# MODULARISATION AND PRE-ASSEMBLY PAPER #1 UNDERPINNING ECONOMIC DEVELOPMENT PARAMETERS

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## INTRODUCTION AND OVERVIEW

This paper has been compiled to give the reader a conceptual overview of the key considerations, parameters, and to some extent the paradigms central in importance to a project owner seeking to adopt modularisation and pre-assembly as a primary project delivery strategy.

A considerable depth of attention and focus related to modularisation and pre-assembly as a project delivery model has been generated in the past five to ten years within the Australian, mining, minerals processing, oil and gas and heavy industry sectors. Many industrial projects have selected modularization and pre-assembly as a project delivery model to great benefit and advantage. However, this has been achieved at the cost of accelerated learning and the requirement to conquer unforeseen challenges not readily apparent at the commencement of the project. As a result, there has been a significant increase in the depth of knowledge related to the project management, engineering development and general execution challenges associated with modular and pre-assembly project delivery models especially for the mining minerals processing industry sectors. This introductory paper will lead the reader from a high level through the various principal topics as follows;

1. Drivers for Project Owners;
2. Paradigms and Key Concepts;
3. Risk and Benefit Considerations;
4. Determining Economic Viability for a Modular or Pre-Assembly Strategies;
5. Development of Economic Cost Models for Module and Pre-Assembly Strategies;
6. Concluding Summary.

This paper is targeted at the keystones of early project development and drivers and how these foundation elements are compared, analyzed and evaluated to establish the applicability and viability of a modular or pre-assembly delivery approach for a specific project. While the principles and paradigms outlined in this paper are valid for all projects located both internationally and domestically, they have strong significance to delivery models for remote and inland based mining, minerals processing and heavy industrial projects.

To augment this paper, the author has compiled a number of supporting papers that address the key concepts related to a modular or pre-assembly project delivery model in more detail.

The reader will notice consistent reference to both module and also pre-assembly in this paper. The author believes there is a fundamental difference in the two items. For the purposes of this paper a module is a section of plant constructed away from its final operational location that effectively incorporates the inclusion of structural, piping, equipment, electric and instrumentation. Pre-assembly refers to less comprehensive sections of plant, less complex in nature and incorporate mainly structural components. A very simple pre-assembly would be a flat pack floor or wall panel for instance. The definitions of scale and variations are more thoroughly discussed in the paper by the author Modularisation And Pre-Assembly Paper #2 - Definitions and Scale.

## DRIVERS FOR MODULARIZATION AND PRE-ASSEMBLY

Modularisation and pre-assembly is without question a captivating concept, rich with the promise of delivering significant benefits and advantages over traditional methods of project delivery. The visual images of large blocks of assembled plant and equipment arriving on site from far away locations by ship and trailer are often the initial introduction project owners have to a modular

"***the decision to progress a project by a modular or pre-assembly delivery must be intrinsically linked to an overall project benefit and viability rooted in fundamental project economics relative to core business objectives and goals***"

or pre-assembly project delivery methodology.

However, the owners and project concept developers of large industrial projects have their fundamental focus on the overall economics of the project from a fundamental position of core business viability. As such, project delivery by any method, traditional site erected or a modular or pre-assembly strategy, is only a single consideration in the spectrum of overall considerations for a project owner. Core business focus includes financial commitment, risk, speed to market and resource investment of the project owner. In short, the decision to progress a project by a modular or pre-assembly delivery must be intrinsically linked to an overall project benefit and viability rooted in fundamental project economics relative to core businesses objectives and goals of the project owner.

Given this perspective platform, not surprisingly it is often the cost of the proposed project execution and delivery that is the principle initial focus of potential benefits. However, safety, as a core value and strategic corporate operational value of project owners is often not presented as a primary benefit of a modular or pre-assembly delivery advantage to the project owner. Cost is by far the easiest element to initially quantify, evaluate and relate to a project economic base, but is in fact only one of a suite of beneficial elements associated with a modular or pre-assembly delivery model. In general, the following suite of key parameters can be enhanced to some extent, both individually, and in some cases collectively by modularisation and pre-assembly delivery methods.

1. **Construction Safety**
2. **Project Delivery Schedule**
3. **Project Delivery Capital Cost**
4. **Project Quality**
5. **Site Environmental Impacts**

The resultant opportunity benefits and risks applicable to each of the key areas is specific to individual project analysis. These points identifying typical areas of potential advantage and provide a checklist of fundamental opportunity analysis and should be the first step in the appraisal of applicability for modularisation or pre-assembly to any project. Safety enhancements by modularisation and pre-assembly are addressed in the paper by the author Modularisation And Pre-Assembly Paper #3 - Fundamental Considerations for Execution.

## PARADIGMS OF MODULARIZATION AND PRE-ASSEMBLY PROJECT DELIVERY

Before a comprehensive evaluation of the viability of a modular or pre-assembly delivery is undertaken, it is important to consider the following fundamental reference perspectives relevant to a modularisation and pre-assembly delivery strategy. Modularisation can be successfully and beneficially applied to a project in the following ways.

- **Complete Modularisation and Pre-Assembly Off Site;**
- **Complete Modularisation and Pre-Assembly On Site.**

These two quintessential aspects of a modular or pre-assembly project delivery model are key considerations that assist in establishing the platform for the scale and effectiveness of a modular or pre-assembly delivery model for a specific project. Further, the sub options available for these two fundamental approaches can be refined to establish hybrid project solutions. The spectrum of solutions is almost infinite between the limits of full modularization down to maximized use of 2 dimensional flat pack wall, floor and roof truss panels. The available range and scale for solutions to project delivery should be adequate for any project to encompass critical internal and external project stakeholder relationships while meeting overall project economic objectives. Some of the hybrid solutions are outlined below.

**“fabrication, for the purposes of this paper should be considered the extent of maximized pre-fabrication to a point short of complex flat pack or three dimensional assembly”**

- Fabrication and Assembly Offshore Australia;
- Fabrication Offshore and Assembly Onshore Australia;
- Fabrication and Assembly Onshore Australia;
- Fabrication Onshore and Assembly On Site.

At this juncture, It should be noted that reference to fabrication for the purposes of this pa-

per should be considered the extent of maximized pre-fabrication to a point short of complex two dimensional flat pack panels. Reference to assembly encompasses the construction of complex flat packs or three dimensional pre-assemblies or modules prior to installation in their operational location. None of the identified options above refer to a traditional site erected or "stick built" delivery methodology. The options identified above, and the mix of hybrids possible from the list assist in appreciation of the flexibility, complexity and inherent potential of a modular or pre-assembly delivery methodology to add value to a project.

## CONSIDERATIONS, RISKS AND BENEFITS

A project delivery model that encompasses a modular and pre-assembly component has the potential to provide significant benefits for safety, schedule, cost, quality and environment impact. However, the complexity of this delivery method is not at the forfeiture of some burden of risk. In fact, the complexity of modular and pre-assembly delivery over tradition site erected construction methodologies inherently introduces a differing risk profile with an increased, but not unachievable, managerial burden required for overall project delivery.

**"Each phase of a projects development, scoping, pre-feasibility, feasibility and execution have varying degrees of potential to be enhanced by modularization and pre-assembly, each project needs careful individual review on this key point prior to initiating a change in delivery strategy. "**

An essential aspect of a modularisation and pre-assembly delivery that a project owner must evaluate is the phase of project development that this project delivery method will be introduced. Each phase of project development, scoping, pre-feasibility, feasibility and execution has varying degrees of potential to be enhanced by modularization and pre-assembly, each project needs careful individual review on this key point prior to initiating a change in delivery strategy. Without question, there is a dramatically increasing impact to cost, schedule and project development momentum the later any change, including change in delivery methodology, is introduced into a developing project. Ideally, the project will begin at a scoping phase with the base execution philosophy of a modular or pre-assembly delivery model for construction. The fundament characteristics of modular and pre-assembled projects as identified in the highlight box are essential points of high level reference for project owners.

1. A modular or pre-assembled design base can always be site erected using traditional "stick build" methodologies. A traditional stick build design is not easily converted to a modular or pre-assembled design without significant rework to basic engineering;
2. Modular or pre-assembly based designs are easily site erected and progressed under traditional site erection methodologies;
3. If concurrent studies for stick build and modular pre-assembly design are undertaken using a stick build design as a bases case, there will be significant rework to the stick build design if modular or pre-assembly proves viable. Procurement for bulk materials and the location for equipment and special materials should not be fixed until a firm decision on the delivery methodology is finalized. This will avoid costly procurement rework but will strain long lead item early procurement advantages. Specific materials of construction such a structural steel needs point of origin confirmation;
4. The latter modularisation is introduced into a project development, concept, pre-feasibility, feasibility or execution phases, the greater the potential for significant engineering reworks, schedule loss and overall disruption to project momentum.

These fundamental considerations require careful analysis by the project owner. When the decision is made to progress a modular or pre-assembly solution, the management team must cement and constantly reinforce the delivery culture from the top down to maximise the extent of the benefits from the delivery approach.

Given that the fundamental delivery philosophies of modularisation and pre-assembly are now more visible to the project owner, the project owner can assess the potential risk and ben-


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efit considerations for a specific project. Although not comprehensive, or fully applicable to all projects, the following generalized list of potential benefits of a modular and pre-assembly project delivery can be considered reasonably applicable for consideration in most projects.

1. Significant site safety enhancements resulting from reduced labor density on site during construction with subsequent requirements for concurrent working at height risks greatly diminished;

2. Cost advantages for off site modular and pre-assembly construction in comparison to "stick built" construction;

3. Schedule advantages associated with opportunities for concurrent work on site and off site for structural, mechanical, piping and E&I at the same time as site civil works progress;

4. Schedule extensions due to unforeseen delays or quantity increases have a less dramatic impact on associated cost overruns when construction hours are concentrated in lower cost off site and offshore centers;

5. Labor and skills availability risks associated with site based resources are reduced through use of higher labor and skills availability in lower cost facilities off site or offshore;

6. Reduction in site construction personnel both direct labor and importantly indirect support personnel;

7. Removing construction hours from site reduces the requirements for construction related infrastructure and temporary construction facilities;

8. With adequate quality management, there is opportunity for consistent quality at constant productivity and cost in off site facilities that is difficult and expensive to consistently achieve in on site environments;

9. Potential to significantly reduce land disturbance by reducing construction lay down and storage requirements on site.

**"Risk profiles for a modular or pre-assembly delivered project have a significant difference to traditionally delivered site erected "stick build" methods"**

To achieve the potential benefits as identified above, the project leadership must evaluate the specific impacts of the considerations identified below and develop strategies for their mitigation.

1. Internal project objectives for cost and schedule must be carefully balanced with external stakeholders such as local commercial communities and labor organizations etc;

2. Planning and scheduling for a modular or pre-assembly delivery approach must be developed in greater detail earlier in the project phases than traditional delivery methods and consistently detailed and communicated to the project delivery team throughout each phase of the project;

3. Engineering development and technique must be structured to meet concurrent works by engineering and other disciplines that would be staggered in sequence with greater float availability in a traditional delivery model;

4. Procurement and logistics strategies must be must be fully integrated with the engineering development to ensure return of vendor data and timely continuity in supply chains to key facilities and the site;

5. Commercial strategies and agreements with facilities and shippers need to have the flexibility to avoid shipment of incomplete modules or pre-assemblies while quarantining the potential for claim based cost over runs. Elimination of potential for importation of construction hours to site from offshore or off site locations must be a central commercial strategy objective;

6. Organizational structures and resources utilization and deployment approaches must be adapted for a modular or pre-assembly delivery that potentially straddles many locations and facilities;

7. Quality management of off site facilities and their supporting sub contractors and materials suppliers requires equal attention for a modular, pre-assembly or stick build execution delivery strategy. Quality control resources must be of adequate strength and strategically located geographically to ensure benefits from low cost off site or offshore facilities are not lost or amplified as a result of rework on site;

8. Project organizational structures must make provision for increased interaction and participation by suppliers, vendors and


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fabrication/assembly resources as strategically key to sustaining project momentum.

While these key considerations are by no means comprehensive, they serve to enlighten the reader to the fundamental issues at a high level. A more detailed discussion on the fundamental considerations relating to a modular or pre-assembly delivered project is provided in the paper by the author titled Modularisation and Pre-Assembly Paper #3 – Fundamental Considerations for Execution.

## RISK PROFILES

Risk profiles for a modular or pre-assembly delivered project have a significant difference to traditionally delivered site erected, "stick build" methods. The most fundamentally enhanced risk profile must be that of safety on site. The safety risk profile for a modular or pre-assembly delivered project is vastly superior to a traditional "stick build" delivery. This key area will be addressed in more detail in the paper by the author Modularisation and Pre-Assembly Paper #4 - Risk Profiles. Further discussion on other fundamental risk aspects of a modular and pre-assembly delivery strategy are also addressed in the paper by the author titled Modularisation and Pre-Assembly #4 – Risk Profiles.

For the purpose of this paper, an introductory outline of the risk profile for a simple cost position related to a module or pre-assembly delivery will be discussed. Given that capital cost is a significant focus for most project owners, it is important to understand the relative profile of cost related risks in a modular or pre-assembly delivered project. For the purpose of this exercise, a typical Australian based, remotely located project has been selected. However, the sensitivity exercise is equally and consistently applicable to projects in any international location. The basic fundamentals of the risk profile associated with construction cost will be similar for internationally located projects. The variances in costs will be different and a differing risk profile will be dictated by the projects geographic location and influencing labor rates and availability.

**"for a modular or pre-assembly delivery, the greatest risk to increase in site construction hours comes from importing construction hours from offshore or off site locations in the form of incomplete modules or pre-assemblies."**

**ASSUMED RATES FOR ON SITE, OFF SITE & OFFSHORE LABOR**

**Australian Project All In On Site Direct Rate Per Hour = AU$150.00 to AU$200.00**

**Australian Project Off Site All In Cost Per Hour = AU$80.00 to AU$100.00**

**South East Asian Average All In Rate Per Hour = AU$18.00 to AU$25.00**

Historically, project costs escalate above initial project commencement forecasts due to the increase in scope and the associated additional quantities including quantity creep. Overall construction scope increases can be generated from project quantity creep or increases linked to engineering definition and development etc. Construction duration can also be increased by schedule extension manifested as a result of delays in availability of engineering detail, materials and equipment delivery and site based factors such as weather and many other causes. However, for a modular or pre-assembly delivery, the greatest risk to increase in site construction hours comes from importing construction hours from offshore or off site locations in the form of incomplete modules or pre-assemblies. The demonstrable potential for these factors to substantially increase total installed project cost are common, and have afflicted many large and small projects executed in recent times.

**100K Construction Hour Increase**

**On Site Cost Increase Exposure**

**= AU$15M**

**Off Site Australia Cost Increase Exposure**

**= AU$8M**

**Offshore Cost Increase Exposure**

**=AU$2.5M**

**1M Construction Hour Increase**

**On Site Cost Increase Exposure**

**= AU$150M**

**Off Site Australia Cost Increase Exposure**

**= AU$80M**

**Offshore Cost Increase Exposure**

**=AU$25M**

By way of a general example of project cost related sensitivity, consider an industrial project with the very conservative rates identified in the panels above for Australian on site construction rates, off site Australian all inclusive rate and offshore all inclusive rates for fabrication and assembly. Applying typical direct construction hour increases of 100,000 hours and then 1,000,000 hours to the applicable rates provides a strong indication of the associated risk profile.

**"From this high level sensitivity analysis, it can be seen that an off site modular or pre-assembly delivery strategy that consolidates construction hours off site provides the project owner with a considerable hedge against cost increases resultant from construction hour increases."**

Using the conservative figures tabled for this sensitivity exercise and applying the conservative range limits of the rates for on site, off site and offshore hourly costs, it can be seen that by consolidating construction hours in offshore facilities the risk exposure to cost over run is an order of magnitude less than the site based construction hour consolidation.

Similarly, the equivalent onshore facility exposure to cost overrun through construction hour increase is multiples less than for on site construction hour consolidation. From this high level sensitivity analysis, it can be seen that an off site modular or pre-assembly delivery strategy that consolidates construction hours off site provides the project owner with a considerable hedge against cost increases resultant from construction hour increases. This is only one risk consideration, and all risks associated with the module or pre-assembly strategy must be considered prior to concluding a project position and overall delivery strategy. To quantify the benefit of consolidating construction hours in an off site location, a clear understanding of the total site versus off site construction hours is required. This invariably leads to the investigation of indirect construction hours to support direct construction hours. The evaluation of risk profiles based on direct on site labour hours yields an under quantified risk position with respect to total cost exposure on a construction hour basis. For every direct site construction hour, there will be an associated supporting indirect construction hour that is difficult to quantify but has a very real impact on the project economics and final execution costs.

## DETERMINING THE ECONOMIC VIABILITY OF MODULARISATION AND PRE-ASSEMBLY PROJECT DELIVERY

As would be expected, the complexity of establishing the economic viability of a modular or pre-assembly project delivery is considerable. Invariably, the point of common benchmark for modularisation and pre-assembly is the traditional site erected methodology. The traditional "stick build" approach has extensive historic reference data within industry, and is commonly grounded as the base case comparative delivery model. It is extremely important to recognise that economic validation of any project economics, regardless of delivery methodology, is evolved and refined through a number of project

**"It should be noted that the fundamental value in a modular or pre-assembly delivery is derived through the concentration of construction hours in each module or pre-assembly through inclusion of base commodity elements. "**

***At this juncture the reader can obtain some benefit by considering the pivotal issue of procurement strategy and its link to module or pre-assembly value development. It should be noted that the economic analysis can be beneficially undertaken with materials and equipment supplies considered equal in cost for both a modular, pre-assembly and a "stick build" case. However, from a strategic project development perspective, significant potential advantage is possible by linking a procurement strategy with the value adding aspects of offshore fabrication strategies undertaken in emerging markets such as China, India and other international locations. In many instances, additional cost benefits can be realized by linking procurement and fabrication in an emerging market even if module and pre-assembly delivery is not an overriding option. A "stick build" delivery methodology can also benefit by linking a procurement strategy with fabrication offshore and hybrid project delivery models using offshore supply and fabrication with measured onshore assembly have a strong potential to optimize project cost balance to match key project drivers and constraints.***


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phases up to the final execution phase. With this as a basis, a discussion on the economic balance between a "stick build" and modular or pre-assembly delivery model prior to execution is possible.

To understand the depth of the economic evaluation process, it is essential to understand and identify the key cost drivers of the modular or pre-assembly delivery method, and the outputs of the analysis. The development of the economic viability of modularization and pre-assembly versus "stick build" through each project phase should provide the following key data related to each option.

1. The cost of both delivery methodologies and the representative cosy delta between the two methodologies;

2. The overall on site hours for a stick build delivery, the on site hours for modular or pre-assembly delivery and by relation, the total construction hours, both direct and indirect, removed from site by a modular or pre-assembly delivery strategy.

It should be noted that the fundamental value in a modular or pre-assembly delivery is derived through the concentration of construction hours in each module or pre-assembly through inclusion of base commodity elements. These commodity elements include structural steel, pipe, equipment, electrical and instrumentation etc.

There are a number of key component activities for both a "stick build" and modular or pre-assembly delivery methodology that are common for each, and some that are uniquely associated with a modular or pre-assembly project delivery. The table following provides an overview summary of the key fundamental components of each delivery method. It should be noted that careful investigation of the components listed in the "stick build" delivery column should be made before they are discounted as having no cost applicability. Stick build deliveries can include large mill sections, rakes, stacker and reclaiming equipment and fully fitted vessels etc arriving at site as pre-assembled units, large assemblies of mobile mining equipment are also by nature, pre-assemblies. Oversize shipping and transport is not exclusively predominant in modular or pre-assembly project delivery, it can also be utilized by some vendors and suppliers as a standard delivery method.

The table following is not intended to provide the exhaustive list of considerations for each method of project delivery. Its purpose is to assist in framing the reader's reference and focus to the key aspects of a project for both project delivery approaches. Costs and associated on site hours developed in each column of the table must be based on directly equivalent project quantities and overall project operational scope. Components of project scope that are locked to site activities such as earthworks and installation of buried services etc do not assist in the economic evaluation of a modular, pre-assembly versus "stick build" delivery. However, areas such as site civil work involving concrete that could be pre-cast are targets for off site construction methodologies by many projects. There are additional civil access preparations required for modular and pre-assembly delivery methods that should not be overlooked in the economic evaluation. The evaluation platform, based on equivalent scope and associated quantities, can be extended to evaluate a range of modular or pre-assembly execution size scales. This range can extend through the scale spectrum from large super modules of large mass and dimension down to small, but still complex, pre-assemblies of low mass and small scale dimension. The single common aspect is the consolidation of construction hours that are economically moved from site after all other shipping, transport and handling parameters are accounted. The resultant cost and on site construction hour balance will assist in identifying the optimum project delivery solution. A multiple size and scale option analysis for a module or pre-assembly project delivery solution requires significantly more engineering effort and is suited to a feasibility level study where a greater definition in overall quantities, design detail and importantly, resources are available to complete the task without extending project development.

Having identified the key components of both modular or pre-assembled and a stick build delivered project, the focus can now be directed at the approach to cost development for each component identified in the table. In order to compare both delivery methodologies on a consistent base of parity, it is essential to use a set of common base elements. Consistent parity in the economic comparison between the delivery methods can be achieved if a commodities basis, at a unit of measure level is adopted as a platform. When based on consistently common scope and associated project quantities, this method of analytical approach is fundamentally applicable to both project delivery methods and can be easily adjusted as quantities change through project development. Project commodities such as piping, structural steel etc are the fundamental building blocks of a project and can be readily reconciled to either site erected or off site assembled status via work breakdown structures and engineering modelling tools. Pre-assemblies and modules can

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| MODULAR / PRE-ASSEMBLY VERSUS STICK BUILD PROJECT DELIVERY COST DEVELOPMENT TABLE | | | |
|---|---|---|---|
| **Module / Pre-Assembly Construction Component** | **Cost** | **Stick Build Construction Component** | **Cost** |
| Site Civil Construction | AU$ | Site Civil Construction | AU$ |
| Material & Equipment Supply | AU$ | Material & Equipment Supply | AU$ |
| *Off site Fabrication Quantities | AU$ | Off site Fabrication Quantities | AU$ |
| Off site Assembly Quantities | AU$ | Off site Assembly Quantities | AU$ |
| Module. Pre-Assembly Load Out | AU$ | Module. Pre-Assembly Load Out | NA |
| Oversize Ocean Freight & Unloading | AU$ | Oversize Ocean Freight & Unloading | AU$ |
| Bulk Ocean Freight | AU$ | Bulk Ocean Freight | AU$ |
| Oversize Land Transport & Handling | AU$ | Oversize Land Transport & Handling | AU$ |
| Road Freight | AU$ | Road Freight | AU$ |
| Site Install Module or Pre-Assembly | AU$ | Site Install Module or Pre-Assembly | NA |
| Site Erect “Stick Build” Quantities | AU$ | Site Erect “Stick Build” Quantities | AU$ |
| Wharf & Customs - Quarantine Facilities | AU$ | Wharf & Customs - Quarantine Facilities | NA |
| Construction Infrastructure & Camp | AU$ | Construction Infrastructure & Camp | AU$ |
| Public Infrastructure Improvements | AU$ | Public Infrastructure Improvements | AU$ |
| **TOTAL DIRECT COST** | **AU$** | **TOTAL DIRECT COST** | **AU$** |
| **TOTAL DIRECT ON SITE HOURS** | **HRS** | **TOTAL DIRECT ON SITE HOURS** | **HRS** |
| Indirect Cost | AU$ | Indirect Cost | AU$ |
| Contractor Distributable Costs | AU$ | Contractor Distributable Costs | AU$ |
| Project Management (EPC, EPCM) Costs | AU$ | Project Management (EPC, EPCM) Costs | AU$ |
| Owners Cost | AU$ | Owners Cost | AU$ |
| **TOTAL INDIRECT COST** | **AU$** | **TOTAL INDIRECT COST** | **AU$** |
| **TOTAL INDIRECT ON SITE HOURS** | **HRS** | **TOTAL INDIRECT ON SITE HOURS** | **HRS** |
| **TOTAL COST** | **AU$** | **TOTAL COST** | **AU$** |
| **TOTAL ON SITE HOURs** | **HRS** | **TOTAL ON SITE HOURs** | **HRS** |
| **Note 1:** * Denotes requirement for additional steel for shipping grillage, transport stiffening and transport lashing above the steel quantities associated with a “stick build” delivery. | | | |
| **Note 2:** Direct on site construction hours strongly influence camp size and subsequent capital required for camp infrastructure. | | | |
| **Note 3:** Site Civil work specific for module/pre-assembly delivery is generally required. Public infrastructure improvements may be required by both module/pre-assembly and s”tick build” delivery. | | | |
| **Note 4:** Cautious review of each side of the component list is required to ensure items are not discounted as “not applicable”, Stick build delivery requires some oversize components and module/pre-assembly delivery always has “stick build” or site erected quantities. | | | |
| **Note 5:** If indirect hours are considered equal for analysis purposes, the economic results will be conservative in favour of a module or pre-assembly delivery. Any construction hours moved from site have a strong impact on economics, given a typical 1.8 multiplying factor for direct cost to account for indirect costs, the link to indirect hours must follow closely and represent personnel on site. | | | |
| **Note 6:** Quarantine, customs and other related services and stipulated activities such as wash down should be accounted for in the Component Item “Oversize Land Transport & Handling”. Any specific export and import country taxes also need to be accounted for on both sides ot the analysis. | | | |


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also be assigned commodity designations based on size and mass. The fundamental key to the evaluation is assigning equivalent base unit quantities to both delivery methods and accurately capturing all logistics, transport and installation costs associated with each delivery method.

Key data related to direct construction labour required for the comparative analysis of a modular or pre-assembly versus a "stick build" delivery can be summarized as follows;

- Cost per commodity on a unit of measure basis for on site installation;
- Hours per commodity on a unit of measure basis for on site installation;
- Cost per commodity on a unit of measure basis for off site assembly;
- *Cost per commodity on a unit of measure basis for off site fabrication.*

Logistics , transportation and site install costs can also be developed for modules and pre-assemblies on a commodities basis by categorizing modules or pre-assemblies as a commodity by size and mass range, and specific installation technique. Quantities associated with on site erection should be subject to traditional estimation development methods for site installation, shipping and transport costs. For the establishment of parity, site installation costs for non modular or pre-assembled quantities should use the same cost and productivity platform for costing as a stick build model. More complicated cost development such as in-

**"The most challenging aspect of the economic evaluation is the development of the total on site construction hours."**

frastructure requirements, EPC or EPCM, indirect, contractors distributable and owners costs must be developed from standard estimating techniques and project data bases and applied consistently across both delivery methods.. The most challenging aspect of the economic evaluation is the development of the total on site construction hours. On site hours associated with the installation of commodities on a unit of measure basis are well established for most areas in Australia and internationally, associated productivity for location can be applied given specific project requirements and productivity burdens. The more difficult aspect of accurately defining on site hours is related to quantifying the indirect support personnel related to a direct construction hour at a commodity level.

The identification of hours per commodity on a unit of measure basis for off site assembly and fabrication is not essential for the economic analysis of the two project delivery options. However, the information can be acquired at the same time as the pertinent off site cost data and will provide a strong

**"The identification of productivity or "hours per commodity on a unit of measure basis" for off site assembly and fabrication is not essential for the economic analysis of the two project delivery options. "**

insight into off site facility productivity and labour requirements at a commodities level that will be useful, if not essential for validation of scheduling strategies for the project execution phase.

While economic models hold levels of accuracy, they are not directly linked to specific contacts or purchase orders, nor do they have contingency budgets that a cost estimate should reflect. Similarly, important factors for consideration during all project phases, foreign exchange, escalation and contingency etc should be accounted for in final cost estimates not in the economic evaluation models associated with delivery viability. Taxes and duty associated with the country of export and import should be included in the economic model. Project currency hedge and financial strategies become increasingly critical as the project phases progress to execution and specific locations for off site and offshore works are confirmed and finalized. The economic model requires a consistent unit of currency to be observed for standardised comparison, it does not have to be the Australian dollar used in the examples of this paper. It should be noted that during progressive project phases, the development of the economic model must increasingly encompass the procurement, commercial and site construction strategies so these base execution plans consolidate and contribute to the base cost platforms. As the project draws closer to the execution phase the reliance on the economic model should reduce and the use of the final cost estimate adopted for project control and management.

It should be noted that economic models should only transition to cost estimates when all strategic bases are confirmed for project execution. An economic model should never be translated into a working project cost estimate unless the basis for all costing of execution principles match the intended execution. Economic models for modularisation and pre-assembly assessment require a depth of work to transform them into cost esti-


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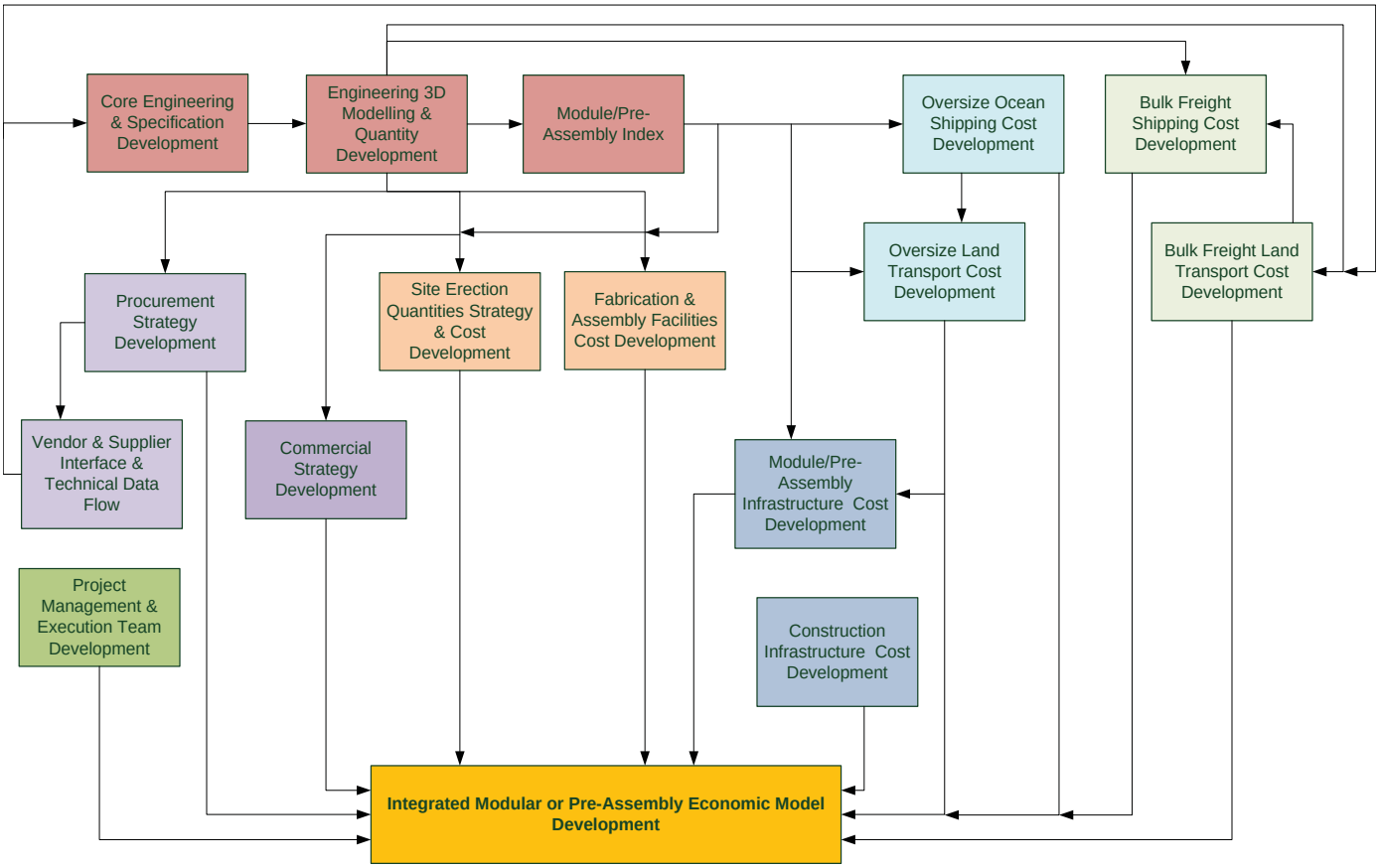
**INTERRELATIONSHIP FOR MODULAR AND PRE-ASSEMBLY ECONOMIC MODEL DEVELOPMENT**




mates for the totality of a project. Economic models should be used as a snapshot for the purposes of making decisions on the direction of project execution in a similar manner to less complex trade off studies for plant and equipment selection, they are not cost control tools, they are more closely linked to decision making tools.

## COMPILING THE ECONOMIC MODEL FOR MODULAR OR PRE-ASSEMBLY ECONOMIC EVALUATION

The validity of the economic analysis of modular versus "stick build" project delivery is directly proportional to the rigour used to establish the integrated modular or pre-assembly cost development. The comparative "stick build" cost development model is compiled in the traditional manner through historical data and productivity per commodity for site installation. There is less complexity associated with the "stick build" cost development model and the process will be omitted for clarity.

The diagram above is provided to illustrate the key areas of contribution and interrelated dependency required to develop an economic cost model for module or pre-assembly project delivery. The model and relationships are valid areas for detail and refinement development through all phases of a project.

The key primary contributing areas can be identified follows;

- Engineering Development and Definition Of Modules and Pre-Assemblies;
- Engineering Quantities Development;
- Module or Pre-Assembly Index Development;
- Procurement & Commercial Strategy Development;

**"As would be expected, there are a number of key elements associated with the development of the cost model that have varying critical impact through all project phases from scoping, pre-feasibility through to feasibility levels of definition."**

- Fabrication/Assembly Facility Costs;
- Oversize Shipping Cost;
- Bulk Shipping Cost;
- Oversize Land Transport Cost;
- Road Freight Cost;
- Module and Pre-Assembly Infrastructure;
- On site Module or Pre-Assembly Installation Cost;
- Project Execution Team Development;
- Composite Economic Cost Model of Module or Pre Assembly Delivery.

As would be expected, there are a number of key elements associated with the development of the cost model that have varying critical impact through all project phases from scoping, pre-feasibility through to feasibility levels of definition. Arguably, the most critical of these can be identified as the computer generated 3 Dimension Engineering Model and its associated importance to module and pre-assembly definition and identification. Additionally, the 3 Dimensional Engineering Model provides essential quantification of quantities at the module or pre-assembly level and also quantifies the totality of the site erected quantities essential to evaluation objectives. Without this essential tool, the full benefits of a module or pre-assembly delivery approach are limited, if not excessively difficult to achieve. Traditional 2 dimensional drawings and layouts are suited to a "stick build" delivery and hold inherent inefficiencies for application in a modular or pre-assembly project delivery.

A general high level discussion of the key areas is provided as follows to give the reader a perspective on the critical aspects of each model component and to define the high level complexities requiring senior management focus. A more comprehensive discussion on the development of modular and pre-assembly economic cost models is provided in the paper by the author titled Modularisation and Pre-Assembly Paper #5 - Development of Economic Models Costs.

### Engineering

The ability to develop an economic model is fundamentally linked to the ability to develop and establish concepts for modules and pre-assemblies. The validity of the delivery concept largely hinges on the ability to establish accurate 3 Dimensional Engineering Models of modules and pre-assemblies that have accurately assigned quantities and can be subject to further engineering analysis such as transportation and ocean acceleration forces. Project quantities must be assigned by base commodities for steel section, plate, pipe, cable etc. Additionally, quantities must be assignable via a work breakdown structure. Allocation of quantities by module or pre-assembly and site erected stick build elements must be identifiable by work break down battery limits, either geographic or process, and subsequently linked to the project controls systems and commercial releases of work packages. Refinement of the module and pre-assembly definition through progressive phases of project development is critical. Mass and dimensional data change through project phase development. These key parameters affect logistics and transport costs and the quantities related to modules and pre-assemblies govern the overall potential to move construction hours from site. The 3 Dimensional Engineering Model is critical for the management of the conceptual through detailed development of modules and pre-assemblies.

### Procurement & Commercial Frameworks

Procurement and commercial strategies have a fundamental impact on the viability of a module or pre-assembly delivery methodology. Procurement from low cost locations such as China, South East Asia, India and other international locations should feature as a key value increasing opportunity for a modular or pre-assembly delivery strategy. Strong purchasing power of some facilities in these locations can dramatically improve overall bulk materials such as structural steel and in some cases equipment procurement cost. This key element should feature as a key consideration for project owners when evaluating the overall potential of a modular or pre-assembly delivery methodology.

Strong consideration must be given to construction resources receiving modular and pre-assembled works at site. Commercial strategies must include provision for quality aspects such as dimensional accuracy, physical survey and workmanship. A number of commercial strategies can be used to address these key issues, they range from comprehensive responsibility of both on site and off site work to integrated off site supervisor and quality management roles by the site construction resource. Importation of off site construction hours to site through failure to complete, or poor dimensional workmanship of modules and pre-assemblies is extremely detrimental to project cost management. Commercial strategies for

logistics and off site fabrication and assembly are also critical aspects of the overall platform of an economic model and need to be refined on an iterative basis throughout the phases of project development.

### Shipping & Transportation

Shipping and transportation is intrinsically linked to module and pre-assembly development and definition. Options for oversize shipping are substantially influenced by module and pre-assembly dimensional and mass characteristics. The options for shipping are also highly dependent on these mass and dimensional parameters. Options for oversize shipping including Lift On – Lift Off, Roll On – Roll Off, Float On – Float Off and barge tow have extensive cost variations and associated beneficial applicability to modular and pre-assembly delivery strategies from a cost and practicality basis. Land transportation, while having a less diverse set of options, by no means lacks associated complexity. Dimensional and mass properties of modules and pre-assemblies govern application of transport equipment and distances from the point of pick up to the point of delivery have a marked effect on cost. Inland project locations require special attention to the balance of construction schedule and transport equipment fleet size.

Both shipping and transportation commercial strategies must be structured to provide flexible integration with logistics flow. Careful consideration must be levelled on modular and pre-assembly delivery solutions that offer large blocks of project delivery responsibility such as fabrication, assembly and shipping under a single corporate umbrella without external commercial interface. These type of innovations have the potential to significantly improve the economics and momentum of larger scale projects.

### Fabrication and Assembly Facilities

This area is a key focus and has a strong requirement for a planned and structured approach to the development, collection and final application of cost data to a module or pre-assembly economic model. The development of cost data from offshore and off site facilities holds a depth of complexity and is arguably the core data of the overall economic model. The reader is directed to the paper by the author Modularisation And Pre-Assembly Paper #6 – Offshore Fabrication & Assembly Cost Development. An overriding consideration in the development of this cost information is that it be developed from all sources on a consistent basis of assumption and parity. All contributing facilities must be provided with a framework in which to provide the cost data on a commodities level that cannot be widely interpreted and all assumptions for the inclusive costs are the same. Parity and consistency of base assumptions and quantities is of the utmost importance.

### Site Installation

The development of the site installation cost components of the economic model is critical. Because these activities are site based, there is a strong sensitivity to cost overrun given the site location, and will have the highest cost direct construction hours. This associated direct cost will have a correspondingly high indirect component. Crucial development aspects for site installation include placement type such as, transporter, crane, jack etc. Each methodology holds cost and risk benefits and considerations. Each project phase should progressively refine and define the most economic and practical solution. Construction equipment pools and fleets are strongly dependent on these site placement parameters. An overriding consideration should be the value of early commercial and technical involvement of the construction resources in the module or pre-assembly delivery methodology. It is not beneficial to assume that a construction resource will be able adopt a concept in the totality of detail at the eleventh hour prior to construction execution.

### Project Team

This component has a fundamental bearing on not only the success of a modular or pre-assembly delivery strategy, but also the overriding cost. A shift in paradigm from traditional project team delivery structures to one that explicitly focus and geographically deploys resources to key areas of historic difficulty is required to produce sustainable delivery momentum during execution. Innovative deployment of resources hold a beneficial key to modular and pre-assembly success. Given the total quantities of a project remain constant for either a modular, pre-assembly or stick build delivery, there should be no expectation that quality management supervision requirements should be less for a module or pre-assembly delivery than they are for a stick build project delivery.

A shift in the method in which project teams are deployed is key to maximizing the benefits of modularisation and pre-assembly delivery method. Construction supervision and management can cycle and move with the center of gravity of the work i.e. start in the design office at the appropriate time, actively contribute during offshore or off site fabrication and assembly and transi-

tion with the completed works to site. With this deployment of managerial resources, all aspects of the module or pre-assembly development are connected to an end user at some level and the overall personnel requirement is minimized for maximum potential benefit. This approach provides greater opportunity for quality management to be undertaken by end site receiver, the potential to identify and correct problems before they are imported to the site location is greatly increased to the advantage of the project.

## CONCLUDING SUMMARY

This paper has highlighted and addressed at a high level many of the key issues, considerations and potential benefits of a modular or pre-assembly project delivery. Given all the underpinning considerations, the driver and goal of this style of project delivery must still be focused on the delivery of overall project value to the project owner at a fundamental NPV, IRR or other economic platform on which a project owner evaluates their business decisions. The ultimate goal of the project delivery market place should be the development of flexible systems and approaches that build on the strengths of modularisation and pre-assembly. Dogged persistence with systems and paradigms associated with traditional project delivery techniques which are often at loggerheads with the innovations required by a modular or pre-assembly methodology and slows the innovative improvement process for modular and pre-assembly delivery methodologies.

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Systems for evaluating the economic benefits of modular or pre-assembly methodology are not readily understood, or available in the market. Conventional corporate structures for engineering, procurement and commercial integration are not generally arranged for a modular or pre-assembly delivery methodology in the bulk of organisations specializing in project delivery. The lack of directed and cultivated focus on the improvement of modular and pre-assembly delivery systems inevitably forces the use of "stick build" systems and paradigms to be superimposed as development and management tools to meet the challenges of modularisation and pre-assembly. While there have been many great successes, and high value delivered to project owners using the constraints of "stick build" systems as applied to a modular and pre-assembly delivery, they are often less than the lofty potential of the delivery method.

The sequences and timing of engineering, procurement, contracts and logistics is substantially more interdependent in a modular and pre-assembly approach in comparison to the sequential, and less critically interdependent "stick build" delivery methods. The battery limits of these key areas are also questionably different. Is the fabrication and assembly facility a supplier or a contractor? How does safety fit in? What is the engineering sequence? Where does oversize logistics best fit in respect to the traditional structure? These questions and many more point to the requirement for a fundamental redevelopment of how a modular or pre-assembled strategy is most effectively and efficiently delivered to a project owner once it is established that the foundation economics support this type of delivery strategy.

Global industry, and especially Australian industry wishing to complete projects in remote locations, has much to gain from the development and refinement of a home grown modular and pre-assembly delivery expertise. The bandwidth of innovative development opportunity extends from development of locally retained inhouse engineering expertise for modularisation and pre-assembly through to systems for procurement, logistics and commercial management. With the rich industrial experience platform of the past five to ten years as a reference base, the potential of future large scale projects to significantly benefit from an improved modular or pre-assembled delivery approach is considerable.

With refined and improved modular and pre-assembly project delivery systems and methodologies, project owners should be able to consistently achieve higher standards of site installation safety as an absolute minimum gain over traditional project delivery techniques. Project owners should also be able to encompass greater project quantities at lower capital investment levels. The fundamental opportunities for improvement in project speed to market should also be a central outcome to improvements in modular and pre-assembly delivery systems and processes. Revision of current systems, approaches and paradigms are the key to unlocking the full potential of modularisation and pre-assembly in the future. Σ


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