



Construction Industry Institute®

Transforming Modular Construction
for the Competitive Advantage
through the Adaptation of Shipbuilding
Production Processes to Construction

Construction Industry Institute

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Transforming Modular Construction for the Competitive Advantage through the Adaptation of Shipbuilding Production Processes to Construction

**Prepared by
Construction Industry Institute
Adaptation of Shipbuilding Production Systems to Construction
Research Team**

**Research Summary 255-1
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Executive Summary

Building on the work of CII Research Team 232 on the potential for adapting shipbuilding techniques to construction, Research Team 255 focused its efforts on evaluating the potential of the shipbuilding industry's **Interim Product Database** process (IPD) approach for use in the construction industry. Simply defined, the IPD process incorporates scalable, pre-designed blocks or modules, consisting of hierarchical interim sub-assemblies and stored in an all-encompassing database.

RT 232 noted in 2006 that the global shipbuilding industry had undergone a transformation over the previous two decades, a shift that brought about dramatic reductions in cost and construction cycle times. In essence, the industry transformed itself from one that made traditional one-off, stick-built constructed products to one that utilizes modularization, automation, design reuse through product families and interim products, along with extensive supply-chain integration. The result of these changes has been the industry's ability to deliver products faster and at lower cost, while still maintaining both quality and safety standards. RT 232 also postulated that this development of reusable, scalable modular product-family designs and interim products—referred to as the Interim Product Database—held significant potential for use in the construction industry.

RT 255 focused on identifying examples of construction projects that had incorporated one or more aspects of the IPD process and that had moved beyond the standard one-off modular construction approach. This effort involved conducting case studies from a broad cross-section of construction projects that included pharmaceutical (manufacturing and R&D), petrochemical, residential, office, hospitality, and civil works

(dams and bridges). The team's subsequent review and findings included the following:

- **Significant use of modular construction** is occurring across many sectors of the industry, with pockets of **enhanced modular execution. This increased use of modularization** is mostly driven by owners' needs for faster project delivery.
- **Significant schedule compression** is being achieved.
- **Hard cost savings are limited** when manufacturing techniques are not used and design reuse is underutilized. However, soft cost savings associated with such areas as quality, safety, site congestion, and workforce stability, were not typically included in the cost-benefit analysis due to quantification challenges.
- The **single-project focus** of today's construction industry **impedes support for investment in the longer-term market that justifies the modular strategy** embraced by shipbuilding.
- **Improved safety and reduced site congestion** result from increased modularization.
- **Implementation barriers** include re-thinking the planning/design process, module size, transportation, code compliance, design scalability/repeatability, customization, and initial investment costs versus long payback.

RT 255 also concluded that there are sufficient data to suggest that the IPD process can generate for the construction industry the same kind of transformation it has effected in the shipbuilding industry. Following are the potential improvements:

1. **Shorter schedule** – The actual time to deliver the constructed facility is significantly reduced. Today's business environment drives many owners to complete construction projects as quickly as possible, so that plants can get their product to market sooner.

2. **Lower material costs** – Standardized sub-assembly materials can be purchased in bulk, reducing material costs through economies of scale and optimization of the supply chain.
3. **Higher quality** – The controlled environment and standard module design associated with a manufacturing-type scenario eliminates issues related to inclement weather, site access, height constraints, and skilled labor. They also allow for more thorough QA checks and inspection.
4. **Innovation improvements** – The manufacturing-type environment facilitates the introduction of labor-saving techniques (e.g., the use of jigs, automation, and robotics) to optimize production at lower cost.
5. **Reduce design time** – The development of a qualified design library allows for the adaptive reuse of standardized designs, resulting in a reduced design completion schedule.
6. **Safer construction** – The manufacturing-type environment can facilitate a safer construction environment and reduce hazards associated with field installation.

Introduction

In its 2006 study of the shipbuilding industry, CII Research Team 232 reported that delivery innovations and practices adopted in Europe and Asia over the preceding two decades have led to a dramatic decline in the U.S. shipbuilding industry. RT 232 also noted that these industry practices have resulted in dramatic efficiencies in the delivery of completed vessels, from initial orders to final commissioning. The results of using these methods have included significant improvements in both time and cost, when compared to the traditional stick-build methods, without sacrificing quality or safety. Because of the many similarities between construction and shipbuilding (e.g., project scale, tools, materials, and processes employed), RT 232 concluded that some of the techniques that have revolutionized shipbuilding (particularly the Interim Product Database [IPD]), could be adopted by the construction industry. Simply defined, the IPD process is typified by a distinct set of standardized, configurable modules, grouped by production process similarity and built in a manufacturing-type environment.

CII established RT 255 to explore the potential for adapting the IPD approach to land-based construction. The primary initial purpose of the study was to quantify the potential costs and benefits of adapting the IPD approach in capital facility construction. This was to be done through a detailed case study in which an IPD-based production system was developed for a capital facility. However, global economic conditions, combined with local issues, caused a protracted delay of the case study project. Therefore, the team refocused its efforts on identifying projects and processes already in progress, using one or more elements of the IPD process. The team then evaluated the case study projects, documenting their IPD elements in detail. For each case, the team considered the drivers and results, and determined what conditions or barriers blocked adoption more broadly.

Interim Product Database (IPD) Process

As the U.S.-based shipbuilding industry moved offshore to Japan and Korea in the last half of the 20th century—initially taking advantage of lower labor costs—another transformation began to take place; this change involved dramatic efficiencies that ultimately gave the Asian producers a competitive advantage. Over time, these efficiencies evolved into the widespread use of the Interim Product Database (IPD) approach in use today. The IPD approach relies on scalable, pre-designed, or qualified modules collected in a database system. This system can create standardized module components for the production of an almost infinite variety of ships—all made from the same basic building blocks. The construction of these standardized modules in a manufacturing or factory environment allows for parallel work, performed with a higher degree of quality and at a faster rate than can be achieved using more traditional methods.

The IPD process incorporates the use of scalable, pre-designed blocks/modules consisting of hierarchical interim sub-assemblies, stored in an all-encompassing database. The process is comprised of the following elements:

- The structure or building is broken down into a **distinct set of standardized zones**.
- Each zone is comprised of **pre-designed assemblies** or modules.
- Each assembly is further broken down into sub-assemblies, **grouped by production process similarity**, to establish interim product families.
- Sub-assemblies are **built in a manufacturing-type environment** and transported to the project site for installation.
- These elements are incorporated into an **Interim Product Database (IPD)** containing product and production processes that are **easily reconfigurable** for follow-on projects through parametric design techniques.

As illustrated in Figure 1, the IPD design process hierarchy begins with the initial requirements for the finished structure. Then, the structure or building is divided into zones in accordance with a previously established set of zone definition guidelines. Each zone, in turn, is broken down into a series of modules taken from the IPD. Then, using parametric design rules, the modules are configured into a set of connected assemblies and parts, also taken from the IPD.

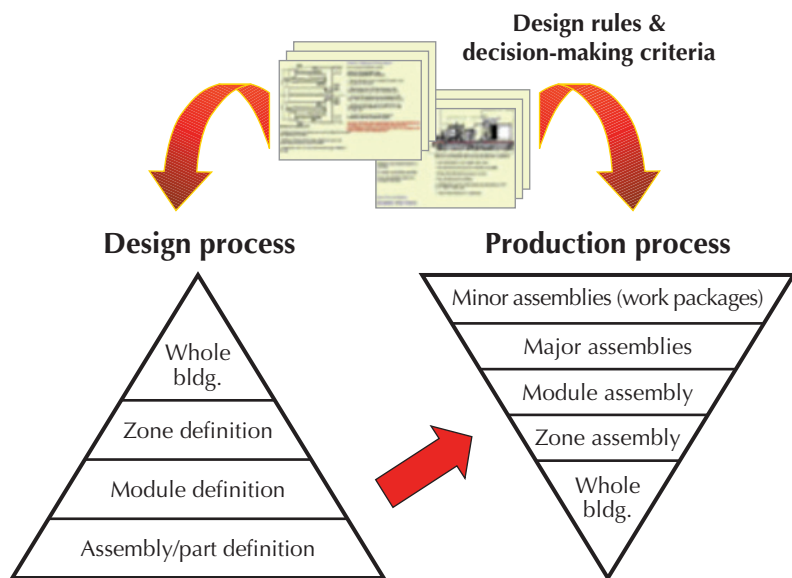


Figure 1. IPD design and production hierarchy

Once all of the assemblies and parts have been identified, the contractor can begin assembling (or purchasing) the minor assemblies, which, in turn, are incorporated into major assemblies and modules. Because all of this work can be performed at floor level in a covered facility with manufacturing techniques such as robotics or moving assembly lines, the approach has the potential to decrease production time. Once completed, the modules are then transported to the site to be erected and connected.

Because the IPD methodology can generate a substantial reduction in the engineering design time for ships—up to 80 percent, with current shipbuilding practices—its use can result in significant time savings on projects. This savings on design is largely realized from the adaptive reuse of a standing database library of qualified and scaleable designs, with very limited new design. The use of qualified designs further benefits the design process by providing a base from which to complete any remaining site-specific and unique design elements, such as structural foundations.

For each project type, zone definition is developed, along with rules and guidelines governing the use, application, and interfaces associated with each zone. Using the same concept of zone breakdown in shipbuilding, a typical facilities zone breakdown would include the following:

- **plant zone(s)** – mechanical areas providing heating, cooling, and other utilities supporting the buildings function
- **sitework zone(s)** – structure/infrastructure beyond the facility envelope (e.g., parking lots, utility tie-ins, substations, and emergency power)
- **public zone(s)** – public space within the facility, (e.g., lobby areas, cafeterias, rest rooms, and auditoriums)
- **circulation zone(s)** – zones for the movement of people, processes, and/or utilities throughout the facility, both horizontally and vertically.
- **function zone(s)** – zones for one or more of the primary functions of the facility, (e.g., administration (offices), manufacturing, medicine, laboratory work, and warehousing).

Rules governing the development of module breakdown include preferred configurations or erection joints, positioning of module breaks, acceptable range of module weights, erection sequence, and optimal structural arrangements. Additionally, rules and guidelines are developed to govern the building sizes for a given module, crane constraints,

erections times, and connections. As a result of this advance design effort, process flowcharts are developed outlining the pre-production and production flow processes for each module family. These flowcharts facilitate the project's planning and schedule process. The resulting IPD contains pre-engineered design components and modules with the following attributes:

module family characteristics

- range of acceptable dimensions
- range of module weights
- range of work content
- range of structural and geometrical variation

module production characteristics

- assembly sequence
- process line/work station capability

module construction cycle time and throughput

- format and content production information
- drawing format and content
- dimensional control procedures
- quality control procedures.

The IPD process can reduce both owner and contractor risks in the following ways:

- **Shorter schedule** – As an enhanced approach to modular construction, the actual time to construct the facility is significantly reduced.
- **Lower material costs** – Standardized sub-assembly materials can be purchased in bulk, reducing material costs through economies of scale and optimization of the supply chain.

- **Higher quality** – Employing a manufacturing-type scenario provides a controlled environment and the elimination of issues related to inclement weather, site access, height constraints, and the evaluation of skilled labor. It also allows for more thorough QA checks and inspection.
- **Promotion of innovation** – The manufacturing-type environment facilitates the introduction of labor-saving techniques (e.g., the use of jigs, automation, and robotics) to realize optimal production at the lowest possible cost.
- **Safer construction** – The manufacturing-type environment can facilitate a safer construction environment and reduce the hazards associated with field installation.