

# AN ANALYSIS ON: THE POTENTIAL OF PREFABRICATED CONSTRUCTION INDUSTRY

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STEPHEN TSE-LUN CHIU



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## ABSTRACT

Prefabricated houses are constructed with components manufactured off-site. In the past, prefabricated homes were often criticized as being monotonic and poor in quality; however, recent modernist movement has stirred interest in prefabricated building methods once again.

Industry leaders argue and debate on almost all aspects of prefabrications. This paper focuses on six factors of prefabrication: cost, time, quality, environment, design capability and safety. Based on analysis, it was found that the greatest strength of prefabricated housing lies in its cost and time saving, and the greatest weaknesses lies in prefabricated housing's incapability to deliver customized designs.

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## DEDICATION

This thesis is dedicated to my family, with love and gratitude.



## KEYWORDS

Prefabrication, prefabricated housing, prefabricated construction, industrialization, offsite assembly, mass production, assembly line production

Advantages and disadvantages, benefits and drawbacks

# 1 INTRODUCTION

## 1.1 DEFINITION

Contemporary housings can be divided into two major construction methods: traditional construction and prefabricated production. Traditional construction refers to buildings that are built and assembled on-site. For instance, most Canadian houses are built with the stick and frame method (also known as framing, or light frame construction), which is a major type of traditional construction. Such method consists of structural members and sheathing units; where structural members like studs and joists are assembled to form the skeleton of a building's foundation, and the sheathing units (such as wall and floor panels) are added to form the outlook of the building.

Prefabricated production, on the other hand, consists of buildings that are assembled with fragments that were manufactured off-site. The extent of prefabrication may vary significantly. The term "prefabrication" is easily mixed up with other commercial terms such as modular or pre-cut construction. However, prefabrication is neither a single nor a combination of processes identifiable and measurable<sup>1</sup>; but an amalgamation of terms used to describe constructions processes involving manufacturing and pre-assembling components off-site.

## 1.2 FOUR TYPES OF PREFABRICATION

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<sup>1</sup> White, R. B. Prefabrication: A History of Its Development in Great Britain,. London: Her Majesty's Stationery Office, 1965. Print.

Four categories of prefabricated construction are: pre-cut, panelized, modular, and manufactured. The difference between the four depends upon the level of manufacturing, and the magnitude of offsite assembly.

### *1.2.1 PRE-CUT*

Pre-cuts are used to refer to building materials that are machined into pre-determined dimension, and are notched and drilled in according to specification. Raw materials are manufactured and processed to be transported in packages, or ready-to-use kits. This method is a type of prefabrication that entails the least amount of off-site assembly.

Pre-cut homes were commonly ordered through catalogues during the early 20<sup>th</sup> century. It is also known as a kit home, ready-cut home, mail-order home, or catalogue home. Between the three decades, from 1908 to 1940, Sears and Roebuck sold over 70,000 units of pre-cut homes. The most popular pre-cut style during the period was the colonial singled detached home. Nowadays, people's preferences have shifted from the traditional revivalist style to a more contemporary, modernist style – reducing the complication of manufacture processes and causing significant changes in the prefabrication housing industry. Today, pre-cuts are being utilized more in building apartments, townhouses, and emergency shelters – where, saving in costs and rapid construction are emphasized. Examples of such prefabrication can be found in: IKEA BoKlok apartments<sup>2</sup> in Norway, Finland, and England, BAKOKO's Onjuku Beach House<sup>3</sup> in Tokyo, Japan, Katrina Cottages<sup>4</sup> in Florida, U.S.A, and DH1 Disaster Houses<sup>5</sup> designed by architectures in California, U.S.A.

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<sup>2</sup> "Welcome to BoKlok." BoKlok. 12 Mar. 2012 <<http://www.boklok.com/theconcept/Start/>>.

<sup>3</sup> "BAKOKO | Design & Development | Tokyo." BAKOKO. 12 Mar. 2012 <<http://www.bakoko.jp/>>.



Figure 1: Pre-cut - BoKlok by IKEA

### 1.2.2 PANELIZED

The second type of prefabrication is the panelized construction. It shares similarities with pre-cut manufacturing; however, panelized construction not only process raw materials into usable fragments, but also assembled the fragments into panel units. That is to say, pre-cut kits are composed of processed lumbar and boards, and panelized units of walls, floors, or roofs that have been pre-wired, insulated, and can be easily assembled into various compartments.

Panelized construction usually uses the same materials as traditional construction – for instance, plywood, oriented strand board, lumber, insulation, and drywall. However, some companies utilize panel production with materials such as thick oriented strand walls<sup>6</sup> and

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<sup>4</sup> 16, Jenny Jarvie Los Angeles Times Staff Writer December. "Post-Katrina cottages get a lukewarm welcome." Los Angeles Times. 16 Dec. 2007. Los Angeles Times. 12 Mar. 2012 <<http://www.latimes.com/news/la-na-cottage16dec16,0,3467479.story>>.

<sup>5</sup> "Design for Disaster â Aid, Victims, Information, Communication, Knowledge, Experiences, Ideas, Projects." Precut Home : Design for Disaster â Aid, Victims, Information, Communication, Knowledge, Experiences, Ideas, Projects. Web. 17 Mar. 2012. <<http://www.design4disaster.org/2011/04/06/precut-home/>>.

<sup>6</sup> "The Stealth Barn by Carl Turner Architects | GBlog." GBlog. Web. 17 Mar. 2012. <<http://blog.gessato.com/2012/02/15/the-stealth-barn-by-carl-turner-architects/>>.

structurally insulated panels<sup>7</sup>. A thick oriented strand wall is the sturdier version of an oriented strand board – a panel that is made with alternating strands glued together. Structurally insulated panels on the other hand, is a composite consisting of a ridged polymer foam insulation, sandwiched between two structural panels. This type of building materials creates a more energy efficient alternative to panelized homes. Due to the construction of panelized building materials and the large size of pieces, the shipment of panels is often constrained due to limitation in the size of trucks and containers.



**Figure 2: SIP – MOD.FAB by Frank Lloyd (Structurally Insulated Panel)<sup>8</sup>**



**Figure 3: Panelized OSB – Stealth Barn by Carl Turner (Oriented Strand Wall)<sup>9</sup>**

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<sup>7</sup> "Thermapan Structural Insulated Panels: The Better Way to Build." Thermapan Structural Insulated Panels: The Better Way to Build. 12 Mar. 2012 <<http://www.thermapan.com/>>.

<sup>8</sup> "Gliving.com." G Living. Web. 17 Mar. 2012. <<http://gliving.com/modfab-frank-lloyd-wright/>>.

### 1.2.3 MODULAR

Modular construction, the third type of prefabrication, takes the panelized construction and adds another level of manufacturing. At this level, the structural shapes of the house become more apparent. Sometimes, modular homes are divided based upon functional units, such as: the kitchen, bedroom, bathroom, and living room. Often, the modules are built as halves, quarters, and other irregular shapes for easier transportation from the place of manufacture.

In terms of structural soundness, modular homes are often considered to be built at a higher quality than other prefabricated buildings<sup>10</sup>. This is due to modular homes having a larger amount of pre-manufactured parts and components. In order to withstand the loads applied during crane lifting and transportation, the modular unit must be constructed with high structural rigidity. A typical modular construction uses about ten to twenty percent more materials than a typical traditional construction<sup>11</sup>.

Examples of modular housing include: Thomas Lind's MoMo<sup>12</sup> in Sweden, Weber Haus' Option House<sup>13</sup> in the United Kingdom, and HIVE's B/C/X<sup>14</sup> in the United States.

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<sup>9</sup> "Carl Turner Architects London." Stealth Barn. Web. 17 Mar. 2012. <<http://www.ct-architects.co.uk/projects/stealth-barn/>>.

<sup>10</sup> "Resource Record Details." FEMA Library. Web. 14 Mar. 2012. <<http://www.fema.gov/library/viewRecord.do?id=2765>>.

<sup>11</sup> "Modular Building." Wikipedia. Wikimedia Foundation, 21 Mar. 2012. Web. 22 Mar. 2012. <[http://en.wikipedia.org/wiki/Modular\\_building](http://en.wikipedia.org/wiki/Modular_building)>.

<sup>12</sup> "MOMO by Thomas Lind, Living Modular Getaway." Jetson Green. 12 Mar. 2012 <<http://www.jetsongreen.com/2007/10/momo-by-thomas.html>>.

<sup>13</sup> "WeberHaus - Building the Future: Option." WeberHaus. 12 Mar. 2012 <<http://www.weberhaus.co.uk/1640.html>>.

<sup>14</sup> "Hive Modular - B-Line Models." Hive Modular m.a Architecture InterModal Design. 12 Mar. 2012 <<http://www.hivemodular.com/Homes/Models/BLines.html>>.



**Figure 4: Modular – X-Line 008 by HIVE**

#### *1.2.4 MANUFACTURED*

The most complex type of prefabrication is the manufactured construction, often referred to as mobile homes. This type of construction is the most comprehensive type of prefabricated construction. Unlike any other prefabricated housings, manufactured buildings are fully assembled prior to shipment. The distinguishing feature of this type of housing is the permanent chassis attached to the housing. In the United States, mobile homes are regulated by the Housing and Urban Development Code (HUD), to have a permanent chassis. Whereas, in Canada, there is no regulation that directly corresponds to the HUD code. All factory built housings must meet the standards regulated by the Canadian Standard Association (CSA). Hence, although manufactured home owners commonly place their houses at a permanent location, the mobility of the manufactured home is never lost.

Manufactured homes are commonly built with 30% more materials than traditional homes, even more than modular homes<sup>15</sup>. However, despite this, manufactured homes are still

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<sup>15</sup> "Thomson Housing." Thomsonhousing. Web. 04 Apr. 2012.  
<[http://www.thomsonhousing.ca/Home\\_Page.php](http://www.thomsonhousing.ca/Home_Page.php)>.

considered to be a less desirable form of prefabricated housing. This is mainly due to the limitation in house size. Most mobile homes are small because of transportation limitations. In other words, manufactured homes are constrained to the width of the roads used during transportation.

Manufactured homes typically come in two sizes: single-wide and double-wide. Single-wide are houses constructed with a width no wider than 5.5 meters, and length no longer than 27 meters. Double-wide homes, on the other hand, are houses with width greater than 6 meters; hence, they must be broken down and transported in units.

Even with these constraints, there are several manufactured homes that are uniquely designed. Examples include: minimalist design Zenkaya<sup>16</sup>, foldable design Habitflex<sup>17</sup>, and luxurious design Marchi<sup>18</sup>.



Figure 5: Manufactured – Zenkaya by Zenkaya

### 1.3 HISTORY: SIX STAGES

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<sup>16</sup> "Zenkaya." Zenkaya. Web. 14 Mar. 2012. <<http://www.zenkaya.com/>>.

<sup>17</sup> "HABITAFLEX Foldable Home." HABITAFLEX. Web. 22 Mar. 2012. <<http://www.habitaflex.com/>>.

<sup>18</sup> "Motorhome? Motormansion, more like... World's most expensive campervan up for sale - for a cool £1.9m." Mail Online. 12 Mar. 2012 <<http://www.dailymail.co.uk/news/article-2050494/Worlds-expensive-motorhome-sale-1-9m.html>>.



The concept of prefabrication can be traced back to Ancient Egypt, where stone blocks are prefabricated to specific dimension and transported to the pyramids<sup>1920</sup>. Yet, the first “true” prefabricated home did not come to existence until the 16<sup>th</sup> century<sup>21</sup>.

### 1.3.1 PRE-1900S

In 1624, there was a panelized wood house constructed in England and transported to Massachusetts for the accommodation of a fishing fleet. This was the earliest known prefabricated home. Until the Industrial Revolution, there was very little activity, as there was no need for prefabricated homes. Without the benefits of mass production, prefabrication was not cost efficient.

During the Industrial Revolution, from 1750 to 1850, there were tremendous developments in the prefabrication industry because of breakthroughs in mass production— due to the growing need of transportable settlement camps and housing caused by England’s colonization frenzy. One of the earliest advertised, and perhaps the most recognized large scale prefabrication production was the Manning Portable Cottage<sup>22</sup>.

### 1.3.2 1908-1940

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<sup>19</sup> "How Were the Pyramids Built?" *Shipping the Stone Blocks for the Pyramids on the Nile and the Nile Channel*. Web. 14 Mar. 2012. <<http://www.cheops-pyramide.ch/khufu-pyramid/nile-shipping.html>>.

<sup>20</sup> "News Articles and Promotional Articles on All Topics â€” Submit Articles." The Pyramids of Egypt. 12 Mar. 2012 <<http://www.centrorisorse.org/the-pyramids-of-egypt.html>>.

<sup>21</sup> "A Timeline of Prefab History." - Design. 12 Mar. 2012 <<http://www.good.is/post/a-timeline-of-prefab-history/>>.

<sup>22</sup> Bergdoll, Barry, Peter Christensen, and Ron Broadhurst. "Projects." *Home delivery: Fabricating the modern dwelling*. New York: Museum of Modern Art, 2008. 40.

During the early 1900's, Sears' catalogue program became a popular source of advertising and sales in the American household. Every item available was listed in the Sears and Roebuck catalogue – this includes houses as well.

During this period, most of the prefabricated houses are not designed to be as simple as for example, the IKEA furniture that we have today. Most of housing designs are for people with some experience in house construction. Regardless, the variety offered by these catalogues was tremendous. Every size, style, and quality imaginable was available, from the simple vacation cottages to complex mansions.



Figure 6: Sears Catalogue Home<sup>23</sup>

After the Great Depression, Sears' catalogue homes became less attractive and sales of Sear's homes was eventually cancelled. This was due to a variety of factors, such as large amounts of defaulted debts caused by the depression, changes in housing laws, increased

<sup>23</sup> "Alcana Ferrin & Her Sears-Roebuck House, Wilmore, Comanche County, Kansas." RootsWeb.com Home Page. Web. 17 Mar. 2012. <[http://www.rootsweb.ancestry.com/~kscomanc/ferrin\\_alcana.html](http://www.rootsweb.ancestry.com/~kscomanc/ferrin_alcana.html)>.

complexity in modern construction, the rise of the middle class [people became wealthier] and changes in housing preference.<sup>24</sup>.

### *1.3.3 1911-1931*

1911 to 1931 was the age of experimentation in the housing industry. Architects such as Frank Lloyd Wright and Walter Gropius experimented with prefabrication as a method of reducing labour cost and solving housing shortage problems. In 1936, Frank Lloyd Wright designed the Usonian House using the grid system – a system that allows repetition of details and dimensions<sup>25</sup>. Walter Gropius also utilized prefabrication on several houses, such as Aluminum City and The Alan I W Frank House.

### *1.3.4 1930-1945*

Between 1930 and 1945, the prefabrication industry experienced its second growth. The reason of this growth was due the poor economy and people's desire for a more affordable home during the depression and war.

There was also a great need of standardized compartment during the Second World War. One of the most recognized prefabricated constructs during this period was the Quonset hut<sup>26</sup>. Approximately 150, 000 to 170, 000 units of these funny half dome shaped houses were built during the war.

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<sup>24</sup> "What is a Sears Modern Home?" Sears Archives Home Page. 12 Mar. 2012

<<http://www.searsarchives.com/homes/>>.

<sup>25</sup> "Frank Lloyd Wright - The Jacobs House 1936." Frank Lloyd Wright. 12 Mar. 2012

<<http://www.usonia1.com/>>.

<sup>26</sup> "Quonset hut." Wikipedia. 03 Oct. 2012. Wikimedia Foundation. 12 Mar. 2012

<[http://en.wikipedia.org/wiki/Quonset\\_hut](http://en.wikipedia.org/wiki/Quonset_hut)>.

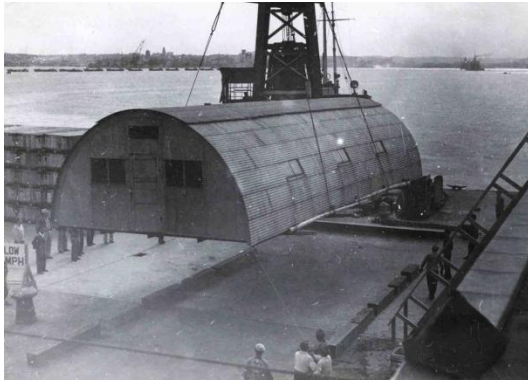


Figure 7: Quonset hut<sup>27</sup>

### 1.3.5 1946-2000

After World War Two, there was strong demand for standardized homes, mostly for returning war veterans. As the economy recovered from the downturn, interest in inexpensive prefabricated housings declined. The role of standardized prefabrication slowly eroded from housing, to camping units and to storage spaces. Decline in the number of prefabrication sales continued into early 21<sup>st</sup> century.

### 1.3.6 2000 AND AFTER

After the turn of the century, there was a sudden influx of interest in the prefabrication industry<sup>28</sup>. Countless contemporary architects attempted to re-evaluate prefabrication housing as a potential way to sustainable living. Several other architects, such as minimalists, also experimented with prefabrication as a possible approach to modern design. Not only that, few others also tested prefabrications as solution to overwhelming

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<sup>27</sup> "HEADQUARTERS." Headquarters U.S. Army Corps of Engineers. Web. 17 Mar. 2012.  
<<http://www.usace.army.mil/>>.

<sup>28</sup> "Victoria University of Wellington." Kiwi Prefab: Prefabricated Housing in New Zealand: An Historical and Contemporary Overviewwith Recommendations for the Future. Web. 15 Mar. 2012.  
<<http://researcharchive.vuw.ac.nz/handle/10063/1111>>.

number of home buyers, emphasizing on providing solutions for high population density countries – through prefabricated apartments, town homes and high-rises<sup>29</sup>.

## 1.4 RESEARCH RATIONALE

### 1.4.1 *OBJECTIVE*

My goal for this paper is to analyze the benefits and drawbacks offered by prefabrication, in hopes of providing evidence to see if prefabrication is a feasible solution for the growing population in British Columbia<sup>30</sup>.

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<sup>29</sup> Chino, Mike. "PREFAB FRIDAY: Unpacking the Prefabs at MOMA!" Inhabitat: Future-forward Design for the World You Inhabit. 8 Aug. 2008. Web. 16 Mar. 2012. <<http://www.inhabitat.com/2008/08/08/prefab-friday-unpacking-the-prefabs-at-moma/>>.

<sup>30</sup> "Population Estimates." , British Columbia and Sub-Provincial. Web. 17 Mar. 2012. <<http://www.bcstats.gov.bc.ca/StatisticsBySubject/Demography/PopulationEstimates.aspx>>.

## 2 BENEFITS

Prefabricated buildings offer two primary advantages over the traditional building – the costs and the time. Many other advantages are achieved using an in-plant manufacturing model, such as quality, environmental, design capability and safety factors.

### 2.1 COST: ECONOMIES OF SCALE

In terms of cost savings, there are several factors that all contribute to the advantages of prefabricated production.

Prefabricated production requires the manufacturer to purchase materials in larger quantities, compared to traditional builders. By purchasing materials in larger quantities, it is more likely that the manufacturer would be able to receive volume discounts from suppliers. Even though a volume discount reflects less profit earnings for the suppliers on a per unit basis, the overall revenue gain from larger volume purchase is still significant. By offering competitive pricing, the suppliers may also benefit from more stable business relationships with the manufacturer. That is to say, prefabricated housing manufacturers may be more willing to sign a long-term contract with the suppliers, to be able to obtain building materials at a lower cost. The suppliers, on the other hand, may feel more confident in offering more attractive pricings, to sustain long-term relationship, and to maintain customer loyalty.

Besides reducing input costs, prefabricated production can also lump together and disperse personnel costs. In prefabricated production, manufacturing plants hire architects, engineers, and other specialists in house. This means overheads, admins, and

technician costs can be distributed over quantity production. The larger the quantity of production, the lower the overhead costs, per unit becomes. This means that the incentive of hiring better or more specialized personnel is higher. And because of this, there is higher potential for prefabricated production to achieve higher quality production. In addition, this also means that the cost of investing in specialized machineries and process is lower – per unit.

In house production allows for more efficient processing. Specialized tools, such as precision cutters and robots, can be used to reduce material wastage. Improved processes, such as coordinated process flows and quality control stations can be implemented to improve the efficiency and quality of production. These specialized investments reduce the amount of material and time wasted and the cost associated with these wastages. Improved process flows also decrease the potential of customer dissatisfaction by implementing “costly” inspection and quality control protocols; thus, come-backs and reworks due to defect and dissatisfaction, as well as costs associated with these issues, can be mitigated.

Prefabrication production uses assembly line production, which breaks tasks into smaller and simpler components. This improves the learning curve of tasks. Lower learning curve means that workers can become skilled quickly. And production efficiency, as well as yield, can be increased, as a result. Better workers reduce the amount of materials wastage, and increase the productivity of the production; which, translates to lowering of costs and improving monetary returns for the company.

Similarly, prefabricated housing manufacturers experiences lower overall cost in labour because of how the tasks are created and assigned. In assembly line production, long and

difficult tasks are broken down into simpler tasks. This means that there are fewer places and positions that require skilled labour – in contrast, traditional construction require all tasks to be carried out by skilled labour. So the salary of these workers can be greatly reduced.

Finally, in terms of cost, prefabricated production utilizes the benefits of globalization. Scratching the surface, globalization enables trade and competition between different economies and countries. Prefabrication companies can benefit from lower material, labour, and other distinctive advantages that various economies possess. Through globalization, prefabrication companies can produce their products at higher quality and lower cost. Prefabricated housing companies can also expand services to markets around the world, which increases size of production and, therefore, further improves the economies of scale.

From the consumer's perspective, globalization suggests the decrease in price due to the increase in competition. It also suggests that customers can enjoy more varieties of housing to choose from because of an increased number of production companies. There will be more diversity in the design of housing and more features to choose from because of the unique culture, material availability and specialization of companies.

## 2.2 TIME: ON-SITE & IN-PLANT

In terms of time, the savings can be broken down into two parts: on-site saving and in-plant saving.

For on-site time saving, prefabricated construction, in its most basic form, have parts and components pre-drilled and pre-cut to specification, which minimizes the amount of setup



and labour time. This is critical, for both builders and end users. If the house can be built in 1 month, as contrary to the typical 6 months building time in traditional construction, the end users can rent the house out and get income. The builder, on the other hand can move on to a new project and increase the number of cases/ amount of revenue per year.

According to a FP innovation Forintek case study, the total number of man hours required to construct a panelized prefabricated housing is about 40% less than traditional housing, and the lumber and sheathing waste generated is 50% less<sup>31</sup>.

In terms of the logistic of prefabrication, there are also the potential areas of time saving. For instance, delivery of material for prefabricated construction is less sophisticated than in traditional construction. In traditional construction, the head contractor coordinates a group of sub-contractors, such as electricians, plumbers, and roof and tile workers. And each of these sub-contractors have their own material suppliers, which means that if one of these suppliers or sub-contractors experience a delay, there is a potential for the whole process to be halted. In prefabricated construction, the possibility of this is greatly reduced. Since almost all materials and parts have to go through and are accounted for in-plant, the potential of components missing or delayed is slim.

Furthermore, in-plant production uses assembly line theory; “parts are added to the product in a sequential manner<sup>32</sup>.” This is faster than traditional “handcrafting” style method because workflow is designed in a way to minimize congestion. In typical traditional construction, parts such as lumber and panels are cut using handheld machineries and small work benches. The logistic of the workflow may be somewhat

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<sup>31</sup> Prefabricated vs. Stick Frame." Pacific Homes. 12 Mar. 2012 <<http://pacific-homes.net/post/2579>>

<sup>32</sup> "Assembly Line." Wikipedia. Wikimedia Foundation, 04 June 2012. Web. 05 Apr. 2012. <[http://en.wikipedia.org/wiki/Assembly\\_line](http://en.wikipedia.org/wiki/Assembly_line)>.

designed to improve the speed of construction. However, these designs are nowhere near efficient. Workers from various sub-contractors move from one station to another, and collide with one another. Additionally, bottlenecks are often created because of the lack of a particular resource or machineries. In the prefabrication construction, congestion is minimized by well-designed workflow. Machineries are placed in fixed positions, based on calculated input-output and process sequence. Moreover, delays caused by human and environment factors are also minimized, as the manufacturing facility is a controlled environment. The advantage of in-plant production is having better control over factors that could influence the efficiency of the production. Having an inventory or a clustering of suppliers – as in automotive manufacturer Toyota’s business model, minimizes the probability of work halts and delays. Having a roof on top of the work area reduces the chance that materials and finished goods are exposed to damaging factors such as weather.

## 2.3 QUALITY: SPECIALIZATION & INSPECTION

Prefabricated construction has the potential of creating higher quality product, for several reasons.

The first reason is that prefabricated construction uses assembly line construction. In assembly line construction, workers get skilled quickly because tasks are broken down into simpler components. Hence, there is a lower learning curve for each task. Skilled workers mean less damage and defects. In assembly line construction, these prefabrication workers can also try out various tasks to see which task they are most proficient in. By choosing the right person for the right task, the company can maximize the quality of the product and minimize the number of products that are returned. One of the most important goals of

most prefabrication manufacturers is to minimize the number returns. Returns are costly, especially for prefabricated housing. In the case of prefabricated housing, returns may involve tedious, costly, and time consuming inspection process. There is also the potential of long distance transportation and delivery of materials. In traditional construction, contractors often only serve local demands, which mean that it is easy for them to replace a part quickly and this suggests little incentive for traditional contractors to implement measures of quality control. Hence the quality of product might not be designed to be as good as it would be in prefabricated setting.

The second reason for prefabricated construction to produce higher quality product is that the construction allows for the potential usage of better and more expensive machineries. Prefabricated production companies often also invest in state of the art machineries – such as precision cutting – to improve consistence and quality of the product, to reduce defects. In traditional constructions, it is difficult to implement expensive machineries, because even though expensive machineries may produce better product quality, traditional methods usually have a smaller budget to begin with, and work is done onsite, which means that the immediate volume processed is too small to justify the setting up of hi-tech machineries.



Figure 8: Example of expensive machinery: Hundegger<sup>33</sup>

The third reason is that prefabricated houses need to meet the strength and load bearing requirements during transportation. As mentioned previously, prefabricated housing are designed to be transported. Not only do they have to be strong enough to withstand its own weight during crane lifting, withstand disturbance during transportation; also, it has to be designed in a way that could survive in various environmental conditions. In most cases, prefabricated housing manufacturers do not know where their houses will end up. They have to over-design the house, to reduce the probability of failure during service. In some cases, this means that the walls of the prefabricated housing have to be sealed on both sides - to reduce exposure of interior parts to moisture, insects, and other harmful substances. These requirements encourage the application of advanced materials that are lightweight, durable and weather resistant. Besides voluntary incentives from manufactures, having assembly line construction also helps the implementation of inspection policies. In the prefabricated construction facility, it is easy to implement quality control because all of the processes are divided into stations – meaning that the addition of monitors between stations would not interfere with normal workflow of the production. In

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<sup>33</sup> "Hundegger Products - World's Leading CNC Machinery." Hundegger USA. Web. 06 Apr. 2012. <<http://www.hundeggerusa.com/products.html>>.

traditional construction, it is difficult for contractor to implement in-process quality control – traditional constructions are often disorganized in the sense that there is no continuous workflow. Workers in some traditional environment are expected to be dynamic, and handle various tasks, which makes in-process inspections even more difficult. Another potential problem that could be found traditional construction is the division of tasks. Commonly, traditional construction work is divided and assigned to sub-contractors. The sub-contractors are responsible for their own work and, strictly speaking – do not have to care about the overall cohesiveness of the work. In addition, they are only inspected by the head contractor when their work is done. So if the head contractor decides to only worry about his or her time and bottom line and cut corners, the customer suffers as a result.

## 2.4 ENVIRONMENT: POLLUTION CONTROL

In terms of the environment, one of the benefits that prefabricated production has over traditional construction is its ability to implement methods of pollution control. In a housing production, there are many potential areas of waste production. For instance, emission of VOC, Volatile Organic Compound, discharge of debris and wood chips, and the leftover short length lumbers. For prefabricated productions, in house waste materials can be collected to be reused or recycled as raw material for another product. For instance, wood chips can be collected, processed and reformed as OSB, oriented strand boards, or as MDF, medium density fibre boards. Leftover lumbers can be stored in inventory to be reused in other production. Emission from over-spraying can be filtered and reused. Unrecyclable waste can be condensed and properly disposed of instead of being released into the atmosphere or end up in landfills. In the case of traditional construction, the reuse and recycle of materials is difficult. Traditional construction occurs on-site; which means

that if the contractor wishes to, for instance, store a piece of left over lumber, the contractor needs to rent a storage facility or bring it back and bring it to the next site. If the contractor wishes to implement emission control, workers need to go through the time consuming process of assembling and disassembling the filtering apparatus. Performing this task at every single house is not only time consuming, but extremely costly.

In addition to pollution control, prefabricated production also allows for noise control. In prefabrication, the products are produced in, generally speaking, a remote location, which means that no matter how loud the production is, neighbours will not feel annoyed about the construction. And, although there might still be some assembly required on-site, the level of noise is much lower, because most of the machining is done in-plant. The duration of final construction and noise pollution will also be much less than traditional construction projects.

Some people also argue that prefabricated production is more environmental friendly as less gas is consumed during transportation compared to traditional construction. The claim is that prefabrication manufacturing plants can be strategically placed in locations that minimized the amount of transportation between suppliers and the plant. By forming alliances and clustering with similar industries, there could be dramatic savings in gas consumption. In addition, the saving could also happen on the workers side. Prefabrication workers usually have a permanent location that they commute to on a daily basis. So they are more likely to live in a location nearby; whereas in the case of traditional worker, the job is temporary and there is little incentive for them to live close by. In one of the debates, Michelle Kaufmann claimed that the average distance that the workers have to travel to

work for prefabrication manufacturing is 15 miles and for traditional construction is 25 miles. The overall material transportation distance is also 1/3 less than that of the traditional construction<sup>34</sup>.

Prefabrication construction encourages energy efficient designs and features. Prefabricated production has a greater incentive to implement special gadgets and other characteristics to differentiate and improve its competitive edge. In traditional constructions, although it is also favourable to differentiate, it is difficult because of the costs of research and design. Each house is designed differently, and it is hard to implement new features because the cost of innovation cannot be dispersed through production quantity. In addition, most traditional contractors lack the expertise to bring out advance designs; for instance, they lack having an architectural and engineering background. Contractors, in general, do not handle any architectural blueprints, they only work with or purchase designs from architects. Any non-standard specification is available by customer request, with a premium. If the customer is unaware of new technologies and energy efficient materials, such as SIP, structurally insulated panels, then it would not be implemented.

## 2.5 DESIGN CAPABILITY: DESIGN & MATERIAL

Besides environmentally friendly designs, prefabricated production also allows the implementation of unique designs, advanced materials, and high-tech features. Unique designs can be simple and clean minimalist style housing such as Zenkaya, it could also be functional designs, such as, Habitaflex's foldable home and Kieran Timberlake's

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<sup>34</sup> "The Great Prefab Debate [3:30 PM EDT]." Jetson Green. Web. 16 Mar. 2012.  
<<http://www.jetsongreen.com/2011/05/the-great-prefab-debate-today.html>>.

reconfigurable home, or it could be the zero energy<sup>35</sup> and passive house<sup>36</sup>. Advance materials includes, as previously mentioned, SIP and lightweight materials, and also other coating materials that cannot be applied using standard tradition construction methods. One of the high-tech features that seem to be catching on nowadays is the solar panel. Solar panels have the potential of save money in the long run. However, solar panels are, at the moment, is still very expensive compared to conventional energy sources, partially because of small scale production<sup>37</sup>. Prefabricated production can mitigate this deficiency, for suppliers, using large quantity orders.

## 2.6 SAFETY: UN-NECESSARY RISKS

Last, but not least, prefabricated production offers a higher level of safety for the workers. Workers spend less time performing high risk tasks such as working on top of 3 stories building in slipper conditions or handling chemicals and substances under minimal safe guards and protection. In-plant manufacturing allows for the implementation of guidelines and safety equipment to combat the task at hand.

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<sup>35</sup> "Startup's prefab homes aim for zero energy bills." Wwww.SFGate.com. 27 June 2011. 12 Mar. 2012 <<http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2009/06/22/BURR187SSG.DTL>>.

<sup>36</sup> "Worldchanging: Bright Green: LEED Platinum Prefab Home Now Available." Worldchanging: Bright Green. 12 Mar. 2012 <<http://www.worldchanging.com/archives/009437.html>>.

<sup>37</sup> "FAQ Section." Solar Is Future: But Isn't Solar Power Is Too Expensive? Web. 06 Apr. 2012. <<http://www.solar-is-future.com/faq-glossary/faq/facts-and-fiction/but-isnt-solar-power-is-too-expensive/index.html>>.



### 3 DRAWBACKS

Prefabricated production's greatest drawback lies in its incapability to deliver customized designs.

#### 3.1 COST: SETUP & FINANCING

Prefabrication may save money due to labour and time saved, but it also involves some costly setups. For instance, the prefabrication manufacturers first need to purchase land to build the factory, these factories require expensive machines and equipment to allow for production; then of course, they need to hire people to operate the facilities, which, when combined is a large budget expenditure. These costs are transferred to the customers, as part of the cost of house purchase. Even after the prefabricated manufacturers break even from the initial investment, and start to make a return, these profits are unlikely to be transferred to the consumers, because companies will try to maximize any possible profit for future investments.

On the other hand, if the capital invested cannot be recouped within the purposed timeframe, the benefits of large scale production cannot be realized; consequently, the accumulated interest of the project will build up. Therefore, as a result, the consumer price of the prefabricated housing will increase.

Besides the costly setup and related financial problems on the production side, prefabricated housing also has issues from the consumer's standpoint. There are arguments about how prefabricated houses are more difficult to finance. Prefabricated housings are not considered for house mortgage until they are permanently installed.

Unless the customer can purchase a piece of property and prefabricated housing outright, they will experience difficulty in obtaining a loan from banks. Most financial institutions feel reluctant to approve loans unless they have some form of collateral to secure their money such as a tangible asset. Builders also require upfront payment or a significant amount of deposit for the prefabricated house because they need to purchase it from the manufactures. In addition, there is also the concern about the depreciation rate of the prefabricated house. One of the methods to finance for prefabricated housing is to secure a bank loan for the land, and then secure a loan for the house through prefabricated manufactures; however, not all prefabricated housing manufactures provides this type of financing option for their customers.

From the bank's perspective, giving out a prefabricated housing loan involves a lot of uncertainty, as it is not like a traditional loan that they give out, there are little safeguards for the investment; on the contrary, they could give out the same loan to traditional construction where there is no need for them to venture into cases that involves unnecessary risks. This issue is further worsened by the preconception that prefabricated houses hold. People often regard prefabricated housing as items instead of real estates and because of this, prefabricated homes suffers from more severe depreciation compared to traditional homes.

### 3.2 TIME: REPAIR

In terms of time, the production time required for prefabricated production may be shorter than traditional construction; however, the time that it requires to replace parts and perform repairs is much longer. Replacing parts in prefabricated housing can be tricky. In

some cases, prefabricated housing uses parts produced using special materials and machineries. This means that in order to repair these parts, the customer would either have to go back to original prefabricated housing manufacture or they have to find special shops that offer this service. In the case of Larry Sass' shotgun house, all of the parts are made with a special machine. The house is joined together by interlocking parts without any glue or nails. These parts are sophisticated. And while repairing one or two parts may not be too big of a problem, if the house is significantly damaged, then the owner of the house would have to go back to Sass for proper repair.



Figure 9: Larry Sass & Shotgun House

### 3.3 QUALITY: VOLUME, VOICE, AND DELIVERY

Onto the subject of quality, while the quality of prefabricated housing may be improved because of engineering techniques and inspections, it is important to note that prefabricated housing production operates on volume basis. This means that if there is saving to be realized, even if it is pennies, the saving over time could be significant enough for the company to use lower grade materials.

In addition, the customer cannot interact with prefabricated housing manufacturers and argue about the quality of the products that they delivered. In many cases, the product is purchased through an intermediate, such as the builder, thus, manufacturers are shielded from customer complaints: so even though if customer may spot some problems half way through the construction, the final quality of the construction cannot be improved upon because of this barrier.

Handling of components is also an issue for prefabricated housing. During the transportation process, prefabricated housing components are often damaged due to it being insufficiently packaged, or from accidents and improper handling. The damage to the prefabricated parts is likely to appear in the finished house because the products are pre-assembled as a complete product. In the case of traditional construction, there may be damage from transportation, the visibility of these blemishes are easily rectified because the parts are not final, and require later processes, such as drywall sealing and painting.. Furthermore, the surface damage in a prefabricated structure may be easily repaired, but less visible damage such as air gaps and micro cracks can cause problems such as leakage and energy inefficiency, later on.

### 3.4 ENVIRONMENT: OVER-ENGINEERING & UN-ECONOMICAL REUSE

Prefabricated homes are often over-engineered compared to traditional housing due to transportation requirements. Parts need to be lifted and transported on truck or rails, both of which are subject to severe environments. The vibrations experienced during transportation may cause the house to lose its structural integrity if it was not reinforced from the factory; that is to say, in modular homes, over-engineering means sealing the

house inside and out. Double layering the house, could mean that the wall panels go back to back with one another, which is inefficient use of space and not environmentally friendly.

There are arguments saying that even though prefabricated production has the capability of implementing waste collection and recycling programs; it is often not cost efficient for them to do so. On-site contractors order materials based upon what is required.

Prefabricated housing producers order materials by bulk. The dimension of lumber, for instance, ordered by the traditional contractor is exactly what they need, but prefabricated producers order lumber of pre-set sizes to lower the cost of inputs – raw materials.

Therefore, more waste will be generated during prefabricated production.

### 3.5 DESIGN CAPABILITY

One of the most criticized design factors for prefabricated housing is the lack of flexibility.

In a sense, prefabricated production can also deal with customized designs and features.

However, the goal of the prefabricated production is to achieve economies of scale. To do so, companies has to utilize the benefits of standardized production; which means that, higher level of customization, in fact, reduces the benefits gained from assembly line production— which is unfavourable for prefabricated producers. So, in short, the trade-off here is market share gained through customization and cost saving gained through standardization.

In today's market, several producers emphasize on the uses of mass customization. This approach can create some room of customization, but it is still subjected to “soft” limitations. Mass customization can only offer a range of standard products that has similar

characteristics, for instance, they all have to use similar material or designs. Truly unique designs, such as large atriums still have to go through the traditional process.

Prefabrication also is not site specific. They are not designed in a way that utilizes local resources and benefits, such as wind, solar, and water. Prefabricated houses cannot utilize water to cool the house, wind to circulate air and refresh the breathing space. On top of that, prefabricated designs are not site tolerant. In most cases, prefabricated products cannot be built on sloped grounds. They can only build on flat beds, mainly due to immature market and lack of development in hillside techniques<sup>38</sup>.

### 3.6 SAFETY: PROBLEMS: LOCAL, HIDDEN

Prefabricated buildings come from various countries; and different countries have different standards and requirements to address local problem. When the prefabricated house is shipped to another country, the problem faced by each country and the natural environment may not be the same, which means that government regulations may not be strict enough to deal with local hazards; whether it is, snow, rain, earthquakes, insects, or termites. Another issue regarding safety is that long distance transportation can create invisible cracks in the structure that may not appear to be an immediate threat to the structural soundness of the house, but may cause issues later on in the life of the structure.

The challenge here is that there is a lack of inspection system in place. Unlike lumber and other raw materials, sampling prefabricated housing is much more complicated.

Prefabricated housing can be customized using the mass customization method.

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<sup>38</sup> "Www.fabprefab.com :: View Topic - Hillside Development in San Francisco Area - Discoveries!" Fabprefab. Web. 07 Apr. 2012. <<http://www.fabprefab.com/phpBB2/viewtopic.php?t=444>>.

Performing quality control inspections would be complex and far too expensive for the end user.

## 4 SUMMARY & ANALYSIS

The benefits of prefabrication in terms of costs lie in its ability to reap benefits from large scale production. Having a larger production means that the company can derive benefits from economies of scale. Such advantages include lower material costs, lumped overhead, more advanced system of production, better machineries, and the lower learning curve from assembly line construction. The drawback of this type of production is larger setup costs, such as cost of land and machineries – as well as challenges in acquiring funds.

The challenge of prefabrication is that it needs to have a large enough production in order to gain benefits from the assembly line production. However, modern prefabrication manufacturers cannot achieve this efficiency because of lingering criticism about prefabrication in the past, as well as the incapability of delivering attractive and cost effective designs. Yet, if this issue can be addressed, the initial setup cost, as well as difficulty for financing prefabricated products from banks will be mitigated. Therefore, I believe cost to be one of the strengths of prefabricated production.

The benefits of prefabrication in terms of time lie in its faster on-site constructions. Most of the parts of prefabricated housings are constructed within an indoor and stocked facility. This means that there will be fewer costly interruptions due to weather interference and material delays. From a builder's perspective, this time saved translates to more projects completed annually and fewer costs associated with renting cranes and other equipment. From an owner's perspective, the time saved translates to more months that could be used for other purposes, such as rental property or being able to move in sooner. The drawback of prefabricated production is the potential complication of repairs. Using local repair for



prefabricated housing may be difficult because of the uniqueness in design or lack of expertise in materials used.

The cost of repair for prefabricated houses will not be too high even after the warranty period expires because most customers will compare the repair cost prior to purchase, if the repair cannot be done locally. Competition from other prefabricated companies will also drive the repair costs down. The end user may have to wait a longer period for repairs – for inspections, production, and shipping of parts. But, the time saved in prefabricated production is easily over six months. Therefore, even though the time lost due to distant repair is great, there is still significant gain in time overall

In terms of quality, although prefabrication manufacturing is regulated by government regulations, the benefits in prefabrication lie in its ability to impose quality control mechanisms and advanced processing options. The drawback is the lack of incentive for the companies to use materials that exceed the basic regulation and the possible damage to components during transportation and handling.

The issue regarding to transportation risks during delivery is easily rectified, but the challenges regarding companies' need to meet bottom-line targets is one that requires much more consideration. If companies decide to use better materials, then it risks losing some customers that are cost sensitive. One solution that could potentially solve the problem is the combination of larger volume of production and greater competition. While larger volumes drives the cost down, competition pressures the company to deliver better products. This emphasizes the importance of globalization. Nevertheless, the current

market situation for prefabricated production is that although there is competition, the volume is low. Quality is both strength and weakness for prefabricated housing.

Environmental benefits are created through the control of pollution, management of waste, lowering of gas consumption, and implementation of energy efficient designs. Drawbacks are due to over engineering products and attempts to save on costs by not implementing recycling and other green programs. The challenge in implementing waste collection is caused by economic factors. In short, waste products are uneconomical to process if they are too small to be utilized in plant or sent to another facility to be converted to useful materials and energies.

The claim of waste being too small and uneconomical to be processed is poor justification and is unethical. The goal of most company is to generate profit. Large manufacturers are more likely to implement policies to reduce the amount of materials wasted during production, as every penny saved on each product translates to significant savings in cost.

In terms of design capability, the strength of prefabrication lies in its ability to implement unique designs and advance materials. Advance materials are too costly to implement in traditional forms of construction; hence, only in prefabricated homes will you find carbon fibre structures utilized. The issue with prefabricated production is that it utilizes assembly line production, and in assembly line production, it is essential to have parts and components standardized. Therefore, regardless of how prefabricated designs claims to be customizable it is limited in flexibility and variability. Prefabricated products are also not site specific – potential benefits that could be gained from environment, such as wind and rain, will be forfeited.

This problem is one that contradicts with the principle of prefabrication, and is also one this is not easily overcome. Even though there might be some mass customization possibilities, the limitation still exists. Hence, design capability is definitely one of the weaknesses of prefabrication.

Prefabricated housing can pose a safety concern for occupants if the unit originates from a foreign location. Building requirements and environmental factors may be different from the place of origin to the place the prefabricated home is ultimately placed. The government can impose regulations and restrictions to reduce the risks; however, inherently not all of these risks can be completely nullified. The onus lies with the manufacturer to match the needs of the targeted consumer and environment.

## 5 CONCLUSION

By analyzing the benefits and drawbacks of the current prefabrication industry, there are a number of issues that need to be overcome before prefabrication can become the norm. Setup costs for prefabricated production can be overcome by increasing the volume of production. Potential time delays due to repair complication, is not likely enough to be considered a serious detriment to the prefabricated time gained through mass production. The problem in sustainability could be mitigated by making a better network for waste recycling and reuse, and an increase in production also creates a higher budget for proper waste disposal. Design limitation can be solved by mass customization and site specific options. Finally, safety standards would require cooperation and implementation of standards and monitors around the world.

The design superiority and to establish an industry wide standard are the two most important factors that needs consideration. These two factors are primary reasons that drive customers to purchase prefabricated homes. If a high quality standard is not imposed and marketed, then people will not feel comfortable purchasing a prefabricated home. If a prefabricated house is not uniquely designed, then there is little advantage for this construction, except for cost savings. And although cost is important, in the modern era that we live in today, people also strive for a higher quality of living.

## 6 POTENTIAL

There is a great potential for prefabricated homes

The current focus of many prefabrication companies is in the town homes, high rises and apartments, due to having standardized configurations. And by perusing these prefabrications, companies can accumulate volume and achieve economies of scale. While this is a viable approach, there is also potential in the singled detached market. One example would be laneway houses<sup>39</sup>. Laneway houses are usually constructed on a lot of 500 to 600 square feet. The living space is minimal, which translates to smaller functional compartments that could be delivered by trucks. If prefabrication manufacturing companies can design a house that fit the needs of laneway housing customers, than there is a large potential for profits.

Another potential area of profit is the high tech home. The living spaces are fairly constrained, not in the sense to reduce the price of the house, but to increase the usability and intractability of the house. By incorporating advanced technologies, companies can differentiate its products from traditional constructions, increasing its market shares.

The future of prefabrication lies not only in cost effectiveness and time efficiency; but also, by creating value for the customers. This is the only feasible way that prefabricated housing can expand its market in the future.

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<sup>39</sup> "Laneway Housing." City of Vancouver. Web. 17 Mar. 2012.  
<<http://vancouver.ca/commsvcs/lanewayhousing/>>.

There are certainly many challenges, in financing and implementation of prefabrications, but the benefits are also quite attractive. Slowly, but surely, the prefabrication industry will grow.

## 7 FUTURE RESEARCH

One of the analyses that I believe would be useful is an in-depth cost analysis between prefabrication and traditional construction. The processes should be broken down into individual stations – perhaps even machineries; where the benefit of each station should be analyzed and compared to the traditional approach of construction. This approach allows the companies to allocate resources to areas of greatest benefits. In addition, this approach also allows the industry to have a more in-depth understanding of the prefab construction process.

This information will also benefit consumers, if they are armed with proper knowledge of the prefabrication industry, previous stereotypical ideas can be overcome. As consumers learn more about the quality and efficiency of prefabricated homes; eventually, the concept of prefabricated homes may become the norm.

I appreciate for your time and consideration in reading my research analysis paper.

Thank-you.

## 8 REFERENCES (MLA)

1. "101 Prefab." - Ideas. Web. 10 Mar. 2012. <<http://www.dwell.com/articles/101-prefab.html>>.
2. 16, Jenny Jarvie Los Angeles Times Staff Writer December. "Post-Katrina Cottages Get a Lukewarm Welcome." Los Angeles Times. Los Angeles Times, 16 Dec. 2007. Web. 12 Mar. 2012. <<http://www.latimes.com/news/la-na-cottage16dec16,0,3467479.story>>.
3. "ACP (Concrete) Ltd - The Home of Precast Concrete Wall Panels, Floors and Stairs." Precast Concrete Wall Panels, Concrete Floors, Concrete Stairs. Web. 22 Mar. 2012. <<http://www.acp-concrete.co.uk/>>.
4. "Alcana Ferrin & Her Sears-Roebuck House, Wilmore, Comanche County, Kansas." RootsWeb.com Home Page. Web. 17 Mar. 2012. <[http://www.rootsweb.ancestry.com/~kscomanc/ferrin\\_alcana.html](http://www.rootsweb.ancestry.com/~kscomanc/ferrin_alcana.html)>.
5. "Assembly Line." Wikipedia. Wikimedia Foundation, 04 June 2012. Web. 05 Apr. 2012. <[http://en.wikipedia.org/wiki/Assembly\\_line](http://en.wikipedia.org/wiki/Assembly_line)>.
6. "BAKOKO | Design & Development | Tokyo." BAKOKO. Web. 12 Mar. 2012. <<http://www.bakoko.jp/>>.
7. Bergdoll, Barry, Peter Christensen, and Ron Broadhurst. "Projects." Home Delivery: Fabricating the Modern Dwelling. New York: Museum of Modern Art, 2008. 40. Print.
8. "Blue Sky Building Systems | Build Better." Blue Sky Building Systems. Web. 16 Mar. 2012. <<http://blueskybuildingsystems.com>>.
9. "Building Permits, Housing Starts and Sales." - BC Stats. Web. 23 Mar. 2012. <<http://www.bcstats.gov.bc.ca/StatisticsBySubject/Economy/BuildingPermitsHousingStartsandSales.aspx>>.
10. "Carl Turner ArchitectsLondon." Stealth Barn. Web. 17 Mar. 2012. <<http://www.ct-architects.co.uk/projects/stealth-barn/>>.
11. Chino, Mike. "PREFAB FRIDAY: Unpacking the Prefabs at MOMA!" Inhabitat: Future-forward Design for the World You Inhabit. 8 Aug. 2008. Web. 16 Mar. 2012. <<http://www.inhabitat.com/2008/08/08/prefab-friday-unpacking-the-prefabs-at-moma/>>.
12. "Clustering." The Economist. The Economist Newspaper, 24 Aug. 2009. Web. 16 Mar. 2012. <<http://www.economist.com/node/14292202>>.
13. "Common Menu Bar Links." CCMC. Web. 22 Mar. 2012. <<http://www.nrc-cnrc.gc.ca/eng/ibp/irc/ci/volume-2-n1-7.html>>.
14. "Design for Disaster â Aid, Victims, Information, Communication, Knowledge, Experiences, Ideas, Projects." Precut Home : Design for Disaster â Aid, Victims, Information, Communication, Knowledge, Experiences, Ideas, Projects. Web. 17 Mar. 2012. <<http://www.design4disaster.org/2011/04/06/precut-home/>>.



15. "The End of the Road for Modern Prefab? This Just Might Be The Beginning!" TreeHugger. Web. 10 Mar. 2012. <<http://www.treehugger.com/modular-design/the-end-of-the-road-for-modern-prefab-this-just-might-be-the-beginning.html>>.
16. "FAQ Section." Solar Is Future: But Isn't Solar Power Is Too Expensive? Web. 06 Apr. 2012. <<http://www.solar-is-future.com/faq-glossary/faq/facts-and-fiction/but-isnt-solar-power-is-too-expensive/index.html>>.
17. "Frank Lloyd Wright - The Jacobs House 1936." Frank Lloyd Wright. Web. 12 Mar. 2012. <<http://www.usonia1.com/>>.
18. "Gliving.com." G Living. Web. 17 Mar. 2012. <<http://gliving.com/modfab-frank-lloyd-wright/>>.
19. "Global Prefabricated Housing Market to Reach 829 Thousand Units by 2017, According to New Report by Global Industry Analysts, Inc." Yahoo! News. Yahoo!, 02 Mar. 2012. Web. 16 Mar. 2012. <<http://news.yahoo.com/global-prefabricated-housing-market-reach-829-thousand-units-100242887.html>>.
20. "The Globe and Mail." Home. Web. 10 Mar. 2012. <<http://www.theglobeandmail.com/life/home-and-garden/real-estate/article1464691.ece>>.
21. "Google Answers: Building a Prefabricated Home vs. Traditional." 301 Moved. Web. 10 Mar. 2012. <<http://answers.google.com/answers/threadview?id=197125>>.
22. "The Great Prefab Debate [3:30 PM EDT]." Jetson Green. Web. 16 Mar. 2012. <<http://www.jetsongreen.com/2011/05/the-great-prefab-debate-today.html>>.
23. GreenBuiltHome. "Stick Built vs Prefabricated Wall Panel House Construction." YouTube. YouTube, 26 Feb. 2011. Web. 10 Mar. 2012. <<http://www.youtube.com/watch?v=YILAxkiYcxw>>.
24. "HABITAFLEX Foldable Home." HABITAFLEX. Web. 22 Mar. 2012. <<http://www.habitaflex.com/>>.
25. "HEADQUARTERS." Headquarters U.S. Army Corps of Engineers. Web. 17 Mar. 2012. <<http://www.usace.army.mil/>>.
26. "Hive Modular - B-Line Models." Hive Modular M.a Architecture InterModal Design. Web. 12 Mar. 2012. <<http://www.hivemodular.com/Homes/Models/BLines.html>>.
27. "Hive Modular M.a Architecture InterModal Design." Hive Modular M.a Architecture InterModal Design. Web. 12 Mar. 2012. <<http://www.hivemodular.com/>>.
28. "Housing.com | Homes." Housing.com. Web. 10 Mar. 2012. <<http://www.housing.com/categories/homes/history-prefabricated-home.html>>.
29. "How Prefab Houses Work." HowStuffWorks. Web. 10 Mar. 2012. <<http://home.howstuffworks.com/prefab-house.htm>>.
30. "Human Error." Google Books. Web. 16 Mar. 2012. <[http://books.google.com/books/about/Human\\_error.html?id=WJL8NZc8lZ8C](http://books.google.com/books/about/Human_error.html?id=WJL8NZc8lZ8C)>.
31. "Hundegger Products - World's Leading CNC Machinery." Hundegger USA. Web. 06 Apr. 2012. <<http://www.hundeggerusa.com/products.html>>.

32. "Industry Voices." Home. Web. 06 Apr. 2012.  
<<http://www.mhmarketingsalesmanagement.com/blogs/industryvoices/>>.
33. "Laneway Housing." City of Vancouver. Web. 17 Mar. 2012.  
<<http://vancouver.ca/commsvcs/lanewayhousing/>>.
34. "The Lifespan of the Modern Home." Web. 17 Mar. 2012. <<http://d-build.org/blog/?p=2546>>.
35. "Manufactured Home Regulation." BC Laws. Web. 21 Mar. 2012.  
<[http://www.bclaws.ca/EPLibraries/bclaws\\_new/document/ID/freeside/10\\_441\\_2003](http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/10_441_2003)>.
36. Meinhold, Bridgette. "Habitat 67: Montreal's Prefab Pixel City | Inhabitat - Green Design Will Save the World." Green Design Will save the World | Inhabitat. 20 Aug. 2009. Web. 16 Mar. 2012. <<http://inhabitat.com/habitat-67-montreals-prefab-pixel-city/>>.
37. "Modern Prefab Homes Are Spread Across the Globe." Articlesbase.com. Articlesbase.com, 26 Mar. 2008. Web. 10 Mar. 2012.  
<<http://www.articlesbase.com/business-articles/modern-prefab-homes-are-spread-across-the-globe-369198.html>>.
38. "Modular Building." Wikipedia. Wikimedia Foundation, 21 Mar. 2012. Web. 22 Mar. 2012. <[http://en.wikipedia.org/wiki/Modular\\_building](http://en.wikipedia.org/wiki/Modular_building)>.
39. "Modular Homes by A-cero | Design Milk." Design Milk: Modern Design. Web. 12 Mar. 2012. <<http://design-milk.com/modular-homes-by-a-cero/>>.
40. "MOMO by Thomas Lind, Living Modular Getaway." Jetson Green. Web. 12 Mar. 2012. <<http://www.jetsongreen.com/2007/10/momo-by-thomas.html>>.
41. "Motorhome? Motormansion, More Like... World's Most Expensive Campervan up for Sale - for a Cool Â£1.9m." Mail Online. Web. 12 Mar. 2012.  
<<http://www.dailymail.co.uk/news/article-2050494/Worlds-expensive-motorhome-sale-1-9m.html>>.
42. "News Articles and Promotional Articles on All Topics â Submit Articles." The Pyramids of Egypt. Web. 12 Mar. 2012. <<http://www.centrorisorse.org/the-pyramids-of-egypt.html>>.
43. PBS. PBS. Web. 12 Mar. 2012.  
<<http://www.pbs.org/flw/buildings/usonia/usonia.html>>.
44. "Population Estimates." , British Columbia and Sub-Provincial. Web. 17 Mar. 2012.  
<<http://www.bcstats.gov.bc.ca/StatisticsBySubject/Demography/PopulationEstimates.aspx>>.
45. "Population Projections." , British Columbia and Sub-Provincial. Web. 23 Mar. 2012.  
<<http://www.bcstats.gov.bc.ca/StatisticsBySubject/Demography/PopulationProjections.aspx>>.
46. "PREFAB CONSTRUCTION: Green or Greenwashing? | Inhabitat - Green Design Will Save the World." Inhabitat. Web. 10 Mar. 2012. <<http://inhabitat.com/prefab-construction-green-or-greenwashing/>>.

47. "PREFAB FRIDAY: Prefab Takes Up Residence At The MOMA! | Inhabitat - Green Design Will Save the World." Inhabitat. Web. 16 Mar. 2012. <<http://inhabitat.com/prefab-friday-prefab-takes-up-residence-at-the-moma/>>.
48. "Prefab Housing | GREEN-R-PANEL Building Systems Inc." Prefab Home Kits. Web. 10 Mar. 2012. <<http://www.greenrpanel.com/category/prefab-housing/>>.
49. "Prefab Is Not the Answer to Affordable, Modern, and Green Homes." Jetson Green. Web. 10 Mar. 2012. <<http://www.jetsongreen.com/2008/09/prefab-is-not-t.html>>.
50. "Prefabricated vs. Stick Frame." Pacific Homes. Web. 10 Mar. 2012. <<http://pacific-homes.net/post/2579>>.
51. "Prefabrication." Wikipedia. Wikimedia Foundation, 03 Sept. 2012. Web. 10 Mar. 2012. <<http://en.wikipedia.org/wiki/Prefabrication>>.
52. "Pretty Fabulous." - Ideas. Web. 10 Mar. 2012. <<http://www.dwell.com/articles/pretty-fabulous.html>>.
53. "Pros and Cons of Buying a Modular Home." Guide for Modular Homes with Reviews, Floor Plans and Prices. Web. 10 Mar. 2012. <<http://www.modulartoday.com/prosandconsofbuyingmodularhome.html>>.
54. "Quonset Hut." Wikipedia. Wikimedia Foundation, 03 Oct. 2012. Web. 12 Mar. 2012. <[http://en.wikipedia.org/wiki/Quonset\\_hut](http://en.wikipedia.org/wiki/Quonset_hut)>.
55. "REBECCA Â L. HUNTER." R.L. Hunter Press: Mail Order House Research. Web. 03 Apr. 2012. <<http://www.kithouse.org/>>.
56. "Reports." Solutions for Wood. Web. 10 Mar. 2012. <[http://www.solutionsforwood.ca/industry\\_info/reports.html](http://www.solutionsforwood.ca/industry_info/reports.html)>.
57. RobinWilsonHome. "CBS: High Technology Home Options with Robin Wilson." YouTube. YouTube, 20 May 2008. Web. 17 Mar. 2012. <<http://www.youtube.com/watch?v=R-ITJUFNXuI>>.
58. "Startup's Prefab Homes Aim for Zero Energy Bills." Wwww.SFGate.com. 27 June 2011. Web. 12 Mar. 2012. <<http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2009/06/22/BURR187SSG.DTL>>.
59. "The Stealth Barn by Carl Turner Architects | GBlog." GBlog. Web. 17 Mar. 2012. <<http://blog.gessato.com/2012/02/15/the-stealth-barn-by-carl-turner-architects/>>.
60. "Tempers Flare as Farming Debate Continues." Save Green Village. Web. 10 Mar. 2012. <<http://www.savegreenvillage.com/2011/06/tempers-flare-as-farming-debate-continues/>>.
61. "Thermapan Structural Insulated Panels: The Better Way to Build." Thermapan Structural Insulated Panels: The Better Way to Build. Web. 12 Mar. 2012. <<http://www.thermapan.com/>>.
62. "Thomson Housing." Thomsonhousing. Web. 04 Apr. 2012. <[http://www.thomsonhousing.ca/Home\\_Page.php](http://www.thomsonhousing.ca/Home_Page.php)>.
63. "A Timeline of Prefab History." - Design. Web. 12 Mar. 2012. <<http://www.good.is/post/a-timeline-of-prefab-history/>>.

64. "Victoria University of Wellington." Kiwi Prefab: Prefabricated Housing in New Zealand: An Historical and Contemporary Overview with Recommendations for the Future. Web. 16 Mar. 2012. <<http://researcharchive.vuw.ac.nz/handle/10063/1111>>.
65. "WeberHaus - Building the Future: Option." WeberHaus. Web. 12 Mar. 2012. <<http://www.weberhaus.co.uk/1640.html>>.
66. "Welcome to BoKlok." BoKlok. Web. 12 Mar. 2012. <<http://www.boklok.com/theconcept/Start/>>.
67. "Welcome to RBC Economics Research." RBC Economics. Web. 17 Mar. 2012. <<http://www.rbc.com/economics/index.html>>.
68. "What Are Economies Of Scale?" Investopedia. Web. 18 Mar. 2012. <<http://www.investopedia.com/articles/03/012703.asp>>.
69. "What Is a Sears Modern Home?" Sears Archives Home Page. Web. 12 Mar. 2012. <<http://www.searsarchives.com/homes/>>.
70. "What Is PassivHaus? | Dovetail Partners INC." Dovetail Partners INC. Web. 10 Mar. 2012. <<http://dovetailinc.org/reportsview/2010/responsible-consumption/pjennifer-garmanp/what-passivhaus>>.
71. White, R. B. Prefabrication: A History of Its Development in Great Britain,. London: Her Majesty's Stationery Office, 1965. Print.
72. "Will Your New Home Still Be Standing in 50 Years?" - MSN Real Estate. Web. 17 Mar. 2012. <<http://realestate.msn.com/will-your-new-home-still-be-standing-in-50-years>>.
73. Wiseman, Paul. USA Today. Gannett. Web. 22 Mar. 2012. <[http://www.usatoday.com/money/industries/banking/2010-08-17-banks17\\_CV\\_N.htm](http://www.usatoday.com/money/industries/banking/2010-08-17-banks17_CV_N.htm)>.
74. "Worldchanging: Bright Green: LEED Platinum Prefab Home Now Available." Worldchanging: Bright Green. Web. 12 Mar. 2012. <<http://www.worldchanging.com/archives/009437.html>>.
75. "Www.fabprefab.com :: View Topic - Hillside Development in San Francisco Area - Discoveries!" Fabprefab. Web. 07 Apr. 2012. <<http://www.fabprefab.com/phpBB2/viewtopic.php?t=444>>.
76. Xaxx, Jagg. "Prefab Housing Disadvantages." EHow. Demand Media, 26 Dec. 2010. Web. 10 Mar. 2012. <[http://www.ehow.com/info\\_7748777\\_prefab-housing-disadvantages.html](http://www.ehow.com/info_7748777_prefab-housing-disadvantages.html)>.

## 9 APPENDICES: TABLE & FIGURES

### 9.1 ADDITIONAL TABLES

**Table 1: Summarized Benefits & Drawbacks**

Benefits	Drawbacks
<b>Cost</b> <ul style="list-style-type: none"> <li>• Economies of Scale</li> <li>• Economies of Scope</li> <li>• Globalization</li> <li>• Efficient Processing</li> <li>• Labour Cost</li> </ul>	<b>Cost</b> <ul style="list-style-type: none"> <li>• Setup</li> <li>• Over-Engineering</li> <li>• Land and Mortgage</li> </ul>
<b>Time</b> <ul style="list-style-type: none"> <li>• On-site Assembly</li> <li>• Assembly Line Construction</li> <li>• Interruptions and Delays</li> </ul>	<b>Time</b> <ul style="list-style-type: none"> <li>• Shipping</li> <li>• Components</li> <li>• Repair and Maintenance</li> </ul>
<b>Quality</b> <ul style="list-style-type: none"> <li>• Specialization</li> <li>• Government Regulation</li> <li>• Inspection</li> <li>• Transportation Requirements</li> <li>• Manufacturing Precision</li> <li>• Preservation</li> </ul>	<b>Quality</b> <ul style="list-style-type: none"> <li>• Material Quality</li> <li>• Handling</li> <li>• Durability</li> </ul>
<b>Environment</b> <ul style="list-style-type: none"> <li>• Controls Pollution</li> <li>• Manage Waste</li> <li>• Gas</li> <li>• Energy</li> </ul>	<b>Environment</b> <ul style="list-style-type: none"> <li>• Over Engineering</li> <li>• Material Waste</li> </ul>
<b>Design Capability</b> <ul style="list-style-type: none"> <li>• Features</li> <li>• Integrated Appliances</li> <li>• Unique Designs</li> <li>• Advanced Materials</li> </ul>	<b>Design Capability</b> <ul style="list-style-type: none"> <li>• Low Flexibility</li> <li>• Lacks Variety</li> <li>• Not Site Specific</li> </ul>
<b>Safety</b> <ul style="list-style-type: none"> <li>• Workers</li> <li>• Consumer</li> </ul>	<b>Safety</b> <ul style="list-style-type: none"> <li>• Standard</li> </ul>

## 9.2 ADDITIONAL FIGURES

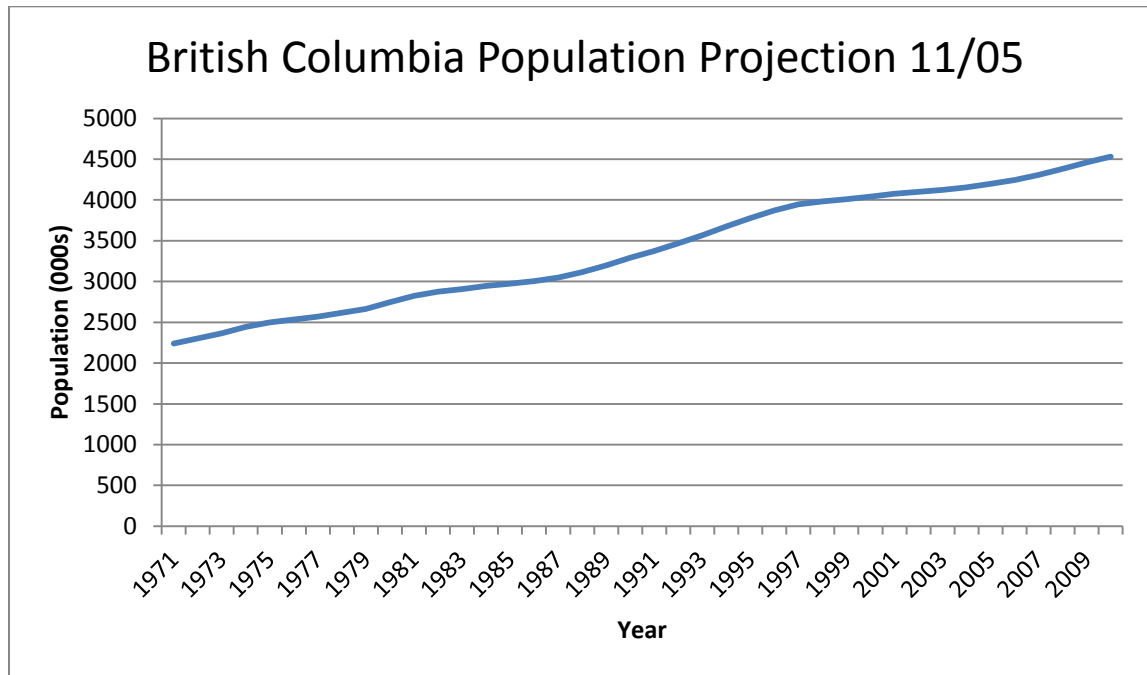


Figure 10: British Columbia Population Projection 11/05<sup>40</sup>

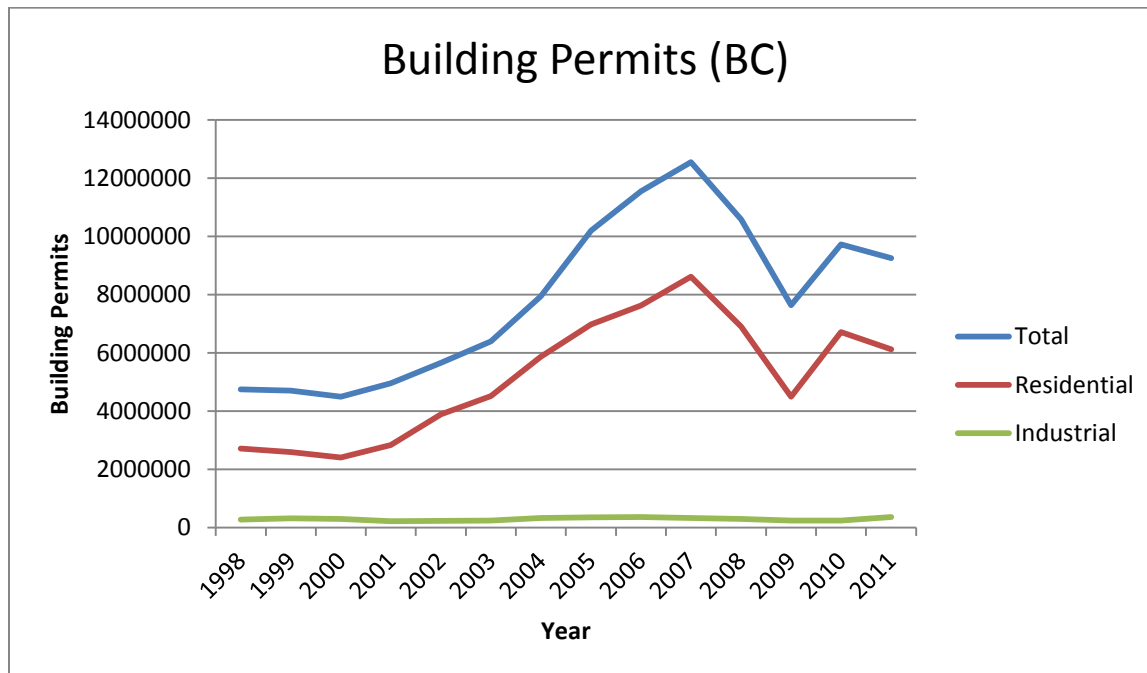


Figure 11: Building Permits (B.C.)<sup>42</sup>

<sup>40</sup> "Population Projections.", British Columbia and Sub-Provincial. Web. 23 Mar. 2012.  
<http://www.bcstats.gov.bc.ca/StatisticsBySubject/Demography/PopulationProjections.aspx>.

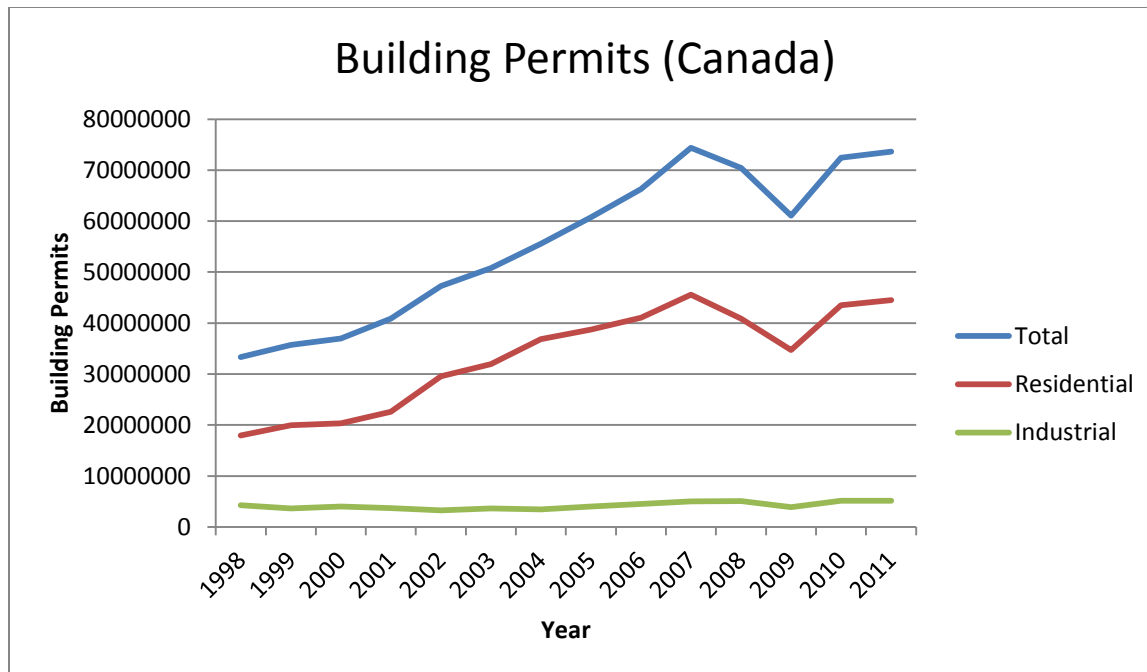


Figure 12: Building Permits (Canada)<sup>41</sup>

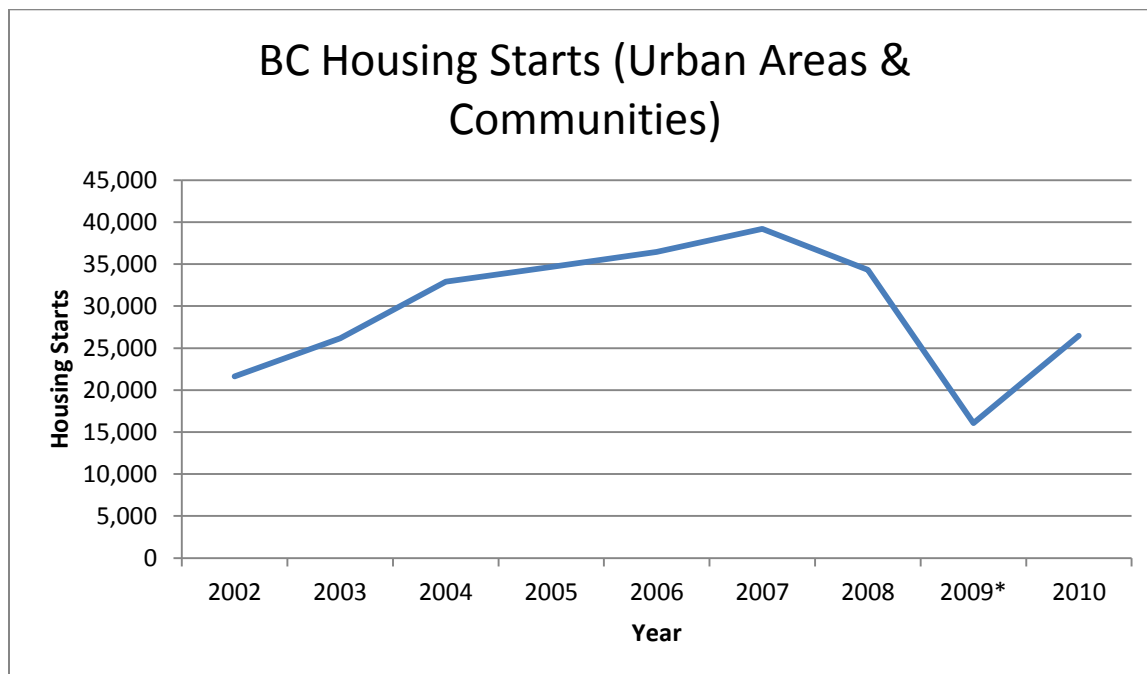


Figure 13: BC Housing Starts (Urban Areas & Communities)<sup>42</sup>

<sup>41</sup> "Building Permits, Housing Starts and Sales." - BC Stats. Web. 23 Mar. 2012.  
<http://www.bcstats.gov.bc.ca/StatisticsBySubject/Economy/BuildingPermitsHousingStartsandSales.aspx>.