Select Topics in Value Engineering:
 Modularisation in the Process Industry

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This is the third contribution in the series of articles on various aspects of value engineering and/or value management. Each article will be independent, but linked by the association with value engineering.

This article deals with modularisation in the process industry. Is this an opportunity for further savings or does it add cost?

Introduction

A module is a transportable pre-assembly of process plant components, designed to minimise site installation and labour costs. Module construction involves building part of a complete facility in an off-site location where specialised resources are readily available and then transporting the module to site for installation. This allows for much improved construction productivity.

In this article we consider the matter of modularisation in the process industry. Modularisation has been identified as a significant factor with the potential to substantially reduce the cost of a plant. Module development has reached the 3rd generation, which implies totally self-contained process modules.

Some definitions

Value engineering

Value engineering is a systematic, creative and organised approach to provide the necessary functions in a project at the lowest cost. The requirements of a project are analysed during value engineering for the purpose of achieving the essential functions at the lowest total costs (capital, staffing, energy, maintenance) over the life of the project. It focuses on the functions of various components and materials, rather than their physical attributes.
Modular fabrication

Modular fabrication is the process of building and constructing equipment off-site in a fabrication facility. The completed product (module) can then be delivered to the worksite and quickly installed and integrated into new or existing field operations. This differs from on-site construction in which the equipment or system is fully built at the worksite.

Modularisation

Modularisation is the process of designing a processing facility in such a manner that it can be constructed in a number of separate, but logical units or modules at a distant construction yard and transported to the factory site. Ideally modules should have as few as possible interfaces with the connecting modules to reduce site work to a minimum.

Classes of modules

Current situation

Depending on where in the industry one is active, the nomenclature for different classes of modules also differs. For instance, in the construction industry, those involved talk of pre-assembled racks (PAR’s), pre-assembled units (PAU’s), vendor assembled racks and units (VAR’s and VAU’s) and remote instrument buildings (RIB’S). Effectively, this means three classes of modules, namely racks, units and buildings, all pre-assembled. Ignoring the buildings for a moment, we thus only have two types or classes of modules. An example of a PAR is shown in Figure 1.

Figure 1: A PAR being installed
Fluor has done sterling work in moving more of the field construction work into modular facility construction workshops. They currently talk of their third generation modules (Chandler, 2013). However, for those who insure large modules during the transportation thereof, we’ve seen mention of fourth generation plant modules, although this seems to refer to very large third generation modules.

**Three generations of modules**

To achieve a better understanding of Fluor’s three generations of modules, each will be discussed in turn:

First generation modules have been constructed since the early ‘90s and were limited to main pipe racks with the main piping pre-installed, or PAR’s.

Second generation modules were built from early 2000. This involved the installation of piping and main equipment in the modules, primarily all steel equipment. This approach reduced the field work by approximately 30 to 40%. An example of a typical second generation module being transported to site is shown in Figure 2.

*Figure 2: Second generation module*

Third generation modules take the concept further to describe modularised process blocks. These process blocks contain 95% of steel work, up to 85% of the electrical installation and up to 95% of the instrumentation. This enables loop checking to be done in the module yard. Third generation modules effectively relocate 90% of the
field work to the module yard. The approach is one of minimising the interconnections between modules. An example of a third generation module is shown in Figure 3.

Fluor’s Fred Haney and his team patented the concept of the modular processing facility, their third generation approach, in 2012 (Haney et al, 2012). In 2015, Fluor’s Third Generation Modular Execution approach won the bronze award for innovation from the distinguished Edison Awards™ organisation (Fluor Corporation, 2015). The awards, inspired by Thomas Edison's inventiveness, recognise innovation, creativity, and ingenuity around four criteria: concept, value, delivery, and impact.

![Figure 3: Third generation module](image)

**When and why to opt for modularisation**

**When modularisation should be considered**

The decision-making process when selecting between conventional stick-build techniques or modular construction is complex and based on a number of factors. The modular construction technique is applicable to almost any project. Under certain conditions, modularisation has specific advantages. These conditions include:

- **Severe weather conditions**: Extreme heat, cold, rain, snow and frozen ground can make conventional construction difficult, expensive and slow;
- **Limited plot space**: Space limitations can preclude conventional construction techniques. Modular construction typically requires less space and does not
require site construction yards;

- **Difficult labour conditions**: A militant labour force at the plant site can lead to strikes and sit-ins, resulting in serious delays and possibly even injuries and equipment damage;

- **High labour cost**: High labour cost at the plant site steers the decision towards modularisation, especially if the site labour productivity <80% of shop productivity;

- **Shortage of skills**: A shortage of suitably qualified construction workers at the site may lead to delays, sub-standard work and low productivity. All these have cost and schedule impacts;

- **Repeatability**: If there is a high probability that a specific plant design will be duplicated, at the present site or elsewhere, a repeatable modular design takes preference;

- **Extensive acceptance testing**: A modular approach is indicated when the client demands extensive factory acceptance testing and the plant construction schedule is tight;

- **Transportation conditions**: Do shipping limits allow module transportation? Can large modules be transported over the access roads? Is crane capacity available and economical?

- **Fabrication capacity**: The availability of suitable fabrication houses for the modules must be confirmed. Non availability means that schedule benefits will not be obtained by using a modular approach, and;

- **Site permits**: Permits, environmental or other, required for starting site construction work may be late or difficult to obtain. Modularisation allows the early start of construction work in supplier workshops;

**Benefits of modularisation**

Modularisation in the process industry offers numerous benefits which can be grouped under three categories, namely cost reduction, schedule reduction and risk reduction, as follows:

- **Cost reduction**
  
  - Possible to reuse existing engineering designs during basic engineering and FEED, detail engineering, manufacturing and construction;
  
  - For multi-unit projects, maximum capital efficiency is achieved by designing once and building exact duplicates;
  
  - Lower capital and labour costs are achieved through efficient use of material and a smaller field crew. Requires less material than traditional stick-built operations due to shorter pipe runs;
Highly trained and experienced assembly and fabrication technicians are already employed by the modular system provider, ensuring consistent work and worker availability;

High quality module assembly & fabrication reduces rework and saves time and money, as well as reducing start-up risks, and;

No extra construction yard space is required on-site as the modules are constructed off-site. Site construction infrastructure and housing is also much reduced.

- **Schedule reduction**
  - Modular skid mounted systems construction occurs in parallel with site civil and facilities work in-plant;
  - Weather delays are eliminated during fabrication as modules are completed inside the module construction yards;
  - Start-up time is minimised since modules are shipped fully assembled and pre-checked;
  - Highly trained and experienced fabrication technicians operate at significantly higher productivity, with schedule and cost benefits, and;
  - Module construction companies need to get involved early on. Long-term partnering with engineering and supply companies is recommended to ensure involvement during the front-end loading phase.

- **Risk reduction**
  - Off-site construction of modular systems does not interrupt or shut-down pre-existing operations;
  - Welding, pipe-fitting and other fabrication processes are performed under ideal conditions, resulting in a better quality product;
  - Systems undergo full process system testing and checkout prior to shipment providing faster and safer start-up;
  - Safety risks are reduced for plant personnel with fewer onsite OSHA exposure hours and smaller crew sizes;
  - Safety risks are reduced because process module construction happens in ideal plant conditions, and;
  - Proprietary process technology is better protected as module fabrication typically occurs behind closed doors.

Should the business needs change to such an extent that relocation of the facility is considered, process modules provide for relatively easy relocation. For instance,
product transportation costs can be lowered by placing modules in locations that are closer to end-users.

**Disadvantages of modularisation**

Although there are some disadvantages to modularisation, these are normally overshadowed by the benefits. The disadvantages include:

- **Early decision on level of modularisation:** The decision regarding the level of modularisation that is desired has to be taken during the basic engineering phase of front-end loading. The owner company may not be ready to make such a decision because of unfamiliarity with modular plants.

- **Higher engineering cost:** It is estimated that the additional engineering required for a modular design accounts for an increase of 10 to 15% for engineering. When a modular and standardised design is duplicated, the engineering cost drops significantly.

- **Need for additional steel:** Additional steel is typically required for larger and more structural members and bracing for transport. A more compact plant layout and shorter pipe runs compensate for this.

- **Reduced adaptability to design changes:** Modular construction increases the interdependency of construction activities. Any design changes can thus disrupt a wide variety of inter-related process and construction activities.

**Closing remarks**

Modularisation is considered to be a practical and economical construction technique for process systems in the chemical, petrochemical, gas processing, and oil refining industry.

Modularisation saves cost by removing labour off site to lower cost, more productive, module manufacturing yards. This will decrease site interference delays, reduce safety risks and lead to a more harmonious labour environment. Modularisation savings are realised from the first plant onwards.

**References**

**Chandler, G.,** 2013, *Smaller, better, faster – Fred Haney’s vision turns modern construction theory on its head*, Oilsands Review.