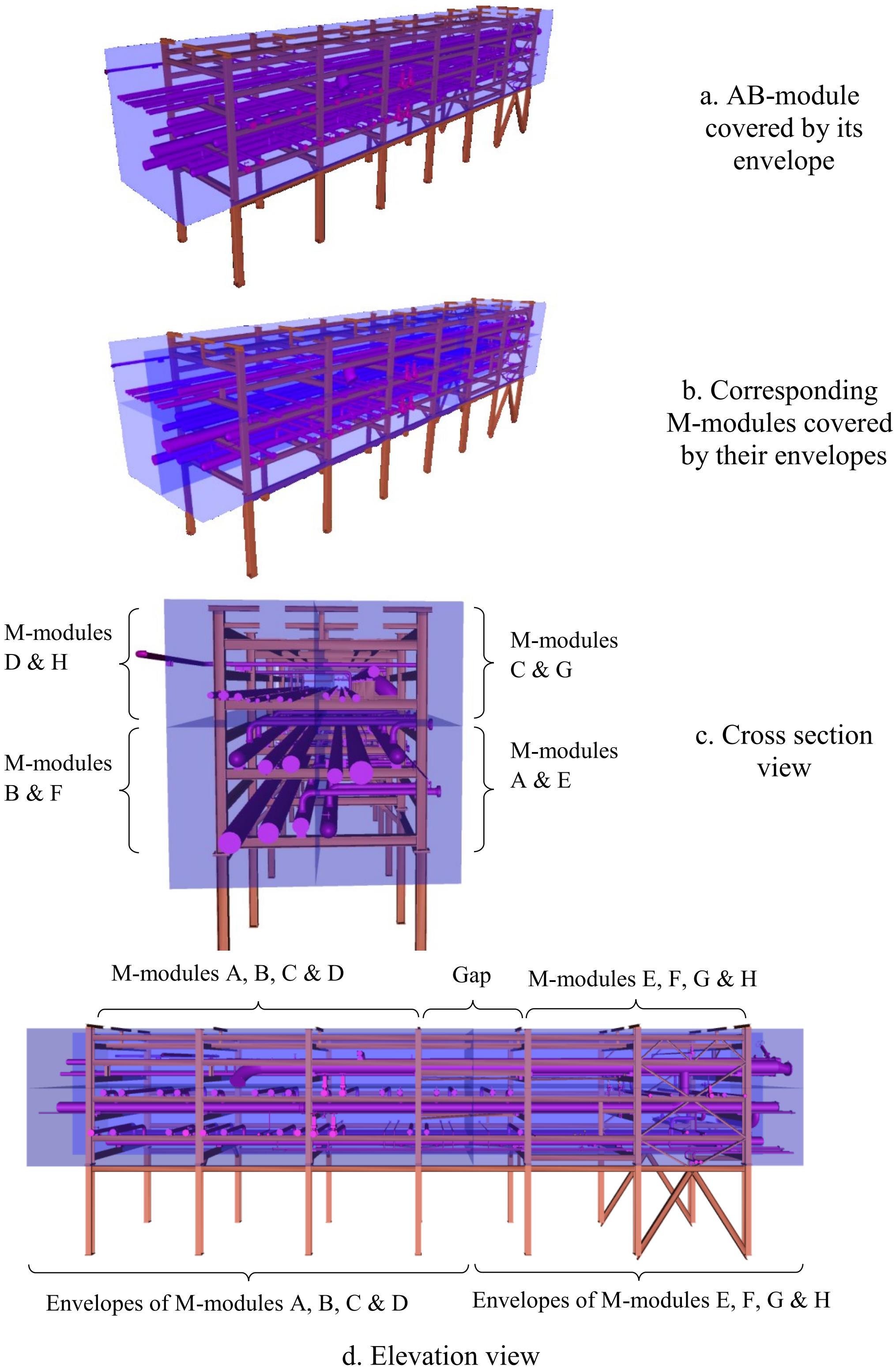


Figure 4.8: Real example of an AB-module and the corresponding M-modules

4.1.2 Results of Module Quantity Comparison - Case Study

Information regarding the initial AB-modules of the sample projects, as well as the corresponding M-modules (i.e. envelope size and module size) can be found in Appendix A. According to these findings, the AB-modules have a range of 3.38 m to 39 m in length, 1.2 m to 7.2 m in width, and 1.58 m to 8 m in height. A few of these modules are larger than the limit; therefore, they are built to the size limit at the assembly yard and the remaining portion is added at the construction site. In one case, the AB-module has a height of 23 m, which is much greater than the size limit. This module is also divided into smaller parts for transportation.

The 75 AB-modules of Project 1 and 108 AB-modules of Project 2 resulted in a data set of 183 AB-modules. All these modules are studied carefully in 3D models and divided into M-modules, based on the criteria described in Section 4.1.1. According to Appendix A, the 183 AB-modules resulted in a total of 685 M-modules: 319 M-modules were required for Project 1 and 366 M-modules were required for Project 2. These M-modules had a range of 4 m to 24 m in length, 1.2 m to 3.8 m in width, and 0.95 m to 4.16 m in height. Due to the large equipment contained inside, size limitations, or unique structure characteristics, 11 AB-modules from project 1 and 18 AB-modules from project 2 could not be divided into M-modules using this method.

4.2 New Method for Comparing Required Structural Steel between AB- and M-Modules

In this section, a new method is proposed to compare the required structural steel between AB- and M-modules. In order to illustrate the application of this method, the AB-modules of the two sample projects, along with the M-modules developed in Section 4.1, are used to conduct a comparison study on the amount of structural steel required for each design scenario (AB- and M-module). Furthermore, this chapter provides the distributions of module structure weight that are used in the simulation model developed in Chapter 5 that predicts the required amounts of structural steel for future projects.

Since the sample projects include completely-designed AB-modules, the drawings of these modules are used to directly estimate the structure weight of modules in this scenario. However, as the M-modules are developed from the AB-modules, no drawings and detailed design are available. To overcome this limitation, a steel structure design on the developed M-modules was performed to estimate their structure weight. The structural design of industrial modules contains multiple load types with unique characteristics, such as dead loads, live loads, thermal loads, friction loads, wind loads, snow loads, erection loads, and impact loads. Moreover, special load combinations should be considered when designing the structure of industrial modules (Bedair 2015). In this study, each M-module was developed to replace the initial AB-module in the same location in the plant. Thus, all load types and combinations considered in the design of the AB-modules can be applied to the corresponding M-modules. However, no information was available in this research study regarding the load conditions for the AB-modules of the sample projects. As a result, the design loads of each AB-module are estimated based on the final steel sections used in the module structure. These estimated loads were subsequently used to design the structure elements of the corresponding M-modules. The design structure of the M-modules was used to calculate the structure weight and develop the weight distribution of the modules. This procedure is described in detail in the following subsections.

4.2.1 Mini-Module Design Process

The steel structure design is done separately for each component (i.e. beam, column and bracing) and is based on the Canadian steel code and according to Kulak and Gilmor (2011). All formulas and equations used in this subsection are extracted from the *Handbook of Steel Construction* (2014).

4.2.1.1 Beam Design

In the division process explained in Section 4.1, the initial transverse beams are divided between the M-modules, while the longitudinal beams remained unchanged, as demonstrated in Figure 4.9. As a result of similar load conditions between AB-modules and the corresponding M-modules, the longitudinal beams of AB-modules can be used directly for M-modules, while the transverse beams should be designed.

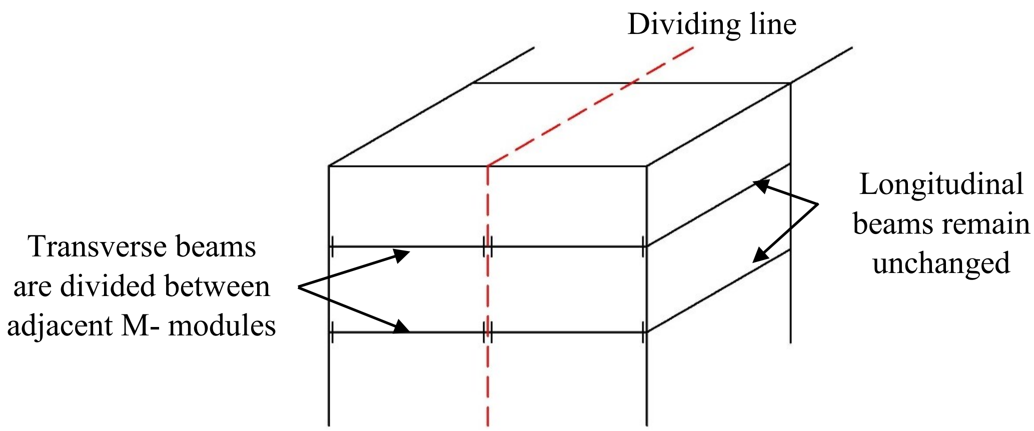


Figure 4.9: Longitudinal and transverse beams in AB-modules and M-modules

The transverse beams are designed assuming that the bending moment is the controlling design parameter. Since a lower accuracy is acceptable for steel cost estimation at the conceptual stage, a simplified method is implemented in beam design.

In this analysis, the bending moment capacity of AB-module transverse beams is measured and then used to determine the allowable load, which is later used to design the M-module beams. Here, uniformly distributed loads are assumed to be carried by each beam, resulting in identical unit loads on AB- and M-beams, as demonstrated in Figure 4.10. Since moment connections are generally used to connect transverse beams to columns, the beams are assumed to be fixed at these two ends.

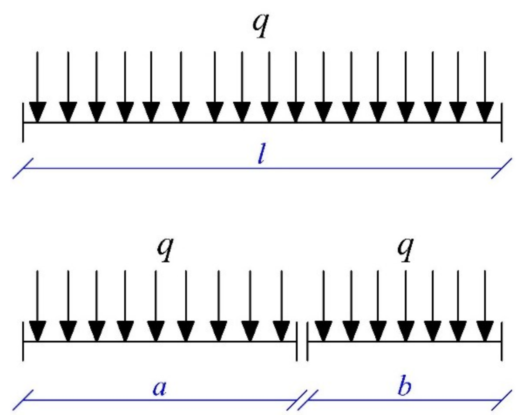


Figure 4.10: Alberta-sized transverse beam divided into mini-sized beams

According to the basic principles of mechanics of material, the maximum allowable stress resulted from bending in the beams should be equal to the yield strength of the material (σ_y), which is calculated using Equation 4.1,

$$\sigma_y = \frac{M_y}{S} \tag{4.1}$$

where M_y is the yield moment and S is the elastic section modulus.

It is assumed that the same material is used in the steel components of AB- and M-modules; therefore, the yield strength (σ_y) is identical for these two cases, resulting in Equation 4.2,

$$\frac{{M_y}_A}{S_A} = \frac{{M_y}_m}{S_m} \tag{4.2}$$

where the subscript A represents the AB-module beam and m represents the M-module beam.

In order to prevent the steel element from yielding, the maximum bending moment in beams should not exceed the yield moment. Generally, the transverse beams are connected to the columns using moment connections, so these beams are considered fixed at the ends and the maximum bending moment is calculated using Equation 4.3,

$$M_{max} = \frac{ql^2}{12} \tag{4.3}$$

where q is the uniformly distributed load on beam and l is the beam length. By replacing the yield moment in Equation 4.2 with the maximum bending moment in Equation 4.3, the two formulas presented in Equation 4.4 and 4.5 are devised.

$$\frac{{l_A}^2}{S_A} = \frac{{l_m}^2}{S_m} \tag{4.4}$$

$$S_m = S_A \times \left(\frac{l_m}{l_A}\right)^2 \tag{4.5}$$

Using Equation 4.5, the elastic section modulus of the M-beams can be calculated based on the elastic section modulus of the AB-beams and the beam lengths. Finally, a proper section for the M-beam can be determined from the *Handbook of Steel Construction* (2014) based on the calculated S_m.

4.2.1.2 Column Design

The M-columns are designed using Equation 4.6, which is provided by the *Handbook of Steel Construction* (2014) as a convenient means to design columns by considering compression and lateral and flexural buckling.

$$C_r = \varphi A F_y (1 + \lambda^{2n})^{-1/n} \tag{4.6}$$

where C_r is the factored compressive resistance, φ is the resistance factor, A is the column cross section area, F_y is the yield strength and n is the compressive resistance, equal to 1.34 for W-shape steel components, which are normally used in industrial modules. In addition, the term λ represents the slenderness ratio (l/r) based on Equation 4.7.

$$\lambda = \frac{Kl}{r}\sqrt{\frac{F_y}{\pi^2 E}} \tag{4.7}$$

where K is the effective length factor, l is the column height, r is the radius of gyration of the column cross-section, and E is the elastic modulus of steel.

In order to employ the AB-columns to design the M-columns, Equation 4.8 is developed using Equation 4.6. Assuming that the same material is used for AB- and M-columns (identical yield strength, F_y), the latter equation is simplified into Equation 4.9 and Equation 4.10.

$$\frac{C_{r_A}}{C_{r_m}} = \frac{\varphi A_A F_y \left(1+{\lambda_A}^{2n}\right)^{-1/n}}{\varphi A_m F_y \left(1+{\lambda_m}^{2n}\right)^{-1/n}} \tag{4.8}$$

$$\frac{C_{r_A}}{C_{r_m}} = \frac{A_A}{A_m} \times \left(\frac{1+{\lambda_A}^{2n}}{1+{\lambda_m}^{2n}}\right)^{-1/n} \tag{4.9}$$

$$\frac{C_{r_A}}{C_{r_m}} = \frac{A_A}{A_m} \times \left(\frac{1+{\lambda_m}^{2n}}{1+{\lambda_A}^{2n}}\right)^{1/n} \tag{4.10}$$

The effective length factor (K) in Equation 4.7 has a theoretical value of 0.5 for columns with fixed ends, yet it has been recommended that K be considered as 0.65 in the column design process. By assuming 350W steel (with F_y equal to 350 MPa), replacing K as 0.65, and the elastic modulus, E, as 200 GPa, Equation 4.7 is simplified to Equation 4.11, where α is equal to 0.008655.

$$\lambda = \alpha \times \frac{l}{r} \quad , \quad \alpha = 0.008655 \tag{4.11}$$

The following equation is developed by replacing Equation 4.11 in Equation 4.10:

$$\frac{C_{r_A}}{C_{r_m}} = \frac{A_A}{A_m} \times \left(\frac{1 + (\alpha \frac{l_m}{r_m})^{2n}}{1 + (\alpha \frac{l_A}{r_A})^{2n}} \right)^{1/n} \tag{4.12}$$

In Equation 4.12, the term $\alpha \frac{l}{r}$ results in a number lower than 1, due to α being close to zero. This small value is powered by *2n* (2.68) and becomes even smaller. Next, it is consolidated with 1, resulting in a value slightly greater than 1. Therefore, the division of the numerator and denominator in Equation 4.12 results in a value close to 1. This value approaches 1 when it is powered by $1/n$ (0.373). Consequently, the multiplier of $\frac{A_A}{A_m}$ in Equation 4.12 is a value very close to 1 and can be assumed to be 1 for simplicity in column design. Equation 4.12 is thus simplified to Equation 4.13, which is used to design M-columns.

$$\frac{C_{r_A}}{C_{r_m}} = \frac{A_A}{A_m} \tag{4.13}$$

The following numerical example is provided to show the accuracy of this assumption. This example is obtained from one of the sample AB-modules and the corresponding M-module. The initial AB-column is W310×118 with a height of 5.97 m and the M-column is designed as W310×86 with a height of 3.8 m. As shown below, the final value for the multiplier of $\frac{A_A}{A_m}$ in Equation 4.12 is very close to 1.

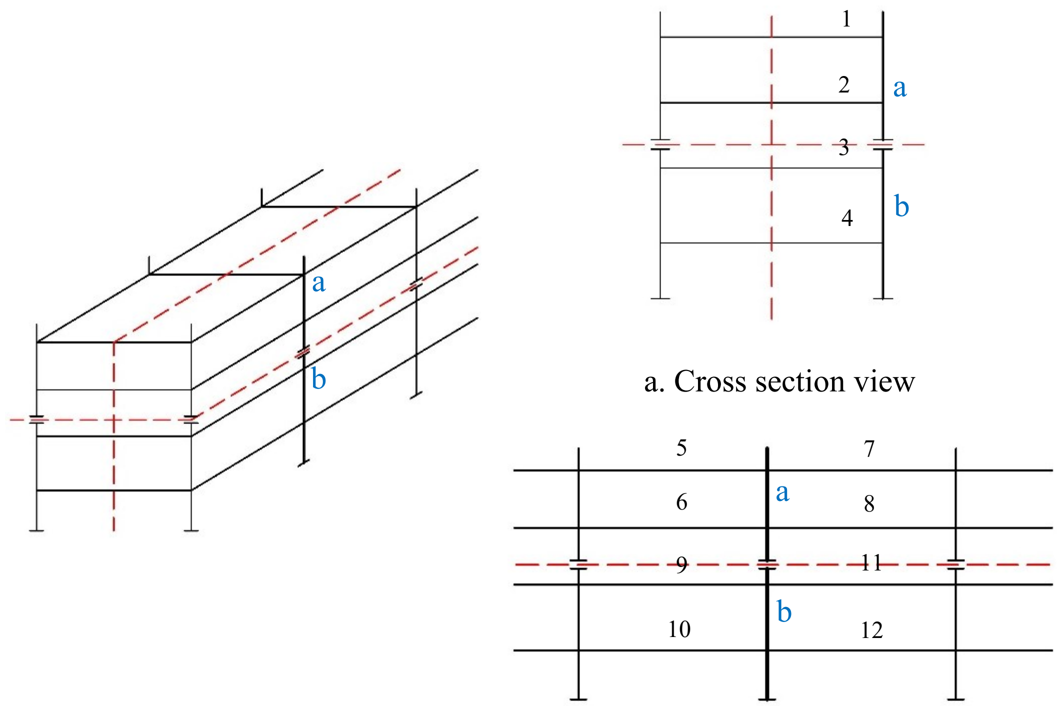
W310×118 , $l = 5970\ mm$, $r = 136\ mm$ ➔ $\lambda = 0.3799$

W310×86 , $l = 3800\ mm$, $r = 134\ mm$ ➔ $\lambda = 0.2455$

$$\left(\frac{1+{\lambda_m}^{2n}}{1+{\lambda_A}^{2n}}\right)^{1/n} = \left(\frac{1+(0.2455)^{2.68}}{1+(0.3799)^{2.68}}\right)^{1/1.34} = \left(\frac{1.0232}{1.0748}\right)^{1/1.34} = (0.9520)^{1/1.34}$$

$$= 0.964 \simeq 1$$

The factored compressive resistance (C_r) in Equation 4.13 should be replaced by the axial force applied to the AB- and M-column. Figure 4.11 demonstrates an AB-module divided into four M-modules with two divisions in height. Since a uniformly distributed load is assumed on the beams, the same load condition is applied to the two adjacent M-modules, resulting in identical loads on their columns. Moreover, the side columns are selected for the design, as they carry higher loads in contrast to the corner columns of the module. Consequently, two columns should be designed for the M-modules presented in Figure 4.11, specified as Columns a and b.



a. Cross section view

a. M-module column division

b. Elevation view

Figure 4.11: Explanation of M-module column division

For each column, the dead load of the connected beams is considered as the column axial load. This dead load consists of the beam weight and the weight of the pipes, cable trays, and any other equipment that is carried by the beams. Therefore, the axial loads of Columns a and b demonstrated in Figure 4.11 are calculated as follows:

$$Axial\ load_{mini,a} = (F_{beam})_{1-2\,\&\,5-8} + (F_{pipe})_{1-2} + (F_{cable\ tray})_{1-2} \quad (4.14)$$

$$Axial\ load_{mini,b} = (F_{beam})_{3-4\,\&\,9-12} + (F_{pipe})_{3-4} + (F_{cable\ tray})_{3-4} \quad (4.15)$$

$$Axial\ load_{Alberta} = (F_{beam})_{1-12} + (F_{pipe})_{1-4} + (F_{cable\ tray})_{1-4} \quad (4.16)$$

where

$$F_{beam} = \frac{W_{beam}}{2} \quad (4.17)$$

and W represents the weight.

It should be noted that the transverse beams used in M-modules are different from those in AB-modules; therefore, the axial load should be calculated for each column.

4.2.1.3 Bracing Design

Horizontal and vertical bracings are used to increase the structure stability. The horizontal bracings improve the rigidity of the module structure. Generally, few horizontal bracings are required to achieve this goal. Thus, the difference in horizontal bracings between the AB-modules and corresponding M-modules is neglected in this study. In the design of vertical bracings, it is assumed that the bracing has buckled under compression; therefore, all the lateral loads are carried by the bracing in tension.

In this analysis, the tension resistance of each AB-bracing is used to calculate the lateral force at the related level. This force is later applied to the corresponding M-modules to design their vertical bracing. The *Handbook of Steel Construction* (2014) suggests three equations to calculate the tension resistance of a steel element, where the resulting minimum value should be considered to be the tension resistance. As module connection details are not available in this research study, the requirements of two of these equations cannot be met. Therefore, only one of them is considered in this study to calculate the tension resistance of bracings, as specified in Equation 4.18,

$$T = \varphi A_g F_y \tag{4.18}$$

where T is the tension resistance, φ is the resistance factor and A_g is the gross section area.

The lateral load at each level (F) is calculated based on Equation 4.19,

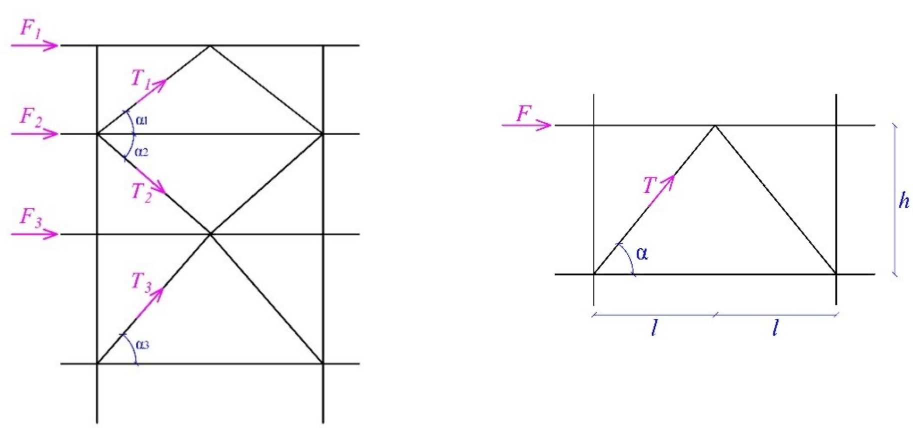
$$F = T \cos \alpha \tag{4.19}$$

where α is calculated using Equation 4.20 and the parameters specified in Figure 4.12b.

$$\alpha = \tan^{-1}\left(\frac{h}{l}\right) \tag{4.20}$$

Based on Equations 4.18 and 4.19, the lateral load at level i, F_i, is calculated as in Equation 4.21:

$$F_i = \varphi A_i F_y \cos \alpha_i \tag{4.21}$$

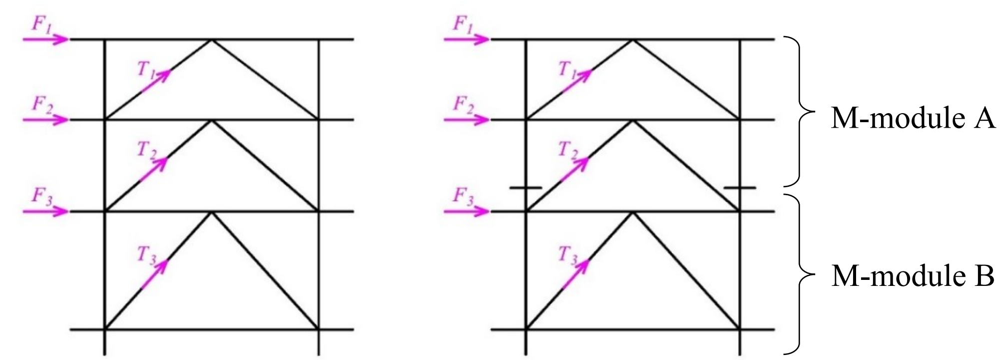


a. Lateral load and tension load in module bracings

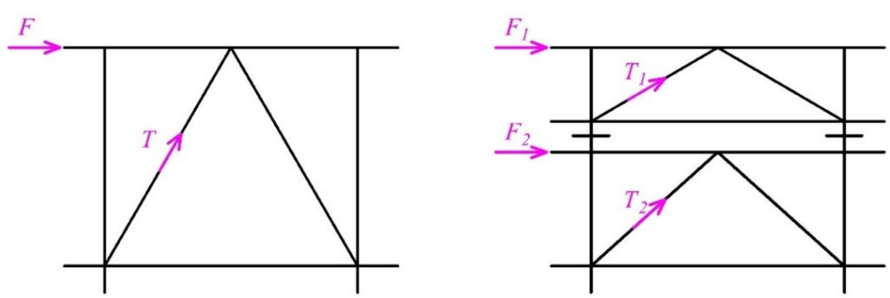
b. Required parameters in bracing design

Figure 4.12: Bracing design parameters

This lateral load is applied to the corresponding M-modules to determine the required bracings. If the longitudinal beams of M-modules are identical to the AB-modules (Figure 4.13a), the AB-bracings can be used directly for the corresponding M-modules. On the other hand, if extra longitudinal beams are added to the M-module structures (Figure 4.13b), the calculated lateral load should be divided between the related levels based on the height proportion to design the new bracings.



a. An AB-module and the corresponding M-modules in partial elevation view. No new longitudinal beams are required for the M-modules.



b. An AB-module and the corresponding M-modules in partial elevation view. As additional longitudinal beams are required for the M-modules, new bracings should be designed.

Figure 4.13: Different M-module bracing design conditions

4.2.2 Example of Calculation

The design method explained in Section 4.2.1 is utilized to design the M-modules developed in Section 4.1.2. A total of 62 AB-modules are selected from the two sample projects for the design process. This selection is based on the position of the corresponding M-modules. In some cases, one of the bays in the set of M-modules is the initial gap between adjacent AB-modules, such as M-modules A and B in Figure 4.14. As no structural design is available for that bay from the design of AB-modules, these M-modules are not selected for the design process. This selection led to the selection of 62 AB-modules, along with 250 corresponding M-modules, for the design process. In this section, the design of one set of M-modules is described in detail.

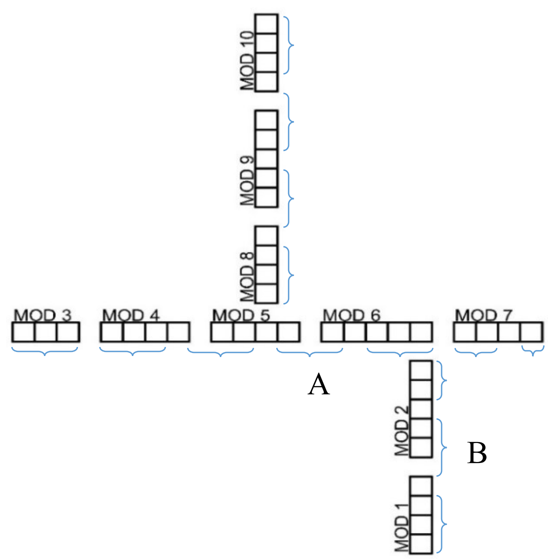


Figure 4.14: Plan view of a modular industrial plant (presented in Figure 4.4). Braces represent the M-modules resulting from module division.

The selected AB-module for this example is illustrated in Figure 4.15. This module is 30 m × 6 m × 1.26 m and is used to carry several pipes and cable trays. The drawings of this module are presented in Figure 4.16.

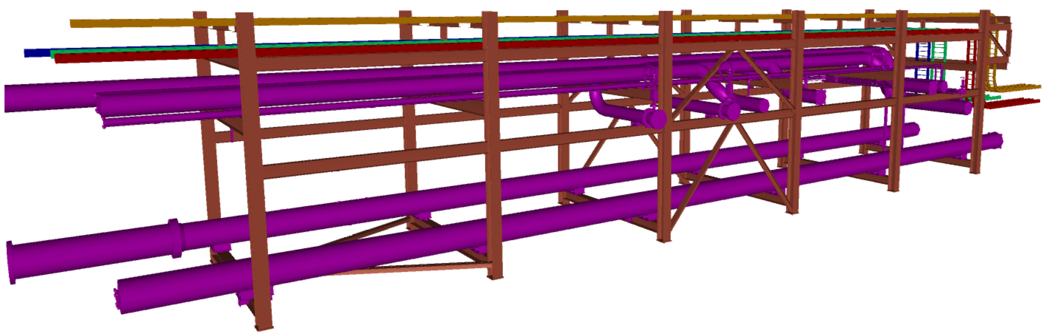
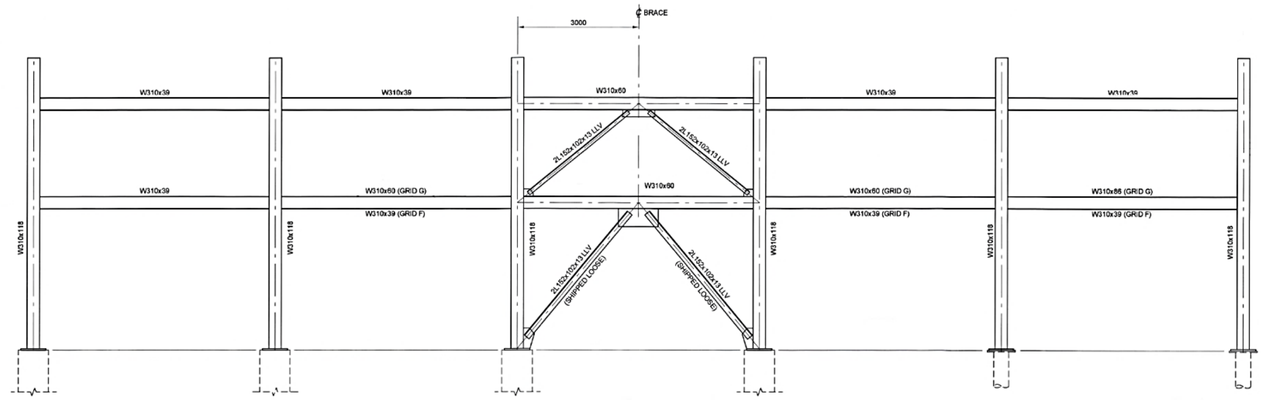
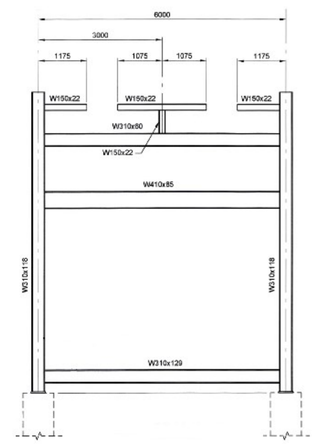


Figure 4.15: The isometric view of the sample AB-module used in the calculation example



a. Details of both longitudinal frames



b. Details of all transverse frames

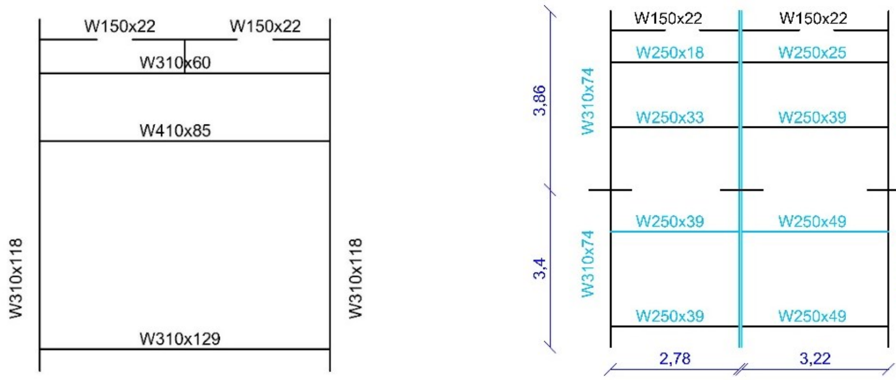
Figure 4.16: Drawings of the sample AB-module used in the calculation example

Simple drawings of the AB-modules and the corresponding M-modules are generated using CAD and are presented in Figure 4.17. In this case, the first three bays of the AB-module are grouped as a set of M-modules. Further division in module width and height is performed according to the criteria explained in Section 4.1.1, resulting in four M-modules. In this figure, black represents the components identical to the initial AB-module and blue represents either newly designed components or additional elements.

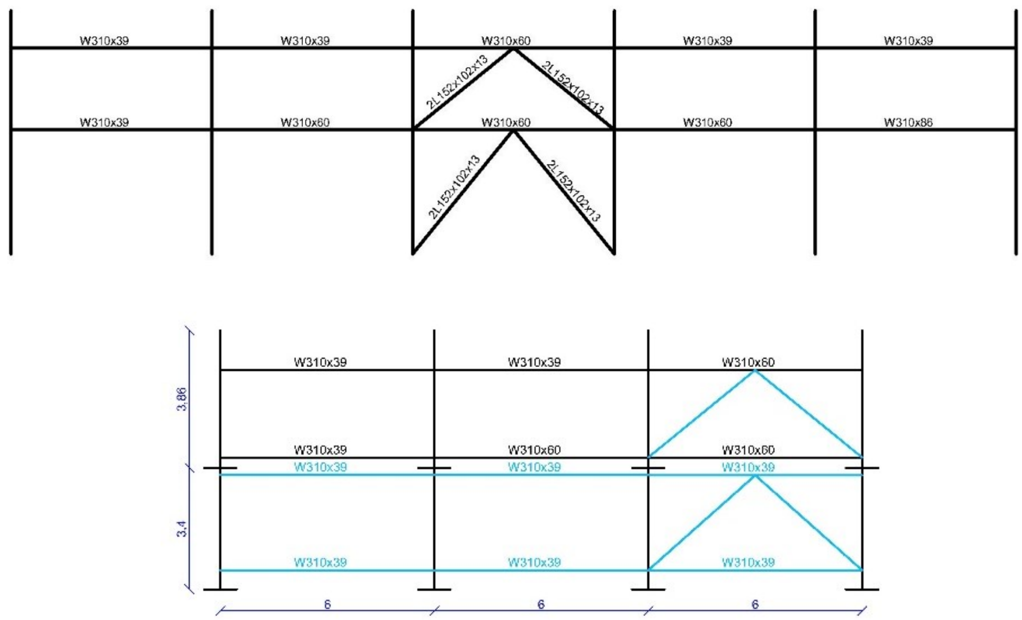
As presented in Figure 4.17b, the longitudinal frames considered for M-modules are similar to the initial AB-module frames. Since no beams are designed at the lower levels of the initial module, additional longitudinal beams are used for the bottom M-modules. Since no load condition is available to design these beams, the same component types as the initial longitudinal beams are used for the bottom M-modules. On the contrary, the transverse beams of the initial module are designed based on Equation 4.6. For instance, the beam at the lowest level (W310×129) is 6 m long and according to the *Handbook of Steel Construction* (2014), its section modulus is equal to 1940 x 10^3 mm^3. This beam is divided into two M-beams, which are 2.78 m and 3.22 m long. By replacing these values in Equation 4.6, the section modulus of the M-beams (S_m) is calculated as follows:

For $l = 2.78$, $S_m = 1940 \times 10^3 \times \left(\frac{2.78}{6}\right)^2 = 416.5 \times 10^3\ mm^3$

For $l = 3.22$, $S_m = 1940 \times 10^3 \times \left(\frac{3.22}{6}\right)^2 = 558.74 \times 10^3\ mm^3$



a. AB- versus M-module transverse frames



b. AB- versus M-module longitudinal frames

Figure 4.17: Details of the initial example of AB-module and the resulting design for M-modules

The calculated section modulus is used to identify the new beam type. In order to maintain design consistency, all transverse beams are selected from W250 sections. In this example, W250×39 (S = 459 × 10^3 mm^3) is used for the 2.78 m beam and W250×49 (S = 572 x 10^3 mm^3) is chosen for 3.22 m beam, as shown in Figure 4.17a. The calculation results of other transverse beams are presented in

Table 4.2. It should be noted that an additional transverse beam is used for the bottom modules to improve the stability of the structure. In this case, the same component type as the lowest beam of the module is assumed for this beam.

Table 4.2: Results of the M-module transverse beams for the calculation example

Module ID	Beam Type	Length (m)
1	W250x49	3.22
2	W250x39	2.78
3	W250x39	3.22
	W250x25	3.22
4	W250x33	2.78
	W250x18	2.78

In order to design the M-module columns, the axial load is initially calculated. The weight of the beams designed at the first step, along with the pipes and cable trays, is calculated and applied to the columns of the primary AB-module. Then, the M-columns are designed using Equation 4.14. A list of the components on each AB-beam, as well as their weight, is presented in Table 4.3. The unit weight of each pipe type is determined using the *Piping Handbook* (2000). Assuming a 6 m length for each piece of pipe on the beams, which is the same length as each bay of the modules, the total weight of components on each beam is calculated. Also, a unit weight of 15 kg/m is assumed for the cable trays. The column design is performed for the M-module with the longer transverse beams (3.22 m) and the result is applied to the other M-modules. The following calculations demonstrate the column design process:

For the AB-module:

Axial force from beam 1 (W310×129) and its components:

$$F = (129\ {}^{kg}/_{m} \times 6\ m + 7312\ kg)/2 = 4043\ kg$$

Axial force from Beam 2 (W410×85) and its components:

$$F = (85\ \times 6 + 3822)/2 = 2166\ kg$$

Axial force from Beam 3 (W310×60) and its components:

$$F = (60\ \times 6 + 4 \times 15 \times 6)/2 = 360\ kg$$

Axial force from small beam pieces at top (W150×22):

$$F = (1.18 + 1.08) \times 22 = 50\ kg$$

Axial force from longitudinal beams for top M-modules:

$$F = (39 + 3 \times 60) \times 6/2 = 657\ kg$$

Axial force from longitudinal beams for bottom M-modules:

$$F = 0\ kg$$

For M-modules with 3.22 m transverse beams:

Axial force from Beam 1 (W250×49) and its components:

$$F = (49\ {}^{kg}/_{m} \times 3.22\ m)/2 + 7312\ kg/4 = 1907\ kg$$

Axial force from Beam 2 (W250×49), the additional beam, and its components:

$$F = (49\ \times 3.22)/2 = 79\ kg$$

Axial force from Beam 3 (W250×39) and its components:

$$F = (39\ \times 3.22)/2 + 3822/4 = 1018\ kg$$

Axial force from Beam 4 (W250×25) and its components:

$$F = (25\ \times 3.22)/2 + 1 \times 15 \times 6 = 130\ kg$$

Axial force from the longest piece of beam at the top (W150×22), 1.3 m long:

$$F = (22 \times 1.3) = 28.6\ kg$$

Axial force from longitudinal beams for top M-modules:

$$F = (39 + 3 \times 60) \times 6/2 = 657\ kg$$

Axial force from longitudinal beams for bottom M-modules:

$$F = (4 \times 39) \times 6/2 = 468\ kg$$

Top M-module column design:

$$C_{r_A} = 2166 + 360 + 50 + 657 = 3233\ kg$$

$$C_{r_m} = 1018 + 130 + 28.6 + 657 = 1834\ kg$$

W310×118 ➔ $A_A = 15000\ mm^2$

$$A_m = 15000 \times \frac{1834}{3233} = 8510.5\ mm^2$$

Bottom M-module column design:

$$C_{r_A} = 4043 + 3233 = 7276\ kg$$

$$C_{r_m} = 1907 + 79 + 468 + 1834 = 4288\ kg$$

W310×118 ➔ $A_A = 15000\ mm^2$

$$A_m = 15000 \times \frac{4288}{7276} = 8840\ mm^2$$

Since the required cross section area of the columns for the bottom and top modules are similar, the same section area is selected for all M-module columns, which is W310×74 (A = 9430 mm^2).

The bracing of the top M-modules are identical to the top bracing of initial AB-module, since no changes are applied to the top beams. As the angle of the bottom bracing is only slightly different, the same bottom bracing can be used for the bottom M-modules. The calculation regarding the bottom bracing is presented below:

AB-module bottom bracing:

2 L152×102×13 ➔ $A = 2 \times 3060 = 6120\ mm^2$

$$\alpha_A = \tan^{-1}\left(\frac{3.7}{6}\right) = 51°$$

For M-module:

$$F = \varphi A F_y \cos\alpha = 6120 \times \cos(51°) \times \varphi F_y = 3851\varphi F_y$$

$$\alpha_m = \tan^{-1}\left(\frac{2.66}{6}\right) = 42°$$

$$T = {}^{F}\!/_{\cos\alpha} \ \ and\ \ T = \varphi A F_y \ \ ➔ \ \ A = {}^{F}\!/_{\varphi F_y \cos\alpha}$$

$$A = \frac{3851\varphi F_y}{\varphi F_y \cos(42°)} = 5182.62\ mm^2$$

2 L152×102×11 ➔ $A = 2 \times 2700 = 5400\ mm^2$

According to the final result, it is accurate to use bracings similar to the AB-modules for the M-modules.

Table 4.4 represents the final results of M-module design. The unit weight of each element is used to estimate the total weight of each M-module and the weight of the overall structure. The same calculation is done below to estimate the structure weight of the initial AB-module. This calculation is done for the first three bays of the AB module to perform a comparison with the M-modules.

Weight of longitudinal beams: $W_1 = 6 \times 39 \ {}^{kg}/_{m} \times 6\,m + 6 \times 60 \ {}^{kg}/_{m} \times 6\,m = 3564\,kg$

Weight of transverse beams: $W_2 = 4 \times (129 + 85 + 60) \ {}^{kg}/_{m} \times 6\,m + 4 \times 22 \ {}^{kg}/_{m} \times (1.18 + 1.08)\,m \times 2 = 6973.76\,kg$

Weight of columns: $W_3 = 8 \times 118 \times 7.26 = 6853.44\,kg$

Weight of bracings: $W_4 = 4 \times 24.1 \times (4.76 + 3.87) = 831.93\,kg$

Module Weight: $W_A = 3564 + 6973.76 + 6853.44 + 831.93 = 18223\,kg$

$$\frac{Mini\ module\ Structure\ Weight}{Alberta\ module\ Structure\ Weight} = \frac{25936\,kg}{18223\,kg} = 1.42$$

The equivalent weight of the M-modules replacing the AB-module was similarly calculated in a similar way, resulting in a structure weight of 25936 kg for the total weight of the M-modules, as presented in Table 4.4. According to the last calculation of the ratio of M-module structure weight to AB-module structure weight, a 42% increase in total steel weight can be expected if this module is designed and constructed overseas.

Table 4.3: Pipe specifications and weights for the calculation example

Beam ID	Beam Type	Component Type	Diameter (in)	Schedule Number /Thickness	No.	Weight (lb/ft.)	Weight (kg/m)	Weight (kg)	Total Weight on beam (kg)
1	W310×129	Pipe	3	XS	1	10.25	15.25	91.50	7311.90
		Pipe	6	XS	1	28.57	42.52	255.12	
		Pipe	4	STD	1	10.79	16.06	96.36	
		Pipe	12	SCH 80	1	88.51	131.72	790.32	
		Pipe	30	0.812 IN	1	253.13	376.70	2260.2	
		Pipe	3	1.4 IN	1	427.64	636.40	3818.4	
2	W410×85	Pipe	20	STD	2	78.60	116.97	701.82	3821.52
		Pipe	24	STD	2	94.62	140.81	844.86	
		Pipe	6	STD	1	18.97	28.23	169.38	
		Pipe	16	STD	1	62.58	93.13	558.78	

Table 4.4: Results of M-module details (presented in Figure 4.17) for the sample calculation

Mini module ID	Element	Component Type	Weight (kg/m)	Length (m)	Quantity	Total Weight (kg)	Total Module Weight (kg)
1	Longitudinal Beam	W310×39	39.0	6.00	12	2808.00	6470
	Transverse Beam	W250×49	49.0	3.22	8	1262.24	
	Column	W310×74	74.0	3.40	8	2012.80	
	Bracing	L152×102×13	24.1	4.01	4	386.56	
2	Longitudinal Beam	W310×39	39.0	6.00	12	2808.00	6075
	Transverse Beam	W250×39	39.0	2.78	8	867.36	
	Column	W310×74	74.0	3.40	8	2012.80	
	Bracing	L152×102×13	24.1	4.01	4	386.56	
3	Longitudinal Beam	W310×39	39.0	6.00	6	1404.00	6819
		W310×60	60.0	6.00	6	2160.00	
	Transverse Beam	W250×39	39.0	3.22	4	502.32	
		W250×25	25.0	3.22	4	322.00	
		W150×22	22.0	2.04	1	44.88	
	Column	W310×74	74.0	3.40	8	2012.80	
	Bracing	L152×102×13	24.1	3.87	4	373.07	
4	Longitudinal Beam	W310×39	39.0	6.00	6	1404.00	6572
		W310×60	60.0	6.00	6	2160.00	
	Transverse Beam	W250×33	33.0	2.78	4	366.96	
		W250×18	18.0	2.78	4	200.16	
		W150×22	22.0	2.48	1	54.56	
	Column	W310×74	74.0	3.40	8	2012.80	
	Bracing	L152×102×13	24.1	3.87	4	373.07	
					Total Structure Weight (kg)		25936

4.2.3 Results of M-Module Structure Design – Case Study

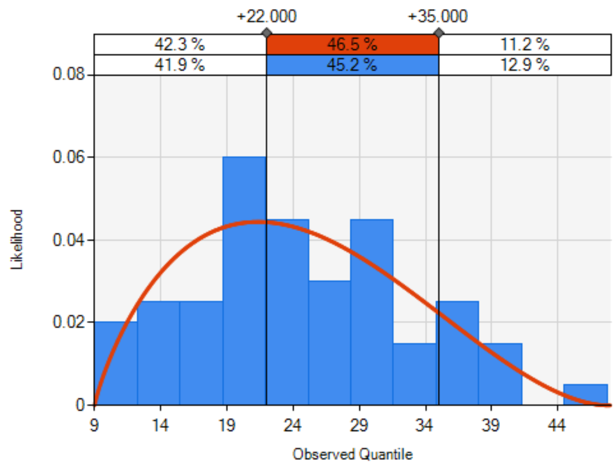
The 62 AB-modules that were studied in the module quantity comparison in Section 4.1 were used to design the structure of the 250 corresponding M-modules. In order to conduct a comparison of the structural steel required for the AB- and M-modules of the sample projects, the modules' structure weights were calculated for both scenarios (Alberta and overseas assembly). The structure weights of the AB-modules were calculated using the module drawings of the sample projects, while the M-module structure weights were calculated based on the design components. Appendix B provides detailed information regarding these AB- and M-modules, including the component type and size and, along with the structure weight of each module. Based on the calculated structure weights, the use of M-modules resulted in a 37% increase in the required steel for Project 1 and a 27% increase in the required steel for Project 2 compared to AB-modules. This increase was due to the extra components used in the structure of M-modules compared to AB-modules.

4.3 Development of Module Structure Weight Distributions

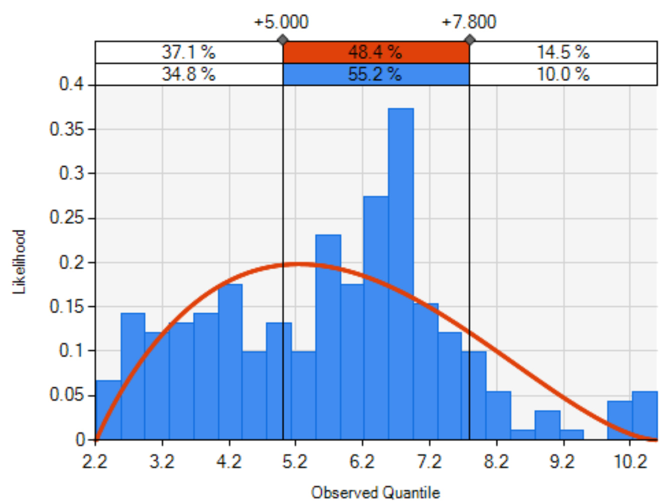
The structure weights of the AB- and M-modules provided in Appendix B were used to develop two separate frequency distributions for each scenario. These distributions can be used for estimating the structure weight of modules at the conceptual phase for future studies. Figure 4.18 presents the fitted distributions of module structure weight for both AB- and M-module scenarios. The proper distributions identified for each scenario are presented below:

AB-modules: Beta (1.85, 2.80, 9.0052, 47.6922), and

M-modules: Beta (1.92, 2.63, 2.2178, 10.5955).



a. Fitted distribution for AB-module structure weight (tonne)



b. Fitted distribution for M-Module structure weight (tonne)

Figure 4.18: Module structure weight distributions for AB- and M-module designs

Beta distributions were selected as the best fit, as they provide close boundaries that result in more appropriate data sampling in the future. The distributions were fit using three different methods of Least Squares, Maximum Likelihood, and Moment Matching, where the quality of fit was tested using Chi-Squared and K-S Test methods. Using beta distribution resulted in a low level of error for each method.

These distributions are used in the simulation model presented in Chapter 5 to estimate the conceptual cost of fabrication and erection of AB- and M-modules.

4.4 Chapter Summary

In this chapter a new method is proposed for comparing the quantity of modules and the required structural steel between different scenarios of Alberta and overseas fabrication and erection. Moreover, a new method is suggested for converting the AB-modules to M-modules using the projects previously designed in Alberta-size. The application of these methods was illustrated using two industrial modular projects designed and constructed in Alberta-size as a case study. In addition, the structure weight of the AB- and M-modules of the two sample projects were used to develop distributions of module structure weight that can be used for estimation purposes of future industrial modular projects.

Chapter 5: A Simulation Model for Performing Conceptual Cost Comparisons on Various Scenarios of Module Fabrication and Erection

The intention of this chapter is to develop a simulation model to estimate the cost of fabrication and erection of industrial modules. Generally, limited information is available at the conceptual phase of construction projects for estimators. In industrial modular projects, the quantity, type, length and height of modules, and the project layout are among examples of the information available for conceptual studies. Lack of detailed information about all cost items at this stage prevents estimators from providing an appropriate estimate of project cost. However, the simulation model developed in this chapter provides cost estimates based on the distributions of module structure weight using historical data from previous projects, which increases the certainty of estimations. This model can be used for estimating the fabrication and erection cost of AB- and M-modules at the initial phases of the project. In this model, the structural weight of the module, including beams, columns, and bracings, forms the basis of estimation.

The structure weight distributions generated in Chapter 4 are used in this simulation model to estimate the structure weight of AB- and M-modules. The fabrication and erection cost of modules is estimated based on the structure weight and using the regression models developed later in this chapter. As modular projects include several risks and uncertainties, this simulation model considers multiple risk factors for both scenarios of Alberta and overseas fabrication and erection and estimates the conceptual cost according to these risk items.

The following sections of this chapter present the regression models developed for estimating the fabrication and erection cost of modules in Alberta, the risk analysis method implemented in the simulation model, and an elaboration of the simulation model. In the last section, a sample case study is provided to illustrate the application of this simulation model in conceptual cost studies of industrial modular projects.

5.1 Fabrication and Erection Regression Models

In order to estimate the cost of fabrication and erection of industrial modules, regression models are developed to determine the cost based on the module structure weight. In general, the fabrication and erection costs of a steel structure depend on the length and unit weight of each component (i.e. beams, columns, and bracing). Therefore, these costs should be calculated for each steel component of the module. However, no information is available at this level of detail about the module components during the conceptual phase of the project. Using the weight distributions provided in Chapter 4, the structure weight of each module can be estimated at the conceptual level. As no other data is available, this weight will be used as the basis of the fabrication and erection cost estimation. Therefore, it is necessary to develop the required equations relating fabrication and erection cost of modules to the structure weight for this purpose. In this section, these costs are estimated for the AB-modules of the two sample projects described in Chapter 4. Since the overseas cost data for fabrication and erection of M-modules is not available for this study, no equations are developed for these activities. These equations can be developed for M-modules by implementing the same methodology outlined in this section.

The differences between AB-modules and M-modules, as well as location factors, should be considered when estimating the fabrication and erection cost of M-modules. A few of these differences are provided in this section. An interview with the estimating team of a leading construction company in modular projects identified the following differences (N. Koo, personal communication, 2016):

- The number of bolts required for each tonne of AB-modules is 33, while M-modules need 50 to 125 bolts/tonne due to more connections in M-modules and
- 3 ft. × 10 ft. grating is required for AB-modules, while M-modules need 3 ft. × 3 ft. grating, which increases the quantity and handling requirements.

In addition, the differences in construction and engineering productivity can be implemented using the location factors provided by the *Front-End/Conceptual Estimating Yearbook* (2015). Based on this data, the location factor that should be considered for petrochemical construction projects is 0.93 in China and 1.05-1.15 in Edmonton, Alberta, Canada. The basis of these factors is Washington D.C., USA, which has a factor of 1.

Tables 5.1 and 5.2 present the erection and fabrication cost of industrial modules in Alberta, respectively. This data is provided by two construction companies in Edmonton, Alberta, with one focusing on steel fabrication and the other focusing on pipe spool fabrication and module assembly. According to Table 5.2, the unit cost of fabrication depends on the type, length, and unit weight of the component. However, the erection cost (provided in Table 5.1) depends only on the unit weight of the component. It should be noted that this dependency is based on the data collected specifically for this thesis work and may differ for other companies. For each AB-module, the fabrication and erection cost of all components are estimated separately and then added together to determine the total fabrication and erection cost. Details of the cost estimation process are presented in Appendix C. An example of these calculations is provided in the subsequent section.

Table 5.1: Unit costs for erection of AB-modules

Description	**Erection** *(MHr/tonne)*	**Erection Unit Price** *($/tonne)*
Rolled Shapes: 0 - 15 kg/m	30	6,071.91
Rolled Shapes: 15.1 - 31 kg/m	19	3,845.54
Rolled Shapes: 31.1 - 61 kg/m	15	3,035.95
Rolled Shapes: 61.1 - 100 kg/m	10	2,023.97
Rolled Shapes: over 100 kg/m	8	1,619.17

Table 5.2: Unit costs for fabrication of AB-modules

Description	**Material Cost** *($/tonne)*	**Detailing** *(MHr/tonne)*	**Fabrication** *(MHr/tonne)*	**Detailing and Fabrication** *($/tonne)*	**Total Unit Price** *($/tonne)*
Columns & Beams up to 2,744 mm Long					
Rolled Shapes: 0 - 15 kg/m	1,236.80	12.19	49.12	5,258.66	6,495.46
Rolled Shapes: 15.1 - 31 kg/m	1,236.80	8.02	31.93	3,487.64	4,724.44
Rolled Shapes: 31.1 - 61 kg/m	1,236.80	5.10	15.08	1,847.87	3,084.67
Rolled Shapes: 61.1 - 100 kg/m	1,236.80	4.44	11.05	1,459.27	2,696.07
Columns & Beams over 2,744 mm Long					
Rolled Shapes: 0 - 15 kg/m	1,236.80	8.02	41.03	4,243.40	5,480.20
Rolled Shapes: 15.1 - 31 kg/m	1,236.80	5.52	26.50	2,830.65	4,067.45
Rolled Shapes: 31.1 - 61 kg/m	1,236.80	4.43	11.75	1,516.08	2,752.88
Rolled Shapes: 61.1 - 100 kg/m	1,236.80	3.88	8.69	1,217.03	2,453.83
Rolled Shapes: 100.1 - 150 kg/m	1,236.80	3.03	6.15	936.03	2,172.82
Rolled Shapes: 150.1 - 200 kg/m	1,236.80	2.59	5.51	846.74	2,083.54
Rolled Shapes: over 200 kg/m	1,770.31	2.18	4.51	771.94	2,542.26

Table 5.2 (continued): Unit costs for fabrication of AB-modules

Description	**Material Cost** *($/tonne)*	**Detailing** *(MHr/tonne)*	**Fabrication** *(MHr/tonne)*	**Detailing and Fabrication** *($/tonne)*	**Total Unit Price** *($/tonne)*
Bracing up to 2,744 mm Long					
Single Angle	1,236.80	20.00	56.30	6,497.26	7,734.06
Double Angle	1,236.80	12.18	39.16	4,430.15	5,666.94
Bracing over 2,744 mm Long					
Single Angle	1,236.80	7.99	24.70	2,884.49	4,121.29
Double Angle	1,236.80	4.20	19.13	2,110.26	3,347.06

5.1.1 Cost Estimation Example

The fabrication and erection costs of the AB-module presented in Section 4.4.2 are estimated in this section. The drawings of this AB-module, which are provided in Figure 4.16, form the basis of the cost estimation presented in Table 5.3. Considering the total weight of this module, which is 28.75 tonnes, the unit fabrication and erection costs of this module are calculated as follows:

Fabrication cost: 2,490.83 $/tonne

Erection cost: 2,222.70 $/tonne

The module fabrication and erection costs are reported as $/tonne for consistency with the practice of practitioners.

Table 5.3: An example of fabrication and erection cost estimation for AB-modules

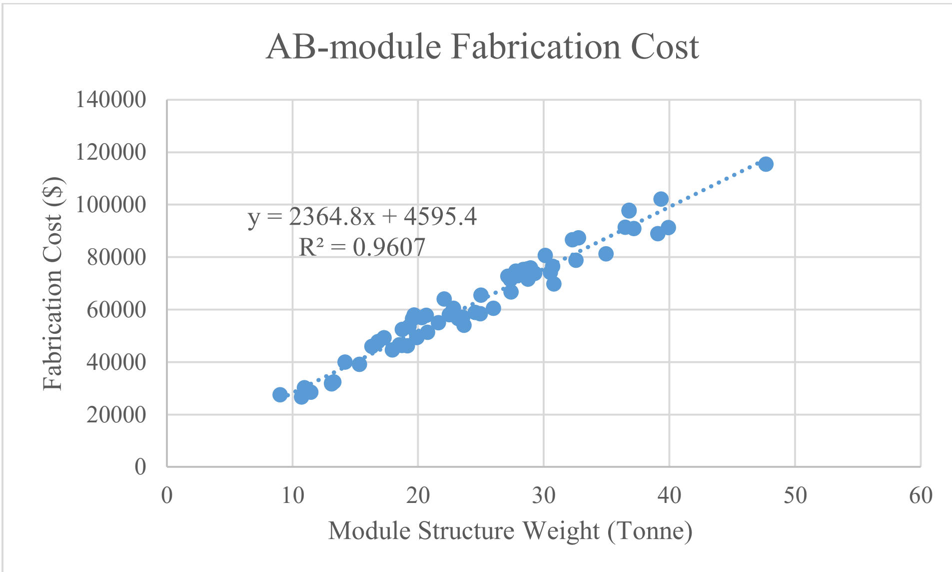
Component Type	Component Unit Weight (kg/m)	Length (m)	Quantity	Component Weight (tonne)	Fabrication Unit Price ($/tonne)	Component Fabrication Cost ($)	Erection Unit Price ($/tonne)	Component Erection Cost ($)
Transverse Beam	129.0	6.00	6	4.644	2172.82	10090.59	1619.17	7519.45
Transverse Beam	85.0	6.00	6	3.060	2453.83	7508.72	2023.97	6193.34
Transverse Beam	60.0	6.00	6	2.160	2752.88	5946.23	3035.95	6557.66
Transverse Beam	22.0	1.08	12	0.285	4724.44	1347.03	3845.54	1096.44
Transverse Beam	22.0	1.18	12	0.312	4724.44	1471.76	3845.54	1197.96
Transverse Beam	22.0	0.70	6	0.092	4724.44	436.54	3845.54	355.33
Longitudinal Beam	60.0	6.00	8	2.880	2752.88	7928.30	3035.95	8743.54
Longitudinal Beam	86.0	6.00	2	1.032	2453.83	2532.36	2023.97	2088.74
Longitudinal Beam	39.0	6.00	10	2.340	2752.88	6441.75	3035.95	7104.13
Bracing	24.1	4.76	8	0.918	3347.06	3071.69	3845.54	3529.16
Bracing	24.1	3.87	8	0.746	3347.06	2497.36	3845.54	2869.30
Column	118.0	7.26	12	10.280	2172.82	22336.98	1619.17	16645.38
					Sum	71,609.30	Sum	63,900.42

5.1.2 Developing Regression Models

As described before, the fabrication and erection costs are calculated based on each steel element in the module. Since the details of module construction, such as length and type of beams, columns, and bracings are not available during conceptual studies, it is not possible to perform fabrication and erection cost estimation using this method at this stage of the project. However, using the weight distributions generated in Chapter 4, the structure weight of modules can be estimated by sampling from the distributions. Accordingly, the discovery of a relationship between the structure module weights and their fabrication and erection cost is required. This objective is achieved by implementing regression modeling on fabrication and erection costs results. Fabrication and erection costs of the 62 AB-modules, which are used to design the M-modules in Chapter 4, are estimated using the gathered cost data. The structure weights of these AB-modules along with their estimated fabrication and erection cost are used to develop the fabrication and erection cost regression models. The results of these models are provided in Figure 5.1. The final linear equations, presented below, can be used in the simulation model to estimate the cost of fabrication and erection for AB-modules based on the sampled structure weight from the distributions.

Fabrication cost: $C_{F_A} = 2364.8\, W_A + 4595.4$ (5.1)

Erection cost: $C_{E_A} = 1934.2\, W_A + 9076.3$ (5.2) where C_{F_A} is the fabrication cost, C_{E_A} is the erection cost and W_A is the structure weight of the AB-module.



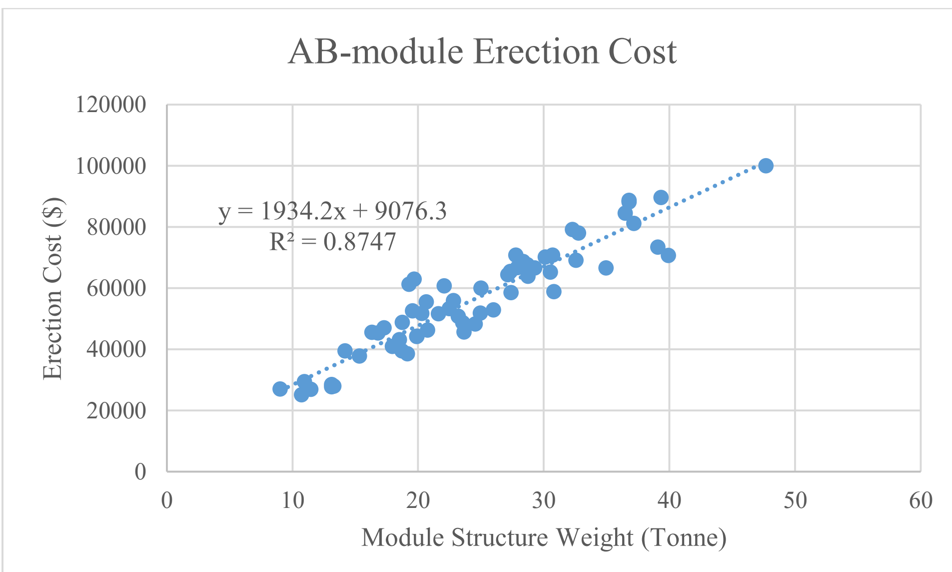


Figure 5.1: Regression models developed for fabrication and erection cost of AB-modules

5.2 Risk Analysis

The main purpose of risk management is to increase the probability and impact of positive events and to decrease the probability and impact of negative events (PMI, 2004). Risk management includes four stages: risk identification, risk analysis, risk mitigation, and risk control (AbouRizk 2009). The primary stage should identify all potential issues or events that may cause harm to the project. Then, the risk factors should be quantified and their influence on the project should be determined. Later, a risk mitigation strategy should be developed and implemented to control the risk events. The last stage should monitor the implementation of risk mitigation strategies and identify new risk events (Hong 2012).

According to AbouRizk (2009), each risk factor should be quantified by considering the severity of the factor, which is an indicator of the risk significance. Severity depends on two parameters that should be identified for each risk factor: likelihood and magnitude of impact. These two parameters can be defined in linguistic terms, numeric measures, or ordinal scale forms by the analyst in any desired scale.

The risk factors considered in the simulation model should consist of three parameters: risk item, likelihood, and impact. The description of the risk factor is specified in the risk item. The likelihood of each risk factor can be determined based on the likelihood scale suggested by AbouRizk (2009), presented in Table 5.4. In this scale, the values reflecting the linguistic terms grow exponentially. Other likelihood scales may be used, based on the desires of the analyst and project conditions. The impact of each risk factor is defined as the percentage of its influence on cost. This percentage should be identified by experts and professionals in modular construction estimation.

The final fabrication and erection costs of each module are calculated by considering the risk factors, as presented in Equation 5.1. This equation can be used for both the fabrication and erection cost.

$$C_i = \overline{C_i} + \sum_m \overline{C_i} \times I_m \tag{5.1}$$

Where C_i is the final cost of the module i (fabrication or erection cost) with consideration of the risk factors, $\overline{C_i}$ is the cost before applying risk factors and I_m is the impact of risk factor m.

Table 5.4: Likelihood scale in risk analysis

Linguistic	Explanation	Probability	Low %	High %	Ordinal [0-100]
Very Likely	Almost certain that it will happen	0.825	65	100	100
Likely	More than 50-50 chance	0.500	35	65	50
Somewhat Likely	Less than 50-50 chance	0.250	15	35	25
Unlikely	Small likelihood but could well happen	0.100	5	15	10
Very Unlikely	Not expected to happen	0.030	1	5	3
Extremely Unlikely	Just possible but would be very surprising	0.005	0.00	0.01	1

The likelihood of each risk factor is applied in the simulation process and is described later in Section 5.3.

Table 5.5 demonstrates sample risk factors in the fabrication and erection process of industrial modules. The factors related to the use of AB-modules are determined using the Module Assembly Framework report, provided by Construction Owners Association of Alberta (COAA, 2016), and factors related to construction using M-modules are identified through interviews with experts in this field. It should be noted that this list provides a few selected risk factors; a comprehensive list should be created by estimators for each project.

Table 5.5: Sample risk factors for AB- and M-module fabrication and erection

AB-modules
Fabrication Risks
Delay in delivery of required material to fabricator prior to fabrication commencement
Erection Risks
Incomplete module design at assembly commencement
Lack of supportive infrastructure at module yard to support the project plan
M-modules
Fabrication Risks
Incompatibility of designed bolt sizes with the standards of Alberta, Canada
Use of weak components for beams or columns, which requires stiffening in Alberta
Erection Risks
Salt attack during shipment through ocean, which requires extra cleaning activities in Alberta
More fireproofing due to more number of connections in M-modules
More man-hours required for the erection of M-modules due to greater number of connections

5.3 Simulation Model Explanation

A screenshot of the developed simulation model is provided in Figure 5.2. Three separate models are generated for three different options involving modular construction: perform fabrication and assembly in Alberta, perform fabrication overseas and assembly in Alberta, and perform fabrication and assembly overseas. However, the modeling procedure and the simulation process are the same for all models. The following is a description of the purpose of each element of the simulation model:

- Create element

  The create element is used in all models made with the General Template in Simphony to produce entities. In this model, each entity represents a module: AB-modules in options one and two and M-modules in option three. Therefore, the number of required AB- or M-modules should be specified by the user as the "Quantity" input of this element. One of the attributes of each entity is also used to store the structure weight of the module. The value of LX (1) of each entity is set to a formula that samples a number from the structure weight distribution of AB-modules for option one and two and M-modules for option three. These distributions are generated according to the description in Section 4.2.3.

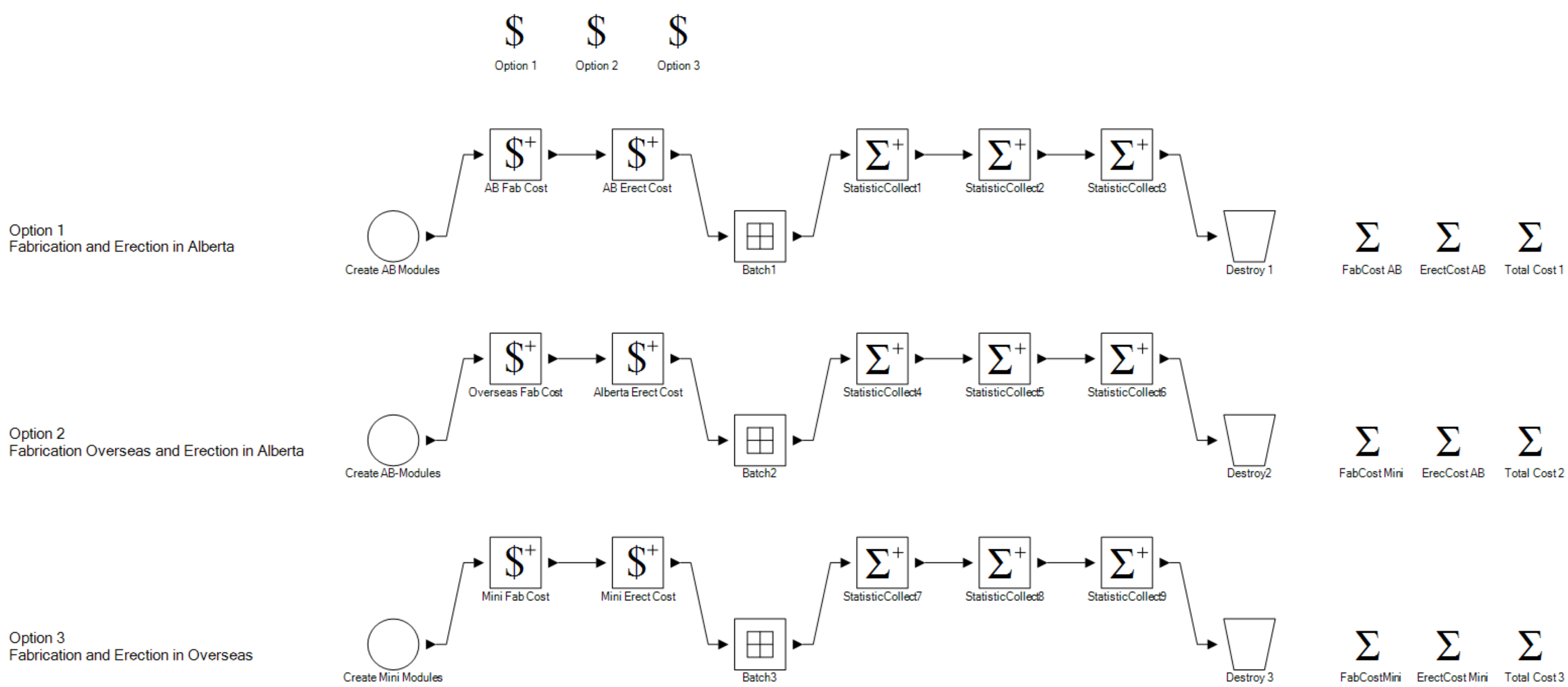


Figure 5.2: Simulation model developed for performing cost comparison study

- Cost Collect element

This element is used to collect the cost of fabrication and erection of each module for each option. Using the final cost reports, the cost range of the fabrication and erection activities is obtainable. For each entity passing from this element, it performs calculations based on its input variables (cost = unit cost × quantity) and stores the result to present in the final cost report. In this model, the quantity of all cost collect elements is set to one and the unit cost is set using a formula to calculate the related cost by considering the influence of risk items. The following is the code used as this formula for "AB Fab Cost" element:

```
Dim x as Decimal
x = CDec(2364.8 * LX(1) + 4595.4)
If sampleuniform(0,100) <= 25
      x = x + x * CDec(0.1)
End If
If    sampleuniform(0,100) <= 40
      x = x + x * CDec(0.2)
End If
GX(1) = GX(1) + x
Return x
```

In this code, the variable x is defined to store the fabrication cost of the AB-modules. The value of this variable is initially calculated based on the equation developed in Section 5.1 using regression analysis to calculate the fabrication cost of the AB-module based on module structure weight, stored as LX (1). The following *if* clauses represent the effect of risk factors on the fabrication cost of the AB-module. In this case, it is assumed that two risk items influence the AB-modules fabrication process: the first risk item has a likelihood of 25% and a cost impact of

10% and the second risk item has a likelihood of 40% and a cost impact of 20%. For each risk item, the concept of risk likelihood is applied to the calculations by sampling a random number between 0 and 100 for each module. If the random number is less than the likelihood of the risk item, the risk is applied to that module and the impact of risk should be considered in the fabrication cost of the module. For instance, if “14” is selected as the random number for the first risk item, this risk should be applied to the fabrication cost of the module, meaning that the fabrication cost should be increased by 10%. However, if the random number is “36”, the risk will not be applied to that module and the fabrication cost will remain unchanged. The global attribute GX (1) is used to store the total fabrication cost of each run for Option 1. It will be reported using the Statistic Collect element, which is explained later.

The same coding structure is used for “AB Erect Cost” element, as presented below:

```
Dim x as Decimal
x = CDec(1934.2 * LX(1) + 9076.3)
If sampleuniform(0,100) <= 35
      x = x + x * CDec(0.15)
End If
If sampleuniform(0,100) <= 30
      x = x + x * CDec(0.25)
End If
GX(2) = GX(2) + x
Return x
```

In this case, the equation developed for the AB-module erection cost is used to estimate the cost of erection based on the module structure weight, stored as LX (1). The same method of risk analysis is used for calculating the erection cost of modules.

The fabrication and erection cost of M-modules is calculated using the same codes as the formula for the "Unit Cost" input of their Cost Collect element. However, the equation for the fabrication and erection cost of M-modules should be provided by the user.

- Batch element

The batch element is used to prevent entities from passing through the last part of the simulation model before finishing the fabrication and erection cost estimation on all modules. Therefore, the "Quantity" input of this element should be equal to the quantity of modules required for that run (i.e. quantity input of the create element).

- Statistic Collect element

These elements are used in each model to collect the total fabrication cost, total erection cost, and overall fabrication and erection cost for each run. For instance, in the model for option one, "StatisticCollect1" reports GX (1), "StatisticCollect2" reports GX (2), and "StatisticCollect3" reports GX (1) + GX (2). Since this part of the model becomes active when the cost estimation is complete for all modules, the GX (1) and GX (2) attributes represent the total cost of each activity.

Table 5.6 presents a list of inputs that should be provided by the user. It should be noted that any desired number of risk items can be considered in this stage of the calculations. In order to apply a risk item to all modules, the likelihood of the risk item should be set to 100.

Table 5.6: List of the initial inputs for the simulation model

Simulation Model Inputs
Create element
Quantity of AB- and M-modules
Cost Collect element
Risk items for fabrication and erection of AB- and M-modules
Likelihood and impact of each risk item
The fabrication and erection equations of M-modules

5.4 Case Study

To further demonstrate the application of the developed simulation model, a sample case study of a hypothetical modular industrial construction project is provided to illustrate the use of this model in conceptual cost estimation studies. The numbers and equations used in this case study are assumptions and are not representative of a real construction project.

5.4.1 Limitations

The intention of this case study is to show the application of the developed simulation model in modular construction industry. As no information was available regarding the overseas fabrication and erection cost, the overseas cost models were developed based on assumptions. These cost models were assumed considering the cost differences between Alberta and China; therefore, they represent lower fabrication and erection cost comparing to Alberta, as presented in Figure 5.4. It should be noted that these cost models cannot be used in practice as they do not represent actual construction costs in China. The quantity of AB-modules is assumed for a relatively small plant and the quantity of M-modules is assumed to be 4.5 times more than AB-modules. This number is assumed based on the results of the case study presented in Section 4.1.2. The risk items used in this case study are selected from the cost items listed in Chapter 3.

It should be noted that the results of the simulation model are project-specific and might change by using different inputs. Although the final results depend on the initial assumptions, the results of this case study are meaningful due to the reasonable assumptions made in this case.

5.4.2 Problem Description

This case study involves a petrochemical industrial plant to be built in the Fort McMurray area in Alberta, Canada. As a result of harsh weather conditions and a shortage of skilled labor in this region, modularization is selected as the main method of construction. There are two possible choices for the location of the fabrication and assembly of modules: Edmonton, Alberta or China. These potential locations lead to a number of feasible options for the method of construction:

1. Perform fabrication in Edmonton, transfer the fabricated components to an assembly yard in Edmonton, assemble the modules, and transfer the completed modules to the construction site using highway transport.

2. Perform fabrication in China, transfer fabricated components by ocean, railway, and highway to assembly yards in Edmonton, assemble modules

in Edmonton, and transfer the completed modules to the construction site by highway. It is also possible to perform fabrication partially overseas and assemble the rest of the components in Edmonton.

3. Perform fabrication and assembly in China and transfer completely assembled modules by ocean, railway, and highway directly to the construction site.

A decision should be made between these options that are based on the total project cost and risk implications of each scenario. It is estimated that 40 modules are required for Options 1 and 2 and 180 modules are required for Option 3. Table 5.7 presents the risk items applicable to this project, along with their likelihood and impact on the project cost. In this case study, the risk items are considered to be the parameters that will affect the initial cost of each activity. The simulation model developed in Section 5.3 is implemented to perform a conceptual cost comparison study on the fabrication and erection cost between the above-mentioned options. The regression models developed in Section 5.2 are used for estimating the fabrication and erection cost of the AB-modules. Since no information were available for the cost of fabrication and erection in China, the cost models for overseas operations are developed based on assumptions. The main consideration in making the assumption is to have lower fabrication and erection cost in China compared to Alberta due to lower labor rates in overseas countries. The fabrication and erection cost models in China were assumed to be as follows:

Fabrication cost: $C_{F_M} = 1400\ W_S + 3600$ (5.3)

Erection cost: $C_{E_M} = 1100\ W_S + 5400$ (5.4)

where C_{F_M} is the fabrication cost, C_{E_M} is the erection cost and W_S is the structure weight of the M-modules.

Table 5.7: Risk items considered for the case study

Risk Item	Likelihood	Impact
Alberta Fabrication		
Delay in delivering required materials	30%	15%
Alberta Erection		
Incomplete module design at assembly commencement	25%	10%
Overseas Fabrication		
Incompatibility of designed bolt sizes with the standards of Canada	35%	20%
Use of weak components for beams or columns	25%	25%
Overseas Erection		
Salt attack during shipment through ocean	60%	15%
More fireproofing due to more number of connections in M-modules	100%	20%
More man-hours required for the erection of M-modules due to greater number of connections	100%	25%

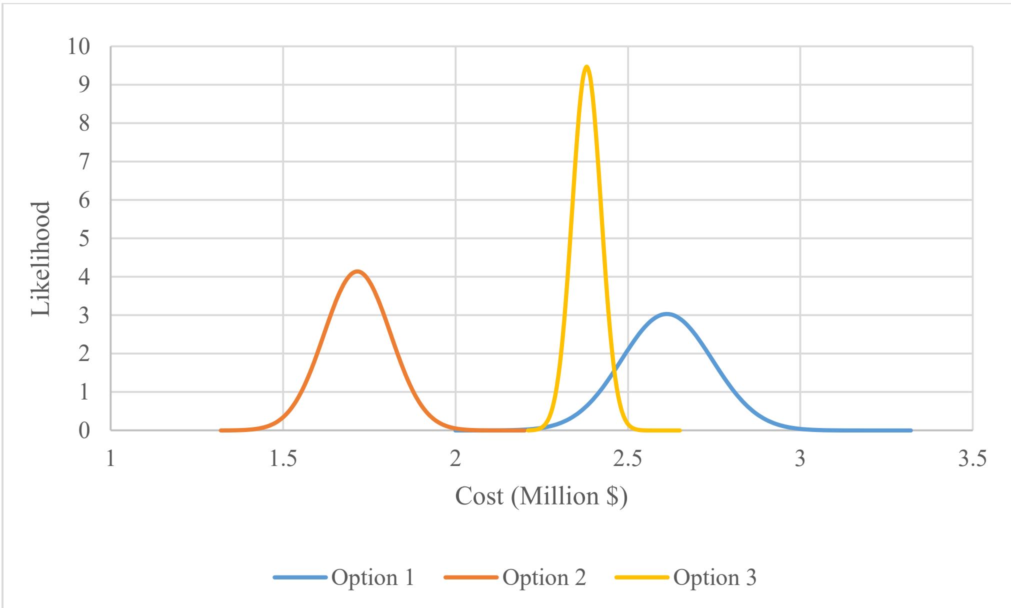
5.4.3 Results of the Sample Case Study

To achieve an acceptable confidence interval for the final results, the simulation model was run 100 times. The results gathered by the Statistic Collect elements are extracted from the model for further analysis. For each option, a distribution is fitted to the cost of fabrication and erection activities as well as the total module cost, resulting in nine separate distributions. The distributions are fit to the simulation data in Simphony using three different fitting methods: Least Squares, Maximum Likelihood, and Moment Matching. The quality of the fit is controlled for each method using Chi-Squared and K-S tests, with the objective of selecting a single distribution type for all nine cases. In this study, normal distributions result in the least error and are selected to represent the cost. These distributions are presented in Table 5.8.

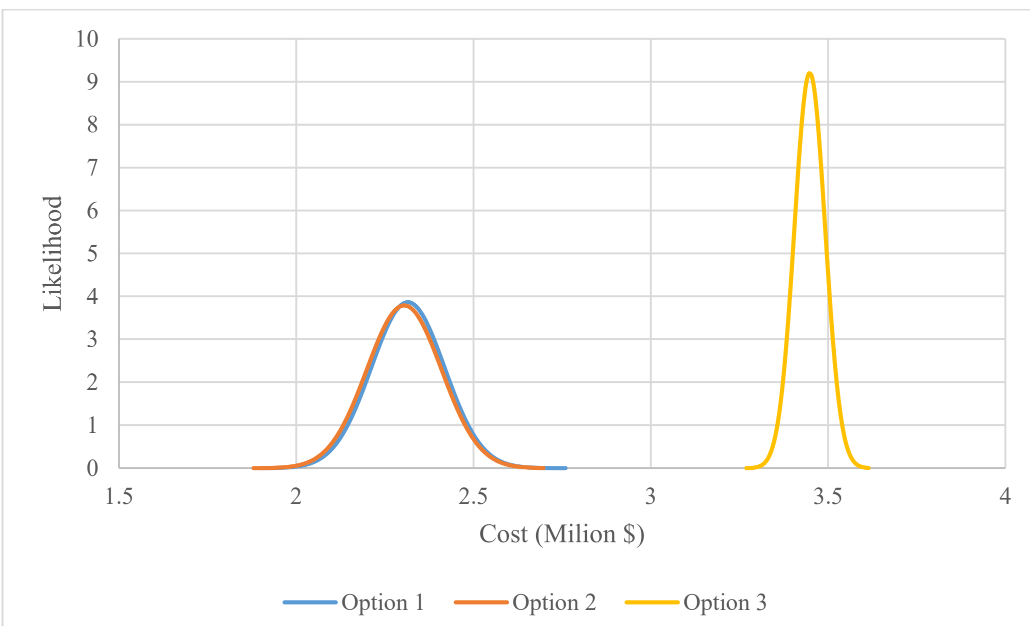
Table 5.8: Fitted distributions for fabrication and assembly

Option No.	Cost Item	Distribution
1	Fabrication Alberta	N (2612972.16, 131683.70)
	Erection Alberta	N (2315434.07, 103333.29)
	Total Cost	N (4929369.28, 232567.33)
2	Fabrication Overseas	N (1715395.97, 96500.78)
	Erection Alberta	N (2304591.89, 105222.36)
	Total Cost	N (4020730.46, 198253.36)
3	Fabrication Overseas	N (2379968.32, 42146.85)
	Erection Overseas	N (3448567.64, 43317.31)
	Total Cost	N (5829021.42, 79251.12)

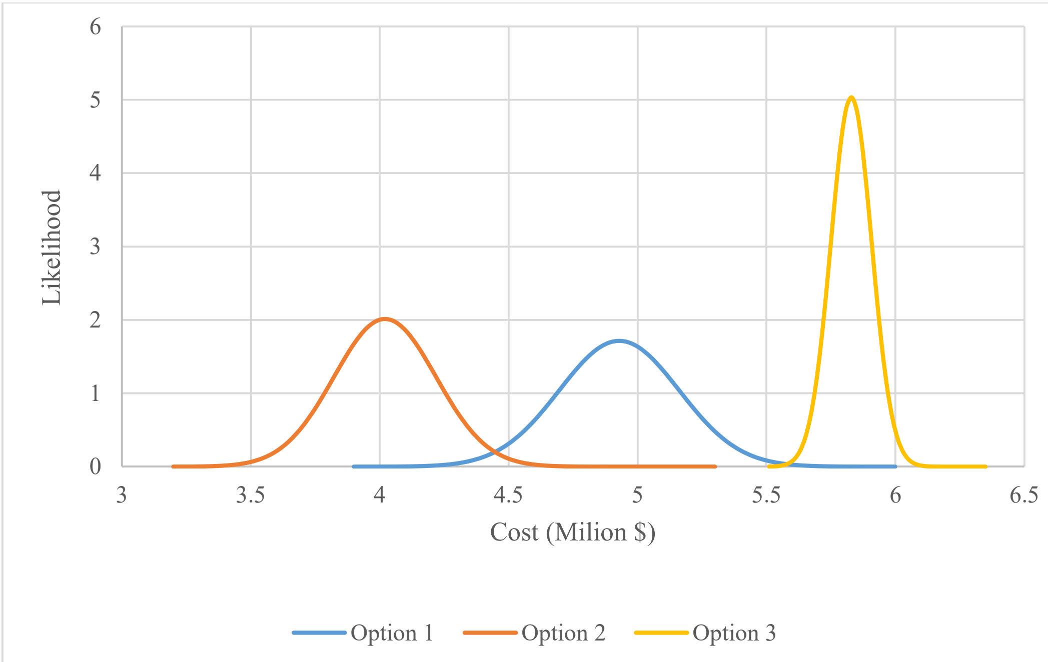
For each activity, a comparison is made between the different options, as presented in Figure 5.3. According to this figure, the lowest fabrication cost is related to Options 2, 3, and 1, respectively. The erection costs of Options 1 and 2 fall in the same range, as they both represent the erection cost associated with AB-modules. However, the erection cost of the M-modules is approximately three times the cost of erection in Alberta, as a result of the greater number of M-module components and the higher risks associated with this option. According to Figure 5.3c, Option 2 has the lowest total cost, while Option 3 is the most expensive one. This difference in cost is primarily related to costs incurred during the erection phase and its associated risks.



a. Fabrication cost



b. Erection cost



c. Fabrication and erection cost

Figure 5.3: Comparison between fabrication and erection costs of different location options

The decision on the construction method should be made based on the total fabrication and erection cost of each option. According to the results presented in Figure 5.3, performing module erection overseas considerably increases the project cost. Although the fabrication cost of Option 2 (fabrication of module components in China and module assembly in Edmonton, AB) is lower than Option 1, the extremely costly requirements of the erection activities of Option 2 result in an expensive construction method. This increase in the erection cost of M-module is directly related to the associated risks and uncertainties. Figure 5.4 demonstrates the fabrication and erection cost per tonne of both AB- and M-modules, without consideration of any risk factors. Based on this graph, the risk-free cost of fabrication and erection in China is lower than in Alberta. This analysis shows that the major increase in the cost of M-module erection is due to the impact of the risk factors associated with this option.

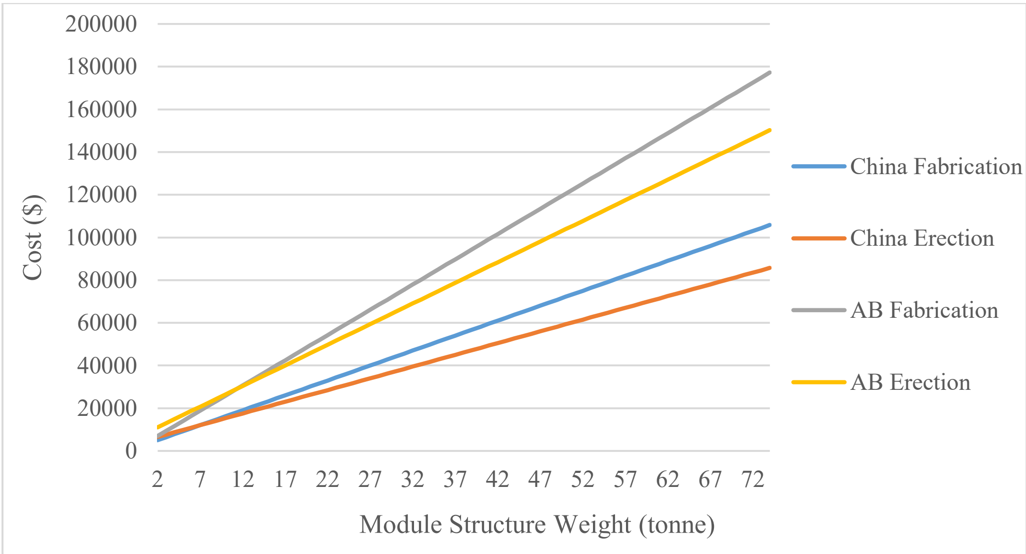


Figure 5.4: Comparison between initial fabrication and erection cost of modules in Alberta compared to China

According to the distributions presented in Table 5.8, the total fabrication and erection cost of each option falls into the following ranges, with 95% confidence:

Option 1 [Lowest boundary, Highest boundary] = [$ 4464k , $ 5394k]

Option 2 [Lowest boundary, Highest boundary] = [$ 3624k , $ 4417k]

Option 3 [Lowest boundary, Highest boundary] = [$ 5670k , $ 5987k]

According to the final results of this sample case study, Option 2 leads to the lowest range of cost among all possible construction options. It should be noted that these results are illustrative in nature and are not intended to recommend any construction method for future modular projects in the industry. The results of the simulation model are highly dependent on the inputs (i.e. the module quantities, the number of risk items as well as their likelihood and impact, and the fabrication and erection cost models). The final result of this case study is only true for this case and may change when considering different risk items or cost models.

5.5 Chapter Summary

In this chapter, a simulation model is developed to compare the cost of various scenarios of fabrication and erection of modules in Alberta and overseas. This model can be used at the conceptual phase of future industrial modular projects to estimate the cost of module fabrication and erection for each construction option and identify the most cost-effective one. Moreover, regression models of fabrication and erection cost of modules in Alberta are developed and used in the simulation model. In addition, a sample case study is provided to demonstrate the application of this simulation model in the construction industry. It should be noted that the results of the case study cannot be applied to other projects as each construction project is unique and should be studied separately.

Chapter 6: Conclusion

In recent years, offshore fabrication and assembly of industrial modules has become a common alternative to local assembly in Alberta, Canada. Due to several differences between the modules assembled in Alberta (AB-modules) and overseas (M-modules), a comprehensive conceptual cost comparison study is required between these two assembly location scenarios. This study was conducted to facilitate conceptual cost comparisons between Alberta and overseas fabrication and assembly of industrial modules. This chapter provides the contributions of this study, along with recommendations for future research.

6.1 Contributions

The main contributions of this thesis are listed below:

1. A comprehensive list of cost items was developed to assist estimators in performing conceptual cost comparisons. These cost items were identified by conducting interviews with professionals in industrial modular construction. By considering the cost items proposed in this study, a conceptual cost comparison can be conducted for future projects between different scenarios involving Alberta and overseas module assembly.
2. A new method was proposed to compare the differences in module quantity and structural steel requirements between Alberta and overseas fabrication and assembly. Another method was also proposed to convert

the AB-modules to M-modules on projects previously designed in Alberta-size. These two methods were applied to two modular industrial construction projects designed using AB-sized modules.

3. Two statistical models, in the form of frequency distributions of AB-module and M-module structure weights, have been generated. These models can be used as decision support tools to estimate structure weights of modules in future projects.

4. Two regression models of the fabrication and erection cost of modules in Alberta have been developed based on module structure weight. These weights can be estimated for future projects using the structure weight distributions developed. The regression models can be used to estimate the fabrication and erection cost of AB-modules for future projects.

5. A statistical simulation model has been generated to assist estimators in conducting conceptual estimations of the fabrication and erection cost of modules. The inputs of this simulation model are the quantity of AB- and M-modules, the cost (dollars per tonne of steel) for overseas fabrication and assembly, and the risk items associated with each activity, along with their likelihood and impact. Using these inputs, the model estimates the fabrication and erection cost of AB- and M-modules in Alberta and overseas and provides a range for the estimated cost according to a particular confidence level. This simulation model is beneficial for the performance of cost comparison studies between different scenarios of fabrication and assembly in Alberta and overseas for future projects.

6.2 Limitations and Future Work

The research presented in this thesis can be extended in the following areas:

- This study is based on the assumption that M-modules experience the same load conditions as AB-modules. However, the impact loads associated with ocean transportation add extra load conditions. The effect of these load conditions should be investigated to develop more accurate designs for M-modules.

- In this study, the difference in module quantities and required amounts of structural steel for Alberta and overseas module assembly is investigated on two modular industrial construction projects. However, due to the lack of access to cost data of overseas fabrication and assembly, a cost comparison between Alberta and offshore assembly of modules was not conducted. Application of overseas fabrication and erection costs to the results of the quantification of the amounts of steel required for AB- and M-modules will allow a cost comparison to be performed on these two projects.

- This study focuses on the cost of the fabrication and erection of the modules. However, several other cost items should be considered in the cost comparison studies, as listed in Chapter 3 (including pipe spools and transportation, etc.). Investigation of these cost items on industrial modular projects will allow for a more comprehensive cost comparison study to be achieved.

- The simulation model developed in this study can be improved to consider other cost items listed in Chapter 3, to perform a comprehensive cost comparison study at the conceptual level. This simulation model can also be improved to consider other module characteristics affecting the projects cost such as quality and complexity of modules.
- A sensitivity analysis is required on the results of the simulation model to determine the effect of each assumption or input of the model on the final results.
- This study investigated the effects of overseas fabrication and assembly of industrial modules on the project cost at the conceptual level. A similar study is required to investigate the application of this new method of analysis of different modularization options to studies of the impacts of modularization on project duration and delivery schedule.

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Appendix A: Alberta-Size and Mini-Size Envelopes and Module Dimensions

Envelope and module size of AB-Modules, Project 1

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0020A	36.11	6.83	6.2	24	6	6
0020B	30	7.32	6.2	24	6	6
0021A	36.74	6.83	5.97	30	6	3.9
0021B	34.13	9.41	7.32	30	6	5.44
0120B	36	7.42	6.1	30	6	6
0121A	36	7.3	6	30	6	6
0121B	36	7.42	6.4	30	6	5.01
0122A	35.35	6.91	6.3	30	6	6
0122B	35.35	7.06	5.49	30	6	5.15
0123A	29.35	6.71	6.1	24	6	6
0123B	29.35	6.71	5.79	24	6	5.15
0124A	34.75	6.71	6.3	30	6	6.02
0124B	34.75	6.71	5.49	30	6	5.15
0125	29.35	7.3	7.62	24	6	7.36
0126A	29.5	7.3	7.36	24	6	7.36
0126B	7.3	7.3	3.4	6	6	3.4
0127	29	7.3	7.7	24	6	7
0128A	41.85	6.86	7.25	36	6	7
0130	39.5	7.3	7	36	6	7
0131	21.24	5.46	6.25	15	4	5.75
0132A	11.85	5.3	6.75	6	4	6.75
0132B	12	6.71	6.86	6	4	4.65
0221A	23.3	7.06	7.77	18	6	7.7
0222A	35.3	7.3	7.98	30	6	7.95

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0223A	34.56	7.3	7.77	30	6	7.7
0320A	32.65	7.3	4.2	30	6	4.2
0320B	32.65	7.3	5.64	30	6	5.6
0321A	34	7.3	4.2	30	6	4.2
0321B	34	7.3	5.65	30	6	5.6
0322A	29	7.3	4.2	24	6	4.2
0322B	29	7.3	5.64	24	6	5.6
0323A	29.85	7.12	6.3	24	6	6.3
0323B	29.85	7.12	6.5	24	6	6.3
0324A	24	7.3	6.3	18	6	6.3
0324B	24	7.3	3.65	18	6	3.65
0421A	34	7.3	7.62	29	6	7.6
0422A	34.5	7.3	6.8	29	6	6.8
0422B	29.5	7.3	5.79	24	6	5.3
0423A	29.35	7.3	6.8	24	6	6.8
0423B	29.35	7.3	5.64	24	6	5.3
0424A	27.65	7.3	5.55	24	6	5.55
0424B	27.65	7.3	6.75	24	6	6.75
0425A	29.25	7.3	5.55	24	6	5.55
0425B	29.25	7.3	5.94	24	6	5.6
0426A	30	7.3	5.55	24	6	5.55
0426B	30	7.3	5.79	24	6	5.6
0427A	35.25	7.3	5.34	30	6	5.34
0427B	35.25	7.3	5.6	30	6	5.6
0428A	27.65	5.3	5.44	24	4	5.44
0428B	27.65	5.3	5.5	24	4	5.5
0429	29.35	7.3	7.7	24	6	7.7
0520A	30	7.3	6.3	24	6	6.3

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0520B	30	7.42	3.65	24	6	3.65
0521A	30	7.32	6.3	24	6	6.1
0522A	27.65	7.3	6.1	24	6	6.1
9243	20.5	8.43	7.62	19.2	7.13	7.04
9202	32.3	8.5	6.4	31	7.2	6.4
9216	28.8	8.5	6.81	27.5	7.2	6.81
9225	39.3	7.32	7.32	38	7.2	6.77
9236	33.1	8.5	7.32	31.8	7.2	6.81
9244	27.3	8.24	7.01	26	7	7.01
9244	27.3	8.24	7.01	26	7	7.01
9253	39.3	8.5	6.81	38	7.2	6.81
M-0030	17.73	7.32	7.77	16	6.8	5.3
M-0031	17.53	7.54	6.1	16	6.89	3.05
M-0032	12.95	7.35	4.42	11.8	6.7	1.87
M-0033	28.96	7.35	4.42	28	6.7	2.77
M-0034	19.81	6.55	6.71	18	6	3
M-0036	6.55	5.33	2.74	5.85	4.87	1.58
M-0146	19.6	7.32	6.55	18	6	3.2
M-0151	11.3	6	5.4	10.65	6	5.4
M-0152	11.3	6	5.4	10.65	6	5.4
M-0155	12.73	4.11	7.77	12	3	5.65
M-0330	8.49	6.3	4.57	7.01	5	3.05
M-0432	13.72	7.75	8	13.2	7.1	8
M-0433	11.05	7.6	6.8	11.05	7.2	6.8

Envelope and module size of M-Modules, Project 1

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0223	001	22.56	3.5	4.09	18	2.85	4.09
	002	22.56	3.8	4.09	18	3.15	4.09
	003	22.56	3.5	3.68	18	2.85	3.61
	004	22.56	3.8	3.68	18	3.15	3.61
0223/0222	005	24	3.5	4.09	18	2.85	4.09
	006	24	3.8	4.09	18	3.15	4.09
	007	24	3.5	3.89	18	2.85	3.86
	008	24	3.8	3.89	18	3.15	3.86
0222	009	23.3	3.5	3.3	18	2.85	3.3
	010	23.3	3.8	3.3	18	3.15	3.3
	011	23.3	3.5	2.3	18	2.85	2.3
	012	23.3	3.8	2.3	18	3.15	2.3
	013	23.3	3.5	2.35	18	2.85	2.35
	014	23.3	3.8	2.35	18	3.15	2.35
0221	015	23.3	3.5	3.3	18	2.85	3.3
	016	23.3	3.8	3.3	18	3.15	3.3
	017	23.3	3.5	2.3	18	2.85	2.3
	018	23.3	3.8	2.3	18	3.15	2.3
	019	23.3	3.5	2.17	18	2.85	2.1
	020	23.3	3.8	2.17	18	3.15	2.1
0322A&B	021	24	3.5	3.4	18	2.85	3.4
	022	24	3.8	3.4	18	3.15	3.4
	023	24	3.5	3.1	18	2.85	3.1
	024	24	3.8	3.1	18	3.15	3.1
	025	24	3.5	3.34	18	2.85	3.3
	026	24	3.8	3.34	18	3.15	3.3

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0322A&B / 0321A&B	027	22	3.4	3.7	16	2.75	3.7
	028	22	3.9	3.7	16	3.25	3.7
	029	22	3.4	3	16	2.75	3
	030	22	3.9	3	16	3.25	3
	031	22	3.4	3.1	16	2.75	3.1
	032	22	3.9	3.1	16	3.25	3.1
0321A&B / 0320A&B	033	22	3.4	3.7	16	2.75	3.7
	034	22	3.9	3.7	16	3.25	3.7
	035	22	3.4	3	16	2.75	3
	036	22	3.9	3	16	3.25	3
	037	22	3.4	3.1	16	2.75	3.1
	038	22	3.9	3.1	16	3.25	3.1
0320A&B	039	18	3.4	3.5	12	2.75	3.5
	040	18	3.9	3.5	12	3.25	3.5
	041	18	3.4	3	12	2.75	3
	042	18	3.9	3	12	3.25	3
	043	18	3.4	3.3	12	2.75	3.3
	044	18	3.9	3.3	12	3.25	3.3
	045	11	3.3	3.75	6	2.65	3.75
	046	11	4	3.75	6	3.35	3.75
	047	11	3.3	3.5	6	2.65	3.5
	048	11	4	3.5	6	3.35	3.5
	049	11	3.3	2.55	6	2.65	2.55
	050	11	4	2.55	6	3.35	2.55

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0323A&B	051	24.5	3.65	4.09	18	3	4.09
	052	24.5	3.65	4.09	18	3	4.09
	053	24.5	3.65	3.1	18	3	3.1
	054	24.5	3.65	3.1	18	3	3.1
	055	24.5	3.65	3.07	18	3	2.71
	056	24.5	3.65	3.07	18	3	2.71
0323A&B / 0324A&B	057	18	3.65	4.09	12	3	4.09
	058	18	3.65	4.09	12	3	4.09
	059	18	3.65	3.1	12	3	3.1
	060	18	3.65	3.1	12	3	3.1
	061	18	3.65	3.07	12	3	2.71
	062	18	3.65	3.07	12	3	2.71
0324A&B	063	12	3.7	3.1	6	3.05	3.1
	064	12	3.7	3.1	6	3.05	3.1
	065	12	3.7	3.2	6	3.05	3.2
	066	12	3.7	3.2	6	3.05	3.2
	067	12	3.7	3.65	6	3.05	3.65
	068	12	3.7	3.65	6	3.05	3.65
0128A	069	24	3.6	4.09	18	3	4.09
	070	24	3.7	4.09	18	3	4.09
	071	24	3.6	3.16	18	3	2.91
	072	24	3.7	3.16	18	3	2.91
	073	17.85	3.4	4.09	12	3	4.09
	074	17.85	3.46	4.09	12	3	4.09
	075	17.85	3.4	3.16	12	3	2.91
	076	17.85	3.46	3.16	12	3	2.91

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0021A&B	077	18.11	3.2	3.8	12	2.785	3.8
	078	18.11	3.63	3.8	12	3.215	3.8
	079	18.11	3.2	3	12	2.785	3
	080	18.11	3.63	3	12	3.215	3
	081	18.11	3.2	3.27	12	2.785	2.54
	082	18.11	3.63	3.27	12	3.215	2.54
	083	18	3.2	4.09	12	2.785	4.09
	084	18	3.63	4.09	12	3.215	4.09
	085	18	3.2	3	12	2.785	3
	086	18	3.63	3	12	3.215	3
	087	18	3.2	2.98	12	2.785	2.25
	088	18	3.63	2.98	12	3.215	2.25
0022A	089	24	3.87	3.4	18	3.22	3.4
	090	24	3.43	3.4	18	2.78	3.4
	091	24	3.87	3.92	18	3.22	3.8
	092	24	3.43	3.92	18	2.78	3.8
	093	10.13	3.87	3.5	6	3.22	3.5
	094	10.13	3.43	3.5	6	2.78	3.5
	095	10.13	3.87	3.82	6	3.22	3.7
	096	10.13	3.43	3.82	6	2.78	3.7
0522A	097	21.65	3.65	3.2	18	3	3.2
	098	21.65	3.65	3.2	18	3	3.2
	099	21.65	3.65	2.9	18	3	2.9
	100	21.65	3.65	2.9	18	3	2.9
0522A / 0521A	101	24	3.66	3.2	18	3	3.2
	102	24	3.66	3.2	18	3	3.2
	103	24	3.66	3.1	18	3	2.9
	104	24	3.66	3.1	18	3	2.9

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0521A/-0520A	105	24	3.66	3.2	18	3	3.2
	106	24	3.66	3.2	18	3	3.2
	107	24	3.66	3.1	18	3	3.1
	108	24	3.66	3.1	18	3	3.1
0520B	109	15.65	3.66	3.65	12	3	3.65
	110	15.65	3.66	3.65	12	3	3.65
0520A	111	18	3.65	3.2	12	3	3.2
	112	18	3.65	3.2	12	3	3.2
	113	18	3.65	3.1	12	3	3.1
	114	18	3.65	3.1	12	3	3.1
0520B	115	18	3.65	3.65	12	3	3.65
	116	18	3.65	3.65	12	3	3.65
0121A&B	117	24	3.55	3.5	18	2.9	3.5
	118	24	3.75	3.5	18	3.1	3.5
	119	24	3.55	3.8	18	2.9	3.8
	120	24	3.75	3.8	18	3.1	3.8
	121	24	3.55	2.3	18	2.9	2.3
	122	24	3.75	2.3	18	3.1	2.3
	123	24	3.55	2.8	18	2.9	1.41
	124	24	3.75	2.8	18	3.1	1.41
0121A&B / 0122A&B	125	24	3.55	3.5	18	2.9	3.5
	126	24	3.75	3.5	18	3.1	3.5
	127	24	3.55	3.8	18	2.9	3.8
	128	24	3.75	3.8	18	3.1	3.8
	129	24	3.55	2.3	18	2.9	2.3
	130	24	3.75	2.3	18	3.1	2.3
	131	24	3.55	2.8	18	2.9	1.55
	132	24	3.75	2.8	18	3.1	1.55

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0122A&B	133	23.35	3.55	3.8	18	2.9	3.8
	134	23.35	3.36	3.8	18	2.71	3.8
	135	23.35	3.55	2.8	18	2.9	2.8
	136	23.35	3.36	2.8	18	2.71	2.8
	137	23.35	3.55	2.6	18	2.9	2.6
	138	23.35	3.36	2.6	18	2.71	2.6
	139	23.35	3.55	2.59	18	2.9	1.95
	140	23.35	3.36	2.59	18	2.71	1.95
0123A&B	141	23.35	3.6	3.8	18	2.95	3.8
	142	23.35	3.31	3.8	18	2.66	3.8
	143	23.35	3.6	3	18	2.95	3
	144	23.35	3.31	3	18	2.66	3
	145	23.35	3.6	2.55	18	2.95	2.55
	146	23.35	3.31	2.55	18	2.66	2.55
	147	23.35	3.6	2.54	18	2.95	1.8
	148	23.35	3.31	2.54	18	2.66	1.8
0123A&B /0124A&B	149	24	3.6	4.09	18	2.95	4.09
	150	24	3.31	4.09	18	2.66	4.09
	151	24	3.6	4.09	18	2.95	4.09
	152	24	3.31	4.09	18	2.66	4.09
	153	24	3.6	3.71	18	2.95	2.99
	154	24	3.31	3.71	18	2.66	2.99
0124A&B	155	16.75	3.6	4.09	12	2.95	4.09
	156	16.75	3.31	4.09	12	2.66	4.09
	157	16.75	3.6	4.09	12	2.95	4.09
	158	16.75	3.31	4.09	12	2.66	4.09
	159	16.75	3.6	3.71	12	2.95	2.99
	160	16.75	3.31	3.71	12	2.66	2.99

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0125	161	23.35	3.75	3.53	18	3.1	3.53
	162	23.35	3.55	3.53	18	2.9	3.53
	163	23.35	3.75	4.09	18	3.1	3.83
	164	23.35	3.55	4.09	18	2.9	3.83
0125 / 0126A	165	24	3.75	3.4	18	3.1	3.4
	166	24	3.55	3.4	18	2.9	3.4
0125 / 0126A / 0126B	167	24	3.75	2.8	18	3.1	2.8
	168	24	3.55	2.8	18	2.9	2.8
	169	24	3.75	3.52	18	3.1	1.16
	170	24	3.55	3.52	18	2.9	1.16
0126A / 0127	171	23	3.95	4.09	17	3.3	4.09
	172	23	3.35	4.09	17	2.7	4.09
	173	23	3.95	3.61	17	3.3	3.27
	174	23	3.35	3.61	17	2.7	3.27
0127 / 0421A	175	23	3.75	4.09	17	3.1	4.09
	176	23	3.55	4.09	17	2.9	4.09
	177	23	3.75	3.61	17	3.1	3.51
	178	23	3.55	3.61	17	2.9	3.51
0421A	179	23.5	3.65	4.09	18	3	4.09
	180	23.5	3.65	4.09	18	3	4.09
	181	23.5	3.65	3.53	18	3	3.53
	182	23.5	3.65	3.53	18	3	3.53
0422A	183	23.5	3.3	4.09	18	2.65	4.09
	184	23.5	4	4.09	18	3.35	4.09
0422A / 0422B	185	23.5	3.3	3	18	2.65	3
	186	23.5	4	3	18	3.35	3
	187	23.5	3.3	3	18	2.65	3
	188	23.5	4	3	18	3.35	3

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0422B	189	23.5	3.3	2.8	18	2.65	2.01
	190	23.5	4	2.8	18	3.35	2.01
0422A / 0423A	191	24	3.3	4.09	18	2.65	4.09
	192	24	4	4.09	18	3.35	4.09
0422A / 0422B / 0423A / 0423B	193	24	3.3	3	18	2.65	3
	194	24	4	3	18	3.35	3
	195	24	3.3	3	18	2.65	3
	196	24	4	3	18	3.35	3
0422B / 0423B	197	24	3.3	2.8	18	2.65	2.01
	198	24	4	2.8	18	3.35	2.01
0423A	199	11.35	3.3	4.09	6	2.65	4.09
	200	11.35	4	4.09	6	3.35	4.09
0423A / 0423B	201	11.35	3.3	3	6	2.65	3
	202	11.35	4	3	6	3.35	3
	203	11.35	3.3	3	6	2.65	3
	204	11.35	4	3	6	3.35	3
0423B	205	11.35	3.3	2.8	6	2.65	2.01
	206	11.35	4	2.8	6	3.35	2.01
0424A	207	21.65	3.65	3.6	18	3	3.6
	208	21.65	3.65	3.6	18	3	3.6
0424A / 0424B	209	21.65	3.65	3.2	18	3	3.2
	210	21.65	3.65	3.2	18	3	3.2
	211	21.65	3.65	2.8	18	3	2.8
	212	21.65	3.65	2.8	18	3	2.8
0424B	213	21.65	3.65	2.7	18	3	2.7
	214	21.65	3.65	2.7	18	3	2.7
0424A / 0426A	215	24	3.65	3.6	18	3	3.6
	216	24	3.65	3.6	18	3	3.6

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0424A / 0424B / 0426A / 0426B	217	24	3.65	3	18	3	3
	218	24	3.65	3	18	3	3
	219	24	3.65	3	18	3	3
	220	24	3.65	3	18	3	3
0424B / 0426B	221	24	3.65	2.7	18	3	2.7
	222	24	3.65	2.7	18	3	2.7
0426A / 0425A	223	24	3.65	3.6	18	3	3.6
	224	24	3.65	3.6	18	3	3.6
0426A / 0426B /- 0425A / 0425B	225	24	3.65	3	18	3	3
	226	24	3.65	3	18	3	3
	227	24	3.65	3	18	3	3
	228	24	3.65	3	18	3	3
0426B / 0425B	229	24	3.65	1.89	18	3	1.55
	230	24	3.65	1.89	18	3	1.55
0425A / 0427A	231	22.5	3.65	4.09	16.5	3	4.09
	232	22.5	3.65	4.09	16.5	3	4.09
0425A / 0425B / 0427A / 0427B	233	22.5	3.65	4.09	16.5	3	4.09
	234	22.5	3.65	4.09	16.5	3	4.09
0425B / 0427B	235	22.5	3.65	3.31	16.5	3	2.97
	236	22.5	3.65	3.31	16.5	3	2.97
0427A	237	24	3.65	3.89	18	3	3.89
	238	24	3.65	3.89	18	3	3.89
0427A / 0427B	239	24	3.65	4.09	18	3	4.09
	240	24	3.65	4.09	18	3	4.09
0427B	241	24	3.65	2.96	18	3	2.96
	242	24	3.65	2.96	18	3	2.96

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0427A / 0428A	243	24	2.65	3.89	18	2	3.89
	244	24	2.65	3.89	18	2	3.89
0427A /- 0427A / 0428A / 0428B	245	24	2.65	4.09	18	2	4.09
	246	24	2.65	4.09	18	2	4.09
0427B / 0428B	247	24	2.65	2.96	18	2	2.96
	248	24	2.65	2.96	18	2	2.96
0428A	249	9.65	2.65	3.89	6	2	3.89
	250	9.65	2.65	3.89	6	2	3.89
0428A / 0428B	251	9.65	2.65	4.09	6	2	4.09
	252	9.65	2.65	4.09	6	2	4.09
0428B	253	9.65	2.65	2.96	6	2	2.96
	254	9.65	2.65	2.96	6	2	2.96
0429	255	17.35	3.75	4.09	12	3.1	4.09
	256	17.35	3.55	4.09	12	2.9	4.09
	257	17.35	3.75	3.61	12	3.1	3.61
	258	17.35	3.55	3.61	12	2.9	3.61
	259	12	3.75	4.09	6	3.1	4.09
	260	12	3.55	4.09	6	2.9	4.09
	261	12	3.75	3.61	6	3.1	3.61
	262	12	3.55	3.61	6	2.9	3.61
0131	263	18.65	2.73	3	15	2	3
	264	18.65	2.73	3	15	2	3
	265	18.65	2.73	3.25	15	2	2.75
	266	18.65	2.73	3.25	15	2	2.75

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
0132A / 0132B	267	11.46	3.3	4.09	6	2.945	4.09
	268	11.46	3.41	4.09	6	3.055	4.09
	269	11.46	3.3	3.21	6	2.945	3.21
	270	11.46	3.41	3.21	6	3.055	3.21
0132B	271	11.46	3.3	3.15	6	2.945	3.15
	272	11.46	3.41	3.15	6	3.055	3.15
	273	11.46	3.3	3.16	6	2.945	0.95
	274	11.46	3.41	3.16	6	3.055	0.95
130	275	21.65	3.55	4	18	2.9	4
	276	21.65	3.75	4	18	3.1	4
	277	21.65	3.55	3	18	2.9	3
	278	21.65	3.75	3	18	3.1	3
	279	17.85	3.55	4	12	2.9	4
	280	17.85	3.75	4	12	3.1	4
	281	17.85	3.55	3	12	2.9	3
	282	17.85	3.75	3	12	3.1	3
M-0155	M-001	12.73	4.11	4.09	12	3	4.09
	M-002	12.73	4.11	3.68	12	3	1.56
M-0151	M-003	12.5	2.8	3	11.85	2.8	3
	M-004	12.5	3.2	3	11.85	3.2	3
	M-005	12.5	2.8	2.4	11.85	2.8	2.4
	M-006	12.5	3.2	2.4	11.85	3.2	2.4
M-0152	M-007	11.3	2.8	3	10.65	2.8	3
	M-008	11.3	3.2	3	10.65	3.2	3
	M-009	11.3	2.8	2.4	10.65	2.8	2.4
	M-010	11.3	3.2	2.4	10.65	3.2	2.4

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
M-0034	M-011	19.81	3.275	2.55	18	3	2.55
	M-012	19.81	3.275	2.55	18	3	2.55
	M-013	19.81	3.275	4.09	18	3	3
	M-014	19.81	3.275	4.09	18	3	3
M-0031	M-015	17.53	3.77	1.65	16	3.45	1.65
	M-016	17.53	3.77	1.65	16	3.45	1.65
	M-017	17.53	3.77	4.09	16	3.45	1.4
	M-018	17.53	3.77	4.09	16	3.45	1.4
M-0030	M-019	17.73	3.5	3.2	16	3.4	3.2
	M-020	17.73	3.82	3.2	16	3.4	3.2
	M-021	17.73	3.5	1.4	16	3.4	1.4
	M-022	17.73	3.82	1.4	16	3.4	1.4
	M-023	17.73	3.5	3.17	16	3.4	3.17
	M-024	17.73	3.82	3.17	16	3.4	2.1
M-0036	M-025	5.33	3.275	2.74	4.87	2.925	1.58
	M-026	5.33	3.275	2.74	4.87	2.925	1.58
M-0330	M-027	8.49	3.15	2.285	7.1	2.5	2.285
	M-028	8.49	3.15	2.285	7.1	2.5	2.285
	M-029	8.49	3.15	2.285	7.1	2.5	2.285
M-0033	M-030	24	3.675	4.42	24	3.35	2.77
	M-031	24	3.675	4.42	24	3.35	2.77
M-0033 / M-0032	M-032	17.91	3.675	4.42	17.91	3.35	2.77
	M-033	17.91	3.675	4.42	17.91	3.35	2.77
M-146	M-034	19.6	3.66	2.6	18	3	2.6
	M-035	19.6	3.66	2.6	18	3	2.6
	M-036	19.6	3.66	3.95	18	3	3.95
	M-037	19.6	3.66	3.95	18	3	3.95

Envelope and module size of AB-modules, Project 2

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
001A	35.59	7.25	7.8	35.18	6	7.27
001B	19.08	7.3	4.16	18.65	6	4.16
002A	35.59	7.3	7.8	35.15	6	7.27
002B	35.59	7.3	4.77	35.15	6	4.77
003A	35.59	7.28	7.8	35.15	6	7.27
003B	35.59	7.28	4.8	35.15	6	4.78
008A	19.23	7.27	7.74	19	6	7.21
008B	38.74	7.91	8.16	36.65	6	7
009A	14.5	7.33	7.74	12	6	7.21
009B	37.5	7.33	7.74	36	6	2.97
010	25.26	7.65	7.66	24	6	6.43
015	7.81	6.5	23.42	6	6	23.04
023	35.59	7.3	7.8	35.2	6	7.27
024	35.59	7.3	6.59	35.15	6	6.06
025	25.45	7.25	7.67	25.21	6	7.14
026	25.4	7.92	7.8	25.3	6	7.26
027	25	6.63	7.8	24.65	6	7.26
030A	25.2	7.78	7.21	24	6.25	7.21
030B	25.2	7.78	6.1	24	6.25	6.1
035A	35.59	7.33	7.8	35.15	6	7.27
035B	35.59	7.1	4.23	34.5	6	4.16
036	35.59	7.3	7.8	35.15	6	7.27
042	20.38	7.31	7.82	19.5	6	6.85
043	20.38	6.9	7.82	19.5	6	6.85
045	20.55	7.15	7.73	19.5	6	6.85
047A	20.65	6.97	7.87	19.5	6	7.2

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
047B	18.27	6.97	7.49	16.5	6	7.49
048A	27.26	7.24	7.68	24	6	7.14
048B	26.75	7.51	7.4	24	6	7.4
048C	21.76	7.07	4.07	20.48	6	4.07
049A	20.5	7.3	6.1	20.3	6	6.1
049B	36.88	7.3	7.4	36.65	6	7.4
049C	31	7.3	8.19	30.63	6	8.19
050A	18.25	7.3	7.76	16.95	6	6.85
050B	18.25	7.3	6.25	17.35	6	6.25
051A	19	7.28	7.59	18.8	6	7.05
051B	18.1	7.28	6.25	17.8	6	6.25
052A	24.93	6.83	7.88	24.65	6	7.8
052B	24.93	6.83	7.28	24	6	6.28
053A	17.8	7.3	7.73	17.8	6	6.85
053B	17.8	7.3	6.25	17.8	6	6.25
054A	19.2	7.43	7.59	18.45	6	6.85
054B	19.2	7.43	6.25	18	6	6.25
055	29.58	7.18	5.88	28.5	6	5.87
056	29.58	7.3	7.24	28.5	6	5.87
057	29.58	7.18	7.24	28.5	6	5.87
058A	28.78	7.3	7.72	27.8	5	5.93
058B	28.85	7.3	6.55	28.45	5	6.18
059A	14.86	7.3	7.78	13.5	6	7.47
059B	14.81	7.3	7.45	14.4	6	5.75
060A	36.76	7.03	7.78	36	6	7.21
060B	14.78	7.03	7.78	14.43	6	5.7
062	32.22	5.27	5.64	31	3.83	5
063	32.5	6.48	5.64	31	5.43	5

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
064	32.5	6.19	5.64	31	5.43	5
065	18.4	6.92	7.23	18.3	6	6.8
066	9.45	7.27	6.8	7	6	6.8
067	12	7.24	6.8	11.06	6	6.8
068	10.63	6.52	7.18	7	6	7.15
069	11.5	6.91	7.23	11.3	6.65	6.8
072	9.95	2.4	6.95	9.78	2.3	6.93
110A	18.92	7.27	7.74	18.65	6	7.21
111A	23.91	7.33	7.74	22.98	6	7.21
138	22.8	7.21	5.47	22.8	7	3.82
139	22.52	7.3	7.78	22.35	6	7.21
140	22.5	7.3	7.87	22.35	6	4.5
141	22.47	7.03	7.93	20.7	6.55	4.5
142	16.33	7.01	7.8	16.3	6	7.26
144	19.82	6.87	6.1	19.45	6	6.1
149	15.2	3.78	6.99	14.7	2	6.46
165	10.88	7.3	7	10.5	6	7
166	18.3	7.45	3.83	17.75	6	2.05
167	16.9	7.39	3.83	16.5	6	2.05
168	9.32	1.56	6	8.95	1.2	6
169	8.73	1.56	5.55	8.23	1.2	5.55
171	17.45	4.15	7.69	17.35	3.75	7.1
004A	30	7.12	6.95	30	6	6.95
004B	30	7.3	8	30	6	8
005A	36	7.4	7.95	36	6	7.95
005B	36	7.3	7.45	36	6	7.3
006A	36.52	7.58	7.95	36	6	7.95
006B	36.52	7.58	9.3	36	6	9.3

Module Name	Envelope Size			Module Size		
	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
007A	35.48	7.3	7.95	30	6	7.95
007B	36	7.3	4.55	36	6	4.55
007C	35.48	7.3	6.6	32.4	6	6.6
011A	36.32	7.15	6.95	33	6	6.95
011B	33.5	6.93	3.55	33	6	3.55
012A	36	7.31	2.85	36	6	2.85
012B	36	7.31	6.9	36	6	6.9
012C	37	7.31	4.1	36.7	6	4.1
013A	36	7.89	2.85	36	6	2.85
013B	36	7.89	7.96	36	6	7.55
013C	36	7.89	4.1	36	6	4.1
014A	30	7.46	7.95	30	6	7.95
014B	28.32	7.46	8.07	27.28	6	6.45
070	37.3	3.71	10	37.28	3	9.49
071	34	4.71	11.1	33.86	3.99	10.77
074	32.5	4.4	10.54	32.48	4	10.35
075	30.72	4.57	6.93	30.6	3	6.9
112	25.14	7.44	7.64	21	6	7.52
113	36.3	7.03	8.09	36.3	6	7
114	7.73	7.25	10.03	3.38	3	9.55
115	39.4	7.06	8.27	39	6	7.63
116	10.64	7.73	10.02	10.4	6	9.05
143A	12.66	7.03	7	11.58	6	6.98
143B	12.9	7.6	6.59	12.8	6	5.85
170	24.99	7.41	4.68	21	6	4.38
513	24.99	7.41	3.85	21	6	3.85
514	36.3	7.03	7.54	36.3	6	7.54

Envelope and module size of M-modules, Project 2

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
112	001	16.14	3.35	2.3	12	2.81	2.3
	002	16.14	4.09	2.3	12	3.19	2.3
	003	16.14	3.35	2.3	12	2.81	2.3
	004	16.14	4.09	2.3	12	3.19	2.3
	005	16.14	3.35	2.5	12	2.81	2.5
	006	16.14	4.09	2.5	12	3.19	2.5
170	007	16.14	3.5	2.7	12	2.81	2.7
	008	16.14	3.91	2.7	12	3.19	2.7
	009	16.14	3.5	2.05	12	2.81	2.05
	010	16.14	3.91	2.05	12	3.19	2.05
112 & 113	011	21	3.315	2.8	15	2.81	2.8
	012	21	3.715	2.8	15	3.19	2.8
	013	21	3.315	4.09	15	2.81	4.09
	014	21	3.715	4.09	15	3.19	4.09
170 & 513 & 514	015	21	3.515	4.09	15	3	4.09
	016	21	3.515	4.09	15	3	4.09
	017	21	3.515	2.325	15	3	2.325
	018	21	3.515	2.325	15	3	2.325
	019	21	3.515	2.325	15	3	2.325
	020	21	3.515	2.325	15	3	2.325

AB-Module Name	M-module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
113 & 514	021	23.77	3.315	4.09	18	2.81	4.09
	022	23.77	3.715	4.09	18	3.19	4.09
	023	23.77	3.315	4.09	18	2.81	4.09
	024	23.77	3.715	4.09	18	3.19	4.09
	025	23.77	3.315	4.09	18	2.81	4.09
	026	23.77	3.715	4.09	18	3.19	4.09
	027	23.77	3.315	3.36	18	2.81	3.36
	028	23.77	3.715	3.36	18	3.19	3.36
116	029	7.73	3	3.8	6	2.7	3.8
	030	7.73	4.09	3.8	6	3.3	3.8
	031	7.73	3	2.8	6	2.7	2.8
	032	7.73	4.09	2.8	6	3.3	2.8
	033	7.73	3	3.42	6	2.7	3.42
	034	7.73	4.09	3.42	6	3.3	3.42
048A	035	19.3	4	4.09	18	3.7	4.09
	036	19.3	3.24	4.09	18	2.3	4.09
	037	19.3	4	3.4	18	3.7	3.4
	038	19.3	3.24	3.4	18	2.3	3.4
048B	039	18	4	4.15	12	3.7	4.15
	040	18	3.24	4.15	12	2.3	4.15
	041	18	4	3.25	12	3.7	3.25
	042	18	3.24	3.25	12	2.3	3.25
048C	043	22	4	4.06	18	3.7	4.06
	044	22	3.24	4.06	18	2.3	4.06

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
010	045	18	3.83	3.6	18	3	3.6
	046	18	3.83	3.6	18	3	3.6
	047	18	3.83	4.06	18	3	4.06
	048	18	3.83	4.06	18	3	4.06
047A	049	16.05	3.485	4	16.5	3	4
	050	16.05	3.485	4	16.5	3	4
	051	16.05	3.485	3.865	16.5	3	3.865
	052	16.05	3.485	3.865	16.5	3	3.865
047B	053	20.65	3.285	3.2	16.5	2.8	3.2
	054	20.65	3.685	3.2	16.5	3.2	3.2
	055	20.65	3.285	2	16.5	2.8	2
	056	20.65	3.685	2	16.5	3.2	2
	057	13	3.285	3	6	2.8	3
	058	13	3.685	3	6	3.2	3
074	059	16.7	2.1	3.9	12	1.9	3.9
	060	16.7	2.3	3.9	12	2.1	3.9
	061	16.7	2.1	3.03	12	1.9	3.03
	062	16.7	2.3	3.03	12	2.1	3.03
	063	15	2.1	3.9	12	1.9	3.9
	064	15	2.3	3.9	12	2.1	3.9
	065	15	2.1	3.03	12	1.9	3.03
	066	15	2.3	3.03	12	2.1	3.03
075	067	4.2	3	4.09	4	3	4.09
	068	15.1	3	2.84	13	3	2.84
	069	12.7	4.09	3.5	9.7	3	3.5
	070	12.7	4.09	3.43	9.7	3	3.43

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
011A	071	24	3.875	3.9	18	3	3.9
	072	24	3.435	3.9	18	3	3.9
	073	24	3.875	3.05	18	3	3.05
	074	24	3.435	3.05	18	3	3.05
011B	075	24	3.875	3.55	18	3	3.55
	076	24	3.435	3.55	18	3	3.55
011A & 012A & 012C	077	24	3.875	3.9	18	3	3.9
	078	24	3.435	3.9	18	3	3.9
	079	24	3.875	3.05	18	3	3.05
	080	24	3.435	3.05	18	3	3.05
011B & 012B	081	24	3.875	3.2	6	3	3.2
	082	24	3.435	3.2	6	3	3.2
	083	12	3.875	3.7	6	3	3.7
	084	12	3.435	3.7	6	3	3.7
012A	085	24	3.875	2.85	18	3	2.85
	086	24	3.435	2.85	18	3	2.85
012C	087	24	3.875	4.1	18	3	4.1
	088	24	3.435	4.1	18	3	4.1
012B	089	24	3.875	4	18	3	4
	090	24	3.435	4	18	3	4
	091	24	3.875	2.81	18	3	2.81
	092	24	3.435	2.81	18	3	2.81
013A	093	24	3.9	2.85	18	3	2.85
	094	24	3.99	2.85	18	3	2.85
013C	095	24	3.9	4.1	18	3	4.1
	096	24	3.99	4.1	18	3	4.1

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
013B	097	24	3.9	4	18	3	4
	098	24	3.99	4	18	3	4
	099	24	3.9	3.96	18	3	3.96
	100	24	3.99	3.96	18	3	3.96
013A & 004A	101	24	3.8	2.85	18	3	2.85
	102	24	4.09	2.85	18	3	2.85
013C & 004A	103	24	3.8	4.1	18	3	4.1
	104	24	4.09	4.1	18	3	4.1
013B & 004B	105	24	3.8	4	18	3	4
	106	24	4.09	4	18	3	4
	107	24	3.8	4	18	3	4
	108	24	4.09	4	18	3	4
004A	109	18	3.68	3.2	12	3.1	3.2
	110	18	3.44	3.2	12	2.9	3.2
	111	18	3.68	3.75	12	3.1	3.75
	112	18	3.44	3.75	12	2.9	3.75
004B	113	18	3.68	4	12	3.1	4
	114	18	3.44	4	12	2.9	4
	115	18	3.68	4	12	3.1	4
	116	18	3.44	4	12	2.9	4
143A	117	12.66	3.24	4.09	6	2.675	4.09
	118	12.66	3.79	4.09	6	3.325	4.09
	119	12.66	3.24	2.88	6	2.675	2.88
	120	12.66	3.79	2.88	6	3.325	2.88
143B	121	12.66	3.24	4	6	2.2	4
	122	12.66	3.79	4	6	3.8	4
	123	12.66	3.24	2.59	6	2.2	2.59
	124	12.66	3.79	2.59	6	3.8	2.59

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
139	125	21.9	3.65	3.9	20.7	3	3.9
	126	21.9	3.65	3.9	20.7	3	3.9
	127	21.9	3.65	3.88	20.7	3	3.88
	128	21.9	3.65	3.88	20.7	3	3.88
140	129	21.95	3.65	3.8	20.7	3	3.8
	130	21.95	3.65	3.8	20.7	3	3.8
	131	21.95	3.25	3.9	20.7	2.6	3.9
	132	21.95	4.05	3.9	20.7	2.6	3.9
059A	133	14.86	3.67	3.9	13.5	3	3.9
	134	14.86	3.63	3.9	13.5	3	3.9
	135	14.86	3.67	3.88	13.5	3	3.88
	136	14.86	3.63	3.88	13.5	3	3.88
059B	137	14.81	3.67	3.8	13.5	3	3.8
	138	14.81	3.63	3.8	13.5	3	3.8
	139	14.81	3.67	3.65	13.5	3	3.65
	140	14.81	3.63	3.65	13.5	3	3.65
165	141	10.88	3.65	3.4	10.5	3	3.4
	142	10.88	3.65	3.4	10.5	3	3.4
	143	10.88	3.65	3.6	10.5	3	3.6
	144	10.88	3.515	3.6	10.5	3	3.6
060A	145	16.5	2.935	4.09	13.5	2.42	4.09
	146	16.5	4.095	4.09	13.5	3.58	4.09
	147	16.5	2.935	3.69	13.5	2.42	3.69
	148	16.5	4.095	3.69	13.5	3.58	3.69
	149	20.26	2.935	3.9	16.5	2.42	3.9
	150	20.26	4.095	3.9	16.5	3.58	3.9
	151	20.26	2.935	3.88	16.5	2.42	3.88
	152	20.26	4.095	3.88	16.5	3.58	3.88

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
141	153	22.47	2.935	3.8	20.7	2.42	3.8
	154	22.47	4.095	3.8	20.7	3.58	3.8
	155	22.47	2.935	3.98	20.7	2.42	3.98
	156	22.47	4.095	3.98	20.7	3.58	3.98
060B	157	14.78	2.935	3.8	13.5	2.42	3.8
	158	14.78	4.095	3.8	13.5	3.58	3.8
	159	14.78	2.935	3.98	13.5	2.42	3.98
	160	14.78	4.095	3.98	13.5	3.58	3.98
144	161	18.72	3.635	3.3	18	3.2	3.3
	162	18.72	3.235	3.3	18	2.8	3.3
	163	18.72	3.635	2.8	18	3.2	2.8
	164	18.72	3.235	2.8	18	2.8	2.8
049A	165	18.15	4.06	3.3	17	3.5	3.3
	166	18.15	3.24	3.3	17	2.5	3.3
	167	18.15	4.06	2.8	17	3.5	2.8
	168	18.15	3.24	2.8	17	2.5	2.8
049B	169	21	4.06	3.5	18	3.5	3.5
	170	21	3.24	3.5	18	2.5	3.5
	171	21	4.06	3.9	18	3.5	3.9
	172	21	3.24	3.9	18	2.5	3.9
	173	15.88	4.06	3.5	12	3.5	3.5
	174	15.88	3.24	3.5	12	2.5	3.5
	175	15.88	4.06	3.9	12	3.5	3.9
	176	15.88	3.24	3.9	12	2.5	3.9

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
49C	177	15.5	4.06	4.09	12	3.5	4.09
	178	15.5	3.24	4.09	12	2.5	4.09
	179	15.5	4.06	4.1	12	3.5	4.1
	180	15.5	3.24	4.1	12	2.5	4.1
	181	15.5	4.06	4.09	12	3.5	4.09
	182	15.5	3.24	4.09	12	2.5	4.09
	183	15.5	4.06	4.1	12	3.5	4.1
	184	15.5	3.24	4.1	12	2.5	4.1
111A	185	23.91	3.965	3.94	23	3.3	3.94
	186	23.91	3.365	3.94	23	2.7	3.94
009A	187	14.5	3.965	3.94	12	3.3	3.94
	188	14.5	3.365	3.94	12	2.7	3.94
009B	189	22.5	3.965	3.7	18	3.3	3.7
	190	22.5	3.365	3.7	18	2.7	3.7
	191	22.5	3.965	4.04	18	3.3	4.04
	192	22.5	3.365	4.04	18	2.7	4.04
014A	193	23.58	3.83	4.09	18	3	4.09
	194	23.58	3.63	4.09	18	3	4.09
	195	23.58	3.83	3.86	18	3	3.86
	196	23.58	3.63	3.86	18	3	3.86
014B	197	22.32	3.83	4	18	3	4
	198	22.32	3.63	4	18	3	4
	199	22.32	3.83	4.07	18	3	4.07
	200	22.32	3.63	4.07	18	3	4.07
014A & 007A	201	24	3.68	4.09	18	3	4.09
	202	24	3.78	4.09	18	3	4.09
	203	24	3.68	3.86	18	3	3.86
	204	24	3.78	3.86	18	3	3.86

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
014B & 007B	205	24	3.68	4	18	3	4
	206	24	3.78	4	18	3	4
014B & 007B & C	207	24	3.68	4.07	18	3	4.07
	208	24	3.78	4.07	18	3	4.07
007 C	209	15	3.68	3.08	18	3	3.08
	210	15	3.78	3.08	18	3	3.08
007 A & 006 A	211	24	3.6	4.09	18	3	4.09
	212	24	3.7	4.09	18	3	4.09
	213	24	3.6	3.86	18	3	3.86
	214	24	3.7	3.86	18	3	3.86
007 B & 006 B	215	24	3.6	4	18	3	4
	216	24	3.7	4	18	3	4
007 B & C & 006 B	217	24	3.6	4.07	18	3	4.07
	218	24	3.7	4.07	18	3	4.07
007 C	219	15	3.6	3.08	18	3	3.08
	220	15	3.7	3.08	18	3	3.08
006 A	221	24	3.84	4.09	18	3	4.09
	222	24	3.74	4.09	18	3	4.09
	223	24	3.84	3.86	18	3	3.86
	224	24	3.74	3.86	18	3	3.86
006 B	225	24	3.84	4	18	3	4
	226	24	3.74	4	18	3	4
	227	24	3.84	4.04	18	3	4.04
	228	24	3.74	4.04	18	3	4.04

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
005 A	229	24	3.65	4.09	18	3	4.09
	230	24	3.75	4.09	18	3	4.09
	231	24	3.65	3.86	18	3	3.86
	232	24	3.75	3.86	18	3	3.86
	233	16.97	3.7	4.09	12	3	4.09
	234	16.97	3.7	4.09	12	3	4.09
	235	16.97	3.7	3.86	12	3	3.86
	236	16.97	3.7	3.86	12	3	3.86
005 B	237	24	3.65	3.7	18	3	3.7
	238	24	3.75	3.7	18	3	3.7
	239	24	3.65	3.75	18	3	3.75
	240	24	3.75	3.75	18	3	3.75
	241	16.97	3.65	3.7	12	3	3.7
	242	16.97	3.65	3.7	12	3	3.7
	243	16.97	3.65	3.75	12	3	3.75
	244	16.97	3.65	3.75	12	3	3.75
65	245	18	3.745	3.2	16	3	3.2
	246	18	3.145	3.2	16	3	3.2
	247	18	3.745	4.03	16	3	4.03
	248	18	3.145	4.03	16	3	4.03
66	249	9.45	3.685	3.5	7	3	3.5
	250	9.45	3.585	3.5	7	3	3.5
	251	9.45	3.685	3.9	7	3	3.9
	252	9.45	3.585	3.9	7	3	3.9
67	253	10.83	3.62	3.5	7	3	3.5
	254	10.83	3.62	3.5	7	3	3.5
	255	10.83	3.62	3.3	7	3	3.3
	256	10.83	3.62	3.3	7	3	3.3

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
68	257	10.63	3.06	4.09	7	3	4.09
	258	10.63	3.46	4.09	7	3	4.09
	259	10.63	3.06	3.49	7	3	3.49
	260	10.63	3.46	3.49	7	3	3.49
69	261	10.7	3.785	4.09	7	3	4.09
	262	10.7	3.125	4.09	7	3	4.09
	263	10.7	3.785	3.14	7	3	3.14
	264	10.7	3.125	3.14	7	3	3.14
050B	265	18.25	3.85	3.5	15	3	3.5
	266	18.25	3.45	3.5	15	3	3.5
	267	18.25	3.85	2.72	15	3	2.72
	268	18.25	3.45	2.72	15	3	2.72
051B	269	17.14	3.64	3.5	15	3	3.5
	270	17.14	3.64	3.5	15	3	3.5
	271	17.14	3.64	2.75	15	3	2.75
	272	17.14	3.64	2.75	15	3	2.75
052A	273	18.46	3.415	4.09	15	3	4.09
	274	18.46	3.415	4.09	15	3	4.09
	275	18.46	3.415	3.79	15	3	3.79
	276	18.47	3.415	3.79	15	3	3.79
052B	277	12.47	3.415	4	9	3	4
	278	12.47	3.415	4	9	3	4
	279	12.47	3.415	3.28	9	3	3.28
	280	12.47	3.415	3.28	9	3	3.28
	281	12.46	3.415	4	9	3	4
	282	12.46	3.415	4	9	3	4
	283	12.46	3.415	3.28	9	3	3.28
	284	12.46	3.415	3.28	9	3	3.28

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
053B	285	17.14	3.5	2.6	15	3	2.6
	286	17.14	3.8	2.6	15	3	2.6
	287	17.14	3.5	3.65	15	3	3.65
	288	17.14	3.8	3.65	15	3	3.65
054B	289	17.42	3.615	3.1	15	3	3.1
	290	17.42	3.815	3.1	15	3	3.1
	291	17.42	3.615	3.15	15	3	3.15
	292	17.42	3.815	3.15	15	3	3.15
55	293	15	3.39	3.2	12	3	3.2
	294	15	3.79	3.2	12	3	3.2
	295	15	3.39	4.04	12	3	4.04
	296	15	3.79	4.04	12	3	4.04
	297	14.58	3.59	3.2	10.5	3	3.2
	298	14.58	3.59	3.2	10.5	3	3.2
	299	14.58	3.59	4.04	10.5	3	4.04
	300	14.58	3.59	4.04	10.5	3	4.04
56	301	15	3.65	3.5	12	3	3.5
	302	15	3.65	3.5	12	3	3.5
	303	15	3.65	3.74	12	3	3.74
	304	15	3.65	3.74	12	3	3.74
	305	14.58	3.65	3.5	10.5	3	3.5
	306	14.58	3.65	3.5	10.5	3	3.5
	307	14.58	3.65	4.04	10.5	3	4.04
	308	14.58	3.65	4.04	10.5	3	4.04

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
57	309	15	3.29	4.09	12	2.7	4.09
	310	15	3.89	4.09	12	3.3	4.09
	311	15	3.29	3.15	12	2.7	3.15
	312	15	3.89	3.15	12	3.3	3.15
	313	14.58	3.29	4.09	10.5	2.7	4.09
	314	14.58	3.89	4.09	10.5	3.3	4.09
	315	14.58	3.29	3.45	10.5	2.7	3.45
	316	14.58	3.89	3.45	10.5	3.3	3.45
72	317	9.95	2.5	3.9	9	2	3.9
	318	9.95	2.5	3.05	9	2	3.05
168	319	7.39	1.56	3	7	1.2	3
169	320	7.39	1.56	3	7	1.2	3
70	321	16	3.71	4.1	12	3	4.1
	322	16	3.71	3.69	12	3	3.69
	323	21.3	3.71	4.1	12	3	4.1
	324	21.3	3.71	3.69	12	3	3.69
23	325	21.545	3.21	4.1	18	3	4.1
	326	21.545	4.09	4.1	18	3	4.1
	327	21.545	3.21	3.7	18	3	3.7
	328	21.545	4.09	3.7	18	3	3.7
	329	14.045	3.21	4.1	10.5	3	4.1
	330	14.045	4.09	4.1	10.5	3	4.1
	331	14.045	3.21	3.7	10.5	3	3.7
	332	14.045	4.09	3.7	10.5	3	3.7

AB-Module Name	M-module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
166	333	18.3	3.725	3.83	16.5	3	3.83
	334	18.3	3.725	3.83	16.5	3	3.83
167	335	16.9	3.695	3.83	16.5	3	3.83
	336	16.9	3.695	3.83	16.5	3	3.83
035A	337	21.545	3.665	3.9	18	3	3.9
	338	21.545	3.665	3.9	18	3	3.9
	339	21.545	3.665	3.9	18	3	3.9
	340	21.545	3.665	3.9	18	3	3.9
035B	341	21.545	3.55	4.09	18	3	4.09
	342	21.545	3.55	4.09	18	3	4.09
	343	14.045	3.55	4.09	10.5	3	4.09
	344	14.045	3.55	4.09	10.5	3	4.09
003B	345	21.545	3.44	2.385	18	3	2.385
	346	21.545	3.84	2.385	18	3	2.385
	347	21.545	3.44	2.385	18	3	2.385
	348	21.545	3.84	2.385	18	3	2.385
002B	349	21.545	3.65	2.385	18	3	2.385
	350	21.545	3.65	2.385	18	3	2.385
	351	21.545	3.65	2.385	18	3	2.385
	352	21.545	3.65	2.385	18	3	2.385
	353	14.045	3.65	2.385	10.5	3	2.385
	354	14.045	3.65	2.385	10.5	3	2.385
	355	14.045	3.65	2.385	10.5	3	2.385
	356	14.045	3.65	2.385	10.5	3	2.385

AB-Module Name	M-Module Name	Envelope Size			Module Size		
		Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)
001A	357	17.045	3.825	3.6	10.5	3	3.6
	358	17.045	3.425	3.6	10.5	3	3.6
	359	17.045	3.825	4.09	10.5	3	4.09
	360	17.045	3.425	4.09	10.5	3	4.09
001B	361	13.08	3.65	4.16	12	3	4.16
	362	13.08	3.65	4.16	12	3	4.16
071	363	17.58	3.9	3.89	17	3	3.89
	364	17.58	4.09	3.71	17	3	3.71
	365	16	3.9	3.89	13	3	3.89
	366	16	4.09	3.71	13	3	3.71

Appendix B: Alberta-Sized and Mini-Sized Module Structure Component Details

AB-Module Structure Details, Project 1

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0021A	W310x86	6	10	W310x118	6	6	W310x118	4.1	12	W310x60	4.35	4
	W310x60	6	2	W410x132	6	6						
	W310x39	6	12									
0021B	W310x39	6	18	W410x100	6	6	W310x118	5.97	12	W310x60	4.07	4
	W310x86	6	2	W310x60	6	12						
	W310x60	6	4	W150x22	1.08	12						
				W150x22	1.18	12						
				W150x22	2.75	6						
0022	W310x60	6	8	W310x129	6	6	W310x118	7.26	12	L152x102x13	4.76	8
	W310x86	6	2	W410x85	6	6				L152x102x13	3.87	8
	W310x39	6	10	W310x60	6	6						
				W150x22	1.08	12						
				W150x22	1.18	12						
				W150x22	0.7	6						
0121 A	W310x67	6	12	W310x143	6	6	W310x118	6.3	12	L152x152x9.5	4.41	4
	W310x107	6	10	W310x107	6	12				L152x152x9.5	3.66	4
	W310x86	6	12									
0121 B	W310x39	6	22	W310x143	6	6	W310x86	5.45	12	L102x102x9.5	3.55	4
	W310x67	6	2	W310x86	6	6				L76x76x9.5	2.3	8
	W310x107	6	2	W310x67	6	12						
	W310x86	6	2	W150x22	1.08	48						
				W150x22	1.18	48						
				W150x22	2.75	6						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0122 A	W310x67	6	8	W310x143	6	6	W310x158	6.3	12	L102x102x9.5	3.66	8
	W310x86	6	18	W310x107	6	12				L102x102x9.5	3.6	8
	W310x39	6	4									
0122 B	W310x39	6	26	W310x143	6	6	W310x107	5.45	12	L102x102x9.5	3.55	8
	W310x86	6	4	W310x67	6	12				L102x102x9.5	3.47	8
				W150x22	1.08	48						
				W150x22	1.18	48						
				W150x22	2.75	6						
0123 A	W310x67	6	4	W310x143	6	5	W310x158	6.1	10	L102x102x9.5	3.66	16
	W310x86	6	6	W310x107	6	10						
	W310x107	6	4									
	W310x39	6	10									
0123 B	W310x39	6	20	W310x143	6	5	W310x118	5.65	10	L102x102x9.5	3.61	8
	W310x67	6	6	W310x67	6	10				L102x102x9.5	3.47	8
	W310x86	6	2	W150x22	1.08	40						
	W150x22	1.08	16	W150x22	1.18	40						
	W150x22	1.18	16	W150x22	2.75	5						
	W150x22	2.75	2									
0124 A	W310x86	6	12	W310x143	6	6	W310x118	6.3	12	L152x152x9.5	3.66	16
	W310x107	6	2	W310x107	6	12						
	W310x39	6	12									
	W310x67	6	4									
0124 B	W310x39	6	30	W310x143	6	6	W310x118	5.45	12	L102x102x9.5	3.51	16
				W310x60	6	12						
				W150x22	2.26	48						
				W150x22	2.75	6						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	**Length (m)**	**No.**	**Beam Type**	**Length (m)**	**No.**	**Column Type**	**Length (m)**	**No.**	**Bracing Type**	**Length (m)**	**No.**
0125	W310x60	6	8	W310x118	6	5	W310x118	7.6	10	L127x89x9.5	4.35	8
	W310x39	6	18	W410x85	6	5				L127x89x9.5	3.91	8
				W310x60	6	5						
				W310x39	6	5						
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.5	5						
0128	W310x67	6	26	W310x143	6	7	W310x118	7.35	14	L102x102x9.5	3.66	16
	W310x39	6	24	W310x107	6	14				L76x76x9.5	2.02	16
				W310x60	6	7						
				W150x22	1.08	14						
				W150x22	1.18	14						
				W150x22	0.5	7						
0131	W310x67	6	16	W310x107	6	4	W310x86	5.75	8	L102x102x9.5	3.49	8
	W310x68	3	4	W310x86	6	8				L76x76x9.5	2.3	8
	W310x39	3	2									
0221	W310x60	6	2	W360x91	6	4	W310x118	8.3	8	L127x89x9.5	4.35	8
	W310x39	6	22	W410x85	6	4				L127x89x9.5	4.65	8
				W310x60	6	4						
				W310x39	6	4						
				W150x22	1.08	24						
				W150x22	1.18	24						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0222	W310x60	6	4	W360x91	6	6	W310x118	7.95	12	L127x89x9.5	3.66	8
	W310x39	6	22	W410x85	6	6				L127x89x9.5	4.65	8
	W310x86	6	8	W310x60	6	6						
		6	4	W310x39	6	6						
				W150x22	1.08	48						
				W150x22	1.18	48						
				W150x22	2.5	6						
0223	W310x60	6	2	W360x91	6	6	W310x118	7.7	12	L127x89x9.5	3.66	8
	W310x39	6	30	W410x85	6	6				L127x89x9.5	4.65	8
				W310x60	6	6						
				W310x39	6	6						
				W150x22	1.08	48						
				W150x22	1.18	48						
				W150x22	2.5	6						
0320 A		6	2	W410x100	6	6	W310x129	4.2	12	L127x89x9.5	4.35	8
	W310x86	6	10	W410x85	6	6						
	W310x39	6	14									
0320 B	W310x39	6	18	W410x85	6	6	W310x86	5.6	12	L127x89x9.5	3.91	8
	W310x60	6	6	W310x60	6	6						
	W150x22	1.08	12	W310x39	6	6						
	W150x22	1.18	12	W150x22	1.08	36						
	W150x22	2.5	2	W150x22	1.18	36						
				W150x22	2.5	6						
0322 A	W310x60	6	2	W410x100	6	5	W310x129	4.2	10	L127x89x9.5	3.66	8
	W310x39	6	2	W410x85	6	5						
	W310x67	6	6									
	W310x86	6	8									

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0322 B	W310x39	6	16	W310x85	6	5	W310x86	5.6	10	L127x89x9.5	3.91	8
	W310x67	6	6	W310x60	6	5						
				W310x39	6	5						
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.5	5						
0323 A	W310x67	6	2	W310x143	6	5	W310x118	6.3	10	L102x102x9.5	3.66	16
	W310x39	6	22	W310x107	6	10						
0323 B	W310x39	6	24	W310x107	6	5	W310x86	3.65	10	L102x102x9.5	3.27	8
				W310x60	6	5				L102x102x9.5	3.33	8
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.75	5						
0324 A	W310x39	6	10	W310x143	6	4	W310x118	6.3	8	L102x102x9.5	3.66	16
	W310x67	6	2	W310x107	6	8						
	W310x107	6	8									
0324 B	W310x39	6	12	W310x107	6	4	W310x86	3.65	8	L102x102x9.5	4.07	8
				W310x60	6	4						
				W150x22	1.08	16						
				W150x22	1.18	20						
				W150x22	2.75	4						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0421	W310x39	6	20	W310x107	6	5	W310x118	7.62	10	L127x89x9.5	4.35	8
	W310x60	6	6	W410x85	6	5				L127x89x9.5	3.91	8
				W310x60	6	5						
				W310x39	6	5						
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.5	5						
0422 A	W310x60	6	8	W410x100	6	5		6.81	10	L152x102x13	4.53	8
	W310x39	6	8	W410x85	6	5				L152x102x13	4.07	8
0422 B	W310x60	6	2	W410x85	6	5	W310x86	5.33	10	L127x89x9.5	3.91	8
	W310x39	6	18	W310x60	6	5						
				W310x39	6	5						
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.5	5						
0423 A	W310x60	6	4	W410x100	6	10	W310x118	6.81	10	L152x102x13	4.07	8
	W310x39	6	12							L152x102x13	4.39	8
04234 B	W310x39	6	18	W410x85	6	5	W310x86	5.6	10	L127x89x9.5	3.91	8
				W310x60	6	5						
				W310x39	6	5						
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.5	5						
0424 A	W310x86	6	4	W410x100	6	10	W310x118	5.55	10	L152x102x13	4.09	8
	W310x39	6	10							L152x102x13	3.67	8
	W310x60	6	4									

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0424 B	W310x86	6	2	W410x85	6	5	W310x86	6.75	4	L127x89x9.5	3.91	8
	W310x39	6	10	W310x60	6	5	W310x86	5.6	6			
	W310x60	6	8	W310x39	6	5						
	W150x22	1.3	12	W150x22	1.08	17						
	W150x22	1.08	12	W150x22	1.18	34						
	W150x22	2.5	6	W150x22	3.65	2						
				W150x22	2.5	3						
0427 A	W310x60	6	10	W310x107	6	6		5.34	12	L152x102x13	4.27	8
	W310x39	6	10	W410x100	6	6				L152x102x13	3.66	8
0427 B	W310x39	6	20	W410x85	6	6	W310x86	5.6	12	L127x89x9.5	3.91	8
	W310x60	6	4	W310x60	6	6						
				W310x39	6	6						
				W150x22	1.18	18						
				W150x22	1.08	36						
				W150x22	2.5	6						
0428 A	W310x60	6	4	W310x60	4	10	W310x118	5.44	10	L152x102x13	3.96	8
	W310x67	6	2							L152x102x13	3.66	8
	W310x39	6	12									
0428 B	W310x39	6	16	W310x60	4	5	W310x86	5.5	10	L127x89x9.5	3.91	8
	W310x60	6	4	W310x39	4	10						
				W150x22	1.18	15						
				W150x22	1.08	15						
				W150x22	2.5	5						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
0429	W310x45	6	24	W410x100	6	5	W310x118	7.7	10	L152x152x13	4.5	16
				W310x67	6	5						
				W310x86	6	5						
				W310x45	6	5						
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.5	5						
520 A	W310x86	6	2	W310x143	6	5	W310x118	6.3	10	L102x102x9.5	3.66	16
	W310x107	6	2	W310x107	6	10						
	W310x39	6	20									
520 B	W310x39	6	16	W310x60	6	10	W310x86	3.65	10	L102x102x9.5	4.07	8
				W150x22	1.08	30						
				W150x22	1.18	30						
				W150x22	2.75	5						
522	W310x107	6	8	W310x143	6	5	W310x118	6.1	10	L102x102x9.5	3.63	16
	W310x39	6	16	W310x107	6	5						
				W310x60	6	5						
				W150x22	1.08	20						
				W150x22	1.18	20						
				W150x22	1.62	5						

Structure Details of M-Modules , Project 1

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
001	W310x39	6	12	W250x33	2.85	8	W310x67	4.09	8	L127x89x9.5	3.66	8
	W310x60	6	2									
002	W310x39	6	12	W250x39	3.15	8	W310x67	4.09	8	L127x89x9.5	3.66	8
	W310x60	6	2									
003	W310x39	6	12	W250x22	2.85	4	W310x67	3.61	8	L127x89x9.5	3.93	8
				W150x22	2.25	16						
				W250x18	2.85	4						
004	W310x39	6	12	W250x25	3.15	4	W310x67	3.61	8	L127x89x9.5	3.93	8
				W150x22	2.25	16						
				W250x18	3.15	4						
009	W310x39	6	2	W250x33	2.85	8	W310x86	3.3	8	L127x89x9.5	3.66	8
	W310x60	6	2									
	W310x49	6	4									
	W310x86	6	8									
010	W310x39	6	2	W250x39	3.15	8	W310x86	3.3	8	L127x89x9.5	3.66	8
	W310x60	6	2									
	W310x49	6	4									
	W310x86	6	8									
011	W310x39	6	12	W250x22	2.85	8	W310x86	2.3	8	L127x89x9.5	3.35	8
				W150x22	2.25	4						
012	W310x39	6	12	W250x22	3.15	8	W310x86	2.3	8	L127x89x9.5	3.35	8
				W150x22	2.25	4						
013	W310x39	6	12	W250x18	2.85	8	W310x86	2.35	8	L127x89x9.5	3.48	8
				W150x22	2.25	8						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
014	W310x39	6	12	W250x18	3.15	8	W310x86	2.35	8	L127x89x9.5	3.48	8
				W150x22	2.25	8						
015	W310x39	6	10	W250x33	2.85	8	W310x86	3.4	8	L127x89x9.5	4	8
	W310x60	6	2									
016	W310x39	6	10	W250x39	3.15	4	W310x86	3.4	8	L127x89x9.5	4	8
	W310x60	6	2									
017	W310x39	6	14	W250x22	2.85	4	W310x86	3.1	8	L127x89x9.5	3.93	8
				W250x18	2.85	4						
				W150x22	2.25	12						
018	W310x39	6	14	W250x49	3.2	4	W310x86	3.1	8	L127x89x9.5	3.93	8
				W250x25	3.2	4						
				W150x22	2.25	12						
019	W310x39	6	12	W250x18	2.85	8	W310x86	1.8	8	L127x89x9.5	3.3	8
020	W310x39	6	12	W250x18	3.15	8	W310x86	1.8	8	L127x89x9.5	3.3	8
021	W310x60	6	6	W250x33	2.85	4	W310x79	3.4	8	L127x89x9.5	3.66	8
	W310x67	6	4	W250x39	2.85	4						
	W310x86	6	2									
022	W310x60	6	6	W250x45	3.15	4	W310x79	3.4	8	L127x89x9.5	3.66	8
	W310x67	6	4	W250x39	3.15	4						
	W310x86	6	2									
023	W310x39	6	6	W250x33	2.85	4	W310x60	3.1	8	L127x89x9.5	3.62	8
	W310x67	6	4	W250x22	2.85	4						
	W310x86	6	2									
024	W310x39	6	6	W250x39	3.15	4	W310x60	3.1	8	L127x89x9.5	3.62	8
	W310x67	6	4	W250x25	3.15	4						
	W310x86	6	2									

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
025	W310x39	6	12	W250x25	2.85	4	W310x60	3.3	8	L127x89x9.5	3.91	8
				W250x18	2.85	4						
				W150x22	2.25	12						
026	W310x39	6	12	W250x22	3.15	4	W310x60	3.3	8	L127x89x9.5	3.91	8
				W250x18	3.15	4						
				W150x22	2.25	12						
039	W310x39	6	4	W250x33	2.75	3	W310x74	3.5	6	L127x89x9.5	4.35	8
	W310x86	6	6	W250x39	2.75	3						
040	W310x39	6	4	W250x49	3.25	3	W310x74	3.5	6	L127x89x9.5	4.35	8
	W310x86	6	6	W250x39	3.25	3						
041	W310x39	6	8	W250x33	2.75	3	W310x52	3	6	L127x89x9.5	3.86	8
				W250x22	2.75	3						
042	W310x39	6	8	W250x39	3.25	3	W310x52	3	6	L127x89x9.5	3.86	8
				W250x22	3.25	3						
043	W310x39	6	8	W250x22	2.75	3	W310x52	3.3	6	L127x89x9.5	3.91	8
				W250x18	2.75	3						
				W150x22	2.25	12						
044	W310x39	6	8	W250x25	3.25	3	W310x52	3.3	6	L127x89x9.5	3.91	8
				W250x18	3.25	3						
				W150x22	2.25	12						
045				W250x33	2.65	2	W310x74	3.75	4	L127x89x9.5	4.35	8
	W310x86	6	4	W250x39	2.65	2						
046				W250x45	3.35	2	W310x74	3.75	4	L127x89x9.5	4.35	8
	W310x86	6	4	W250x58	3.35	2						
047	W310x60	6	4	W250x33	2.65	2	W310x52	3.5	4	L127x89x9.5	3.86	8
	W150x22	2.25	4	W250x22	2.65	2						
				W150x22	2.25	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
048	W310x60	6	4	W250x45	3.35	2	W310x52	3.5	4	L127x89x9.5	3.86	8
	W150x22	2.25	4	W250x25	3.35	2						
				W150x22	2.25	4						
049	W310x60	6	4	W250x18	2.65	4	W310x52	2.55	4	L127x89x9.5	3.91	8
	W150x22	2.25	4	W150x22	2.25	4						
050	W310x60	6	4				W310x52	2.55	4	L127x89x9.5	3.91	8
	W150x22	2.25	4	W250x18	3.35	4						
				W150x22	2.25	4						
051	W310x39	6	10	W250x45	3	4	W310x60	4.09	8	L102x102x9.5	3.66	8
	W310x67	6	2	W250x39	3	4						
052	W310x39	6	10	W250x45	3	4	W310x60	4.09	8	L102x102x9.5	3.66	8
	W310x67	6	2	W250x39	3	4						
053	W310x39	6	12	W250x39	3	8	W310x60	3.1	8	L102x102x9.5	3.7	8
				W150x22	2.25	4						
054	W310x39	6	12	W250x39	3	8	W310x60	3.1	8	L102x102x9.5	3.7	8
				W150x22	2.25	4						
055	W310x39	6	12	W250x22	3	8	W310x60	2.76	8	L102x102x9.5	3.6	8
				W150x22	2.25	4						
056	W310x39	6	12	W250x22	3	8	W310x60	2.76	8	L102x102x9.5	3.6	8
				W150x22	2.25	4						
063	W310x39	6	2	W250x45	3	2	W310x60	3.1	4	L102x102x9.5	3.66	8
	W310x67	6	2	W250x39	3	2						
064	W310x39	6	2	W250x45	3	2	W310x60	3.1	4	L102x102x9.5	3.66	8
	W310x67	6	2	W250x39	3	2						
065	W310x39	6	4	W250x39	3	2	W310x52	3.2	4	L102x102x9.5	3.66	8
				W150x22	3	2						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
066	W310x39	6	4	W250x39	3	2	W310x52	3.2	4	L102x102x9.5	3.66	8
				W150x22	3	2						
067	W310x39	6	4	W250x22	3	2	W310x52	3.65	4	L102x102x9.5	4.07	8
				W150x22	2.25	8						
				W250x39	3	2						
068	W310x39	6	4	W250x22	3	2	W310x52	3.65	4	L102x102x9.5	4.07	8
				W150x22	2.25	8						
				W250x39	3	2						
069	W310x67	6	12	W250x45	3	4	W310x52	4.09	8	L102x102x9.5	4.15	8
				W250x39	3	4						
070	W310x67	6	12	W250x45	3	8	W310x52	4.09	8	L102x102x9.5	4.15	8
				W250x39	3	8						
071	W310x39	6	12	W250x39	3	4	W310x39	3.26	8	L102x102x9.5	3.73	8
				W250x22	3	4						
				W150x22	2.25	4						
072	W310x39	6	12	W250x39	3	4	W310x39	3.26	8	L102x102x9.5	3.73	8
				W250x22	3	4						
				W150x22	2.25	4						
073	W310x67	6	10	W250x45	3	4	W310x52	4.09	6	L102x102x9.5	4.15	8
				W250x39	3	4						
074	W310x67	6	10	W250x45	3	8	W310x52	4.09	6	L102x102x9.5	4.15	8
				W250x39	3	8						
075	W310x39	6	8	W250x39	3	4	W310x39	3.26	6	L102x102x9.5	3.73	8
				W250x22	3	4						
				W150x22	2.25	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
076	W310x39	6	8	W250x39	3	4	W310x39	3.26	6	L102x102x9.5	3.73	8
				W250x22	3	4						
				W150x22	2.25	4						
077	W310x39	6	4	W250x49	2.8	4	W310x86	3.8	6	W310x60	4.35	4
	W310x86	6	8	W250x33	2.8	4						
078	W310x39	6	4	W250x67	3.2	4	W310x86	3.8	6	W310x60	4.35	4
	W310x86	6	8	W250x45	3.2	4						
079	W310x39	6	2	W250x39	2.8	4	W310x86	3	6	W310x60	3.92	4
	W310x86	6	6	W250x18	2.8	4						
080	W310x39	6	2	W250x49	3.2	4	W310x86	3	6	W310x60	3.92	4
	W310x86	6	6	W250x25	3.2	4						
081	W310x39	6	8	W250x18	2.8	8	W310x86	3.27	6	W310x60	4.07	4
082	W310x39	6	8	W250x25	3.2	8	W310x86	3.27	6	W310x60	4.07	4
083	W310x39	6	8	W250x49	2.8	4	W310x86	3.8	6	W310x60	4.35	4
				W250x33	2.8	4						
084	W310x39	6	8	W250x45	3.2	4	W310x86	3.8	6	W310x60	4.35	4
				W250x67	3.2	4						
085	W310x39	6	4	W250x39	2.8	4	W310x86	3	6	W310x60	3.92	4
	W310x86	6	4	W250x18	2.8	4						
086	W310x39	6	4	W250x49	3.2	4	W310x86	3	6	W310x60	3.92	4
	W310x86	6	4	W250x25	3.2	4						
087	W310x39	6	8	W250x18	2.8	8	W310x86	3.27	6	W310x60	4.07	4
088	W310x39	6	8	W250x25	3.2	8	W310x86	3.27	6	W310x60	4.07	4
089	W310x39	6	12	W250x49	2.78	8	W310x74	3.4	8	L152x102x13	4.29	8
090	W310x39	6	12	W250x39	3.22	8	W310x74	3.4	8	L152x102x13	4.29	8

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
091	W310x39	6	6	W250x33	2.78	4	W310x74	3.86	8	L152x102x13	3.87	8
	W310x60	6	6	W250x18	2.78	4						
092	W310x39	6	6	W250x39	3.22	4	W310x74	3.86	8	L152x102x13	3.87	8
	W310x60	6	6	W250x25	3.22	4						
093	W310x39	6	4	W250x49	2.78	8	W310x74	3.4	4	L152x102x13	4.29	8
094	W310x39	6	4	W250x39	3.22	8	W310x74	3.4	4	L152x102x13	4.29	8
095	W310x39	6	2	W250x33	2.78	4	W310x74	3.86	4	L152x102x13	3.87	8
	W310x60	6	2	W250x18	2.78	4						
096	W310x39	6	2	W250x39	3.22	4	W310x74	3.86	4	L152x102x13	3.87	8
	W310x60	6	2	W250x25	3.22	4						
097	W310x107	6	4	W250x39	3	4	W310x74	3.2	8	L102x102x9.5	3.62	8
	W310x39	6	8	W250x45	3	4						
098	W310x107	6	4	W250x39	3	4	W310x74	3.2	8	L102x102x9.5	3.62	8
	W310x39	6	8	W250x45	3	4						
099	W310x39	6	12	W250x22	3	8	W310x74	2.9	8	L102x102x9.5	3.62	8
				W150x22	9	4						
100	W310x39	6	12	W250x22	3	8	W310x74	2.9	8	L102x102x9.5	3.62	8
				W150x22	9	4						
111				W250x39	3	4	W310x74	3.2	6	L102x102x9.5	3.66	8
	W310x39	6	8	W250x45	3	4						
112	W310x39	6	8	W250x39	3	4	W310x74	3.2	6	L102x102x9.5	3.66	8
				W250x45	3	4						
113	W310x39	6	8	W250x39	3	4	W310x74	3.1	6	L102x102x9.5	3.66	8
				W250x22	3	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
114	W310x39	6	8	W250x22	3	4	W310x74	3.1	6	L102x102x9.5	3.66	8
				W250x22	3	4						
115	W310x39	6	8	W250x22	3	8	W310x52	3.65	6	L102x102x9.5	4.07	8
				W150x22	2.25	12						
116	W310x39	6	8	W250x22	3	8	W310x52	3.65	6	L102x102x9.5	4.07	8
				W150x22	2.25	12						
117	W310x67	6	8	W250x49	2.9	4	W310x74	3.5	8	L152x152x9.5	4.14	4
	W310x107	6	6	W250x33	2.9	4						
118	W310x67	6	8	W250x49	3.1	4	W310x74	3.5	8	L152x152x9.5	4.14	4
	W310x107	6	6	W250x39	3.1	4						
119	W310x107	6	8	W250x33	2.9	4	W310x74	3.8	8	L152x152x9.5	3.66	4
	W310x67	6	4	W250x49	2.9	4						
120	W310x107	6	8	W250x39	3.1	4	W310x74	3.8	8	L152x152x9.5	3.66	4
	W310x67	6	4	W250x49	3.1	4						
121	W310x107	6	2	W250x28	2.9	4	W310x60	2.3	8	L102x102x9.5	3.55	4
	W310x67	6	2	W250x22	2.9	8						
	W310x39	6	8	W150x22	2.25	4						
122	W310x107	6	2	W250x33	3.1	4	W310x60	2.3	8	L102x102x9.5	3.55	4
	W310x67	6	2	W250x25	3.1	8						
	W310x39	6	8	W150x22	2.25	4						
123	W310x39	6	12	W250x22	2.9	8	W310x60	2.15	8	L76x76x9.5	2.22	8
				W150x22	2.25	8						
124	W310x39	6	12	W250x25	3.1	8	W310x60	2.15	8	L76x76x9.5	2.22	8
				W150x22	2.25	8						
125	W310x39	6	12	W250x22	2.9	8	W310x67	2.55	8	L102x102x9.5	3.47	8
				W150x22	2.25	8						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
126	W310x39	6	12	W250x25	3.1	8	W310x67	2.55	8	L102x102x9.5	3.47	8
				W150x22	2.25	8						
133	W310x67	6	4	W250x49	2.9	4	W310x97	3.8	8	L102x102x9.5	3.66	8
	W310x86	6	8	W250x33	2.9	4						
134	W310x67	6	4	W250x49	3.1	4	W310x97	3.8	8	L102x102x9.5	3.66	8
	W310x107	6	8	W250x39	3.1	4						
135	W310x39	6	8	W250x33	2.9	4	W310x97	2.8	8	L102x102x9.5	3.55	8
	W310x67	6	4	W250x49	2.9	4						
136	W310x39	6	8	W250x39	3.1	4	W310x97	2.8	8	L102x102x9.5	3.55	8
	W310x67	6	4	W250x49	3.1	4						
137	W310x86	6	8	W250x49	2.9	4	W310x67	2.6	8	L102x102x9.5	3.44	8
	W310x39	6	4	W250x22	2.9	4						
				W150x22	2.25	4						
138	W310x86	6	8	W250x49	3.1	4	W310x67	2.6	8	L102x102x9.5	3.44	8
	W310x39	6	4	W250x25	3.1	4						
				W150x22	2.25	4						
141	W310x107	6	4	W250x45	3	4	W310x97	3.8	8	L102x102x9.5	3.66	8
	W310x86	6	4	W250x39	3	4						
	W310x67	6	2									
	W310x39	6	2									
142	W310x107	6	4	W250x45	3	4	W310x97	3.8	8	L102x102x9.5	3.66	8
	W310x86	6	4	W250x39	3	4						
	W310x67	6	2									
	W310x39	6	2									
143	W310x86	6	4	W250x45	3	4	W310x97	3	8	L102x102x9.5	3.66	8
	W310x67	6	4	W250x39	3	4						
	W310x39	6	4									

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
144	W310x86	6	4	W250x45	3	4	W310x97	3	8	L102x102x9.5	3.66	8
	W310x67	6	4	W250x39	3	4						
	W310x39	6	4									
145	W310x86	6	2	W250x25	3	8	W310x67	2.55	8	L102x102x9.5	3.61	8
	W310x67	6	2	W150x22	2.25	4						
	W310x39	6	8									
146	W310x86	6	2	W250x25	3	8	W310x67	2.55	8	L102x102x9.5	3.61	8
	W310x67	6	2	W150x22	2.25	4						
	W310x39	6	8									
147	W310x67	6	4	W250x25	3	8	W310x67	2.4	8	L102x102x9.5	3.47	8
	W310x39	6	8	W150x22	2.25	8						
148	W310x67	6	4	W250x25	3	8	W310x67	2.4	8	L102x102x9.5	3.47	8
	W310x39	6	8	W150x22	2.25	8						
155	W310x86	6	4	W250x45	3	4	W310x67	4.09	6	L152x152x9.5	3.66	8
	W310x39	6	4	W250x39	3	4						
156	W310x86	6	4	W250x45	3	4	W310x67	4.09	6	L152x152x9.5	3.66	8
	W310x39	6	4	W250x39	3	4						
157	W310x86	6	2	W250x45	3	4	W310x67	4.09	6	L152x152x9.5	4.26	8
	W310x67	6	2	W250x39	3	4						
	W310x39	6	4									
158	W310x86	6	2	W250x45	3	4	W310x67	4.09	6	L152x152x9.5	4.26	8
	W310x67	6	2	W250x39	3	4						
	W310x39	6	4									
159	W310x39	6	8	W250x22	3	8	W310x67	3.57	6	L102x102x9.5	3.8	8
				W150x22	2.25	16						
160	W310x39	6	8	W250x22	3	8	W310x67	3.57	6	L102x102x9.5	3.8	8
				W150x22	2.25	16						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
161	W310x60	6	6	W250x39	2.9	4	W310x67	3.53	8	L127x89x9.5	4.1	8
	W310x39	6	6	W250x33	2.9	4						
162	W310x60	6	6	W250x45	3.1	8	W310x67	3.53	8	L127x89x9.5	4.1	8
	W310x39	6	6	W250x39	3.1	8						
163	W310x39	6	12	W250x22	2.9	4	W310x67	4.09	8	L127x89x9.5	3.91	8
				W250x18	2.9	4						
				W150x22	2.25	12						
164	W310x39	6	12	W250x22	3.1	4	W310x67	4.09	8	L127x89x9.5	3.91	8
				W250x18	3.1	4						
				W150x22	2.25	12						
179	W310x60	6	6	W250x39	3	4	W310x74	4.06	8	L127x89x9.5	3.88	8
	W310x39	6	6	W250x33	3	4						
180	W310x60	6	6	W250x39	3	4	W310x74	4.09	8	L127x89x9.5	3.88	8
	W310x39	6	6	W250x33	3	4						
181	W310x39	6	14	W250x22	3	4	W310x74	3.51	8	L127x89x9.5	3.91	8
				W250x18	3	4						
182	W310x39	6	14	W250x22	3	4	W310x74	3.51	8	L127x89x9.5	3.91	8
				W250x18	3	4						
183	W310x60	6	2	W250x33	2.65	4	W310x79	4.09	8	L152x102x13	4.53	8
	W310x39	6	10	W250x18	2.65	4						
184	W310x60	6	2	W250x58	3.35	4	W310x79	4.09	8	L152x102x13	4.53	8
	W310x39	6	10	W250x25	3.35	4						
185	W310x60	6	6	W250x28	2.65	4	W310x79	3	8	L152x102x13	3.61	8
	W310x39	6	6	W250x18	2.65	4						
186	W310x60	6	6	W250x45	3.35	4	W310x79	3	8	L152x102x13	3.61	8
	W310x39	6	6	W250x25	3.35	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
187	W310x60	6	2	W250x28	2.65	4	W310x60	3	8	L127x89x9.5	3.52	8
	W310x39	6	10	W250x18	2.65	4						
188	W310x60	6	2	W250x45	3.35	4	W310x60	3	8	L127x89x9.5	3.52	8
	W310x39	6	10	W250x25	3.35	4						
189	W310x39	6	12	W250x18	2.65	8	W310x60	2.05	8	L127x89x9.5	3.38	8
				W150x22	2.35	4						
190	W310x39	6	12	W250x18	2.65	8	W310x60	2.05	8	L127x89x9.5	3.38	8
				W150x22	2.35	4						
199	W310x39	6	4	W250x33	2.65	2	W310x67	4.09	4	L152x102x13	4.39	8
				W250x18	2.65	2						
200	W310x39	6	4	W250x58	3.35	2	W310x67	4.09	4	L152x102x13	4.39	8
				W250x25	3.35	2						
201	W310x39	6	4	W250x33	2.65	2	W310x67	3	4	L152x102x13	3.62	8
				W250x18	2.65	2						
202	W310x39	6	4	W250x58	3.35	2	W310x67	3	4	L152x102x13	3.62	8
				W250x25	3.35	2						
203	W310x39	6	4	W250x28	2.65	2	W310x52	3	4	L127x89x9.5	3.69	8
				W250x18	2.65	2						
				W150x22	2.35	4						
204	W310x39	6	4	W250x45	3.35	2	W310x52	3	4	L127x89x9.5	3.69	8
				W250x25	3.35	2						
				W150x22	2.35	4						
205	W310x39	6	4	W250x18	2.65	4	W310x52	2.32	4	L127x89x9.5	3.26	8
				W150x22	2.35	4						
206	W310x39	6	4	W250x18	2.65	4	W310x52	2.32	4	L127x89x9.5	3.26	8
				W150x22	2.35	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
207	W310x86	6	2	W250x45	3	4	W310x74	3.58	8	L152x102x13	4.09	8
	W310x60	6	2	W250x22	3	4						
	W310x39	6	8									
208	W310x86	6	2	W250x45	3	4	W310x74	3.58	8	L152x102x13	4.09	8
	W310x60	6	2	W250x22	3	4						
	W310x39	6	8									
209	W310x86	6	4	W250x45	3	4	W310x74	3.2	8	L152x102x13	3.95	8
	W310x60	6	4	W250x33	3	4						
	W310x39	6	4									
210	W310x86	6	4	W250x45	3	4	W310x74	3.2	8	L152x102x13	3.95	8
	W310x60	6	4	W250x33	3	4						
	W310x39	6	4									
211	W310x86	6	2				W310x60	2.8	8	L152x102x13	3.58	8
	W310x60	6	4	W250x22	3	8						
	W310x39	6	6	W150x22	2.15	4						
212	W310x86	6	2	W250x22	3	8	W310x60	2.8	8	L152x102x13	3.58	8
	W310x60	6	4	W150x22	2.15	4						
	W310x39	6	6									
213	W310x60	6	6	W250x18	3	8	W310x60	1.57	8	L152x102x13	3.91	8
	W310x39	6	6	W150x22	2.15	4						
	W150x22	21.75	2									
214	W310x60	6	6	W250x18	3	8	W310x60	1.57	8	L152x102x13	3.91	8
	W310x39	6	6	W150x22	2.15	4						
	W150x22	21.75	2									
237	W310x60	6	4	W250x45	3	4	W310x79	3.89	8	L152x102x13	4.27	8
	W310x39	6	8	W250x39	3	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
238	W310x60	6	4	W250x45	3	4	W310x79	3.89	8	L152x102x13	4.27	8
	W310x39	6	8	W250x39	3	4						
239	W310x60	6	4	W250x22	3	4	W310x60	4.09	8	L152x102x13	4.4	8
	W310x39	6	8	W250x33	3	4						
240	W310x60	6	4	W250x22	3	4	W310x60	4.09	8	L152x102x13	4.4	8
	W310x39	6	8	W250x33	3	4						
241	W310x39	6	12	W250x18	3	8	W310x60	2.96	8	L127x89x9.5	3.91	8
				W150x22	2.35	12						
242	W310x39	6	12	W250x18	3	8	W310x60	2.96	8	L127x89x9.5	3.91	8
				W150x22	2.35	12						
249	W310x67	6	2	W250x22	2	8	W310x74	3.89	4	L152x102x13	4	8
	W310x39	6	2									
250	W310x67	6	2	W250x22	2	8	W310x74	3.89	4	L152x102x13	4	8
	W310x39	6	2									
251	W310x60	6	2	W250x22	2	4	W310x67	4.09	4	L152x102x13	4.4	8
	W310x39	6	2	W250x18	2	4						
252	W310x60	6	2	W250x22	2	4	W310x67	4.09	4	L152x102x13	4.4	8
	W310x39	6	2	W250x18	2	4						
253	W310x39	6	4	W250x18	2	8	W310x67	2.96	4	L127x89x9.5	3.91	8
				W150x22	1.175	8						
254	W310x39	6	4	W250x18	2	8	W310x67	2.96	4	L127x89x9.5	3.91	8
				W150x22	1.075	8						
255	W310x45	6	8	W250x39	2.9	4	W310x67	4.09	6	L152x152x13	4.5	8
				W250x22	2.9	4						
256	W310x45	6	8	W250x45	3.1	4	W310x67	4.09	6	L152x152x13	4.5	8
				W250x25	3.1	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
257	W310x45	6	8	W250x28	2.9	4	W310x67	3.61	6	L152x152x13	3.85	8
				W250x18	2.9	4						
				W150x22	2.25	12						
258	W310x45	6	8	W250x33	3.1	4	W310x67	3.61	6	L152x152x13	3.85	8
				W250x18	3.1	4						
				W150x22	2.25	12						
259	W310x45	6	4	W250x39	2.9	4	W310x60	4.09	4	L152x152x13	4.5	8
				W250x22	2.9	4						
260	W310x45	6	4	W250x45	3.1	4	W310x60	4.09	4		4.5	8
				W250x25	3.1	4						
261	W310x45	6	4	W250x28	2.9	4	W310x60	3.61	4	L152x152x13	3.85	8
				W250x18	2.9	4						
				W150x22	2.25	12						
262	W310x45	6	4	W250x33	3.1	4	W310x60	3.61	4	L152x152x13	3.85	8
				W250x18	3.1	4						
				W150x22	2.25	12						
263	W310x67	6	8	W250x39	2	4	W310x60	3	8	L102x102x9.5	2.85	8
	W310x67	4	4	W250x33	2	4						
264	W310x67	6	8	W250x39	2	8	W310x60	3	8	L102x102x9.5	2.85	8
	W310x67	4	4	W250x33	2	8						
265	W310x67	6	8	W250x33	2	8	W310x60	2.75	8	L76x76x9.5	2.3	8
	W310x67	4	2									
	W310x39	4	2									
266	W310x67	6	8	W250x39	2	8	W310x60	2.75	8	L76x76x9.5	2.3	8
	W310x67	4	2									
	W310x39	4	2									

Structure Details of AB-Modules, Project 2

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
010	W530x92	6	8	W530x92	6	5	W310x67	6.4	10	2L152X102X16	6.8	8
	W250x49	6	8	W310x60	6	5						
				W360x64	6	12						
				W200x36	6	3						
052 A	W530x92	3	4	W530x101	6	6	W310x118	7.8	12	2L127X89X13	4.37	8
	W250x33	3	8	W410x54	6	2				2L127X89X13	3.99	8
	W530x92	6	4	W310x60	6	6						
	W310x45	6	8	W530x92	6	6						
	W310x67	6	4	W310x45	6	2						
	W530x101	6	2	W250x33	3	8						
052 B	W310x46	3	8	W530x101	6	8	W310x118	6.28	12	2L127X89X13	2.83	8
	W410x54	3	4	W310x45	6	7				2L127X89X13	3.18	8
	W410x100	6	4	W410x100	6	2				2L127X89X13	3.84	16
	W310x45	6	6	W410x54	6	6						
	W410x54	6	4	W250x33	3	13						
	W530x92	6	2	W310x45	3	2						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
055	W530x92	4.5	2	W530x101	6	9	W310x118	5.88	12	2L152X102X16	5.66	16
	W410x54	4.5	2	W530x92	6	6						
	W530x150	6	2	W310x60	6	4						
	W530x92	6	4	W530x150	6	1						
	W530x101	6	2	W310x45	6	5						
	W410x54	6	8	W410x100	6	1						
	W410x54	4.5	2	W410x54	6	1						
	W410x54	6	6									
	W530x101	6	2									
065	W410x74	6	2	W410x74	6	4	W310x79	6.8	8	2L102x76x9.5	3.61	8
	W310x60	6	2	W310x45	6	6				2L102x76x9.5	4.88	8
	W360x64	6	4	W360x64	6	8						
	W360x101	6	2	W310x45	3	1						
	W310x39	3	6	W250x33	3	1						
	W410x74	7	6	W250x34	2.2	1						
				W310x45	3	1						
				W250x33	3	14						
066	W410x74	7	4	W410x74	6	5	W360x101	6.8	4	2L102x76x9.5	4.03	8
	W360x74	7	2	W360x64	6	4				2L102x76x9.5	5.2	8
				W350x33	3	2						
				W310x45	3.5	4						
				W250x33	3.5	2						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
067	W360x64	7	4	W410x100	6	2	W360x147	6.8	4	2L127X89X13	4.57	16
	W610x113	7	2	W360x45	6	1						
				W360x64	6	2						
				W410x74	6	2						
				W610x113	6	1						
				W310x45	3.5	4						
069	W360x64	7	6	W410x74	6	2	W360x101	6.8	4	2L102x76x9.5	4.03	8
				W360x64	6	7				2L102x76x9.5	5.2	8
				W250x33	3.5	4						
				W250x49	3	1						
				W250x49	3.5	1						
004 A	W250x49	6	20	W460x128	6	5	W310x118	6.95	10	2L127X89X13	3.31	8
	W310x79	6	4	W310x79	6	9				2L127X89X13	3.5	8
	W310x45	6	6	W310x118	6	1				2L102x102x9.5	2.19	16
				W310x45	3	6						
				W460x74	3	2						
004 B	W310x79	6	4	W310x118	6	5	W310x118	8	10	2L127X89X13	4.76	8
	W250x49	6	14	W200x31	6	4						
				W310x79	6	10						
				C200x21	6	8						
				W150x30	2.52	20						
				W250x49	6	4						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
006 A	W250x58	6	4	W460x113	6	6	W310x118	7.95	12	2L127X89X13	3.66	16
	W250x49	6	22	W310x79	6	12				2L127X89X13	3.55	16
	W310x45	6	8	W310x67	6	4				2L127X89X13	3.5	16
				W200x36	6	1						
				W200x46	3	1						
006 B	W250x49	6	18	W310x118	6	6	W310x118	7.75	12	2L127X89X13	4.88	16
	W200x36	6	4	W310x79	6	6						
	W250x58	6	4	W410x100	6	6						
	W360x79	6	4	W310x97	6	2						
				W310x67	6	6						
				C200x21	6	10						
				W150x30	2.52	24						
011 A	W310x45	6	6	W460x113	6	6	W310x118	6.95	12	2L127X89X13	3.84	8
	W250x49	6	18	W310x79	6	12				2L127X89X13	3.39	8
	W310x79	6	6									
011 B	W250x49	6	20	W310x79	6	12		3.55	12	2L127X89X13	3.91	8
				C200x21	6	10						
				W150x30	2.52	24						
013 A	W310x79	6	14	W460x113	6	6	W310x118	2.85	12	2L127X89X13	3.32	8
	W250x49	6	4	W310x45	6	2						
				W250x49	3	1						

AB-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
013 B	W250x49	6	26	W310x118	6	6	W310x118	7.55	12	2L127x89x13	4.88	8
	W310x60	6	4	W200x31	6	5						
				W310x79	6	12						
				W250x49	6	7						
				W200x36	6	1						
				C200x21	6	10						
				W150x30	2.52	24						
013 C	W250x49	6	20	W310x79	6	12	W310x118	4.1	12	2L127x89x13	3.5	8
012 A	W310x45	6	10	W460x113	6	6	W310x118	2.85	12	2L127x89x13	3.35	8
	W250x49	6	2	W310x45	3	7						
				W460x74	3	1						
012 B	W250x49	6	24	W310x118	6	6	W310x118	6.9	12	2L127x89x13	3.61	8
	W310x60	6	2	W200x31	6	4				2L127x89x13	4.14	8
				W310x79	6	12						
				W200x36	6	1						
				C200x21	6	10						
				W150x30	2.52	24						
012 C	W250x49	6	20	W310x79	6	12	W310x118	4.1	12	2L127x89x13	3.42	8
										2L127x89x13	3.55	8
071	W250x49	6	18	W250x49	3	30	C200x21	7.8	12	2L127x89x13	3.38	8
	W200x36	6	14							2L127x89x13	3.97	8
	W200x46	5	4							2L127x89x13	4.26	8
	W250x49	5	6									
	W200x36	5	4									
074	W250x39	6	30	W200x46	4	17	W250x49	6.9	12	2L102x76x9.5	4.04	8
				W200x36	4	29				2L102x76x9.5	4.8	8

M-Modules' structure details, Project 2

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
027	W250x58	6	2	W250x58	3	4	W310x67	4.09	8	2L127x89x13	3.66	8
	W310x45	6	6	W250x28	3	4						
	W250x49	6	4	W200x46	3	1						
028	W250x58	6	2	W250x58	3	4	W310x67	4.09	8	2L127x89x13	3.66	8
	W310x45	6	6	W250x28	3	4						
	W250x49	6	4									
051	W530x92	6	6	W250x45	3	4	W310x52	3.6	8	2L102x76x9.5	4.39	8
	W250x49	6	6	W250x25	3	9						
				W250x22	3	4						
052	W530x92	6	6	W250x45	3	4	W310x52	3.6	8	2L102x76x9.5	4.39	8
	W250x49	6	6	W250x25	3	9						
				W250x22	3	4						
053	W250x49	6	12	W250x22	3	8	W310x52	2.8	8	2L76x76x6.4	3.53	8
				W150x14	3	3						
054	W250x49	6	12	W250x22	3	8	W310x52	2.8	8	2L76x76x6.4	3.53	8
				W150x14	3	3						
065	W250x39	6	8	W250x18	2	2	W250x33	3.9	6	2L102x76x9.5	4.57	8
				W250x14	2	9						
066	W250x39	6	8	W250x18	2	2	W250x33	3.9	6	2L102x76x9.5	4.57	8
				W250x14	2	9						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
067	W250x39	6	8	W250x18	2	6	W250x33	3	6	2L102x76x9.5	3.69	8
				W250x14	2	8						
068	W250x39	6	8	W250x28	3	6	W250x33	3	6	2L102x76x9.5	3.69	8
				W150x18	3	8						
077	W250x79	6	2	W250x58	3	4	W310x74	3.9	8	2L127x89x13	3.84	8
	W310x45	6	6	W250x28	3	4						
	W250x49	6	4									
078	W250x79	6	2	W250x58	3	4	W310x74	3.9	8	2L127x89x13	3.84	8
	W310x45	6	6	W250x28	3	4						
	W250x49	6	4									
079	W250x49	6	12	W250x28	3	8	W310x74	3.05	8	2L127x89x13	3.39	8
080	W250x49	6	12	W250x28	3	8	W310x74	3.05	8	2L127x89x13	3.39	8
081	W250x49	6	12	W250x28	3	8	W310x74	3.55	8	2L127x89x13	3.91	8
				W150x30	2.515	8						
082	W250x49	6	12	W250x28	3	8	W310x74	3.55	8	2L127x89x13	3.91	8
				W150x30	2.515	8						
091	W310x45	6	12	W250x58	3	4	W310x74	2.85	8	2L127x89x13	3.35	8
				W310x45	3	1						
				W250x28	3	4						
				W460x74	3	1						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
092	W310x45	6	12	W250x58	3	4	W310x74	2.85	8	2L127x89x13	3.35	8
				W250x28	3	4						
093	W250x49	6	12	W250x28	3	8	W310x74	4.1	8	2L127x89x13	4.24	8
094	W250x49	6	12	W250x28	3	8	W310x74	4.1	8	2L127x89x13	4.24	8
095	W250x49	6	12	W250x39	3	4	W310x67	4	8	2L127x89x13	3.61	8
				W250x28	3	4						
				W150x13	3	3						
096	W250x49	6	12	W250x39	3	4	W310x67	4	8	2L127x89x13	3.61	8
				W250x28	3	4						
				W150x13	3	3						
097	W250x49	6	12	W250x28	3	8	W310x67	2.9	8	2L127x89x13	4	8
				W150x13	3	1						
098	W250x49	6	12	W250x28	3	8	W310x67	2.9	8	2L127x89x13	4	8
				W150x13	3	1						
099	W310x79	6	10	W250x58	3	4	W310x74	2.85	8	2L127x89x13	3.32	8
	W250x49	6	2	W310x49	3	1						
				W250x28	3	4						
100	W310x79	6	10	W250x58	3	4	W310x74	2.85	8	2L127x89x13	3.32	8
	W250x49	6	2	W250x28	3	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
101	W250x49	6	12	W250x28	3	8	W310x74	4.1	8	2L127x89x13	3.5	8
102	W250x49	6	12	W250x28	3	8	W310x74	4.1	8	2L127x89x13	3.5	8
103	W250x49	6	12	W250x39	3	4	W310x67	4	8	2L127x89x13	4.16	8
				W250x28	3	4						
				W150x13	3	3						
104	W250x49	6	12	W250x39	3	4	W310x67	4	8	2L127x89x13	4.16	8
				W250x28	3	4						
				W150x13	3	3						
105	W250x49	6	8	W250x28	3	4	W310x67	3.55	8	2L127x89x13	4.03	8
	W310x60	6	4	W150x18	3	4						
106	W250x49	6	8	W250x28	3	4	W310x67	3.55	8	2L127x89x13	4.03	8
	W310x60	6	4	W150x18	3	4						
115	W250x49	6	2	W250x58	3	3	W310x67	3.2	6	2L102x102x9.5	2.19	8
	W310x45	6	4	W250x28	3	3						
				W460x74	3	1						
	W310x79	6	2	W310x45	3	1						
116	W250x49	6	2	W250x58	3	3	W310x67	3.2	6	2L102x102x9.5	2.19	8
	W310x45	6	4	W250x28	3	3						
				W460x74	3	1						
	W310x79	6	2	W310x45	3	1						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
117	W250x49	6	8	W250x28	3	6	W310x67	3.75	6	2L127x89x13	3.5	8
118	W250x49	6	8	W250x28	3	6	W310x67	3.75	6	2L127x89x13	3.5	8
119	W250x49	6	8	W250x39	3	3	W310x60	4	6	2L89x76x7.9	4.19	8
				W250x28	3	3						
				W150x13	3	2						
120	W250x49	6	8	W250x39	3	3	W310x60	4	6	2L89x76x7.9	4.19	8
				W250x28	3	3						
				W150x13	3	2						
121	W250x49	6	8	W250x28	3	6	W310x60	4	6	2L89x76x7.9	4.16	8
122	W250x49	6	8	W250x28	3	6	W310x60	4	6	2L89x76x7.9	4.16	8
229	W250x49	6	12	W250x28	3	8	W310x67	3.86	8	2L127x89x13	3.5	8
230	W250x49	6	12	W250x28	3	8	W310x67	3.86	8	2L127x89x13	3.5	8
231	W250x49	6	12	W250x39	3	4	W310x67	4	8	2L127x89x13	4.04	8
				W250x28	3	4						
				W150x30	2.515	4						
232	W250x49	6	12	W250x39	3	4	W310x67	4	8	2L127x89x13	4.04	8
				W250x28	3	4						
				W150x30	2.515	4						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
233	W250x49	6	2	W250x39	3	4	W310x67	3.75	8	2L127x89x13	3.86	8
	W250x58	6	2	W250x33	3	2						
	W200x36	6	2	W150x30	2.515	4						
	W310x67	6	2	W250x25	3	4						
	W360x79	6	4									
234	W250x49	6	2	W250x39	3	4	W310x67	3.75	8	2L127x89x13	3.86	8
	W250x58	6	2	W250x33	3	2						
	W200x36	6	2	W150x30	2.515	4						
	W310x67	6	2	W250x25	3	4						
	W360x79	6	4									
251	W410x74	6	6	W250x33	3	4	W310x49	3.2	6	2L102x76x9.5	3.61	8
	W310x60	6	2	W250x25	3	4						
	W360x64	6	2	W250x18	3	4						
	W310x39	3	4	W250x33	3	1						
252	W410x74	6	6	W250x33	3	4	W310x49	3.2	6	2L102x76x9.5	3.61	8
	W310x60	6	2	W250x25	3	4						
	W360x64	6	2	W250x18	3	4						
	W310x39	3	4	W250x33	3	1						
253	W410x74	6	4	W250x25	3	8	W310x49	3.6	6	2L102x76x9.5	4.2	8
	W360x101	6	2	W250x18	3	2						
	W360x64	6	2	W250x33	3	2						
	W310x39	3	4									

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
254	W410x74	6	4	W250x25	3	8	W310x49	3.6	6	2L102x76x9.5	4.2	8
	W360x101	6	2	W250x18	3	2						
	W360x64	6	2									
	W310x39	3	4									
255	W360x64	7	4	W250x33	3	4	W360x57	3.5	4	2L102x76x9.5	4.03	8
				W250x25	3	4						
256	W360x64	7	4	W250x33	3	2	W360x57	3.5	4	2L102x76x9.5	4.03	8
				W250x25	3	4						
257	W410x74	7	2	W250x33	3	3	W360x57	3.3	4	2L102x76x9.5	4.5	8
	W360x64	7	2	W250x25	3	3						
258	W410x74	7	2	W250x33	3	3	W360x57	3.3	4	2L102x76x9.5	4.5	8
	W360x64	7	2	W250x25	3	3						
259	W360x64	7	4	W250x39	3	2	W360x79	3.5	4	2L127x89x13	4.45	8
				W250x25	3	2						
				W250x18	3	1						
260	W360x64	7	4	W250x39	3	2	W360x79	3.5	4	2L127x89x13	4.45	8
				W250x25	3	2						
				W250x18	3	1						
261	W360x64	7	2	W250x25	3	2	W360x79	3.3	4	2L127x89x13	4.55	8
	W610x113	7	2	W250x58	3	2						
				W250x33	3	2						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
262	W360x64	7	2	W250x25	3	2	W360x79	3.3	4	2L127x89x13	4.55	8
	W610x113	7	2	W250x58	3	2						
				W250x33	3	2						
267	W360x64	7	4	W250x33	3	2	W360x57	4.09	4	2L102x76x9.5	4.45	8
				W250x25	3	4						
				W250x49	3	1						
268	W360x64	7	4	W250x33	3	2	W360x57	4.09	4	2L102x76x9.5	4.45	8
				W250x25	3	4						
269	W360x64	7	4	W250x25	3	5	W360x57	2.71	4	2L102x76x9.5	4.05	8
270	W360x64	7	4	W250x25	3	5	W360x57	2.71	4	2L102x76x9.5	4.05	8
279	W250x33	3	4	W250x49	3	4	W310x67	4.09	6	2L127x89x13	4.37	8
	W310x67	6	4	W250x25	3	2						
	W310x45	6	4	W250x22	3	4						
280	W250x33	3	4	W250x49	3	4	W310x67	4.09	6	2L127x89x13	4.37	8
	W310x67	6	4	W250x25	3	2						
	W310x45	6	4	W250x22	3	4						
281	W250x33	3	2	W250x45	3	4	W310x67	3.71	6	2L127x89x13	3.99	8
	W530x92	3	2	W250x18	3	6						
	W530x92	6	4									
	W310x45	6	2									
	W310x67	6	2									

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
282	W250x33	3	2	W250x45	3	4	W310x67	3.71	6	2L127x89x13	3.99	8
	W530x92	3	2	W250x18	3	6						
	W530x92	6	4									
	W310x45	6	2									
	W310x67	6	2									
283	W410x54	3	2	W250x49	3	2	W310x67	4	6	2L127x89x13	3.84	8
	W410x54	6	2	W250x73	3	1				2L127x89x13	2.83	8
	W310x45	3	2	W250x39	3	1						
	W310x45	6	2	W250x18	3	3						
284	W410x54	3	2	W250x49	3	2	W310x67	4	6	2L127x89x13	3.84	8
	W410x54	6	2	W250x73	3	1				2L127x89x13	2.83	8
	W310x45	3	2	W250x39	3	1						
	W310x45	6	2	W250x18	3	3						
285	W310x45	3	4	W250x25	3	4	W310x67	2.28	6	2L127x89x13	2.18	8
	W310x45	6	2	W250x49	3	2						
	W410x100	6	2	W250x39	3	1						
286	W310x45	3	4	W250x25	3	4	W310x67	2.28	6	2L127x89x13	2.18	8
	W310x45	6	2	W250x49	3	2						
	W410x100	6	2	W250x39	3	1						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	**Length (m)**	**No.**	**Beam Type**	**Length (m)**	**No.**	**Column Type**	**Length (m)**	**No.**	**Bracing Type**	**Length (m)**	**No.**
299	W530x92	4.5	2	W250x49	3	5	W310x67	3.2	6	2L102x76x9.5	3.76	8
	W530x150	6	2	W250x22	3	4						
	W410x54	10.5	2	W250x73	3	1						
	W310x60	6	1									
300	W530x92	4.5	2	W250x49	3	5	W310x67	3.2	6	2L102x76x9.5	3.76	8
	W530x150	6	2									
	W410x54	10.5	2	W250x22	3	4						
	W310x60	6	1	W250x73	3	1						
301	W410x54	10.5	4	W250x22	3	4	W310x67	2.68	6	2L102x76x9.5	3.56	8
				W250x45	3	3						
				W250x25	3	1						
302	W410x54	10.5	4	W250x22	3	4	W310x67	2.68	6	2L102x76x9.5	3.56	8
				W250x45	3	3						
				W250x25	3	1						
303	W530x92	6	2	W250x49	3	4	W310x67	3.2	6	2L102x76x9.5	3.76	8
	W530x101	6	2	W250x22	3	3						
				W250x39	3	1						
	W410x54	6	4	W250x18	3	1						
304	W530x92	6	2	W250x49	3	4	W310x67	3.2	6	2L102x76x9.5	3.76	8
	W530x101	6	2	W250x22	3	3						
				W250x39	3	1						
	W410x54	6	4	W250x18	3	1						

M-Module ID	Longitudinal Beams			Transverse Beams			Columns			Vertical Bracing		
	Beam Type	Length (m)	No.	Beam Type	Length (m)	No.	Column Type	Length (m)	No.	Bracing Type	Length (m)	No.
305	W410x54	6	8	W250x22	3	3	W310x67	2.68	6	2L102x76x9.5	3.56	8
				W250x45	3	3						
				W250x18	3	2						
306	W410x54	6	8	W250x22	3	3	W310x67	2.68	6	2L102x76x9.5	3.56	8
				W250x45	3	3						
				W250x18	3	2						
369	W200x36	6	4	W250x49	3	6	W250x58	3.89	6	2L127x89x13	4.31	8
	W250x49	6	2									
	W200x46	6	2									
370	W200x36	6	4	W250x49	3	9	W250x58	3.91	6	2L127x89x13	4.26	8
	W250x49	6	4									

Appendix C: Cost Estimation of Alberta-Sized Module Fabrication and Erection

Cost estimation of AB-Module fabrication and erection, Project 1

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0021 A	118	6	6	2172.82	1619.17	57418	48297	24.54	2340	1968
	132	6	6	2172.82	1619.17					
	86	6	10	2453.83	2023.97					
	60	6	2	2752.88	3035.95					
	39	6	12	2752.88	3035.95					
	60	4.35	4	2752.88	3035.95					
	118	4.1	12	2172.82	1619.17					
0021 B	100	6	6	2453.83	2023.97	64169	59993	24.99	2567	2400
	60	6	12	2752.88	3035.95					
	22	1.08	12	4724.44	3845.54					
	22	1.18	12	4724.44	3845.54					
	22	2.75	6	4067.45	3845.54					
	39	6	18	2752.88	3035.95					
	86	6	2	2453.83	2023.97					
	60	6	4	2752.88	3035.95					
	60	4.07	4	2752.88	3035.95					
	118	5.97	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0121 B	143	6	6	2172.82	1619.17	81046	70192	30.11	2691	2331
	86	6	6	2453.83	2023.97					
	67	6	12	2453.83	2023.97					
	22	1.08	48	4724.44	3845.54					
	22	1.18	48	4724.44	3845.54					
	22	2.75	6	4067.45	3845.54					
	39	6	22	2752.88	3035.95					
	67	6	2	2453.83	2023.97					
	107	6	2	2172.82	1619.17					
	86	6	2	2453.83	2023.97					
	14.5	3.55	4	5480.2	6071.91					
	10.7	2.3	8	6495.46	6071.91					
	86	5.45	12	2453.83	2023.97					
0122 A	143	6	6	2172.82	1619.17	90688	73414	39.08	2321	1879
	107	6	12	2172.82	1619.17					
	67	6	8	2453.83	2023.97					
	86	6	18	2453.83	2023.97					
	39	6	4	2752.88	3035.95					
	14.5	3.66	8	5480.2	6071.91					
	14.5	3.6	8	5480.2	6071.91					
	158	6.3	12	2083.54	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0122 B	143	6	6	2172.82	1619.17	77256	67596	28.68	2694	2357
	67	6	12	2453.83	2023.97					
	22	1.08	48	4724.44	3845.54					
	22	1.18	48	4724.44	3845.54					
	22	2.75	6	4067.45	3845.54					
	39	6	26	2752.88	3035.95					
	86	6	4	2453.83	2023.97					
	14.5	3.55	8	5480.2	6071.91					
	14.5	3.47	8	5480.2	6071.91					
	107	5.45	12	2172.82	1619.17					
0123 A	143	6	5	2172.82	1619.17	71570	58886	30.81	2323	1911
	107	6	10	2172.82	1619.17					
	67	6	4	2453.83	2023.97					
	86	6	6	2453.83	2023.97					
	107	6	4	2172.82	1619.17					
	39	6	10	2752.88	3035.95					
	14.5	3.66	16	5480.2	6071.91					
	158	6.1	10	2083.54	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0123 B	143	6	5	2172.82	1619.17	74382	64378	27.13	2742	2373
	67	6	10	2453.83	2023.97					
	22	1.08	40	4724.44	3845.54					
	22	1.18	40	4724.44	3845.54					
	22	2.75	5	4067.45	3845.54					
	39	6	20	2752.88	3035.95					
	67	6	6	2453.83	2023.97					
	86	6	2	2453.83	2023.97					
	22	1.08	16	4724.44	3845.54					
	22	1.18	16	4724.44	3845.54					
	22	2.75	2	4067.45	3845.54					
	14.5	3.61	8	5480.2	6071.91					
	14.5	3.47	8	5480.2	6071.91					
	118	5.65	10	2172.82	1619.17					
0124 A	143	6	6	2172.82	1619.17	82208	66598	34.95	2352	1905
	107	6	12	2172.82	1619.17					
	86	6	12	2453.83	2023.97					
	107	6	2	2172.82	1619.17					
	39	6	12	2752.88	3035.95					
	67	6	4	2453.83	2023.97					
	22	3.66	16	4067.45	3845.54					
	118	6.3	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0124 B	143	6	6	2172.82	1619.17	76385	70775	27.77	2751	2549
	60	6	12	2752.88	3035.95					
	22	1.08	48	4724.44	3845.54					
	22	1.18	48	4724.44	3845.54					
	22	2.75	6	4067.45	3845.54					
	39	6	30	2752.88	3035.95					
	14.5	3.51	16	5480.2	6071.91					
	118	5.45	12	2172.82	1619.17					
0125	118	6	5	2172.82	1619.17	73619	66669	27.9	2638	2389
	85	6	5	2453.83	2023.97					
	60	6	5	2752.88	3035.95					
	39	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	60	6	8	2752.88	3035.95					
	39	6	18	2752.88	3035.95					
	15.4	4.35	8	4067.45	3845.54					
	15.4	3.91	8	4067.45	3845.54					
	118	7.6	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0128	143	6	7	2172.82	1619.17	117558	100023	47.69	2465	2097
	107	6	14	2172.82	1619.17					
	60	6	7	2752.88	3035.95					
	22	1.08	14	4724.44	3845.54					
	22	1.18	14	4724.44	3845.54					
	22	0.5	7	4724.44	3845.54					
	67	6	26	2453.83	2023.97					
	39	6	24	2752.88	3035.95					
	14.5	3.66	16	5480.2	6071.91					
	10.7	2.02	16	6495.46	6071.91					
	118	7.35	14	2172.82	1619.17					
0131	107	6	4	2172.82	1619.17	47314	39528	18.72	2527	2111
	86	6	8	2453.83	2023.97					
	67	6	16	2453.83	2023.97					
	67	3	4	2453.83	2023.97					
	39	3	2	2752.88	3035.95					
	14.5	3.49	8	5480.2	6071.91					
	10.7	2.3	8	6495.46	6071.91					
	86	5.75	8	2453.83	2023.97					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0221	91	6	4	2453.83	2023.97	61271	55964	22.83	2684	2452
	85	6	4	2453.83	2023.97					
	60	6	4	2752.88	3035.95					
	39	6	4	2752.88	3035.95					
	22	1.08	24	4724.44	3845.54					
	22	1.18	24	4724.44	3845.54					
	22	2.5	4	4724.44	3845.54					
	60	6	2	2752.88	3035.95					
	39	6	22	2752.88	3035.95					
	15.4	4.35	8	4067.45	3845.54					
	15.4	4.65	8	4067.45	3845.54					
	118	8.3	8	2172.82	1619.17					
0222	91	6	6	2453.83	2023.97	98319	88181	36.79	2672	2397
	85	6	6	2453.83	2023.97					
	60	6	6	2752.88	3035.95					
	39	6	6	2752.88	3035.95					
	22	1.08	48	4724.44	3845.54					
	22	1.18	48	4724.44	3845.54					
	22	2.5	6	4724.44	3845.54					
	60	6	4	2752.88	3035.95					
	39	6	22	2752.88	3035.95					
	86	6	8	2453.83	2023.97					
	49	6	4	2752.88	3035.95					
	15.4	3.66	8	4067.45	3845.54					
	15.4	4.65	8	4067.45	3845.54					
	118	7.95	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0223	91	6	6	2453.83	2023.97	87355	79180	32.28	2706	2453
	85	6	6	2453.83	2023.97					
	60	6	6	2752.88	3035.95					
	39	6	6	2752.88	3035.95					
	22	1.08	48	4724.44	3845.54					
	22	1.18	48	4724.44	3845.54					
	22	2.5	6	4724.44	3845.54					
	60	6	2	2752.88	3035.95					
	39	6	30	2752.88	3035.95					
	15.4	3.66	8	4067.45	3845.54					
	15.4	4.65	8	4067.45	3845.54					
	118	7.7	12	2172.82	1619.17					
0320 A	100	6	6	2453.83	2023.97	57407	48750	23.55	2438	2070
	85	6	6	2453.83	2023.97					
	118	6	2	2172.82	1619.17					
	86	6	10	2453.83	2023.97					
	39	6	14	2752.88	3035.95					
	15.4	4.35	8	4067.45	3845.54					
	129	4.2	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0320 B	85	6	6	2453.83	2023.97	64355	60776	22.08	2914	2752
	60	6	6	2752.88	3035.95					
	39	6	6	2752.88	3035.95					
	22	1.08	36	4724.44	3845.54					
	22	1.18	36	4724.44	3845.54					
	22	2.5	6	4724.44	3845.54					
	39	6	18	2752.88	3035.95					
	60	6	6	2752.88	3035.95					
	22	1.08	12	4724.44	3845.54					
	22	1.18	12	4724.44	3845.54					
	22	2.5	2	4724.44	3845.54					
	15.4	3.91	8	4067.45	3845.54					
	86	5.6	12	2453.83	2023.97					
0322 A	100	6	5	2453.83	2023.97	46542	38584	19.15	2431	2015
	85	6	5	2453.83	2023.97					
	60	6	2	2752.88	3035.95					
	39	6	2	2752.88	3035.95					
	67	6	6	2453.83	2023.97					
	86	6	8	2453.83	2023.97					
	15.4	3.66	8	4067.45	3845.54					
	129	4.2	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0322 B	85	6	5	2453.83	2023.97	52782	48820	18.74	2816	2605
	60	6	5	2752.88	3035.95					
	39	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	39	6	16	2752.88	3035.95					
	67	6	6	2453.83	2023.97					
	15.4	3.91	8	4067.45	3845.54					
	86	5.6	10	2453.83	2023.97					
0323 A	143	6	5	2172.82	1619.17	60222	51790	24.95	2414	2076
	107	6	10	2172.82	1619.17					
	67	6	2	2453.83	2023.97					
	39	6	22	2752.88	3035.95					
	14.5	3.66	16	5480.2	6071.91					
	118	6.3	10	2172.82	1619.17					
0323 B	107	6	5	2172.82	1619.17	47566	45613	16.32	2914	2794
	60	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.75	5	4067.45	3845.54					
	39	6	24	2752.88	3035.95					
	14.5	3.27	8	5480.2	6071.91					
	14.5	3.33	8	5480.2	6071.91					
	86	3.65	10	2453.83	2023.97					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0324 A	143	6	4	2172.82	1619.17	55767	45706	23.64	2359	1933
	107	6	8	2172.82	1619.17					
	39	6	10	2752.88	3035.95					
	67	6	2	2453.83	2023.97					
	107	6	8	2172.82	1619.17					
	14.5	3.66	16	5480.2	6071.91					
	118	6.3	8	2172.82	1619.17					
0324 B	107	6	4	2172.82	1619.17	31256	29395	10.94	2857	2687
	60	6	4	2752.88	3035.95					
	22	1.08	16	4724.44	3845.54					
	22	1.18	20	4724.44	3845.54					
	22	2.75	4	4067.45	3845.54					
	39	6	12	2752.88	3035.95					
	14.5	4.07	8	5480.2	6071.91					
	86	3.65	8	2453.83	2023.97					
0421	107	6	5	2172.82	1619.17	72259	65408	27.35	2642	2392
	85	6	5	2453.83	2023.97					
	60	6	5	2752.88	3035.95					
	39	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	39	6	20	2752.88	3035.95					
	60	6	6	2752.88	3035.95					
	15.4	8.26	8	4067.45	3845.54					
	118	7.62	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0422 A	100	6	5	2453.83	2023.97	52531	46261	20.74	2532	2230
	85	6	5	2453.83	2023.97					
	60	6	8	2752.88	3035.95					
	39	6	8	2752.88	3035.95					
	24.1	4.53	8	4067.45	3845.54					
	24.1	4.07	8	4067.45	3845.54					
	129	6.81	10	2172.82	1619.17					
0422 B	85	6	5	2453.83	2023.97	49563	47074	17.28	2868	2724
	60	6	5	2752.88	3035.95					
	39	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	60	6	2	2752.88	3035.95					
	39	6	18	2752.88	3035.95					
	15.4	3.91	8	4067.45	3845.54					
	86	5.33	10	2453.83	2023.97					
04234 A	100	6	10	2453.83	2023.97	50512	44325	19.91	2536	2226
	60	6	4	2752.88	3035.95					
	39	6	12	2752.88	3035.95					
	24.1	4.07	8	4067.45	3845.54					
	24.1	4.39	8	4067.45	3845.54					
	118	6.81	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
04234 B	85	6	5	2453.83	2023.97	48151	45358	16.8	2867	2700
	60	6	5	2752.88	3035.95					
	39	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	39	6	18	2752.88	3035.95					
	15.4	3.91	8	4067.45	3845.54					
	86	5.6	10	2453.83	2023.97					
0424 A	100	6	10	2453.83	2023.97	50509	44154	19.89	2540	2220
	86	6	4	2453.83	2023.97					
	39	6	10	2752.88	3035.95					
	60	6	4	2752.88	3035.95					
	24.1	4.09	8	4067.45	3845.54					
	24.1	3.67	8	4067.45	3845.54					
	118	5.55	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0424 B	85	6	5	2453.83	2023.97	56162	52548	19.55	2872	2687
	60	6	5	2752.88	3035.95					
	39	6	5	2752.88	3035.95					
	22	1.08	17	4724.44	3845.54					
	22	1.18	34	4724.44	3845.54					
	22	3.65	2	4067.45	3845.54					
	86	6	2	2453.83	2023.97					
	39	6	10	2752.88	3035.95					
	60	6	8	2752.88	3035.95					
	22	1.3	12	4724.44	3845.54					
	22	1.08	12	4724.44	3845.54					
	22	2.5	6	4724.44	3845.54					
	86	6.75	4	2453.83	2023.97					
	86	5.6	6	2453.83	2023.97					
0427 A	107	6	6	2172.82	1619.17	57736	50821	23.19	2490	2192
	100	6	6	2453.83	2023.97					
	60	6	10	2752.88	3035.95					
	39	6	10	2752.88	3035.95					
	24.1	4.27	8	4067.45	3845.54					
	24.1	3.66	8	4067.45	3845.54					
	129	5.34	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0427 B	85	6	6	2453.83	2023.97	58115	55497	20.66	2813	2687
	60	6	6	2752.88	3035.95					
	39	6	6	2752.88	3035.95					
	22	1.18	18	4724.44	3845.54					
	22	1.08	36	4724.44	3845.54					
	22	2.5	6	4724.44	3845.54					
	39	6	20	2752.88	3035.95					
	60	6	4	2752.88	3035.95					
	15.4	3.91	8	4067.45	3845.54					
	86	5.6	12	2453.83	2023.97					
0428 A	60	4	10	2752.88	3035.95	40197	37854	15.34	2620	2468
	60	6	4	2752.88	3035.95					
	67	6	2	2453.83	2023.97					
	39	6	12	2752.88	3035.95					
	24.1	3.96	8	4067.45	3845.54					
	24.1	3.66	8	4067.45	3845.54					
	118	5.44	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
0428 B	60	4	5	2752.88	3035.95	40257	39469	14.18	2840	2784
	39	4	10	2752.88	3035.95					
	22	1.18	15	4724.44	3845.54					
	22	1.08	15	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	39	6	16	2752.88	3035.95					
	60	6	4	2752.88	3035.95					
	15.4	3.91	8	4067.45	3845.54					
	86	5.5	10	2453.83	2023.97					
0429	100	6	5	2453.83	2023.97	76760	68669	28.36	2707	2421
	67	6	5	2453.83	2023.97					
	86	6	5	2453.83	2023.97					
	45	6	5	2752.88	3035.95					
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.5	5	4724.44	3845.54					
	45	6	24	2752.88	3035.95					
	29	4.5	16	4067.45	3845.54					
	118	7.7	10	2172.82	1619.17					
520 A	143	6	5	2172.82	1619.17	62282	52910	25.99	2396	2036
	107	6	10	2172.82	1619.17					
	86	6	2	2453.83	2023.97					
	107	6	2	2172.82	1619.17					
	39	6	20	2752.88	3035.95					
	14.5	3.66	16	5480.2	6071.91					
	118	6.3	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
520 B	60	6	10	2752.88	3035.95	28477	27048	9.01	3162	3004
	22	1.08	30	4724.44	3845.54					
	22	1.18	30	4724.44	3845.54					
	22	2.75	5	4067.45	3845.54					
	14.5	4.07	8	5480.2	6071.91					
	86	3.65	10	2453.83	2023.97					
522	143	6	5	2172.82	1619.17	68513	58570	27.39	2501	2138
	107	6	5	2172.82	1619.17					
	60	6	5	2752.88	3035.95					
	22	1.08	20	4724.44	3845.54					
	22	1.18	20	4724.44	3845.54					
	22	1.62	5	4724.44	3845.54					
	107	6	8	2172.82	1619.17					
	39	6	16	2752.88	3035.95					
	14.5	3.63	16	5480.2	6071.91					
	118	6.1	10	2172.82	1619.17					

AB-Modules' fabrication and erection cost estimation, Project 2

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
010	92	6	5	2453.83	2023.97	59224	53315	22.49	2634	2371
	60	6	5	2752.88	3035.95					
	64	6	12	2453.83	2023.97					
	36	6	3	2752.88	3035.95					
	92	6	8	2453.83	2023.97					
	49	6	8	2752.88	3035.95					
	29.7	6.8	8	4067.45	3845.54					
	67	6.4	10	2453.83	2023.97					
052 A	101	6	6	2172.82	1619.17	79777	69144	32.57	2449	2123
	54	6	2	2752.88	3035.95					
	60	6	6	2752.88	3035.95					
	92	6	6	2453.83	2023.97					
	45	6	2	2752.88	3035.95					
	33	3	8	2752.88	3035.95					
	92	3	4	2453.83	2023.97					
	33	3	8	2752.88	3035.95					
	92	6	4	2453.83	2023.97					
	45	6	8	2752.88	3035.95					
	67	6	4	2453.83	2023.97					
	101	6	2	2172.82	1619.17					
	20.3	4.37	8	4067.45	3845.54					
	20.3	3.99	8	4067.45	3845.54					
	118	7.8	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
052 B	101	6	8	2172.82	1619.17	78068	70784	30.7	2543	2305
	45	6	7	2752.88	3035.95					
	100	6	2	2453.83	2023.97					
	54	6	6	2752.88	3035.95					
	33	3	13	2752.88	3035.95					
	45	3	2	2752.88	3035.95					
	45	3	8	2752.88	3035.95					
	54	3	4	2752.88	3035.95					
	100	6	4	2453.83	2023.97					
	45	6	6	2752.88	3035.95					
	54	6	4	2752.88	3035.95					
	92	6	2	2453.83	2023.97					
	20.3	2.83	8	4067.45	3845.54					
	20.3	3.18	8	4067.45	3845.54					
	20.3	3.84	16	4067.45	3845.54					
	118	6.28	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
055	101	6	9	2172.82	1619.17	92799	81189	37.16	2497	2185
	92	6	6	2453.83	2023.97					
	60	6	4	2752.88	3035.95					
	150	6	1	2172.82	1619.17					
	45	6	5	2752.88	3035.95					
	100	6	1	2453.83	2023.97					
	54	6	1	2752.88	3035.95					
	54	4.5	2	2752.88	3035.95					
	54	6	6	2752.88	3035.95					
	101	6	2	2172.82	1619.17					
	92	4.5	2	2453.83	2023.97					
	54	4.5	2	2752.88	3035.95					
	150	6	2	2172.82	1619.17					
	92	6	4	2453.83	2023.97					
	101	6	2	2172.82	1619.17					
	54	6	8	2752.88	3035.95					
	29.7	5.66	16	4067.45	3845.54					
	118	5.88	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
065	74	6	4	2453.83	2023.97	56771	51649	21.61	2626	2389
	45	6	6	2752.88	3035.95					
	64	6	8	2453.83	2023.97					
	45	3	1	2752.88	3035.95					
	33	3	1	2752.88	3035.95					
	33	2.2	1	3084.67	3035.95					
	45	3	1	2752.88	3035.95					
	33	3	14	2752.88	3035.95					
	74	6	2	2453.83	2023.97					
	60	6	2	2752.88	3035.95					
	64	6	4	2453.83	2023.97					
	101	6	2	2172.82	1619.17					
	39	3	6	2752.88	3035.95					
	74	7	6	2453.83	2023.97					
	12.6	3.61	8	5480.2	6071.91					
	12.6	4.88	8	5480.2	6071.91					
	79	6.8	8	2453.83	2023.97					
066	74	6	5	2453.83	2023.97	30483	26922	11.46	2660	2349
	64	6	4	2453.83	2023.97					
	33	3	2	2752.88	3035.95					
	45	3.5	4	2752.88	3035.95					
	33	3.5	2	2752.88	3035.95					
	74	7	4	2453.83	2023.97					
	64	7	2	2453.83	2023.97					
	12.6	9.23	8	5480.2	6071.91					
	101	6.8	4	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
067	100	6	2	2453.83	2023.97	33518	27982	13.29	2522	2105
	45	6	1	2752.88	3035.95					
	64	6	2	2453.83	2023.97					
	74	6	2	2453.83	2023.97					
	113	6	1	2172.82	1619.17					
	45	3.5	4	2752.88	3035.95					
	64	7	4	2453.83	2023.97					
	113	7	2	2172.82	1619.17					
	20.3	4.57	16	4067.45	3845.54					
	147	6.8	4	2172.82	1619.17					
069	74	6	2	2453.83	2023.97	28588	25145	10.72	2666	2345
	64	6	7	2453.83	2023.97					
	33	3.5	4	2752.88	3035.95					
	49	3	1	2752.88	3035.95					
	49	3.5	1	2752.88	3035.95					
	64	7	6	2453.83	2023.97					
	12.6	4.03	8	5480.2	6071.91					
	12.6	5.2	8	5480.2	6071.91					
	101	6.8	4	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
004 A	128	6	5	2172.82	1619.17	74586	66579	29.28	2547	2274
	79	6	9	2453.83	2023.97					
	118	6	1	2172.82	1619.17					
	45	3	6	2752.88	3035.95					
	74	3	2	2453.83	2023.97					
	49	6	20	2752.88	3035.95					
	79	6	4	2453.83	2023.97					
	45	6	6	2752.88	3035.95					
	14.5	2.19	16	6495.46	6071.91					
	20.3	3.31	8	4067.45	3845.54					
	20.3	3.5	8	4067.45	3845.54					
	118	6.95	10	2172.82	1619.17					
004 B	118	6	5	2172.82	1619.17	76467	66038	28.95	2642	2281
	31	6	4	4067.45	3845.54					
	79	6	10	2453.83	2023.97					
	21	6	8	4067.45	3845.54					
	30	2.52	20	4724.44	3845.54					
	49	6	4	2752.88	3035.95					
	79	6	4	2453.83	2023.97					
	49	6	14	2752.88	3035.95					
	20.3	4.76	8	4067.45	3845.54					
	118	8	10	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
006 A	113	6	6	2172.82	1619.17	93910	84454	36.47	2575	2315
	79	6	12	2453.83	2023.97					
	67	6	4	2453.83	2023.97					
	36	6	1	2752.88	3035.95					
	46	3	1	2752.88	3035.95					
	58	6	4	2752.88	3035.95					
	49	6	22	2752.88	3035.95					
	45	6	8	2752.88	3035.95					
	20.3	3.66	16	4067.45	3845.54					
	20.3	3.55	16	4067.45	3845.54					
	20.3	3.5	16	4067.45	3845.54					
	118	7.95	12	2172.82	1619.17					
006 B	118	6	6	2172.82	1619.17	103237	89596	39.35	2624	2277
	79	6	6	2453.83	2023.97					
	100	6	6	2453.83	2023.97					
	97	6	2	2453.83	2023.97					
	67	6	6	2453.83	2023.97					
	21	6	10	4067.45	3845.54					
	30	2.52	24	4724.44	3845.54					
	49	6	18	2752.88	3035.95					
	36	6	4	2752.88	3035.95					
	58	6	4	2752.88	3035.95					
	79	6	4	2453.83	2023.97					
	20.3	4.88	16	4067.45	3845.54					
	118	7.75	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
011 A	113	6	6	2172.82	1619.17	74962	65289	30.53	2456	2139
	79	6	12	2453.83	2023.97					
	45	6	6	2752.88	3035.95					
	49	6	18	2752.88	3035.95					
	79	6	6	2453.83	2023.97					
	20.3	3.84	8	4067.45	3845.54					
	20.3	3.39	8	4067.45	3845.54					
	118	6.95	12	2172.82	1619.17					
011 B	79	6	12	2453.83	2023.97	57346	51766	20.3	2824	2550
	21	6	10	4067.45	3845.54					
	30	2.52	24	4724.44	3845.54					
	49	6	20	2752.88	3035.95					
	20.3	3.91	8	4067.45	3845.54					
	118	3.55	12	2172.82	1619.17					
013 A	113	6	6	2172.82	1619.17	32445	27746	13.11	2476	2117
	45	6	2	2752.88	3035.95					
	49	3	1	2752.88	3035.95					
	79	6	14	2453.83	2023.97					
	49	6	4	2752.88	3035.95					
	20.3	3.32	8	4067.45	3845.54					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
013 B	118	6	6	2172.82	1619.17	98387	88629	36.78	2675	2410
	31	6	5	4067.45	3845.54					
	79	6	12	2453.83	2023.97					
	49	6	7	2752.88	3035.95					
	36	6	1	2752.88	3035.95					
	21	6	10	4067.45	3845.54					
	30	2.52	24	4724.44	3845.54					
	49	6	26	2752.88	3035.95					
	60	6	4	2752.88	3035.95					
	20.3	4.88	8	4067.45	3845.54					
	118	7.55	12	2172.82	1619.17					
013 C	79	6	12	2453.83	2023.97	45071	40949	17.94	2512	2282
	49	6	20	2752.88	3035.95					
	20.3	3.5	8	4067.45	3845.54					
	118	4.1	12	2172.82	1619.17					
012 A	113	6	6	2172.82	1619.17	32019	28513	13.1	2444	2176
	45	3	7	2752.88	3035.95					
	74	3	1	2453.83	2023.97					
	45	6	10	2752.88	3035.95					
	49	6	2	2752.88	3035.95					
	20.3	3.35	8	4067.45	3845.54					
	118	2.85	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
012 B	118	6	6	2172.82	1619.17	88260	77997	32.78	2693	2380
	31	6	4	4067.45	3845.54					
	79	6	12	2453.83	2023.97					
	36	6	1	2752.88	3035.95					
	21	6	10	4067.45	3845.54					
	30	2.52	24	4724.44	3845.54					
	49	6	24	2752.88	3035.95					
	60	6	2	2752.88	3035.95					
	20.3	3.61	8	4067.45	3845.54					
	20.3	4.14	8	4067.45	3845.54					
	118	6.9	12	2172.82	1619.17					
012 C	79	6	12	2453.83	2023.97	47363	43116	18.51	2559	2330
	49	6	20	2752.88	3035.95					
	20.3	3.42	8	4067.45	3845.54					
	20.3	3.55	8	4067.45	3845.54					
	118	4.1	12	2172.82	1619.17					

AB-Module ID	Component Weight (kg/m)	Length (m)	No.	Fabrication Unit Price ($/Tonne)	Erection Unit Price ($/Tonne)	Module Fabrication Cost ($)	Module Erection Cost ($)	Module Weight (Tonne)	Fabrication Cost per Weight ($/Tonne)	Erection Cost per Weight ($/Tonne)
071	49	3	30	2752.88	3035.95	59259	62887	19.69	3010	3194
	49	6	18	2752.88	3035.95					
	36	6	14	2752.88	3035.95					
	46	5	4	2752.88	3035.95					
	49	5	6	2752.88	3035.95					
	36	5	4	2752.88	3035.95					
	20.3	3.38	8	4067.45	3845.54					
	20.3	3.97	8	4067.45	3845.54					
	20.3	4.26	8	4067.45	3845.54					
	21	7.8	12	4067.45	3845.54					
074	46	4	17	2752.88	3035.95	55485	61214	19.27	2879	3176
	36	4	29	2752.88	3035.95					
	39	6	30	2752.88	3035.95					
	12.6	4.04	8	5480.2	6071.91					
	12.6	4.8	8	5480.2	6071.91					
	49	6.9	12	2752.88	3035.95					