

**IS MODULAR BUILDINGS/CONSTRUCTION
BENEFICIAL TO
THE CONSTRUCTION INDUSTRY**

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Submitted in fulfillment of part of the requirements for the
Degree of BSc (Hons) (Quantity Surveying)

In the faculty of Engineering, Built Environment and Information
Technology



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October 2010

TABLE OF CONTENTS

Chapter 1: Introduction

1.1 Introduction_____	1
1.2 Statement of main problem_____	2
1.3 Statement of sub-problem_____	2
1.4 Sub-problem_____	2
1.4.1 Design limitation and considerations of modular building_____	3
1.4.2 Can modular buildings be green and will it be beneficial to the construction industry?_____	4
1.4.3 Market and financial consideration of modular construction_____	5
1.4.4 Sustainability and life cycle of modular to conventional construction_____	5
1.5 Conclusion_____	6
1.6 Delimitations_____	6
1.7 Methods of research_____	7
1.8 Importance of this study_____	7

Chapter 2: Design limitation and considerations of modular construction

2.1 Introduction_____	8
2.2 Design and dimensional consideration_____	9
2.2.1 Design parameters_____	9
2.2.2 Level of finish_____	10
2.2.3 Physical consideration_____	10

2.3 Site considerations_____	11
2.3.1 The site_____	11
2.3.2 Vendor selection_____	14
2.4 Hypothesis_____	14
2.4.1 Design for the builder_____	14
2.5 Conclusion_____	15
2.6 Testing of hypothesis_____	15

Chapter 3: Can modular buildings be green and will it benefit the construction industry?

3.1 Introduction_____	16
3.2 Why make the transition_____	16
3.3 The problems experienced when going green modular_____	17
3.3.1 Initial cost_____	17
3.3.2 Funding_____	17
3.3.3 Availability of materials_____	17
3.3.3.1 What makes material green_____	18
3.3.4 Location_____	18
3.3.5 Time frame_____	18
3.4 The advantages of modular construction being green_____	18
3.5 What are the economic benefits_____	19
3.6 Steps to ensure success_____	20
3.7 Conclusion_____	22
3.8 Testing of hypothesis_____	22

Chapter 4: Market and financial considerations of modular construction

4.1 Introduction_____	23
4.2 Problems experienced in market and financial considerations_____	23
4.2.1 Financial considerations_____	23
4.2.2 Material cost control_____	24
4.2.3 Labour cost environment_____	25
4.2.4 Pricing and site instructions_____	25
4.3 Financial impact_____	26
4.4 Case study_____	27
4.4.1 The results of the case study_____	28
4.4.2 Lessons learned_____	28
4.5 Conclusion_____	29
4.6 Testing of hypothesis_____	29

Chapter 5: Sustainability and life cycle of modular to conventional construction

5.1 Introduction_____	30
5.2 Purpose of this study_____	30
5.3 The analysis of life cycle of modular buildings_____	35
5.3.1 Material consumption_____	35
5.3.2 Transportation_____	35
5.4 The analysis of life cycle of conventional buildings_____	35
5.4.1 Material consumption_____	35
5.4.2 Transportation_____	36
5.5 Conclusion_____	36
5.6 Testing of hypothesis_____	36

Chapter 6: Final chapter

6.1 Summary_____	37
6.2 Conclusion_____	41
6.3 Future research_____	41

LIST OF TABLES

Table 1: Assumptions and simplification in this study categories assumption_____	31
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LIST OF FIGURES

Figure1: Poor site considerations planning of a modular house 1a_____	12
Figure 2: Poor site considerations planning of a modular house 1b_____	12
Figure 3: Poor site considerations planning of a modular house 1c_____	13
Figure 4: Modular building cycle_____	21
Figure 5: Life cycle system of modular homes_____	33
Figure 6: Life cycle systems of conventional homes_____	34

Abstract

Title of thesis : Is modular buildings/construction beneficial to the
construction industry

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Date : October 2010

The objective of this thesis is to define and explain the benefits as well as the limitations of modular construction. It will try to educate and familiarize the reader, builder and consumer about modular buildings/construction and how this alternative construction method is beneficial to the South African construction profession and property market. The knowledge contained in this thesis will address issues pertaining to modular construction for the first time builder/consumer and how such issues can be avoided or dealt with when it arises.

Declaration by student

I, the undersigned, hereby confirm that the attached thesis is my own work and that any source adequately acknowledged in the text and listed in the bibliography

Signature of acceptance and confirmation by student

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1.0 Chapter One: Introduction Chapter

1.1 Introduction

Modular construction is based on the term where a building is assembled from a series of volumetric modules, linked or joined together to form a complete structure. The modules which are manufactured, finished and fitted-out off-site, under factory conditions, are then transported to the construction site and lifted into place. Modular construction involves much more and can be characterized further:

- Modular construction involves modular parts assembled in a factory, transported by road and installed on a building site to create a modular building
- Modular parts have established grid dimensions
- Parts just small enough to be transported by road are called modules
- The modular buildings are assembled, transported and installed by specially trained professionals
- The components on the modular parts and modules are kept in stock at the factory
- The point at which an order can be broken down into its individual components precedes the assembly of modular parts
- Modular parts and modules are manufactured according to customer specification
- A modular building can be taken apart then reused to create the same or other type of building

(Gassel van F, 2006)

The housing demand at the end of World War II caused the market to expand and evolve. The soldiers returning from war mostly in the United States of America were looking to purchase a home quickly and the market industry could not cope with the demand. The shortage in traditional construction led to builders seeking lower cost and efficient construction. The modular construction was the answer to both these needs.

The modular construction industry has made significant advances in implementing processes and materials to build and deliver more sophisticated and complex facility types with improved computer aided architectural modeling and the pioneering engineering process of assembling homes with overhead cranes. By using this system, larger units can be constructed and transported by ship and moved across country.

Modular construction is known for its time saving capabilities, modular construction is now being recognized and marketed for being more resource-efficient, inherently greener process. (Cameron, Di Carlo, 2007)

1.2 Statement of Main problem:

Is Modular Buildings/Construction beneficial to the Construction Industry?

1.3 Statement of Sub-problems:

- 1. Design Limitation and Considerations of Modular Construction**
- 2. Can Modular buildings be Green and will it be beneficial to the Construction Industry?**
- 3. Market and Financial considerations of Modular Construction**
- 4. Sustainability and Life Cycle of Modular to Conventional Construction**

1.4 Sub-problems:

1.4.1 Sub-problems 1: Design Limitations and Considerations of Modular Construction

There are many challenges that may be encountered when it comes to designing such as a largely poor defined market, the production plans involves many assumptions and many clients especially in South Africa want an attractive and sustainable building and not a semi permanent one.

Other design considerations involve:

1. Design Parameters: The dimension of the box or unit makes it a challenge for open space planning. If the designer wants to increase width space, he or she must increase the ceiling height and therefore an increase in the cost
2. Level of Finish: Pricing levels are influenced by specific location and the type of finish
3. Physical Considerations: Miscommunication plays an major role in the design limitations
4. Site Considerations: Dealing with a particular site, the designer of the modular unit must take into account challenging weather, remote location and urban locations
5. Vendor Selections: Selecting a vendor is difficult in South Africa; it is not as convenient as a conventional building where a client can view previous work projects. In South Africa there are very few projects that utilized modular construction

Hypothesis

The use of computer aided drawing software and building information modeling, design and customization has become easier to specify and build. Advances in technologies have also advanced the modular construction industry.

1.4.2 Sub-problem 2: Can Modular Buildings be Green and will it benefit the Construction Industry

There are problems experienced when going green modular

1. Initial Cost: The lack of eco-friendly building materials for modular construction leads to higher prices of the materials as compared to conventional buildings
2. Funding: Finding financial institutions that fund non-conventional buildings may be problematic
3. Availability of Materials: In less developed areas such as townships, material could be scarce.
4. Location: Location plays a large role in making projects feasible
5. Time Frame: By applying green principals an encouraging the use of recycled materials, time may become a disadvantage

Hypothesis

Less wastage due to more precise cutting of material in the planning phases which is beneficial in keeping with the requirements of going green. There is a greater energy efficiency which cost the owner less due to its superior insulation rating.

1.4.3 Sub-problem 3: Market and Financial considerations of Modular Construction

Problems experienced with Market and Financial Considerations:

1. Financial Considerations: Financial impact will vary from region, state and country as well as developer and economic situation for debt and property market.
2. Material Cost Control: Purchasing in bulk can serve as a price hedge to counter act price escalation
3. Labour Cost Environment: Problems are intensified by areas with high labour cost and unionized workforce

Hypothesis

Financing can be a problem if financial institutions are unfamiliar with this type of construction method there for it is important to market the project well and define all advantages that modular construction can offer. Promote clear communication between manufacturers and local trades, this ensures cost savings.

1.4.4 Sub-problem 4: Sustainability and Life Cycle of Modular to Conventional Construction

Material transportation is dependent on the material supply chain. The material consumption the material used for the building and the amount of waste the building generates.

Hypothesis

By examining the life cycle of modular construction, it indicates that the buildings are durable over a 40 year life span, there is reduction in the wastage of materials on site and correct allocation of manufacturing plants of modular units, transportation problems can be minimized.

1.5 Conclusion

Modular technology considerably reduces construction time. It is safer, less noisy and cleaner than most conventional methods of construction. It reduced the likelihood of defects and allows easy and low cost maintenance. It offers designers flexibility which is also effective. With the saving in construction time, programme time and associated preliminary costs are reduced. All of which leads to a greater speed, productivity, quality and safety thus ensuring earlier completion and greater revenue generated.

1.6 Delimitations:

Due to the vast spectrum in which modular construction and design can be applied the research is limited to countries that have practiced modular construction for the past forty years, such as United States of America and Holland. Since South Africa has a very poor defined market for modular buildings, reference will be made to certain examples and case studies conducted in the United States of America.

1.7 Methods of research:

Because of the lack of information the South African construction industry can provide, the research will take a quantitative approach based on the following:

- Electronic Media – various databases
- Journals and reports conducted by different individuals in the academic construction industry
- Human information resources - Personal observation during site meetings and consultation with the different consultants in the construction industry
- Surveys conducted for personal opinions

1.8 Importance of this study:

The purpose of this study is to acquaint individuals about modular construction and how it can benefit the South African construction industry by examining the efficiency and cost effectiveness a modular approach.

This thesis will also provide information about the potential benefits and limitations on modular construction and whether it can be applicable to the South African housing or commercial market.

2.0 Chapter Two: Design Limitations and Considerations of Modular Construction

2.1 Introduction

Most clients sometimes have specific requirements that need to be met when acquiring a new building, such as short delivery time, special financing, a specific location and whether the building is for long term or short term use. The architect or designer has to bear these special requirement or demands when designing. The following challenges may be encountered:

- There is no personal client but a largely poor defined market
- The establishment of a production plan involves quite a number of assumptions
- The client or society wants a safe, sustainable and attractive building, not a semi permanent one

To manage these short-comings, can be the task of the architect or designer. This chapter will focus on the problems of design of modular construction and how it can be alleviated, making it advantageous to the construction industry. Modular builders or vendors have to manage four processors when designing a modular building, which are market research, product development, production and sales. Feedback and information exchange are essential and the designer/architect should take a multidisciplinary approach. Feedback tools helps make sure the co-operation runs as smoothly as possible. (Gassel van F, 2006)

2.2 Design and Dimensional Consideration

2.2.1 Design Parameters

The design limitations come from transportation regulations and from the structural nature of the box. The 3m width makes it a greater challenge for open planning space or rooms with wide open space. To alleviate this short coming, the designer can place two modules together without any additional structural support and creating a desired open space plan but this is the maximum. If the designer/architects want to increase the open space, they have to increase ceiling height and similar to site-build construction, the higher the ceiling height the higher the construction or production cost. The increase in the width or height becomes market driven and in expanding the dimensions will increase construction cost, transportation permits, off hour's shipment and police escort which could possibly double the transport cost. (Cameron, Di Carlo, 2007)

In a multistory modular building, the underground parking plays a considerable drive to cost in the design department. Lining up of a multistory modular unit should be so that the load bearing walls are lined up under one another throughout the floor and if this can't be designed then a transfer beam may be used but which is not only expensive but also increases risk of moisture and mold. It should be recommended that a local architect or engineer should design full sets of drawings including plumbing and drainage, mechanical and electrical. (Cameron, Di Carlo, 2007)

Value engineering should also be considered throughout the design process. A developer or designer who is not familiar with the design and construction can make costly errors if they are to rely solely on the modular manufacture's in-house architecture and engineer team. While the manufacturers team may be extremely knowledgeable about the design that can be efficiently built but may not be familiar with potential market of a certain district which will influence value engineering outcome. (Cameron, Di Carlo, 2007)

2.2.2 Level of finish

The construction industry both conventional and modular buildings work within a market environment, therefore pricing levels are greatly influenced by specific locations and demand factors. Designers should cost compare for several finish components for cost saving purposes based on market conditions. There are some components which should be considered site build as opposed to factory fitted, these are:

Flooring: Most units come about 70-80% done and receive another one to two months of construction on it, increasing the probability of damaging the floor area high.

Siding: Sidings can come in a number of different specifications such as vinyl, timber and even brickwork which leads to the possibility that the sidings will get damaged during the construction phase and may require patch work which may not necessary match and in a multi-story building the sidings may not align along the vertical plane.

Pitched Roofs: Due to the advances in hinged roof, roofs can be made fairly steep pitched built in the factory but also a bulky and low cost item to ship, therefore the cost of site build and hoisting the roof may be cheaper than factory fitted. (Cameron, Di Carlo, 2007)

2.2.3 Physical Considerations

The major issues are not engineering design but communication related. Inexperience and unfamiliarity of both the manufacturer unable to comprehend beyond the module of what the module will become, and plumbers and electrician who don't understand or dislike what they have to do. Communications that are both verbal and written must always be taken into account to ensure that all parties understand their responsibilities and avoid major cost fluctuations. (Cameron, Di Carlo, 2007)

2.3 Site Considerations

2.3.1 The Site

When considering the use of modular buildings, many issues come to the forefront but one in particular is the site. Consideration on how to deal with a particular site must be addressed. Conveniently modular construction has become a possible solution in building in challenging weather but other issues have to be considered:

- Building in tight or urban locations
- In remote locations
- In situation where you have to compress or cut on-site construction time such as universities or adjacent to a difficult or challenging neighbor

The above situations or issues affect the potential of the modular building and one must work with the manufacturer and transportation vendor early. In urban locations for a large project, one needs to determine where the modules can be set down upon arrival prior to set up or erection. The question also arises if the site is too small for storing or stacking up, can the adjacent site be used to store the inventories and avoid the increase of days in hiring and using a crane. (Cameron, Di Carlo, 2007)

Consideration should also be made to check if the street/site or property can allow for flatbed truck turning radii. If the site poses limitations, the manufacturer should drive to the site and inspect the site to understand how transportation, set up and installation should be done and what they can rectify in design of the modular building to overcome the shortcomings. (Cameron, Di Carlo, 2007)

Figure 1 Poor site conditions planning of a modular house 1a



Source (Di Carlo, Cameron, 2007)

Figure 2 Poor site conditions planning of a modular house 1b



Source (Di Carlo, Cameron, 2007)

Figure 3 Poor site conditions planning of a modular house 1c



Source (Di Carlo, Cameron, 2007)

The above figures indicate lack of transportation planning and research done before transportation should occur.

Some sites have nothing to do with logistics and location as their primary issues but their tenants and occupancy plays a major role in design. Universities loath portions of their campus becoming construction sites due to noise pollution and marketing purposes. Universities should consider modular construction in the case of student accommodation, the modular units can be manufactured at the factories during the course of the year and when students leave for December vacation, the modular units can then be assembled on site ready for occupancy once they come back. (Cameron, Di Carlo, 2007)

2.3.2 Vendor Selection

The selections of a modular building can be extremely challenging in South Africa than with selecting a traditional type building construction. With traditional buildings, the developer can always visit previous completed projects and have a sense of the quality and competence of the contractor but in South Africa modular contractors are difficult to come by and therefore comparison for competitive tenderers are also a problem.

Other factors in the vendor selection process are the type of exterior finishes, dimensional changes in the module versus structural integrity and quality of bathrooms, kitchens and staircases. These factors vary between different manufacturers. (Cameron, Di Carlo, 2007)

2.4 Hypothesis

The construction industry has benefited significantly in the advances in technologies such as engineering and computer software, therefore the modular construction has also advanced due to these advances. Design and customization has become easier to specify and build. The use of CAD (computer aided drawing) software has made easy to specify documentation and priced the bill. The use of BIM (building information model) allows the design to create a module of the building for a prospective client, in which the client can view the module in three dimensional, enabling them to take virtual tours of the project before a single module can be manufactured. (Cameron, Di Carlo, 2007)

2.4.1 Design for the builder

Some guidelines may be used to monitor the design process in creating the modular structure. It should take into account the limitations for each of the four processes as discussed in the introduction of chapter.

Each step of the process should be divided into four parts:

- Part 1: input – the limitations that the final product bears in mind
- Part 2: process – the elaboration of all its input parameters
- Part 3: output – the changed model
- Part 4: evaluation – a check is done to confirm whether the limitations are taken into account

(Gassel van F, 2006)

2.5 Conclusion

This chapter was aimed at understanding the limitation experienced with the design of modular constructions. It has been established that each market or location has its own set of characteristics that influence the decisions in design. Due to the advances in computer technology, issues affecting visual appeal of modular construction are becoming less restrictive. Modular construction has become a potential advantage over traditional site-build construction that gives the developer a greater choice in their decision with which construction method is more beneficial to them or their clients.

Modular builder or designers that include in their portfolio their production experience with other building products reduces the risk of failure. (Gassel van F, 2006)

2.6 Testing of hypothesis

By considering the design parameters and limitations of modular construction, one can alleviate these shortcomings by working early in the design stage with the professional team

Yes, modular construction can benefit the construction industry

3.0 Chapter Three – Can modular buildings be green and will it benefit the Construction industry

3.1 Introduction

What are green buildings?

“Green buildings are also known as green construction or sustainable buildings is the practice of creating of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s life cycle: from setting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of the economy, utility, durability and comfort.”

“In creating greener structures that complement current practices, new technologies are constantly being developed but the objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water and other resources
- Protecting occupants health and improving employee productivity
- Reducing waste, pollution and environmental degradation”

(www.Wikipedia.com/green buildings, 2008)

3.2 Why make the transition?

In any building type, homes will have to contain numerous activities in the near future owing to the fact of the pending crisis in the healthcare industry, houses and living dwellings should become more proactive in keeping people healthy and providing a positive environment. There are still difficulties arising from building with centralized power plants, houses should try to influence more distribution of energy production, so energy can be saved. (MIT open source building alliance, 2005)

Markets indicate that people or home buyers are now more financially enabled consumer's that want choice and tailored solutions in homes that reflect their needs and over time are willing to adapt to their family financial and health conditions changes. (MIT open source building alliance, 2005)

In South Africa, the construction industry is fragmented, resistant to change, labor intensive and wary of new processes and technologies.

3.3 The problems experienced when going green modular:

3.3.1 Initial Cost

This could be the first and definitely one on the most problematic disadvantage of going green, is the up-front cost. Due to the lack of availability of eco-friendly building materials for modular construction, prices may be higher than standard conventional building materials. (Waters T L, www.ehow.com, 2008)

3.3.2 Funding

Although initial cost could be a major setback, finding a financial institution who offers loans for buildings that are non- conventional may be difficult. In some cases, the financial institutions may impose certain restrictions that a homeowner or builder may find it extremely difficult to follow. (Waters T L, www.ehow.com, 2008)

3.3.3 Availability of Materials

In some areas such as well developed cities may have no difficulty locating green building materials, this could be a problem in areas less developed such as townships or rural areas where materials are scarce. Some materials may require special ordering which may increase the cost such as internet ordering therefore shipping and handling cost has to be taken into account. (Waters T L, www.ehow.com, 2008)

3.3.3.1 What makes material green?

- Products made with salvaged, recycled or agricultural waste content
- Products that conserve natural resources
- Products that avoid toxic or other harmful emissions
- Products that save energy and water
- Products that contribute to a safe, healthy built environment

3.3.4 Location

The location usually plays a large role in making green building not feasible. Areas with high humidity levels may restrict certain green designs and principals to be applied. (Waters T L, www.ehow.com, 2008)

3.3.5 Time Frame

When applying green design principles to the construction, projects will encourage the use of recycled materials, time may become a disadvantage. Finding the materials may take extra time which the builder does not have on the project. It could lead to a decrease in float and a disruption on the critical path that leads to the project construction time period being extended. (Waters T L, www.ehow.com, 2008)

3.4 The advantages of modular construction being green

Considering modular construction has several environmental benefits if being utilized. There is less waste due the more precise cutting of material in the planning process. If building in an environmentally sensitive area, modular construction disturbs the site less than conventional on-site construction. There is a greater energy efficiency which cost the owner less due to its superior insulation rating. (Cameron, Di Carlo, 2007)

Manufacturing of the units may be very energy intensive, the use of a durable material both last longer and require less maintenance therefore saves energy and contribute less to solid waste. Purchasing of locally produced building materials

contributes to the saving of transportation energy caused by importing the materials. The use of salvaged building material reduces landfill issues and helps preserve natural resources. (Cameron, Di Carlo, 2007)

Process logistics adds to the environmentally superior benefits, it helps shorten the production time leading to less energy needed to construct a building. Sub-contractors and suppliers that use vehicles to travel to the conventional site may reduce/replace the distance travelled by a more direct route to the factory (sub-contractors may be replaced by workers who travel straight to the factory) and suppliers can shorten their amount of trips by supplying in bulk to the assembly plant. Manufacturing plants that are built close to areas where employees live nearby are an added benefit. (Cameron, Di Carlo, 2007)

3.5 What are the Economic Benefits?

A modular green building may initially be expensive up front but saves the consumer or occupants lower operating cost over the life of the building. By applying project life-cycle cost analysis, the client will be able to determine the up-front expenditure. These cost savings can only be realized by incorporating in at conceptual design phase with the assistance of the professional team. (www.calrecycle.ca.gov/greenbuilding/basics, 2008)

3.6 Steps to Ensure Success

- “Establish a vision that embraces sustainable principles and an integrated design approach”
- “Develop a clear statement of the project’s vision, goals, design criteria and priorities”
- “Develop a project budget that covers green building measures. Allocate contingencies for additional research and analysis of specific options. Seek sponsorship opportunities”
- “Seek advice of a design professional with green building experience”
- “Select a design and construction team that is committed to the project vision. Modify the adjudication process to ensure that the tenderer have the appropriate qualifications to identify, select and implement an integrated system of modular green buildings measures”
- “Develop a project schedule that allows for systems testing and commissioning”
- “Develop a contract plans and specifications to ensure that the building design is at a suitable level of building performance”

(www.calrecycle.ca.gov/greenbuilding/basics, 2008)

Figure 4 Modular building cycle

Source: Verbus systems

Figure 4 indicates how modular buildings/units can be dismantled, refurbish and re-assembled therefore decreasing solid waste disposal. This indicates the superiority of modular construction as oppose to conventional construction.

3.7 Conclusion

When using modular green building design or going modular green, it brings together practices and techniques that help reduce and eliminate the impacts that buildings have on the environment and human health, by taking advantage of renewable resources such as using passive solar (use of sunlight to lighten up the room) and photovoltaic techniques (plants as rain garden). These are great advances in helping the modular building industry benefit the construction industry. (Wikipedia, 2008)

3.8 Testing of hypothesis

Although there are solid environmental benefits that favors modular construction, it is important to note that structural integrity of modular construction is largely dependent on additional materials being used. While fewer natural resources are wasted or leads to waste, more materials are being used to construct a modular building. (Cameron, Di Carlo, 2007)

Modular can be as green as any on-site building as one would like to make it, by utilizing ground source heat pumps for cooling and heating, low U value window glazing, etc. (Cameron, Di Carlo, 2007)

Yes, modular buildings can be green and benefit the construction industry but one must be certain that the manufacturer's teams are well knowledgeable and trained in the installation on the green material for it is both expensive to install and purchase and costly to repair.

4.0 Chapter Four: Market and Financial consideration of modular constructions

4.1 Introduction

Marketing and financing in any development, whether it be conventional site build construction or modular construction poses a problem for the developer. Careful consideration must be utilized and considers these setbacks before choosing which construction method is best suited.

4.2 Problems experienced Market and Financial Consideration

There has been a stigma associated with modular construction with being made of poor quality, low ceiling, not aesthetically pleasing, poor layout and buildings being boring (lack of intelligent building being incorporated in the design and construction). (Cameron, Di Carlo, 2007)

These problems are very much existent today but to a much lesser extent. Consumers, architects and clients are becoming aware and knowledgeable of the benefits and advantages that modular construction has to offer. (Cameron, Di Carlo, 2007)

4.2.1 Financial Considerations

The potential financial impact and consideration should be taken into account before choosing to go modular. The financial impacts will vary from region, state and country, as well as developer and economic situation for both debt and property market and should be evaluated before selecting between site-built and modular. (Cameron, Di Carlo, 2007)

There may not be any visible difference in fees and interest rates associated with financing modular projects. Some of the complications may be appraisal and payment terms. It is better to make sure that the lender (financial institution) and the manufacturer are in agreement with the times of disbursement. (Cameron, Di Carlo, 2007)

In some instances the manufacturer may want payment upon delivery prior to the modules being set up but the developer resist to this. The reason for this is that a manufacturer wants to avoid the conversion from personal property to real property as soon as it is set as this can add some additional legal complications if there is a payment dispute. A lender favours the module to be set first before payment so that the contractor can waive his liens. (Cameron, Di Carlo, 2007)

It is better for developers to seek financial backing from institutions who are familiar with modular construction methods as it can solve the problem with splitting payment up or holding enough retention to ensure the project is executed efficiently. (Cameron, Di Carlo, 2007)

4.2.2 Material Cost Control

Cost control can also come from the fact that manufacturers buy material in bulk or in advance. With recent price escalation, this could serve as a price hedge as conventional site building contractors are more conscious of the need to improve purchasing policies. The economic market also enjoys the reduction in price by suppliers that can ship large volume of the same unit to clients with the same payment plans. (Cameron, Di Carlo, 2007)

It is good practice with the repetition of business between the suppliers as it creates a good working relationship, placing manufacturers “first in line” with new technologies from the suppliers. This creates an added advantage in times when fuel and transportation cost are high. If modules come pre-assembled with fittings, theft can be reduced as modules are installed immediately on site and ready for use. (Cameron, Di Carlo, 2007)

4.2.3 Labour cost environment

The most visible advantage modular construction has over site-built or conventional buildings is the labour cost savings. Most factories where modular units are manufactured tend to be situated where labour costs are low and there is an ample supply of workers. (Cameron, Di Carlo, 2007)

Many manufacturers can recruit and train employees with little or no construction background as compared to conventional builders where the need for skilled labour is highly recommended. This provides an advantage in communities where lack of skill is high. With modular construction the result on training employees are fairly quick and can perform a specific task at ease. Most problems are intensified by area with high labour cost and unionized workforce. (Cameron, Di Carlo, 2007)

4.2.4 Pricing and Site instructions

The total time decided on the use of modular construction does not have the same advantage or leeway as one with experience during conventional site build. The advantage of having inviting tenders, accepting tenders and commencing construction before complete drawings are issued and then deciding on the final design are basically non-existent in modular construction. Materials being used and drawings must be completed and fully specified before a single sheet of metal can be cut. The positive to approach is that it avoids site instructions being issued and cost overrun of the projects. (Cameron, Di Carlo, 2007)

4.3 Financial Impact

The impact of utilizing modular construction is greatly affected by material cost control, financial and labour environments. If the developer or client wishes to use modular buildings there is a significant advantage to the shortened construction timeframe. (Cameron, Di Carlo, 2007)

The underlining financial benefit or advantages that most clients and developers look for in modular construction are the physical cost savings. It appears to be both locationally and market specific as a benefit. But the soft cost savings for projects that are well conceived with predictable market demands can be significant regardless of location. (Cameron, Di Carlo, 2007)

Assumption is made for a multi-storey building that finances its cost on an interest only basis over a nine to twelve month period. The average outstanding loan balance would be 60%, with the rental income beginning around month eight that helps with interest repayments. Interest on the loan will compound unless the project is sold. (Cameron, Di Carlo, 2007)

For a similar project with the use of modular units, the first phases of the development are fully complete and are ready for tenant occupancy. As long as there is a market for the units, the developer will be able to earn income of the units in half the time. Assumption being made that the project is completed of a third faster, interest payments are reduced to the effects of a shorter loan period. Additional cost savings from a shorter construction period are lower builders risk insurance and lower general conditions. (Cameron, Di Carlo, 2007)

Because of the speed of modular construction that provides significant advantages of a shortened construction time period helps allow the client or developer to mitigate or eliminate uncertainty about what the future markets will be. For an example if the development is a for-sale project that buyers have to make a deposit and then pay the rest on close up of the project, buyers are less likely to change their minds if the construction only takes four months instead of nine to complete. (Cameron, Di Carlo, 2007)

“A possible risk that could arise with the speed of development comes when a project meets tremendous difficulty in marketing or market conditions that abruptly change. With modular, it can be too late to halt production because the entire project may be complete before it is possible to gauge the market response. This with cause the developer of a modular project to have expanded the entire budget and incur interest and carrying cost for the entire project. A site build project encountering the same problem at the same time may only be half complete before recognizing the issue and halting the project and would therefore have a smaller construction loan to service. A more reserved approach when deciding to use modular construction in an uncertain market is to either build to pre-sales or in manageable phases. If the product is well received, one would open the construction spigot, if not, they would damper it down or close it fast.” (Cameron, Di Carlo, 2007)

4.4 In a case study conducted by Di Carlo and Cameron

Project: Cambridge Cohousing, 174 Richdale Avenue, MA, USA

Developer: Oaktree Green

Modular Company: Epoch homes

Architects: Bruce Hampton Architects

Contractor: CB Construction Company

Cambridge cohousing consists of 41 units, the development consist of 1, 2 and 3 bedroom housing with underground parking. The vision of this development is to maximize quality and value by emphasizing good design. This development also emphasized unique green modular design. The partners of Oaktree Green felt that modular construction was a way to potentially obtain some cost savings. (Cameron, Di Carlo, 2007)

4.4.1 The result of the case study:

Although the project experienced delays, the development still sold out shortly after opening with reasonable success. By communicating with the future occupants of the project, skepticism and stigma of the modular construction was reduced and marketing was not an issue. They were successful when they pitched the units as being superior in quality with less wastage consumed. (Cameron, Di Carlo, 2007)

The manufacturers approach to set up training for builders and developers who wish to educate themselves in the modular construction made a positive step towards eliminating both unrealistic scheduling and subcontractor complications. (Cameron, Di Carlo, 2007)

4.4.2 Lessons Learned:

1. Understand the realistic production capacity and backlog of the manufacturer to establish a realistic timeframe for production and delivery of module units
2. Promote clear communication and between manufacturer and local trades or select a manufacturer that self performs installation and utility connections
3. Monitor quality control early and at all levels of production, including transport and set phases.
4. Financing can be a problem if financial institutions are unfamiliar with this type of construction method

5. Large scale projects has the potential to offer more cost saving because there is a greater opportunity to perfect the manufacturing and connection process
6. Use an architect familiar with modular construction. Do not use a regular architect and expect the manufacturers in-house architect to make the necessary changes
7. Understand transportation issues and plan accordingly

(Cameron, Di Carlo, 2007)

4.5 Conclusion

Market issue stigmas need to be considered carefully and an understanding of local opinions in the targeted market and demography are imperative. As more emphasis is placed on environmental conscious developments, developers can market products and processes in modular construction for the “green” consumer.

Modular buildings have both potential risks and benefits. One major benefit is the greater level of detail required before the commencement of the project leads to the elimination of cost overruns due to inaccurate allowances and material cost spikes.

4.6 Testing of Hypothesis

As stated throughout the chapter, modular construction has many benefits and offers the developer different advantages in the economic markets.

Yes, modular construction is beneficial to the industry

5.0 Chapter Five: Sustainability and Life Cycle of Modular to Conventional Construction

5.1 Introduction

Construction of buildings as well as the use and demolition of buildings can generate substantial social and economic benefits to society, but on the other hand may have serious negative impacts to the environment. Residential buildings are the biggest section in the construction industry and therefore this chapter will focus primarily on the impact modular buildings have on the environment. As a relatively new construction technology, modular buildings are gaining in popularity throughout the world. In modular buildings, components of the house are assembled in the factory and delivered to site as fully volumetric units. According to the National Modular Housing Council, 2008, the modular home is considered superior in quality to the conventional site built home. The research by the US Department of Housing and Urban Development indicated that specialized equipment used in assembly line operations of modular housing raises labor productivity and product quality. Workers are generally not subcontracted, and can be scheduled, managed and deployed by a single authority in the interest of productivity and efficiency. Also, the controlled environment of modular construction minimizes risks and delays due to poor weather. Modular buildings can be built quicker than onsite buildings or conventional buildings. It takes about an average of eight weeks to construct a modular building whereas it takes three to four months to build a conventional building on site. This can maximize the efficiency of work, quality of production and therefore save energy consumption in relation to shorter construction period. Conventional construction has been studied by industry whereas modular construction has not due to the relatively new application of it. For this reason many assumption are being made due to lack of knowledge. (Kim, 2008)

5.2 Purpose of this chapter

Modular construction and buildings can offer sustainability in the construction industry, providing quality, time, productivity and efficiency. Referring to conventional residential buildings, they significantly influence energy consumption, green house gas emissions and solid waste discharge. It is expected that modular construction will help reduce environmental impact as compared to conventional buildings. The case being used is based on an American housing units constructed by Redman homes and compiled by Kim. (2008)

Table 1 Assumptions and Simplifications in this study Categories Assumptions

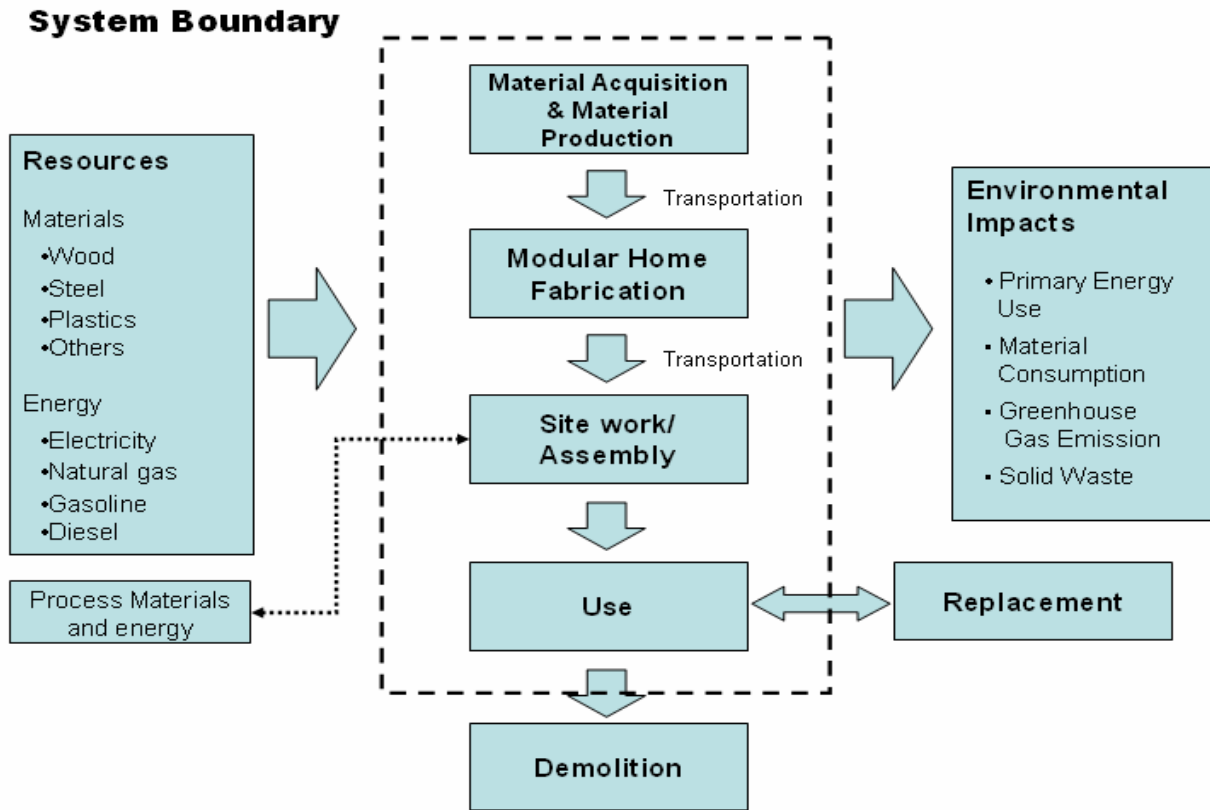
Categories	Assumptions
Building materials	It is assumed that the two housing types are built with the same Materials. Materials taken into account for the modular and conventional home are based on data for the 150 building Materials provided by Redman Homes.
Building component difference	The perceived building component differences between the Modular and conventional home are stud size, marriage wall and Folding roof truss. Other differences are assumed to be negligible
Construction energy	Construction energy for the conventional home is assumed to be equal to the modular home fabrication energy.
Building energy consumption	Energy consumption of each home only accounts for internal house energy consumption. Energy consumption related to the house surroundings (e.g. outside lighting) is excluded.
Waste	It is assumed that all wastes generated from fabrication or construction is disposed in a landfill. The end of life management phase, however, was not modeled.

Material supply transportation	Truck (16 ton load carrying capacity) is assumed as the mode of Material transportation. A simplified material supply is modelled with supplier locations provided by Redman Homes and Douglas Construction. The material supply model only pertains to the building site, the modular home factory and supplier locations chosen in this study. The material supply transportation modelled In this study is not applicable to other building sites.
Employee transportation	One passenger per vehicle occupancy is assumed for employee Transportation. Employees use standard passenger cars for commuting

Source: (Kim, 2008)

Redman Homes reported that it takes about 4-5 days to fabricate a modular unit; this reduced cycle time means a reduction in time spent by employees constructing a building which translate to less employee's transportation energy costs, beneficial to the industry considering it takes 3-4 months to construct a conventional building. Materials used for modular buildings are purchased in large quantities and procured directly from suppliers which indicate that material cost and transportation energy is less for this type of construction. The materials used for modular construction are stored in inventories with controlled environments in factories therefore reduction in damage which indicates less quality problems than experienced in conventional buildings. Modular buildings need a much stiffer structure when transporting units to survive transportation damage, during transportation, modular units experience significant loads on trucks and crane hoisting therefore units are made with additional supports and stiffeners which add to the total cost but added advantage are stronger, more load resistant units. (Kim, 2008)

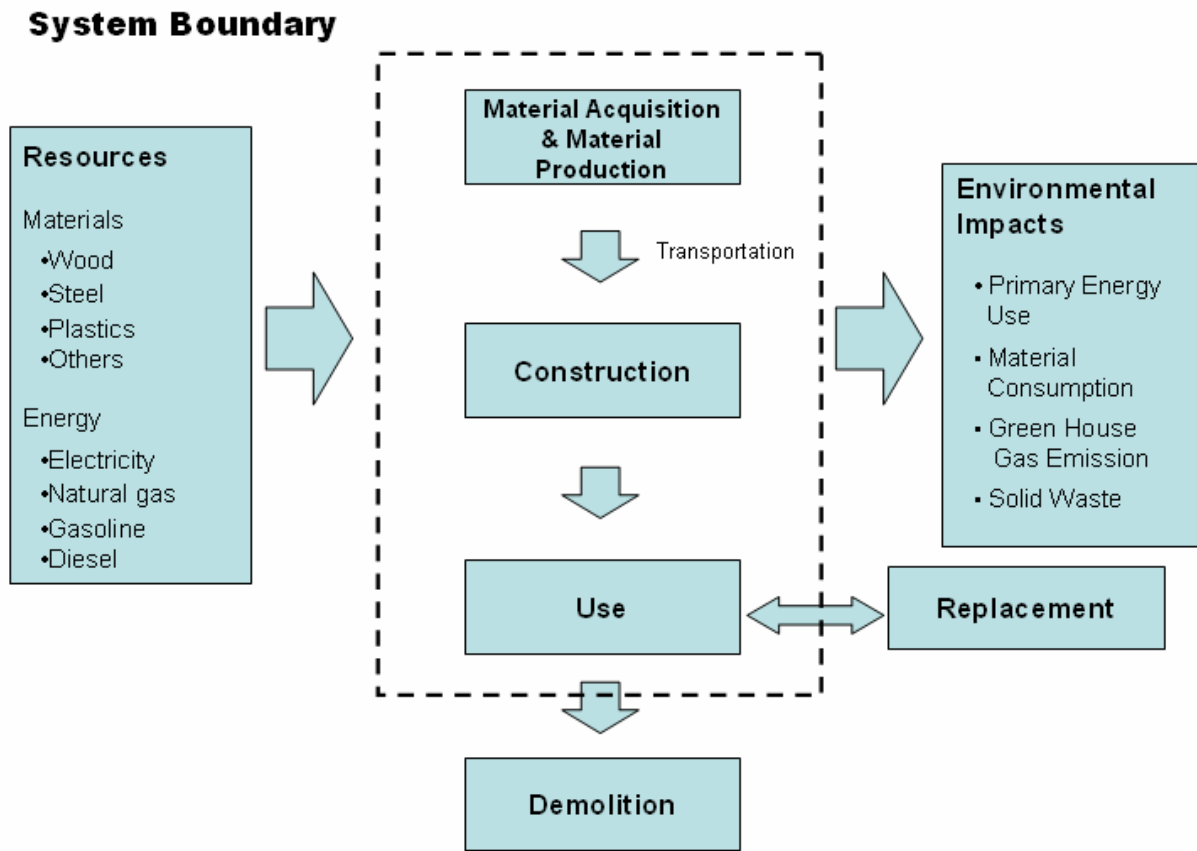
Figure 5 Life Cycle System of Modular Home



Source: (Kim, 2008)

Figure 5 explains the life cycle of modular homes and indicates four phases: material acquisition/material production, modular fabrication, site work and use. Replacement includes maintenance and renovations of the building. The material acquisition phase includes activities such as mining of raw material and material production comprises of engineering the raw material into finish products. Fabrication stage includes adding of windows, doors etc. site work includes delivery of units on site and assembly of it. Transportation has three phases such as material transportation of moving material between each phase, employee transportation which is commuting of employee's energy transportation to site used and unit transportation to site assembly.

Figure 6 Life Cycle System of Conventional Home



Source: (Kim, 2008)

Figure 6 indicates a life cycle of conventional buildings which differs from modular buildings due to the different construction processes. The conventional building indicates three phases: material acquisition/ production phases which is similar of that of modular building, construction phases which differs significantly to modular buildings in that the construction in started and completed on site entirely, it includes material and energy required inputs and process during the entire construction phases, the transportation phase consists of two inputs that are material transportation to site and employees commuting transportation energy to site. (Kim, 2008)

5.3 The analysis of life cycle of modular buildings

5.3.1 Material consumption

The total material consumption counts the material used for building a modular building and amount of waste generated. The survey was based on Redman Homes production line, and was reported that fabrication processed are approximately 3% of total materials used. Due to the efficient assembly line modular buildings can reduce waste as compared to conventional buildings.

5.3.2 Transportation

Material transportation is highly dependent on the material supply chain. The closer the distributor is to the manufacturer, the less energy will be used and vice versa. Employee's transportation is determined to the number of employees and commuting distance. The delivery distance of modular buildings are important to the calculation of the energy used. It includes weight of shipment as well as distance covered. The weight includes all material weight installed. (Kim, 2008)

5.4 The analysis of life cycle of conventional buildings

5.4.1 Material consumption

Material consumption of conventional buildings includes all materials used on site therefore material wastage is more than that of modular buildings. Because there are more employees working on site and the construction manager does not have the resources to monitor every single employee on site. (Kim, 2008)

5.4.2 Transportation

Material transportation differs from modular buildings due to the fact that construction starts from scratch and all materials are needed on site but at different intervals, therefore higher transportation energy is used. Also there is a greater employee total on site which indicates a greater transportation energy consumed when commuting to site.

5.5 Conclusion

Based on the study, the modular construction provides a better environmental performance than conventional construction. The modular buildings efficient construction time, quality which are factored into the sustainability context. The reduction on production time reduces employees transportation energy consumed. The modular units might have a greater transportation energy used due to the delivery location of the units to site. If this can be reduced by reducing delivery distance of the unit then modular units will be more environmental efficient than conventional buildings. Modular buildings can be environmentally and socially sustainable.

5.6 Testing of Hypothesis

Throughout this chapter, reference has been made to the life cycle and sustainability of modular buildings with analysis to transportation and materials consumption and how it benefits the environment.

Yes, modular construction is beneficial to the construction industry.

6.0 Chapter Six – Final Chapter

6.1 Summary

In chapter one, modular buildings were defined as a term where a building is assembled from a series of volumetric modules, linked or joined together to form a complete structure. The main problem of this thesis, are modular buildings beneficial to the construction industry? And the sub problems that followed were:

1. Design Limitation and Considerations of Modular Construction
2. Can Modular buildings be Green and will it be beneficial to the Construction Industry?
3. Market and Financial considerations of Modular Construction
4. Sustainability and Life Cycle of Modular to Conventional Construction

Each sub problem was explained in general and the conclusion made reference that modular construction benefits were:

- It reduces construction time
- Hence the reduction on construction time, preliminary cost are lower
- It is safer, less noisy and cleaner than traditional construction methods
- It reduces the likelihood of defects in workmanship
- Low cost maintenance

In chapter two, Design Limitation and Considerations of Modular Construction was the sub-problem and the challenges encountered during the research on this chapter were:

- The market for modular construction is poorly defined
- Assumptions are needed for the establishment of production plans
- Society wants a sustainable and attractive building, not a semi permanent one

These short-comings can be the task of the designer or architect and they must manage the four processors when designing a modular building. Feedback and information exchange are key to the success of the project. Design parameters, level of finish, physical and site consideration as well as vendor selection are all problematic when it comes to modular buildings. With the use of advanced technologies in the engineering and computer fields, such as computer aided drawings, it was able to overcome the short-comings experienced stated in this chapter.

In conclusion of this chapter, is the appearances of modular buildings are becoming less restrictive due to advances in technologies and computer software. Architects and manufacturers are becoming more familiar and adept with the design of modular buildings. There is still the primary issue with the height and width of the units with delivery also a main issue. The site requirements and complication will alter the dimensional specifications of the unit and alter the cost but these limitations are marginal and can be overcome by proper design phase planning.

In chapter three, the sub-problem stated was considering if modular construction can go green and will it offer any benefits. With the use of green concepts in design, a building should be able to:

- Efficiently utilize energy, water and other resources
- Protecting occupants health and improving productivity
- Reducing pollution and environmental degradation

The South African market is fragmented, resistant to change, labour intensive and wary of new processes. The problems experienced are the initial cost, funding, availability of materials, location and time frame when going green.

The advantages of modular going green has environmental benefits, there is less wastage due to more precise cutting of materials. The economic benefit is that it saves the owner or consumer with lower operating costs over the life of the building.

In conclusion of this chapter, good practice and well knowledgeable and trained manufacturers can ensure that the building will impact less negatively on the environment and ensuring that the building is green.

In chapter four, the sub-problem, market and financial problems were discussed. It was experienced that there is a stigma associated with modular construction being made of poor quality, building being boring and not aesthetically pleasing, low ceilings and poor layout. Financial considerations with regards to economic situation for both debt and property market should be evaluated.

Modular construction has both financial benefits and risks. The shorter construction period can reduce the market risks. Other factors that were considered were:

- Material cost control – Cost control can be established by manufacturers buy in bulk, this reduces the price of materials.
- Labour cost environment – this is one of the most visible advantage modular construction has over traditional construction. Most modular factories are situated where labour cost are low and there are ample supply of workers
- Pricing and site instructions – the disadvantage is that drawings must be completed and full specifications must be issued before any production of the units are made.

In conclusion of this chapter, the fact that drawings need to be completed with a great level of detail before commencement of the project, the costs overruns are reduced. The key lessons learned are:

- Financing can be a problem if institutions are unfamiliar with the type of construction method
- Monitor quality and control early and at all levels of production
- It is important to use an architect that is knowledgeable with modular construction

In chapter five, life cycle and sustainability were discussed in detail, making reference to material consumption and transportation in both modular and conventional buildings. Based on the study, modular provides a better performance than conventional construction. It proves to be efficient in construction time and quality which are factored into the sustainability context. The reduction in production time reduced employees transportation energy consumed.

6.2 Conclusion

In summary, modular construction adds diversity and complexity to the typical construction industry. It should not be used to eliminate construction management. It should rather be used or considered as an alternative to traditional practices, where a developer is looking in reduction in costs.

6.3 Future Research

Due to the vast advantages that modular construction has to offer the industry, the South African industry should try to incorporate modular design in their principles and design. Future research should consider if this relatively different practices can be cost effective and efficient to the South African market.

Looking Ahead, where is the Industry headed?

Foreign invasion: Several international companies such as Verbus are looking to enter the South African market. Although there are additional transportation issues to manage, they feel that they can capitalize on their competitive and operational advantage to be more cost effective.

One-stop Shopping: There is a lack of turnkey construction services in South Africa for modular construction. Large companies should consider handling the entire site works to module building, transportation and service connections with inhouse/domestic sub-contractors.

Labour: There is a declining pace of skilled people entering the building trades. This is where modular is advantages because workers are trained in a skilled and safe factory environment, in which they can progress at the work they output very easily.

Technological advances: Due to the increasing user friendly application of CAD, clients are allowed more interaction at design process with the manufacturers.

Education: It was found that there is a need for modular education and training. The modular industry should make an effort to build the awareness of modular by conducting orientation and educational programmes for new clients. This can help eliminate issues that may arise with inexperience developers, builders and sub-contractors working on modular for the first time.