Industrialization of the Construction Industry through Prefabrication and Adoption of Current Technologies

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Executive Summary

In the current construction industry, conventional, on-site building methods are much more prevalent than off-site building methods, such as prefabrication. Prefabrication is the construction of building assemblies or sub-assemblies in a factory and then transporting them to site. The use of prefabrication in construction dates back to the mid-1800s, but has yet to gain wide-spread adoption in the industry. Today, prefabrication is once again gaining popularity, driven by the inherent benefits associated with the construction method, as well as global environmental and social factors. Prefabrication is also being seen as a means of improving the industrialization of the construction industry.

The advantages of prefabrication address many of the concerns associated with conventional construction methods - skilled-labour intensive, has variable quality, is inefficient, and has high environmental impacts. In prefabrication, construction is performed in a factory, allowing for the use of automated equipment to reduce labour and full-time factory employees ensure that project delays due to the unavailability of skilled tradespeople are avoided. Improved product quality is achieved through highly sophisticated equipment, better supervision, and climatic protection. Factory fabrication results in improved efficiency, ultimately reducing costs. Environmentally-sustainable principles are also incorporated into prefabrication, most importantly the reduction of construction waste.

Many of the benefits offered by prefabrication have already been realized in other manufacturing industries through industrialization. Industrialization is the replacement of crafts-based production processes with more standardized, machine-based processes. In the construction industry, prefabrication is seen as the first degree of industrialization, followed by mechanization, automation, robotics, and reproduction. With implementation of current systems and technologies and a greater environmental awareness, industrialization of the construction industry can be attainable.

List of Key Words

Manufactured housing

Factory fabrication

Modularization

Mechanization

Automation

Robotics

Reproduction

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1.0 Introduction

There has been little innovation in house construction over the last 150 years (Luther, 2009; O'Brien, Wakefield & Beliveau, 2000). In the current residential construction industry, the most prominent form of construction is site-built construction. Site-built construction is the traditional practice of transporting raw materials to site to be assembled. A second, less commonly used, method of construction is factory-built construction, or prefabrication. In factory-built construction, assemblies or sub-assemblies of a structure are built in a factory and then transported to a building site to be erected (as cited in Galindo, 2008).

Although prefabrication of some construction elements, such as roof trusses and wall framing, has been adopted by the mass housing market, conventional, on-site building methods still dominate this industry. In comparison to more automated industries, there is a lot of room for improvement in current construction practices (Luther, 2009). In an effort to improve the industrialization of the current construction industry, many have analyzed past efforts in this area and have looked to the automated manufacturing processes used in other industries (Luther, 2009; O'brien et al., 2000; West, 2008). Prefabrication is said to be the first degree of industrialization that can be implemented in the construction industry (Richard, 2005).

Prefabrication is not a new construction method, but it is once again gaining popularity in the industry. Today, a number of environmental and social factors are driving the adoption of prefabrication. Prefabrication enables the development of affordable, mass-produced housing that is environmentally-benign, a critical factor to achieving global sustainability (Luther, 2009).

The environmental impact of construction is a growing concern. In developed countries, there is a growing need for an alternative form of housing that is less resource- and energy-intensive than what is

currently offered (O'brien et al., 2000). One of the main factors affecting the resource-intensity of construction is construction waste (Tam, Tam, Zeng, & Ng, 2007). Prefabrication has been shown to effectively reduce waste and has therefore been used to achieve sustainable development and conserve landfill capacity. Two additional methods of reducing the environmental impact of housing are to use renewable and/or recycled materials and to decrease the operating energy required by buildings.

Apart from reducing the environmental impact of housing, other social factors are contributing to a growth in prefabricated building. In developing countries, growth in the demand for housing is being driven by growing squatter settlements and a growing middle class (O'brien et al., 2000). Around the world, urbanization is also causing an influx of people into cities, increasing the demand for housing in these urban areas (Luther, 2009). To better cope with this increased demand, the construction industry must become more productive and efficient.

Another social factor is the growing lack of affordable housing in many places, increasing the demand for sustainable architecture. In most Canadian markets, housing affordability is within historically 'normal' or safe ranges (Royal Bank of Canada, 2013). In the past three years, the Canadian market has demonstrated cyclical behaviour with alternating improvement and deterioration in housing affordability, showing no clear directional trend. However, signs of unaffordability have been seen among two-storey homes in Toronto, and to a lesser extent, Montreal. Vancouver remains the least affordable market in Canada and is said to be "…in a class by itself at the unaffordable end of the spectrum" (RBC, 2013, p. 1).

The goal of this report is to investigate past and current use of prefabrication in the construction industry and to discuss the use of prefabrication as a means of improving the industrialization of the industry.

2.0 Background

2.1 Development of prefabricated construction

Factory-built construction, or prefabrication, is not a new concept in the construction industry. Early uses of prefabrication date back to the mid-1800s when prefabricated components were shipped from eastern U.S. to California and Australia during their gold rushes (O'brien et al., 2000). Prefabrication was also used in the construction of field barracks during the American Civil War. Through the late-1800s to early-1900s, experimentation in pre-cut kit houses and mass-produced housing occurred. The system of prefabricated wood-stud panels used today was developed in the 1930s by Howard T. Fisher, in an attempt to make home building more accessible to the average homeowner.

Prefabrication was most prominently employed during the aftermath of the World Wars in both the U.S. and the United Kingdom (UK) (O'brien et al., 2000; West, 2008). In the U.S., the widespread desire among Americans to return to "normality" and the flood of veterans returning to the U.S. resulted in a large increase in the demand for housing (West, 2008). Following WWII, in response to a severe lack of housing and skilled labour in the U.S., over 70 companies produced more than 200,000 prefabricated homes. The most prominent company was led by the Levitt Brothers. In the late 1940s to early 1950s, the Levitt Brothers developed Levittown, New York to support housing for 12 to 16 million Americans (O'brien et al., 2000). At Levittown, the construction process adopted was more industrialized than what was commonly pursued and incorporated modularization and an assembly line process. The assembly line process had workers moving from site-to-site, building a limited number of standard models with pre-cut lumber and conventional construction methods.

During the mid- to late-1900s, the use of prefabrication was most prominent in the mobile home industry in the U.S. (O'brien et al., 2000). These homes were originally constructed without any regulation, as they lacked permanent foundations. This changed in 1974 when the U.S. Department of

Housing and Urban Development (HUD) gained approval to impose a construction code on the mobile home industry. In the U.S., the term 'mobile homes' was later replaced by manufactured housing, now referred to as "HUD code housing." Modular building appeared in the 1980s and 1990s and helped to improve the public's perception of manufactured housing.

Prefabricated construction methods have continued to evolve. Today, a new form of prefabrication is emerging, characterized by automated production, integrated building services, and environmentally-sustainable designs (Luther, 2009). These characteristics are integrated throughout planning, design, and manufacturing processes, in order to construct buildings that are both affordable and sustainable.

2.2 Prefabricated building systems

2.2.1 Methods of prefabrication

According to the Canadian Manufactured Housing Institute, an organization representing the manufactured building industry in Canada, there are currently four types of prefabricated housing methods used in the industry. The four types of homes produced are: modular, manufactured, panelized, and pre-engineered (Canadian Manufactured Housing Institute, 2013). Prefabricated houses can be produced in a wide variety of sizes, with flexible designs and layouts. Houses are completed to varying degrees within a factory before being transported to site. Methods of production can be used alone or in combination.

Modular homes are built in three-dimensional units that are combined on site (CMHI, 2013). The homes are completed to a fairly high degree before leaving the factory. A completed module will contain plumbing and electrical systems, as well as exterior and interior finishing work. Bathroom fixtures may also be included. When the modules are situated on site, the time required for finishing work will depend on the size, style, and features of the house, but will generally take a couple of weeks.

Manufactured homes are essentially complete sections of a house that are often ready to move into when transported to site (CMHI, 2013). A manufactured home is typically built in one section, but some manufacturers may build homes in two sections as well. Due to the structural design of these homes, they can be installed on surface-mount foundations, significantly reducing the price of the homes. Manufactured homes can also be relocated, but many are left in their original location.

Panelized homes consist of wall, floor, and roof assemblies (CMHI, 2013). Some manufacturers produce partially finished panels, consisting of framing and sheathing, while other manufacturers produce fully completed or closed panels. The build-up of completed panels depends on the manufacturer, but completed panels often contain insulation and are closed with drywall on the inside and sheathing and siding on the outside. Services, such as plumbing and electrical systems, windows, and doors may also be installed in the panels. Completed panels are flat-packed to be transported to site. The construction and transportation of panels, as opposed to modules, has some associated advantages, such as reduced factory space requirements, reduced transportation requirements, and less 'air' is shipped to site.

These methods of prefabrication are being adopted in response to a number of issues with current, on-site building methods.

2.2.2 Issues with current construction methods

The main criticisms of current construction methods are that it is skilled-labour intensive, has variable quality, is inefficient, and has high environmental impacts (Luther, 2009). Construction requires a number of skilled tradespeople including electricians, plumbers, and carpenters, and unavailability of these skilled tradespeople can lead to project delays. The quality of construction projects is also highly variable, due to exposure to environmental conditions and variation in the performance of employees. Building processes that require specialized on-site construction often achieve a much lower productivity compared to industries in which fabrication is completed in a controlled environment, such as a

production facility (Luther, 2009). Low productivity increases project costs and the amount of time required to bring a project to completion. It is estimated that it takes up to 6 times longer to bring a construction project to lock-up stage when using conventional methods compared to off-site, modular prefabrication (Luther, 2009). The most demanding process during construction is the installation of building services, such as plumbing, electrical, and HVAC systems, and there is a need for better integration of services.

Conventional construction is also criticized for its high environmental life-cycle impacts, resulting in buildings with a large environmental footprint. The materials used in construction are often energy-intensive to produce and are non-recyclable, resulting in structures with high-embodied energy content and a large environmental footprint (Luther, 2009). During operation, buildings often have high energy requirements, contributing to the environmental impact of the buildings. During construction and deconstruction, large amounts of on-site waste are produced. Considering construction and deconstruction during the design stage of a building or designing a building for re-use of building components can lessen the environmental impacts.

Many of the issues associated with current, on-site construction methods can be addressed with prefabrication.

2.2.3 Advantages of prefabrication

Numerous benefits of prefabricated building have been identified. These benefits include reduced environmental impacts and gained efficiencies through factory fabrication.

Prefabricated homes are designed and built with the environment in mind. During the design of buildings, prefabricated architecture can result in buildings that are diverse in design, while still ensuring a reduction in waste, integration of building systems, and optimal performance during operation

(Luther, 2009). During construction, factory fabrication encourages a greater attention to detail on behalf of employees and materials are used more efficiently, further reducing waste (CMHI, 2013). The use of prefabrication also reduces disruption to the building site.

Efficiencies are also gained through building in a factory, such as improved product quality, reduced project durations and improved project scheduling (CMHI, 2013). Fabrication in a factory ensures controlled environmental conditions, allowing for the use of highly-automated and sophisticated equipment, improving the precision of construction. Factory fabrication also provides climatic protection (Richard, 2005). This is especially important in wood-frame construction, as water can be damaging to the wood material. Improved product quality is also achieved through better supervision, as prefabricated assemblies are tested and inspected before being installed on site (Tam et al., 2007). Controlled conditions in a factory also reduce the risk of unexpected project delays due to poor weather or the unavailability of skilled tradespeople. This reduces the duration of a project and allows for more accurate project scheduling.

Improved efficiency of construction can ultimately reduce costs, resulting in more affordable housing (Tam et al., 2007). Cost reductions are most prevalent when standardized designs are used in prefabrication. When modularization is incorporated, prefabrication becomes particularly effective (West, 2008). Modularization is the practice of repeating some aspect of a building's form, or building multiple copies of the same structure. Bulk purchasing of building materials can also reduce costs (Richard, 2005).

Along with the advantages of prefabrication, the disadvantages of the construction method are also discussed.

2.2.4 Disadvantages of prefabrication

As with any construction method, there are disadvantages associated with prefabrication. A main disadvantage described by Tam et al. (2007) is the inflexibility of prefabrication for changes in design. If the design is not set during the development stage, consultants and clients may be reluctant to adopt prefabrication. The design development stage is also more time-consuming in prefabrication than in conventional construction (Tam et al., 2007). Another disadvantage is higher initial construction costs. If setting up a prefabricated housing factory, high capital costs will be required and the construction costs may be higher until economies of scale are realized. When joining prefabricated building components, leakage problems may occur; however, this is most likely due to a current lack of research, knowledge, and experience on behalf of contractors. In some regions, lack of demand for prefabricated building components may also pose as a disadvantage.

It is important to note that the incorporation of prefabrication into existing construction methods will not be met without challenges (West, 2008). Challenges may be technical in nature, such as data handling, transportation of products to site, or supply chain logistics, or they may be broader challenges such as obtaining financing or dealing with negative public perceptions. The use of prefabrication in a project should be assessed based on the nature of the specific project at hand.

2.3 Current state of the prefabricated construction industry in Canada

Information can be gathered on the current state of the manufactured housing industry in Canada from the Canadian Manufactured Housing Institute's (CMHI) annual Manufactured Building Survey (CMHI, 2011). The survey is of producers in both the residential and non-residential sectors. In the 2011 Annual Report, there were approximately 90 CSA-certified builders of factory-built structures across Canada. The value of manufactured housing in Canada in 2011 was $1.3 billion, showing an improvement of about 13% from 2010, marking the first annual improvement in the industry since 2007.

The global economic recession affected the trade balance for manufactured buildings in Canada. In 2011, the industry experienced a second annual deficit, with imports exceeding exports (CMHI, 2011). This deficit was greatly affected by imports, which were significantly higher than the previous year. Some improvements were seen in exports, but due to the recession, Canada's main markets for manufactured buildings, the U.S. and Japan, remained at a fraction of previous levels. The majority of manufactured buildings, 87.6%, were sold to builders, developers, and retailers, while only 11.3% were sold to consumers.

In the residential sector, factory-built homes are capturing a larger proportion of new housing starts in Canada. About 14,427 factory-built homes were started in 2011, an improvement of 22% from the previous year (CMHI, 2011). According to the Canada Mortgage and Housing Association (CMHA) the total number of new housing starts in 2011 was 193,950 units, showing growth of only 2% from the previous year. In 2011, single-family homes, including single-detached, semi-detached, and row house units, saw a decline as a result of high apartment housing starts. Factory-built homes represented 12.5% of single-family home starts in 2011, up from 9.5% in 2010. In 2011, the average size of a factory-built, single-family unit was 1,263 ft^2 and had been declining for the past four years. A vast majority of factory-built, single-family homes were between 1,000 to 1,499 ft^2, a total of 67.9% of homes. In multi-family buildings, the average size per unit was slightly smaller, at 1,105 ft^2 per unit. Production of manufactured single-family homes is scattered across Canada, but the building method is most prominent in New Brunswick, Nova Scotia, Alberta, and Ontario.

Although the prefabricated construction industry is still relatively small in Canada, it is showing signs of growth. In other regions around the world, prefabrication is much more prominent.

2.4 Current state of the global prefabricated construction industry

The global prefabricated building market was estimated to be worth over $65 billion US in 2011 (NewsRx, 2012). The three largest regional markets for prefabricated building in 2011 were the European, Asia-Pacific, and North American markets (see Figure 1 below). The largest regional market was the European market at 52.9% market share.

Development of the global prefabricated building market has been forecasted to 2016. It is expected that 50% of the demand for prefabricated building will be attributable to the non-residential sector, with iron and steel building being the key contributor. The use of prefabricated building for residential construction will also increase. Shifts in the market share held by the largest regional markets are also likely to occur. The market share of the European market is expected to decline to 49.5% in 2016, driven by the uncertain economic conditions in Europe. The North American market is also predicted to decline from a market share of 15.40% in 2011 to 14.10% in 2016. Slow economic growth in the U.S. will contribute to this decline. Demand in the Asia-Pacific region is expected to rise, as people are becoming more aware of the benefits of prefabricated buildings and the building method is gaining popularity. The growing economies of China and India will most likely begin to erode the market shares of North America and Europe.

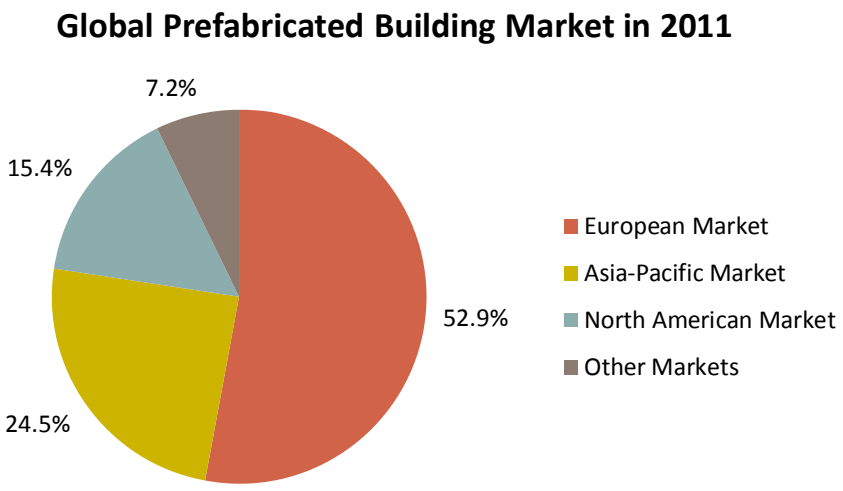

Figure 1 Market share of the top regional markets in the global prefabricated building industry in 2011

Prefabrication has been deemed a solution to improving both the productivity and efficiency of conventional construction methods used worldwide (NewsRx, 2012). In order to ensure future growth in demand in the global prefabricated building industry, technological improvements will be necessary.

3.0 Discussion

Industrialization has been applied to the production of many goods available in the market today to reduce costs, improve product quality, and deliver complex products to mass markets (Richard, 2005). Industrialization is based on the production of large quantities of goods in order to spread the initial costs of investment over an increasing number of units. In the construction industry, industrialization has been used in the production of some building components, such roof trusses, windows, and concrete slabs, but has had limited application in the production of entire buildings.

3.1 Industrialization of manufacturing

Industrialized manufacturing of a product is the use of machines and repetition to achieve mass production (O'Brien et al., 2000). During industrialization, traditional, crafts-based production processes are replaced with more standardized, machine-based processes. This production improvement results in a higher quality product that is more consistent and affordable. Industrialization has been implemented in many manufacturing industries.

3.1.1 Past industrial revolutions

It is suggested that there has been three industrial revolutions (Luther, 2009; O'Brien et al., 2000). The first occurred in the 17th and 18th centuries, bringing about great advances in the industrialization of agriculture, power generation, and the textile industry. The first industrial revolution was also accompanied by a scientific and political revolution and England was said to be a major player (O'Brien et al., 2000). The second industrial revolution happened around the turn of the 20th century, characterized by new technologies in a number of industries. New technologies were seen in steel manufacturing, the chemical industry, electricity, aviation, and automobiles. Although more unofficial, a third revolution was said to have occurred when the Japanese introduced the ideas of quality, efficiency, and customer value into manufacturing (Luther, 2009; O'Brien et al., 2000). The Japanese developed 'Just-in-Time' manufacturing, which became the basis for today's lean manufacturing techniques.

3.1.2 Industrialization in other industries

The industrial revolutions offered numerous benefits to many manufacturing industries, such as reduced costs, improved product quality, faster production; however, industrialization and automation of house construction has been limited (O'Brien et al., 2000). If the building industry had made technological improvements similar to the aircraft and automotive industries, we would be living in much more technologically advanced houses today (as cited in Horden, 2001). If products such as cars and

computers were produced in a similar manner to buildings, they would be very expensive (Richard, 2004). There are many lessons to be learned from other industrialized industries.

In the case of the automotive industry, before the breakthrough of the assembly line, Ford motors built cars by hand, one at a time (Luther, 2009). This process required hours of skilled labour, resulting in high costs and high product prices. In April of 1913, a breakthrough occurred; the production process for a flywheel magneto was divided into a series of steps and employees were instructed to perform one step each before passing the flywheel onto the next person. This technique significantly reduced the time required to assemble the part and the technique was slowly applied to the assembly of other parts within the factory. In October of 1913, Ford put together a simple assembly line in which a car chassis was dragged across the floor while employees attached parts to the car. The production method significantly reduced the time required to assemble a car and Ford continued to improve the process.

Apart from the adoption of assembly lines, other processes have increased the competitiveness of industrialized manufacturers (O'Brien et al., 2000). The integration of computer systems into production has increased the accessibility of project data to various stakeholders. The use of three-dimensional object modelling, computer-aided design (CAD) programs, and computer-aided machinery has also improved the consistency and accuracy of production methods.

Just-in-time (JIT) manufacturing has also been widely implemented to improve production efficiency. The three goals of a JIT system are to minimize product inventories and waste, to strive for continuous improvement, and to maintain respect for all employees. Developing partnerships with component suppliers is also necessary to developing a successful JIT system.

Many of these systems and processes can also be applied to the construction industry to improve the productivity and efficiency of construction.

3.2 Industrialization in the construction industry

Industrialization in the construction industry was first introduced in 1851 by architect Sir Joseph Paxton. Paxton designed an exhibition for London that came to be known as the 'Crystal Palace.' The design of the exhibition demonstrated an early use of modularisation in building design. A glass panel was used as the building system module and the building was designed according to the dimensions of the panel. Unfortunately, the adoption of Paxton's innovative building techniques has been limited.

The main technological advancements in the industry have been in material substitutions and building locations, not in construction methods (O'Brien et al., 2000). For example, steel-frame construction is often used as a replacement for wood-frame construction, but the construction processes for both systems remain the same. Industrialization has only occurred on a small-scale with small site factories, innovations in modular homes, and prefabricated structural panels, but the industry at large is still highly labour intensive and characterized by low productivity, large amounts of waste, and out-of-date technologies.

Richard (2005) identified five stages of industrialization in the building industry: prefabrication, mechanization, automation, robotics, and reproduction. While the first four stages require significant investments in production facilities, they tend to replicate traditional construction practices. The fifth stage, reproduction, requires the development of innovative processes to simplify the construction process.

Prefabrication is the first stage of industrialization (Richard, 2005). As previously discussed, prefabrication implies the production of building components or modules in a factory. Even if automated devices are used, the same building processes and materials used in on-site building are very often used in prefabrication as well. However, if a prefabrication plant is able to achieve mass production, economies of scale can be realized and construction costs can be reduced by as much as

15% (Richard, 2005). Prefabrication is often accompanied by mechanization, the second stage of industrialization. Mechanization is the use of machinery to ease the work of employees. In prefabrication, machinery such as pneumatic hammers and Computer Numerical Controlled (CNC) bridges are often used.

The third stage of industrialization is automation (Richard, 2005). Automation is the process by which the tasks performed by employees are completely taken over by machinery. Although automation results in a reduction in labour requirements, industrial engineers, programmers, and supervisors are still needed to run the machinery. In Sweden, automated production of wood-framed panels for single-detached homes in the 1990s resulted in up to 27% savings, compared to conventional construction methods (Richard, 2005). In order to achieve this economy, a large production quantity was needed.

Robotics is the fourth stage of industrialization (Richard, 2005). Robotics allows for mass customization as complex parts can be produced, and the parts can vary from one unit to the next. Robots have multi-axis flexibility and are used in combination with computer-aided manufacturing (CAM). In Japan, the building industry is particularly advanced in the areas of robotics and computer control systems, developed in response to a shortage of skilled labour (O'Brien et al., 2000). Although robots perform well in specific applications, building processes would need to be modified in order to integrate the technology throughout the entire construction process.

The final stage of industrialization is reproduction, a term borrowed from printing technology (Richard, 2005). Reproduction is the use of innovative technologies to simplify the production of complex products and is often used in combination with other stages of industrialization. Reproduction is implemented to avoid the repetitive tasks that characterize crafts-based production, such as nailing wood studs. In order to generate new innovative ideas, it is important to recognize what a system is meant to do, and not what it used to be. An example of reproduction is the development of printed

circuits, and further, the integrated circuit, resulting in low-cost electronic devices (Richard, 2005). In the construction industry, a similar innovation has been proposed. An innovative residential plumbing system has been developed that is formed by two pre-moulded sheets with embossed conduits. When the sheets are bonded together, the system of plumbing conduits is formed.

Adoption of these systems and technologies into the current construction industry will depend on a number of factors. Recommendations can be made to ensure success in adopting new production processes and technologies.

3.3 Considerations for success in prefabricated housing

Industrialization of the construction industry is believed to be attainable by developing innovative, yet practical uses, of current systems and technologies (O'Brien et al., 2000). In particular, firms need to integrate current technologies, such as advanced CAD systems, numerical control methods, and other production technologies, into all operations.

Success in modularization and prefabrication also requires a greater degree of preconstruction planning compared to conventional construction (Luther, 2009). During the design stage, there are a number of important considerations. Firstly, it is important to look for building components (modules) that can be repeated throughout a structure and connected or integrated together, leading to efficiencies in design and construction. Systems should also be developed in which components are repeated to create structures of different sizes and components can be added or replaced with minimal impacts on the building system, allowing for modifications of the building with changes in technology. These considerations are characteristics of a practice known as 'modular architecture,' a practice that can improve the flexibility of a structure during use and maintenance.

Improving environmental awareness is also considered to be an important factor in the development of prefabricated building systems (Richard, 2005). In order to better promote the environmental benefits and reductions in waste achieved through prefabrication, training and education for the construction industry is recommended. The reduced environmental impacts associated with prefabrication should be the primary consideration for adopting the construction method (Richard, 2005). To ensure that contemporary design and construction is sustainable, renewable energy systems should also be incorporated into building services (Luther, 2009).

There are also external factors that can influence the success of increased prefabrication. West (2008) identified four factors that supported the boom in prefabricated housing in the U.S. during the 1950s. The first factor was the availability of finance, ultimately the availability of mortgage loans for prefabricated housing. The second factor was an adequate supply of land in suburban areas to support low density prefabricated housing. The third factor was support among the population for timber construction, a factor relevant in the construction of wood-frame buildings. Finally, there was a desire in the market for prefabricated housing, due to a shortage of housing and mainstream marketing of prefabrication.

4.0 Conclusion

Prefabrication should be seen as an opportunity to increase the efficiency and productivity of the current construction industry. Prefabrication is said to be the first step in achieving industrialization in the construction industry and can result in reduced costs, improved product quality, and faster construction times, benefits that have already been realized in many manufacturing industries. Higher degrees of industrialization can be achieved through mechanization, automation, robotics, and reproduction.

The use of prefabrication in construction should be assessed for the specific case of a company or individual project and both the advantages and disadvantages should be considered. The main advantages of prefabrication are improved efficiency and reduced environmental impacts. The controlled environmental conditions in a factory allow for the use of automated equipment and reduce the risk of project delays, resulting in reduced project durations and improved project scheduling. Climatic protection and better supervision during prefabrication improve product quality. Prefabrication can also result in buildings that are diverse in design, while ensuring reduced construction waste, better integration of building systems, and reduced operating energy requirements. The main disadvantages of prefabrication are inflexibility to changes in design and high initial construction costs. The incorporation of prefabrication into existing construction methods will not be met without challenges, but a number of considerations for success can be made.

Success in prefabrication is believed to be attainable through the development of innovative uses of current systems and technologies. Current technologies include CAD systems, numerical control methods, and other production technologies. To ensure success, the use of prefabrication and modularization need to be considered during the design stage of a project. External factors including the availability of finance, land supply, public perception, and demand will also affect the success of prefabrication. Finally, improving environmental awareness is considered to be an important factor in the development of prefabrication in the construction industry.

Although traditional construction methods may be able to satisfy current housing demands in Canada, companies that continue to be successful into the future must develop innovative products and production processes and must address the growing environmental concerns associated with construction. There is a growing need to change the way we build and prefabrication is a step in the right direction.

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