# Some Economic Facts of the Prefabricated Housing

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*Abstract*: We compare and contrast the current practice of the prefabricated housing among three countries: the U.S., Japan and China, to illustrate the advantages and challenges of this relatively new approach in the construction industry. We also exemplify the operations management practice through real-world practice for the prefabricated housing and point out the future trends.

# Contents

# 1 Definition

Fig. 1.1 Steps of Construction

In classical construction process, suppliers ship the raw materials (including cement, bricks, reinforcing steel bar, sand, and woods) to construction sites. Using these materials, workers make customized housing components on-site and assemble them to build the house. In classical construction, most of the cost (e.g., 90%, Shang 2006) occurs on site. In contrast, "Prefabricated housing" refers to a construction process where the housing components (e.g., walls, floors, balcony, stairs, etc.) are prefabricated in batches in factories, and then shipped to sites for assembly (see Figure 1.2 for a comparison). Although the complexity of the pre-fabricated housing components and off-site procurement cost vary from project to project, from one country to the other, one common feature of prefabricated housing is off-site production plus on-site installation/assembly.

Fig. 1.2 Classical Construction vs. Prefabricate Housing Construction

“Prefabricated housing” borrows key ideas from the manufacturing industry. In the latter, products are modularized and components are standardized. On-site labor is replaced by off-site machine. Although scope is reduced, productivity, quality and cost are improved by batch production in a controlled environment. In some sectors of the construction industry where the construction process is sufficiently repetitive, the concept of prefabricated housing can be applied to achieve greater productivity, higher quality and lower cost for construction projects. In such cases, housing components such as exterior walls, floors, doors, windows, or even stairs and batch-rooms can be made in factories. On-site workers only have to assemble them to build the house. We refer to Figure 1.3a for an illustration. Such a case applies, for example, in many large real estate companies that construct thousands residential and/or commercial buildings annually.

There are several phrases that are related to “prefabricated housing”, such as “manufactured housing”, “modular homes”, “modular building”, “building industrialization”, etc. “Manufactured housing” refers to a more specific type of “prefabricated housing” (see below). “Modular homes” refer to an even higher level of prefabrication – the whole house prefabrication (Figure 1.3b) where the whole house is prefabricated in factory and delivered to the site. This approach has its own limitations and is not widely used.

In the U.S., “manufactured home” means a structure, transportable in one or more sections, which, in the traveling mode, is eight body feet or more in width or forty body feet or more in length, or, when erected on site, is three hundred twenty or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air-conditioning, and electrical systems contained therein; except that such terms shall include any structure which

Fig. 1.3a: On-Site Assembly

meets all the requirements of his paragraph except the size requirements and with respect to which the manufacturer voluntarily files a certification required by the Secretary and complies with the standards established under this title (the National Manufactured Housing Construction and Safety Standards Act).

Fig. 1.3b Modular Homes

In Japan, the “prefabricated housing” has its own standard but refers to the same philosophy: batch production of housing components in factory and the on-site assembly of components. Specifically, a building is broken down to several components or modules, such as walls, floors, doors, stairs; the industrial standard is established for these components and modules. Precisely, “prefabricated housing” refers to houses for which 2/3 or more construction processes are finished in factory and the main parts of house, such as walls and floors, are prefabricated following certain industry standard (Chu 2008b).

For the residential sector of the US and Japan, prefabricated housing components are used almost everywhere even if the buildings are not labeled “manufactured housing”. In almost all such projects, raw construction materials (such as sand, lumber, bricks, etc.) are nearly eliminated from on-site operations. Other countries in which “pre-fabricated housing” is widely used are Denmark, Hong Kong, Singapore, etc.

# 2 History and Current Status

“Prefabricated housing” or “Manufactured housing” was driven by the significant gap between demand and supply in residential housing sector. Traditional housing construction focuses on on-site operations and results in long cycle time and high cost of construction. Such a supply process cannot satisfy the huge demand generated by industrial evolution. This is evident by Figure 2.1 which shows how people sleep in a night-club in London in 1840. This scenario did not only happen in UK, but also in Japan after the WWII, in US, and in many Asian countries, currently in China.

Fig. 2.1 Night Club in London in 1840

## 2.1 United States

In United States, “manufactured housing” was originated in 1950s. It starts with the mobile house (Figure 2.2). It is the rudiment stage in the development of manufactured housing.

Fig. 2.2 Mobile House

In 1976, Congress passed the National Manufactured Housing Construction and Safety Act. At the same year, HUD (Department of Housing and Urban Development) started to establish the industrial standard for manufactured housing.

According to the data from MHI (Manufactured Housing Institute) – Cost and Size Comparisons of Manufactured Homes & Site Built Homes (1990-2008), the manufactured housing takes 12% percent of all residential homes in 2008 (Table 2.1).

| **Housing Starts & MH Shipments (thousands of units)** | | | | | |
|---|---|---|---|---|---|
| Year | 2004 | 2005 | 2006 | 2007 | 2008 |
| **New Single Family Housing Starts** | **1,611** | **1,716** | **1,465** | **1,046** | **622** |
| Percent of Total | 92% | 92% | 93% | 92% | 88% |
| **Manufactured Homes Shipments Shipped** | **131** | **147** | **117** | **96** | **82** |
| Percent of Total | 8% | 8% | 7% | 8% | 12% |
| **Total** | **1,742** | **1,863** | **1,582** | **1,142** | **704** |

Table 2.1 Manufactured Homes vs. Site Built Homes

Table 2.1 only shows the market share of the "manufactured housing" for residential homes. In commercial real estate, most of the buildings are made by the prefabricated modules. Moreover, in US, nearly 100% housing construction (either residential or commercial) use prefabricated materials, which implies that every house is prefabricated to a certain degree even if it does not satisfy the criteria of "manufactured housing". Although the complexity of the prefabricated housing components varies among projects, the procurement cost (for materials) accounts for a significant percentage of the total housing budget. On average, cost shares of material and labor in the construction of new residential houses are approximately 65% and 35% (Somerville 1999).

## 2.2 Japan

The manufactured housing in Japan starts around 1960s. Due to WWII, lots of houses were destroyed. After the baby boom, the demand for residential house is urgent. In order to construct more houses without sacrificing on quality, Japanese companies used the "prefabricated housing" approach. Some of the leading companies are Taisei Corporation (Figure 2.3), Sekisui House, Daiwa House, Misawa House.

Japan has its own industrial standard for prefabricated housing, which is different from the US. It is said that a house is made by prefabricated housing if the 2/3 or more (Chu 2008a) construction process is finished in factory and the main parts of house, such as walls and floors, are pre-made following certain industry standards. In this sense, 20%~25% of new residential houses are prefabricated housing in year 2002. If we include houses that used the prefabricated modules, then the percentage goes to nearly 85% and more for year 2002 (Chu 2008a).

Fig. 2.3 Prefabricated Housing Project by Taisei Corporation

## 2.3 China

In Hong Kong, the housing industrialization began at 1953 when a big fire occurred and a lot of houses were burnt down. Nearly 53000 people became homeless. By the end of 2002, the prefabricated materials take up to 17% of the total construction materials in respect of cubic meters of cement. This percentage increased to 65% in 2007 (Chu 2009).

In Mainland China, the housing industrialization began in 1998. In this year, the Chinese government implemented the commercial residential building reform. In about ten years (from 1998 to 2008), there is a significant growth in demand in the housing market. Different from the US, Chinese people usually lives in apartment buildings with many floors because of the huge population and limited land. How to build more houses faster and with higher quality is an important problem for Chinese real estate companies.

Vanke is the leading residential developer in China with RMB 41 Billion sales, 2.34% market share, 5,570,000 square meters sold in 2008 (Vanke annual report 2008). Vanke started the prefabricated housing research in 1999. In 2006 and 2007, Vanke has finished two prefabricated housing projects (Figure 2.4a-b).

Fig. 2.4a Vanke Xinlicheng Residential Housing Project in 2007

For the Xinlicheng project, Vanke used the method of precast concrete (PC). 37% of the construction process is finished in factory. For the structure of the building, they use precast concrete with steel beans. Except certain connection points that require on-site cast of concrete, all other parts are precasted in factory. For the building structure, 90% of construction process is done in factory (see http://gumingwang.blog.163.com/blog/static/60604324200982342542495/).

Overall, the manufactured/prefabricated housing in China has just started. The average prefabricated level is less than 10% in terms of construction process. Even for Vanke, prefabricated level is about 20% on average (Yang 2008).

Fig. 2.4b Vanke Holiday-View Residential Housing Project in 2006

## 3 Advantages of Prefabricated Housing

Faniran and Caban (1998) mentioned that the five most significant sources of construction waste were design changes, leftover material scraps, wastes from packaging and non-reclaimable consumables, design/detailing errors, and poor weather. The prefabricated housing approach could mitigate some of these problems.

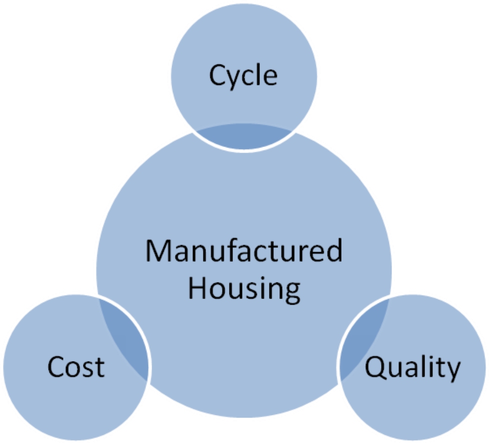

Fig. 3.1 Advantage of Manufactured/Prefabricated Housing

The advantage of manufactured/prefabricated housing usually lies in shorter construction cycle time, better quality, lower cost and better environmental protection. We shall use recent examples of Vanke for illustration.

## 3.1 Construction Cycle Time

In the approach of prefabricated/manufactured housing, housing components such as exterior wall, floors, stairs and balcony are manufactured in batches in factory. On-site labor is replaced by off-site machinery, and production cycle time is compressed. Moreover, factory production can better utilize parallel production. For instance, exterior walls at different floors can be made simultaneously rather than sequentially when done on-site.

In prefabricated housing, personnel can be better managed and utilized than in classical construction. In the former, personnel only needs to be trained on one task while the latter, personnel has to be trained to do multiple tasks.

Once designed and steel mode is made, the prefabricated housing components cannot be changed without significant cost. Thus, it is less likely to incur changes under prefabricated housing.

As an example, for the Vanke Xinlicheng Project, Shanghai, the prefabricated housing approach – precast concrete, reduced the construction cycle time by about 1/3 relative to the classical construction process – on-site cast of concrete (Yang 2009).

## 3.2 Quality

In prefabricated housing, the modules are made in factories under a controlled environment and thus do not subject to weather conditions. Because they are produced by machines, they have much better and more consistent quality than those made on-site by labor. For example, in the classical approach, if one builds a wall with cement, sand, and bricks, the worker first mixes the cement with sand and water, then uses it to join bricks. This procedure depends on weather and the skills of the worker. In the prefabricated housing approach, the module production is less sensitivity to labor errors and adverse weather conditions.

As an example, for the Vanke Xinlicheng Project, Shanghai, the prefabricated housing approach has increased the lifecycle of the exterior wall to 70 years from 20 years (made by the classical construction process). In addition, the concrete surface flat rate is controlled within 0.1% (Yang 2009).

## 3.3 Cost and Environmental Issues

The cost of construction projects includes labor wages, material cost, equipment rentals, delay penalties, inventory holding cost, on-site utility consumptions and recycling costs. These costs can be classified into off-site and on-site costs.

Off-site cost is mainly material cost and logistics cost. This cost will rise as one moves from classical construction to prefabrication as more complex housing components are produced off-site and need to be warehoused and shipped to sites. Essentially, on-site labor cost is replaced by manufacturing cost which demonstrates economies of scale (e.g., the cost of making the steel module/mode and tools can be regarded as a fixed cost). In addition, the shipping and storage costs for prefabricated housing components will increase due to geographic distance between factories and sites and the high value of premade housing components. On the other hand, prefabrication can reduce material usage and waste relative to the classical construction where all production occurs on-site. On-site cost is mainly labor cost, equipment costs, utility (energy, water usage) cost, delay penalty and recycling cost. Prefabrication can significantly reduce these on-site costs. The net cost depends on the trade-off between labor and manufacturing costs/ logistics/supply chain costs.

As an example, for the Vanke Xinlicheng Project, Shanghai, the prefabricated housing approach (37% PC) has reduced energy usage by 70%, raw materials usage by 50%, construction waste by 40%, on-site labor by at least 50% (Yang 2009). Additional benefit includes fewer safety issues and lower noises. The net cost of this project is however higher than classical construction. In fact, the construction cost raised by 40% due to off-site pre-made housing components (Sina Real Estate 2008). This is true mainly because of the small manufacturing scale and extremely low labor cost in China. It is expected that the net construction cost will decrease after the economies of scale in production are achieved (Yang 2007). Because of the high labor cost and relative low manufacturing cost, the net cost of such a project would have been most likely lower under prefabrication in the US and Japan.

# 4 Challenges

The challenges come from two aspects: Technology and management. In terms of technology, prefabrication requires breaking houses into modules and designing a universal industry standard for each module so that components made by different suppliers can match. While the US and Japan have developed such standards in past 40-50 years, such standards are still under development in China. These standards are typically designed by government. Following modularization and standardization, it is the development of value chain – suppliers, manufacturers, and distributors. This clearly relies on the industry-wide effort. While standardization is essential to prefabricated housing, it does reduce the variations and the degree of customization in houses.

In terms of management, prefabrication requires project management for on-site activities and supply chain management for off-site activities (production, transportation, warehousing, etc.), as well as managing the interface between projects and material supplies. As more and more cost and time are shifting from on-site operations to off-site, supply chains and logistics become more important and harder to manage for residential housing construction companies. Clearly, project management, supply chain management and their interface determines the operational efficiency (cost competitiveness) of individual construction companies.

One of the main challenges is the coordination between supply chain and project operations. This is unique for prefabricated housing but negligible in classical construction because the classical construction process stresses on early delivery of all construction materials on-site. Because of the low value of raw materials, the supply chains of such materials are often ignored as compared to the project operations because they take most of the budget and determine the project duration. As a result, project management and supply chain management (of raw materials) are often decoupled.

In contrast, the prefabricated housing process requires just-in-time delivery of high value and long lead-time housing components to construction sites. The time and money spent on off-site activities are comparable to those spent on on-site. For these higher value larger size components (than raw materials), it is no longer suitable to hold inventory on-site. As a result, management should coordinate the delivery schedule of prefabricated materials with on-site project schedule. In conclusion, the supply chain and project management are highly coupled. It is important to consider these two problems jointly rather than separately.

# 5 Operations Management Examples for Prefabricated Housing

We present examples from various countries to showcase the current practice of project and supply chain management in prefabricated housing (in residential, commercial or industrial sector).

**Pulte Homes**

Pulte homes is the largest US homebuilder in 2009 (Walsh 2009). As observed by Kerwin (2005), in the first half of 2005, Pulte receives 25,650 new orders for residential construction. Motivated by Toyota's manufacturing systems, Pulte has reduced the floor plans from 2200 to about 600 to remove complexity and improve operational efficiency. Pulte also makes upscale features standard to get economies of scale. Pulte also utilize its scale to build a more efficient supply chain by buying directly from material suppliers in bulk (for quantity discounts) and using regional distribution centers to deliver materials upon needs.

Standardization of components and prefabrication are utilized also in other US homebuilders, e.g., KB Home is standardizing housing components such as window frames using some of the lean-manufacturing techniques, Toll Brothers and Centex Corp (now part of Pulte) are manufacturing some housing components off-site to boost efficiency.

### Quadrant Homes

Brown et al. (2004) provides detailed information on the management practice by Quadrant Homes, a subsidiary of Weyerhaeuser Corporation – a Fortune 500 company. In 2003, Quadrant is a 170-person company that sold over 1000 houses mainly in Seattle area with revenue over $250 million. Quadrant is essentially a project-driven company. Starting from 1996, it builds houses to order by giving customer choices but controlling their nature and extent to reduce complexity, cost and cycle time.

| Design element | Lean benefits |
|---|---|
| Design footprints are limited in number | Creates opportunities for standardization, for example, foundations<br>Simplifies operations |
| Designs do not include basements | Designs are applicable to multiple building sites and terrains |
| Multiple designs within each footprint category and exterior design allow multiple room arrangements | Can prepour foundations without severely limiting options<br>Can provide several room arrangement choices within a footprint template by rearranging non-load-bearing walls |
| Part commonality across designs and across price points(for example, limited window options, roof pitches, and column types) | Suppliers can offer volume discounts<br>Standardized, simplified construction methods save time and money |
| Seeks supplier feedback to continuously improve designs and constructability | Reduces flow time<br>Reduces cost<br>Improve conformance qualify |

Table 5.1 Quadrant's Design Principles

Quadrant uses standardized processes to construct houses. The tasks performed in each of the 54 days of throughput time are the same for every house. The first five days at construction site looks like follows:

Day 1: Deliver lumber; install first-floor joists.
Day 2: Conduct under-floor inspection; frame garage walls.
Day 3: Start first-floor walls.

Day 4: Finish first-floor walls.
Day 5: Install second-floor joists.

The success of this standardized process requires the support of a value chain. With only 170 personnel, Quadrant relies on outside subcontractors for labor and materials. Subcontracts are well integrated into Quadrant's value chain, and are mostly solely sourced suppliers under long term contracts. Suppliers provide just-in-time delivery of housing components to match material delivery schedule with installation rate.

Enabled by close collaboration, suppliers now try to prefabricate housing components to reduce construction cycle time, cost and improve quality. Under the old business model (on-site construction), Quadrant bought all wood products on site on the first day of construction. It then hired a framing crew to build the house on-site, often standing in the rain. Quality varied and wood waste was high. In the new model, a single supplier, Woodinville Lumber (WL) supplies both labor and materials for framing. It prefabricates components, e.g., wall panels, trusses, floor panels and I-joists with a lead time of 10 days to marry them on site. In addition, WL also prefabricate stair systems and front porch posts. The result is better quality, less waste and shorter cycle time (see table 5.2).

| | 1996-Before lean transformation | 2003-After lean transformation |
|---|---|---|
| Houses built per year | 150-200 | 1,500 |
| Construction throughput time | 135 days with wide variation | 54 days with little variation |
| Work in process | 75 houses | 324 houses |
| Typical finished goods inventory | 20-25 houses | 0 houses |
| Demand backlog for houses not yet started | 0 customers waiting | 550 customers waiting |
| Average cost per square foot | $60 | $30 |

Table 5.2 Quadrant's operational performance (Brown, et al. 2004)

## Typical Residential Developers

Large residential developers, such as Pulte and Quadrant, sometimes build multiple houses in a certain area; see an example in Figure 5.1, where there are 55 houses. Due to the labor limitation, the houses are not constructed simultaneously but sequentially. Constructor usually divides them into groups, and uses a method similar to Quadrant's procedure to construct each house.

Fig. 5.1 Common Appartment Construction

Construction companies follow standard procedures to build residential houses. Below we showcase a standard gantt chart for residential housing under prefabrication in the US. Procedures are from *"A Sample Residential Construction Schedule - for a 6,000 square foot custom home"* (B4UBUILD.com); costs are from *"Construction Costs for Single-Family Unit"*, NAHB, National Association of Home Builders.

| Name | Duration (day) | Start | End | Cost | Details |
|---|---|---|---|---|---|
| Site work | 7 | Mon 7/28/08 | Tue 8/5/08 | 1.7%<br>1.4%<br>1.6% | Building Permit Fees<br>Impact Fee<br>Water and Sewer Inspection |
| Foundation | 24 | Wed 8/6/08 | Mon 9/8/08 | 7.0% | Excavation, Foundation, and Backfill |
| Rough carpentry | 44 | Tue 9/9/08 | Fri 11/7/08 | 0.8% | Steel |
| Concrete slabs | 8 | Thu 9/18/08 | Mon 9/29/08 | | |
| HVAC | 17 | Fri 10/10/08 | Mon 11/3/08 | 3.9% | HVAC |
| Plumbing, electric, specialty rough-in | 47 | Fri 10/10/08 | Wed 11/26/08 | 5.4%<br>3.9%<br>1.0% | Plumbing<br>Electrical Wiring<br>Lighting Fixtures |
| Roofing | 68 | Fri 10/17/08 | Tue 1/20/09 | 3.2%<br>5.7% | Roof Shingles<br>Siding |

| | | | | | |
|---|---|---|---|---|---|
| | | | | 0.8%<br>15.8% | Stairs<br>Framing and Trusses |
| Insulation | 5 | Fri 11/28/08 | Thu 12/4/08 | 1.6%<br>0.4% | Insulation<br>Gutters and Downspouts |
| Drywall | 26 | Fri 12/5/08 | Fri 1/9/09 | 5.1% | Drywall |
| Floor | 76 | Tue 1/13/09 | Tue 4/28/09 | 0.9%<br>1.5%<br>2.9%<br>1.6% | Exterior Doors<br>Interior Doors and Hardware<br>Windows<br>Sheathing |
| Paint | 59 | Wed 1/7/09 | Mon 3/30/09 | 3.4% | Painting |
| Trim | 85 | Tue 1/13/09 | Wed 4/8/09 | 3.1%<br>5.7%<br>1.7%<br>5.0% | Trim Material<br>Cabinets and Countertops<br>Appliances<br>Tiles and Carpet |
| Final Punch-out | 9 | Wed 4/1/09 | Mon 4/13/09 | 2.8%<br>0.7%<br>1.4%<br>9.7% | Landscaping and Sodding<br>Wood Deck or Patio<br>Asphalt Driveway<br>Other |
| Cleaning | 14 | Fri 3/27/09 | Wed 4/15/09 | | |

Table 5.3 Standard Procedure Sample for Constructing Residential Houses

### Vanke

The operations management practice of Vanke is evolving and so far not well documented. By Yang (2009), Vanke targets at 100% indoor decoration in 2009. As Pulte, it attempts to buy directly from material manufacturers to achieve economies of scale in material procurement.

### Commercial and Industrial Examples

Zhao (2009) provides detailed information for a New Jersey based construction company, ICC, who does regular work for the military (about 5-6 construction projects a year with possible multiple buildings at each site). In ICC's construction projects, materials on average account for 65% of the total project cost, while labor accounts for 15% and equipment accounts for 20% of the cost. Structural steel is prefabricated and is one of the most expensive items required in all ICC's projects. Structural steel is typically used in the foundation of the building or in making certain columns of the building and thus needed early in the projects. There's no provision of inventory storing on site so material should be delivered "Just in time". For all military housing construction projects, the company follows a standard construction process with total duration ranging from 29 weeks to 32 weeks. The delivery of structural steel is required at the beginning of the 5th week (after a project is inaugurated). However, the structural steel supply chain is consist of two production stages and requires a lead time of 4-6 weeks. Upon delay of this material, ICC typically expedites construction work later on to catch up the schedule.

# 6 Trends in Construction Management

People typically view projects as unique kinds of operations that require unique blueprint, operational planning and scheduling. However, projects may not be entirely unique (Brown, et al. 2004) and do not have to be (Tommelein, et al. 2003). Schmitt and Faaland (2004) demonstrated the applicability of assembly-line concepts to recurrent construction problems taking place in making airplanes, houses and ships. In the construction management community, there is a trend to integrate supply chain management in construction – construction supply chain management which starts in middle 1990s. The key idea is to consider the continuity of projects and plan them jointly rather than independently. Tommelein, et al. (2003) provides an excellent comparison between the classical project-based management and the recent supply-based management.

| **Project-based** | **Supply-based** |
|---|---|
| Plan each project separately | Plan for the need of multiple projects over time |
| Uniquely engineered facilities and components | Assembly of unique facilities from standardized modules/components |
| Competitive bidding | Emphasis on long-term working relationships |
| Information hoarding | Information visibility |
| Long and uncertain lead times with extensive use of expediting | Short and reliable cycle times from raw materials to site installation |
| Early delivery of all materials to the site | Phased delivery of materials to the site to match installation rates |

Table 6.1 Project-based vs. Supply-based management

The recent construction management literature provides many case studies and conceptual framework to illustrate this trend. In what follows, we summarize a few representative studies.

Walsh, et al. (2004) provides a case study for a food manufacturer who does repetitive expansion of its production facilities. Facing long and extremely fluctuated lead time for a prefabricated component – stainless steel pipes and fittings (used in every expansion project), the company used to experience costly delay penalty or extensive expediting. Utilized the supply-based management principle, the company has come up with an innovative solution which positions a certain amount of raw steel inventory in the stainless steel supply chain. Doing so has reduced the lead time by 75% and allowed projects to stay on schedule without expensive expediting.

O'Brien, et al. (2002), noted two research streams of construction supply chain management: (1) industrial organization economics to better understand market structure and forces and their effect on firm and supply chain behavior and (2) Analytic modeling of supply chains to improve supply chain performance along metrics such as speed, cost, reliability, quality, etc. Both industrial organization and analytic modeling provide useful but ultimately incomplete perspectives and prescriptions for construction supply chain management. As such, he proposes development of an interdisciplinary research agenda that draws from both fields. Towards that agenda, a review of research is presented to introduce the main ideas, relevant literature, and theory and methods in each of the two areas. From these independent reviews, applications that could benefit from a combined perspective are identified and used as a basis for development of an interdisciplinary research agenda.

Wong (1999) has delineated the supply chain management issues in total quality for construction projects. Through the use of an in-depth case study on the TQM system of a leading construction company in Hong Kong, the strategy, structure and tasks for managing supplier/subcontractor relationships are examined. The study concludes with identification of some supply chain management issues in the construction industry.

Dainty, et al. (2001) focus on the integration of small and medium-size enterprises (SMEs) in the subcontractor and material supply sectors. It presents the findings of research that focused on the role of these SMEs in re-engineered construction supply chains. It was found that significant barriers exist to supplier integration within the construction sector, which stem from SME skepticism over the motives behind supply chain management practices. It is suggested that the industry must make greater efforts to extol the mutual benefits of supplier integration to SMEs if significant performance improvement is to be achieved.

Briscoe, et al. (2001), examines the skills requirements necessary for effective supply chain partnerships in the UK construction industry. Current SME skills are explored in terms of their relevance to developing more efficient supply networks. A range of SME companies are interviewed in order to determine if their current knowledge, skills and attitudes are appropriate for achieving better supply chain integration. The implications of current skills and attitudinal deficiencies are assessed in terms of whether they act as barriers to effective supply chain partnering in the future.

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