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# U.S. modularization—Keep an eye toward the most economical approach

Modularization has been discussed extensively as a means to facilitate the construction of significant projects. Many benefits exist for modularization, including controlled construction and schedule improvement. Due to the controlled environment for module construction, quality is more easily achieved and weather is not an issue. In addition, construction in remote areas (where field labor is a concern) is minimized.

However, modularization comes with a price—so it pays to keep costs in check. In the U.S., shop labor can be costly, and supplemental steel needed for shipping can add further cost. An option is to investigate module construction overseas, where fabrication labor can be a small percentage of labor in the U.S. and steel is also less costly. Shipping is a large concern, so the feasibility of shipping from overseas must be weighed against higher modularization costs in the U.S.

An optimum approach may be to fabricate small modules in the U.S. and consider the fabrication of large modules offshore. Small modules are often defined as structures that are easily truckable or less than 100 t in weight. By fabricating large modules overseas, full advantage can be taken of lower labor costs. Smaller modules can achieve an acceptable cost-benefit ratio in the US because labor hours are low. Of course, shipping must be considered in both cases. However, it has been shown that large modules (including shipping) can be economical from overseas because of the large differential in labor costs.

In the past, code compliance and communication were viewed as concerns in working overseas. Offshoring has become so prevalent that most international companies now work routinely to U.S. codes, and communications are not an issue. International fabricators often employ U.S. representatives to facilitate project communications.

In planning a project, consideration should be given to modularization as a construction technique. Once this decision is made, the best location for developing modules at lower cost should be investigated. Small modules are generally most economically fabricated in the U.S., and larger modules may be more economical to buy from overseas fabricators. All factors, including schedule, must be considered; however, modularization can still offer an economical alternative to "stick-building" if low-cost module fabrication locations are considered.

**Early planning.** During the bid stage, it is important to plan the desired approach to construction, including the idea of using modules for a portion or all of the project. While module construction is often thought to be more economical than stickbuilt, this is not always the case. If field labor is inexpensive and construction conditions present no obstacles, stickbuilt may be the best choice. However, if schedule is crucial, then modules may be considered even if they are slightly more expensive. A hybrid approach of both stickbuilt and modules represents a viable approach in some circumstances. The selected approach should be the basis throughout the project. Deciding on one approach initially and then switching during execution can lead to major budget problems.

Assuming that modules are to be used for one or more reasons discussed in earlier articles,[1] it is important to structure the estimate accordingly to capture all supplemental costs. For example, modules require additional engineering to be self-supporting units and often require temporary support steel that can be removed when the module is in place. Also, care must be taken to ensure that all piping components and instrumentation and electrical (I&E) components can "match up" across modules. Sufficient engineering must be completed in the bid stage so that preliminary bids can be obtained from fabricators. Experienced domestic and international module fabricators can work from piping and instrumentation diagrams (P&IDs) and conceptualize modules. Such companies should be considered, but owner review is important to ensure that serviceability of the module(s) is achieved.

Choosing the right fabricator to contain costs and provide high-quality modules deserves considerable focus, as depicted by **FIG. 1.** Quality and schedule are always important, but cost also must be carefully considered. Using modules for construction convenience and then blowing the budget by magnitudes will not be viewed as a successful project. Since fabrication labor costs in the U.S. can be much greater than those of foreign companies, international companies should be considered.

However, all factors must be taken into account. Shipping is a huge portion of module costs and must be factored into the evaluation process. Since significant

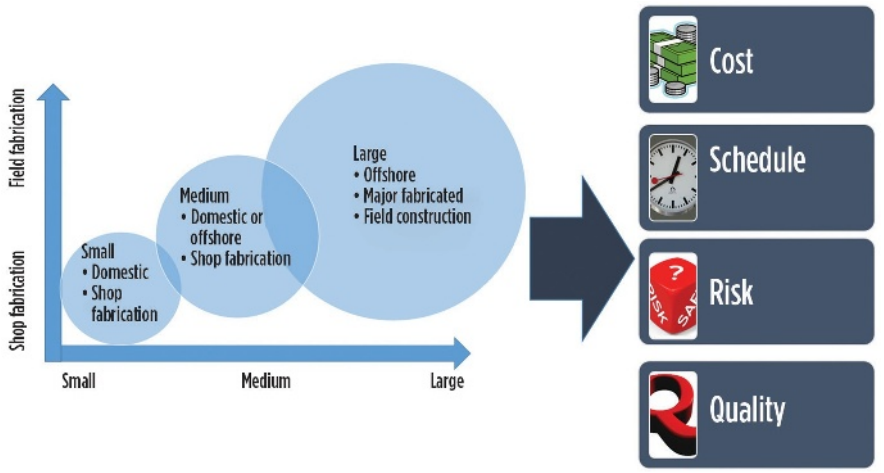


**FIG. 1.** Cost, schedule, risk and quality factors must be considered when choosing a module fabricator.

labor savings are seen with large modules fabricated overseas, there is a considerable margin to address shipping. Smaller modules that are easily truckable are best fabricated domestically because low shipping costs can offset higher fabrication costs.

Whatever the module size, it is important to involve prospective module fabricators early in the project bid phase. In addition to providing detailed cost breakdowns, fabricators also offer ideas for improving module design. This is important to ensure the best design early. With their experience, fabricators can often offer suggestions to make the modules more easily transportable. Experienced module fabricators can also offer ideas to limit the supplemental steel needed for shipping.

Smaller modules should be limited to domestic suppliers since the minimal shipping can offset the higher labor costs. Anything larger than 100 t should be evaluated both domestically and internationally. It is likely that international fabrication/shipping will be most economical for large modules, but medium-size modules may vary on best price between domestic and international, depending on the circumstances and intricacies of the modules.

**Execution guidelines.** After a project is authorized, early steps should be taken to ensure that costs are contained and quality modules are delivered to the field. Important factors to consider include:

1. **Achieve a certified P&ID early.** This is necessary to ensure that certified equipment drawings can be obtained early in the design. Late certification of P&IDs often results because of late hazard and operability studies (HAZOPs), so there should be focus on this key activity. Having holds on design drawings leads to schedule problems.
2. **Start engineering early.** Starting early on module engineering is more important than when stickbuilding. Modularization represents an additional activity in the overall project schedule and, therefore, accommodations must be made to fit it into the overall time frame. It is also important to configure modules to a manageable size—an important outcome of early engineering.
3. **Bid module fabrication to experienced companies with ready access to appropriate transportation.** For small modules, it is wise to consider a local fabricator. For example, it is not a good idea to bid modules to East Coast companies for a project on the West Coast. For large modules fabricated internationally, it is important to make sure that shipping ports are available on either end of the transport.
4. **Ensure that free-issue components arrive on time at the fabricator.** The effectiveness of modules is diminished if mechanical or I&E components need to be installed in the field, so extra effort should be spent to specify and receive these components in a timely manner.
5. **Require fabricators to "match up" adjacent modules at their facility.** Many field problems can be avoided if modules come together easily in the field.
6. **Invite the field contractor to visit the module fabricator during fabrication.** This can help in catching any problems early and avoid possible back charges later.
7. **Ensure that a detailed shipping plan is developed early.** Whether domestic or international, it is important to develop a shipping plan early. This will ensure no surprises on size limitations later, and it will allow ample time to secure permits.

**Considerations for small modules fabricated domestically.** Smaller modules refer to self-contained process systems that are less than 100 t in total weight. These systems can include small reverse osmosis systems for water purification, membrane and adsorption systems for gas separation, and combined heat and power systems (CHP) for distributed power generation.

These modular systems are made to standard specifications and typically come in standard sizes with well-defined break points in terms of capacity and performance. The units are often skid-mounted (FIG. 2) and contain all the major equipment, piping, instrumentation and controls so that the module can be described as "plug and play." The rationale for modular systems is to save money on engineering by using the same design for a number of identical modules.

In terms of module fabrication, it is possible to capture additional savings in purchased equipment, material and labor if multiple units are executed at the same time. Volume discounts are possible for purchased equipment and materials by buying these items in bulk. In addition, it is possible to minimize the waste of materials by using all the steel and piping in the actual fabrication of the modules instead of discarding the excess. Labor savings can be realized by sequencing activities efficiently and minimizing setup time. Small skids can be fabricated in a normal fabrication shop with minimal staff, which helps keep costs down. Compared to larger modules, shipping is relatively simple and usually involves a regular-size tractor-trailer truck.

**Considerations for large modules fabricated internationally.** As noted earlier, fabricating large modules (**FIG. 3**) overseas offers the opportunity to save considerable money because of the large labor cost differential between the US and some international companies. The authors have experience that considerable project savings can be achieved by fabricating modules overseas, even when tariffs and shipping costs are taken into account. However, such savings require scrutiny when selecting a fabricator. The fabricator should be able to design and fabricate to U.S. codes, which is generally not a problem for most fabricators doing business for U.S. companies. The foreign company should have an engineering group that can create appropriate, detailed drawings. Also, shipping ports should be within a short distance of the fabrication shop to avoid damages and delays during the transportation of modules. Communication methods should be discussed early in the bidding, and appropriate systems should be put in place to facilitate communications.

To achieve these goals, a U.S. representative can serve as an interface point to address communications on a "same-time" basis as the owner. However, given today's excellent internet and satellite communication techniques, work can be performed with foreign companies as if they were located next door. Quality must be verified on a continuous basis, but the authors have found that most foreign companies doing business for U.S. companies have very high quality standards.

Fabricating modules overseas offers several opportunities for cost containment, in addition to lower labor costs. Steel purchased to American Institute of Steel Construction (AISC) specifications limits the availability of low-cost shapes. If there is owner agreement that Japanese Industrial Standards (JIS) or Deutsches Institut für Normung (DIN) standards can be used, the possibility for cost savings is increased. Use of these standards should pose no problems for the creation of properly detailed fabrication drawings. The same logic can be applied to refractory and other fabrication items, but it is important to obtain engineer approval early for alternate products or materials.

**Takeaway.** Modularization offers the opportunity to carry out construction in a controlled environment, which can greatly enhance the schedule and quality. However, these enhancements come with a cost and, therefore, must be carefully managed to make sure that budgets are not exceeded. Focused, early planning is one way to make sure costs stay within reason. Early engineering is important to ensure that bids are within reason, and involving the right fabricator is also critical.

The size of modules is a determining factor in deciding on the most economical fabricator. Small modules are best built by a U.S. fabricator, preferably one near the jobsite. Labor on a small module is modest in magnitude and not a significant impact on the overall project cost. However, large modules require significant fabrication labor hours, so international fabricators should be considered. Since labor is high on large modules, considerable savings in labor costs can be achieved by using an international fabricator instead of a domestic one. All factors (e.g. U.S. code compliance and quality) must be considered, but many international fabricators have a demonstrated history of building major modules to applicable codes at high quality.

Modularization is a significant enhancement for construction, but it is important to consider all factors before building the modules. By weighing the different fabrication options discussed in this article, there is a greater likelihood that all factors will remain in check, including cost. HP

**FIG. 2.** Small modular process skid.

**FIG. 3.** Large ethylene furnace with modular sections.

**LITERATURE CITED**

Complete literature cited available online at www.HydrocarbonProcessing.com.

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