EVALUATING THE ADOPTION AND USAGE OF OFF-SITE MODULAR CONSTRUCTION ON BUILDING PROJECTS IN NORTH CYPRUS

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By

CHRISLYN OMOCHIERE EGEGE

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Architecture

NICOSIA, 2018

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my late father...

ABSTRACT

Off-site (modular) construction is an innovative and environmentally sustainable technique of carrying out construction project and has been on the increase lately. This method has the ability to address challenges being faced by on-site construction. Issues such as high construction cost, low health & safety of workers and reduced quality of works are all associated with on-site construction. All these issues identified above inevitably leads to reduced productivity output in project delivery. The aim of this thesis is to evaluate the adoption and usage of off-site modular construction in the building industry in North Cyprus.

A total of 15 case study examples of off-site construction around the world were studied. A quantitative research method which involved the use of structured survey questionnaire was also used for this research. The questionnaire was administered to professionals in the building industry to assist in gathering data pertaining to this discuss. After which the data gathered was analysed using SPSS 25 statistical tools and the results discussed.

The results show high construction cost, low workers safety, low quality of works and use of unskilled personnel as the major challenges faced in the TRNC building industry. Most professional in the industry have a positive perception about off-site construction and are also willing to adopt precast/pre-stressed concrete and modular construction techniques on future building projects. The result also suggested that clients are responsible for the decision to use off-site on project while stating that it is important to involve the general contractor and manufactured during design stages. Reduction in schedule/time, cost control, increased workers safety and profit margins as well as waste reduction are the top benefits for using off-site construction while clients perception & knowledge, historical stigma, designers knowledge and availability of manufacturers remains the major constraints to the full adoption of off-site construction in TRNC. Organising conferences, workshops and seminars are suggested as the best ways of raising awareness about off-site construction in TRNC.

Off-site construction is ideal for urban infill where there's need to building multi-storey buildings due to large population. But considering the case of TRNC with a small economy and population of less than 500,000 it wouldn't be cost effective and necessary to fully implement the adoption of this technique on all of its building projects.

Keywords: On-site construction; off-site construction; modular construction; sustainable construction; T.R.N.C.

ÖZET

Şantiye dışı (modüler) yapım, inşaat projesinin yürütülmesi için yenilikçi ve çevresel olarak sürdürülebilir bir tekniktir ve son zamanlarda artmaya devam etmektedir. Bu yöntem, yerinde yapım ile karşılaşılan zorlukların üstesinden gelme yeteneğine sahiptir. Yüksek yapım maliyeti, işçilerin sağlık ve güvenliğinin düşüklüğü ve işlerin kalitesinin düşürülmesi gibi konular, yerinde yapım ile ilişkilidir. Yukarıda belirtilen tüm bu sorunlar, kaçınılmaz olarak proje teslimatında daha az üretkenlik çıktısına yol açar. Bu tezin amacı, Kuzey Kıbrıs'taki inşaat endüstrisindeki şantiye dışı modüler yapımın benimsenmesini ve kullanılmasını değerlendirmektir.

Dünya çapında şantiye dışı yapım örneklerinden 15 örnek çalışma incelenmiştir. Bu araştırmada yapılandırılmış anket kullanımını içeren niceliksel bir araştırma yöntemi de kullanılmıştır. Anket, bu tartışmaya ilişkin verilerin toplanmasına yardımcı olmak için inşaat endüstrisindeki profesyonellere uygulanmıştır. Daha sonra toplanan veriler SPSS 25 istatistik araçları kullanılarak analiz edilmiş ve sonuçlar tartışılmıştır.

Sonuçlar, yüksek inşaat maliyeti, düşük iş güvenliği, düşük iş kalitesi ve vasıfsız işçinin, KKTC inşaat sektörünün karşılaştığı en büyük zorluklar olduğunu göstermektedir. Endüstrideki çoğu profesyonel, şantiye dışı yapım konusunda olumlu bir algıya sahiptir ve aynı zamanda, gelecekteki inşaat projelerinde prefabrik / ön-gerilmeli beton ve modüler yapım tekniklerini benimsemeye isteklidir. Sonuç aynı zamanda, genel yüklenicinin dahil edilmesinin ve tasarım aşamaları sırasında imal edilmesinin önemli olduğunu belirtirken, projede şantiye dışı yapım kullanımı kararından müşterilerin sorumlu olduğunu göstermektedir. KKTC'de şantiye dışı yapımın tam kabulü için zamanlama/süre, maliyet kontrolü, artan iş güvenliği ve kar marjları ile atık azaltma, KKTC'de şantiye dışı yapımı kullanmanın en büyük faydaları iken, müşterilerin algısı ve bilgisi, tarihsel damgalaması, tasarımcıların bilgisi ve üreticilerin bulunabilirliği başlıca kısıtlamalar olmaya devam etmektedir. Toplantılar, çalıştaylar ve seminerler düzenlemek KKTC'de şantiye dışı yapım konusunda farkındalık yaratmanın en iyi yolları olarak önerilmektedir.

Şantiye dışı yapım, nüfusun büyüklüğü nedeniyle çok katlı binaların inşa edilmesi gereken kentsel dolgu için idealdir. Ancak KKTC'nin küçük bir ekonomiye ve 500.000'den az nüfusa

sahip olması dikkate alındığında, tüm inşaat projelerinde bu tekniğin tam olarak uygulanmasının benimsenmesi, maliyet etkin ve gerekli olmayacaktır.

Anahtar Kelimeler: Konvansiyonel yapım, santiye dışı yapım, modüler yapım, sürdürülebilir yapım, K.K.T.C.

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LIST OF ABBREVIATIONS AND SYMBOLS

BIM:	Building Information Modelling
BRE:	Building Research Establishment
BSRIA	Building Services Research and Information Association
CIB	International Council for Research and Innovation in Building and Construction
CIR:	International Council for Research and Innovation
CIRIA:	Construction Industry Research and Information Association
CLT:	Cross Laminated Timber
CRC:	Cooperative Research Centre for Construction Innovation
GLULAM:	Glue Laminated Timber
HBS:	Hickory's Building System
IBM:	International Business Machines
LCI	Lean Construction Institute
LEED:	Leadership in Energy and Environmental Design
MMC:	Modern Method of Construction
OSB:	Oriented Strand Board
OSC:	Off-Site Construction
OSF:	Off-Site Fabrication
OSM:	Off-Site Manufacturing
OSP:	Off-Site Production
m^2:	Square Meter
MBI:	Modular Building Institute
MC:	Modular Construction
MMC:	Modern Method of Construction
MEP:	Mechanical, Electrical and Plumbing
NYC	New York City
PMC:	Permanent Modular Construction
RMC:	Relocate-able Modular Construction
SPSS:	Statistical Package for Social Sciences

TRADA:	Timber Research and Development Association
T.R.N.C.:	Turkish Republic of Norther Cyprus
U.K.	United Kingdom
U.S.A.	United States of America
WRAP:	Waste and Resources Action Program

CHAPTER 1
INTRODUCTION

1.0 Background of the Study

Traditional construction (on-site) method has over time proofed to be quite labour-intensive and as such comes with many drawbacks. The lack of innovation in the techniques that are being utilize for building construction in North Cyprus leads to the question of what is holding the industry back from adopting off-site construction on most or all of its building projects.

McGraw Hill Construction a construction firm based in the United States of America carried out a survey in 2011. The survey were conducted amongst building owners, architects, engineers and contractors. The survey reported that off-site modular construction speeds up the time of completion of a project while reducing the level of wastage. The level of impact on the environment and the total cost of construction decreases when this method is employed and there is bound to be increase in the quality of finished products and workers safety (Mcgraw-hill, 2011)

The educational sector in North Cyprus has recorded a tremendous boom in the last 10 years while attracting thousands of international students, lecturers and foreign investors likewise. This has led to gradual urbanization in North Cyprus hence the inevitable need for more housing on the island.

Off-site Modular Construction is a type of construction that involves the construction of buildings using structures or components that are pre-engineered. They are typically flexible and able to surpass or satisfy the requirements of conventional construction (on-site construction). These buildings can be re-located or totally re-used. As a result, construction will move from the regular everyday site to a regulated factory facility. This is where most part of the project takes place. Major parts and components of the building are being assemble here thereby reducing the cost of both labour and material. The overall construction productivity is increased and inherent risk during construction eliminated. The reduction in construction cost using off-site modular construction results from the well compacted and compressed schedules which also facilitate sustainability. Industrialization and standardization of a country's building industry tends to increase by its usage.

The adoption of Off-site Modular Construction as a sustainable construction method is taking a new leap worldwide (mostly in developed countries). Off-site construction is done to increase and enhance productivity level in the construction sector. This result in significantly reducing the social and environmental effects of the conventional construction technique and its activities. The adoption of off-site construction is somehow low despite thorough documentation of the achievable benefits obtainable using this technique (Bottom, 1996; Brown, 2002; Gibb et al., 1999; Gibb & Isack, 2003; Neale et al., 1993; Wilson et al., 1999).

As a result, this research will importantly examine and evaluate the level of acceptance and usage of this construction method in developing countries while concentrating on North Cyprus.

1.1 Problem Statement of Research

Due to the recent urbanization taking place which has somewhat increased its economic development, North Cyprus is facing a serious challenge in providing quality and affordable housing to it populace. Some of this populace are foreigners (international students/instructors) from other countries. Building developments such as residential/apartment buildings, office buildings and hospitality buildings such as hotels to mention a few can be seen springing up all over the island. These developments occur in the major cities of Lefkoşa (Nicosia) to Mağusa (Famagusta) and Girne (Kyrenia). Most of these developments are executed using on-site (conventional/traditional) method of construction. Due to the intricate nature of construction, there are numerous challenges being dealt with by construction stakeholders in the use of on-site construction. Some of the challenges includes but not limited to environmental impact (noise, weather and waste), low construction quality and workers' safety. There is also increase in construction cost due to several negative situations, longer completion time and low productivity. The building industry in North Cyprus is not exempted from all the above mentioned challenges. Most if not all of the challenges mentioned which are associated with on-site construction method can be addressed if off-site modular construction were to be adopted for the execution of building projects. Therefore, it is highly important to tap into the positive attributes which off-site construction brings so as to achieve innovative and sustainable construction practices.

1.2 Aim of the Research

The aim of this research was to critically examine and evaluate the building industry in North Cyprus in other to determine the level of adoption and usage of Off-site Modular Construction on building projects on the Island. Furthermore, the level of knowledge and exposure of the building industry stakeholders to Off-site Modular Construction was evaluated while highlighting the importance and benefits of adopting this method of construction on building projects.

1.3 Objectives of the Research

The objectives of this research includes but not limited to the following;

- Evaluate the North Cypriot building industry.
- Evaluate the construction industry stakeholders' knowledge of off-site modular construction.
- Evaluate the construction industry stakeholders' perception of off-site modular construction.
- Evaluate the construction industry stakeholders' exposure and usage of off-site modular construction.
- Evaluate the constraints and barriers in the adoption of off-site modular construction.
- Promote off-site modular construction while discussing its attributes.
- Critically discuss the benefits and limitations of off-site modular construction.

1.4 Research Methodology

This thesis adopted a systematic review of literatures relevant to the study which comprising of text (digital and printed), articles in journals, technical reports, conference papers and case study examples together with a quantitative research method. Some self-administered structured questionnaire were distributed amongst major stakeholders in the building industry in North Cyprus. These stakeholders comprised of professionals in the building industry such as architects, engineers, project managers. The reason for this is to gather information and data pertaining to very vital areas in the industry as regards its acceptance, adoption and usage of off-site modular construction. An overview of the building Industry in North Cyprus was also studied to understand the construction methods currently in use in North Cyprus**.**

1.5 Importance of the Research

The importance of conducting this research is primarily for the promotion of off-site modular construction as an innovative and sustainable construction method and the importance of adopting it on building projects in North Cyprus. At the long run, the productive attributes of this method will yield a positive effect on the building sector and also be beneficial to the growing economy of North Cyprus should it be adopted.

1.6 Scope and Limitations of the Research

This thesis centred its research, evaluation and findings on just the building industry that is in charge of constructing building structures and not the general construction industry that involves civil engineering works such as bridges, roads, dams and canals. To also narrow this thesis down, the material used for off-site modular construction that were discussed are those which are predominantly used for the construction of structural elements, these materials are steel, timber, reinforced and precast concrete.

There were some limitations encountered by the researcher during the course of this thesis study. The research limitations include; the availability of few researches which have been carried out about the North Cypriot construction and building industries recently, hence some data used are as old as a decade ago. Secondly, there were also challenges finding case study examples of projects carried out using off-site construction in North Cyprus online. Though the respondents to the survey did agree to the use of this method on some construction projects, the proper documentation of these examples with detailed information seems to be absent online. Attempts to reach some companies who seems to carry out construction using this technique proved abortive before the conclusion of this thesis thus it was quite difficult providing in-depth examples in North Cyprus. Thirdly, there was the issue of language barrier during the industry survey. The questionnaire had to be translated into

Turkish before it started getting responses after 3 weeks of being hosted on the survey-monkey website. Some professional association whom got the invitation to participate the survey neglected it resulted in the researcher not getting the desired amount of responses he would have wanted.

1.7 Overview of the Thesis

Chapter 1: this chapter is the introduction of the study.

Chapter 2: this chapter concentrates on literature review of previously published books, articles, journals, conference papers and other academic resources that are in close relation with the thesis topic.

Chapter 3: covers the theoretical framework for the analysis of off-site modular construction. The different aspect of off-site construction were discussed as well as its benefits, constraint and barriers in its adoption. The differences between off-site and on-site construction were also studied as well as the review of cases studies around the globe.

Chapter 4: discussed the research methodology adopted for the thesis which is quantitative in nature. It involves the use of self-administered structured questionnaire containing about 32 questions which was divided into 4 sections. Data gotten were analysed in chapter 5.

Chapter 5: collected data from the survey questionnaire were presented and analysed. Data presentation were shown in a percentage bar chart as well as tabular method which showing both the number and percentage of respondents to a question.

Chapter 6: Discussed the results from the data obtained from respondents. The conclusions and recommendations to this research were drawn as well as suggestion to areas for future research.

CHAPTER 2
RELATED RESEARCH

2.1 Off-site Construction

Off-site manufacturing (OSM), off-site production (OSP), off-site fabrication (OSF), Modern Methods of Construction (MMC), Permanent Modular Construction (PMC) and Prefabricated Construction are relative terms that are used interchangeably in describing off-site construction (OSC) in this research.

OSC is described as a method of construction through which the planning, design, fabrication and generally assembly of building elements are carried out in a regulated facility (Smith, 2017). Smith further explained that these locations in all cases are different from the structure's final location of installation and it's done so that permanent structures can be constructed efficiently and rapidly. Arif and Egbu (2010) explained that the intent of OSC is to shift most construction processes to a more regulated environ of a manufacturing facility.

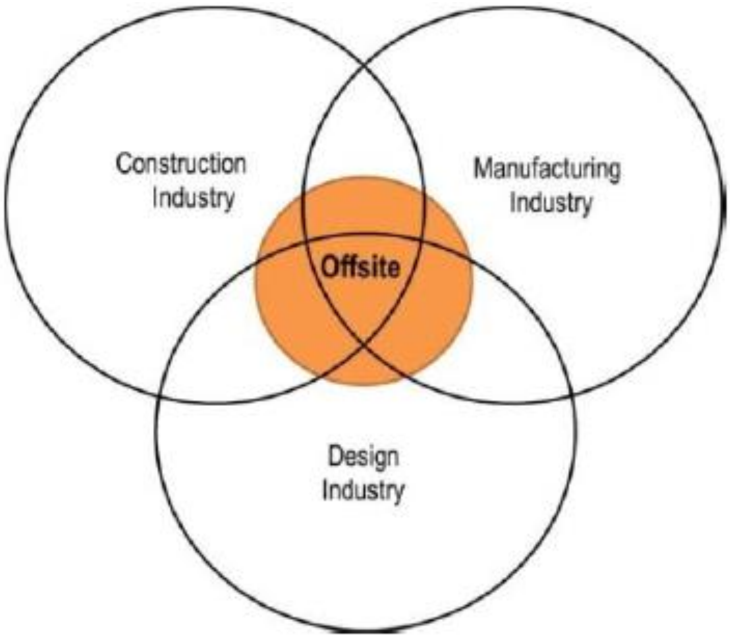


Figure 2.1: Design, manufacturing, and construction: off-site interrelationships (Goulding & Arif, 2013)

In a recent research carried out by the International Council for Research and Innovation in Building and Construction, Goulding & Arif (2013) suggested that the idea of OSM constitutes and integrates three major industries such as construction, design and manufacturing (Figure 2.1). The findings of the research further pointed out that the three above mentioned industries in many ways are homogeneous and interwoven.

One main strategy of off-site for better optimization is the integration of systems and supply chain through research, design, testing and prototyping (R. E. Smith & Quale, 2017). There is a relative difference between this method of construction and the conventional on-site construction in the sense that conventional construction manufactures most of its building elements and components on-site (Azman, Ahamad, Majid, & Hanafi, 2010; Pan, Gibb, & Dainty, 2007).

It was argued by (Nadim & Goulding, 2010) that the off-site construction itself falls under modern method of construction (MMC).

2.2 Historical Background of Off-site Construction

The utilization of manufactured building structures should not be seen as a contemporary occurrence (Taylor, 2010). Burkhart & Arieff (2002) recounts that the history of off-site construction can be linked back to the prefabricated construction which emerged when Great Britain tried to subjugate the world. Settling in those part of the world such as present day Africa, Canada, India, Middle-East, New Zealand and U.S. was quite challenging. Due to the several unknown construction materials available in those regions, the desideratum for an expeditious building initiative which saw them shipping in manufactured components from England by boats. The first set of these structures that were recorded in 1624 were manufactured in Great Britain were then delivered to Cape Anne (Massachusetts) (Burkhart & Arieff, 2002).

Around 1790, a prefabricated hospital and store emerged as the earliest settlement reported inside New South Wales and were being transported to Sydney. The whole building including its frames, walls, floors and roofs were entirely fabricated from timber. Couple of years later, it was reported that a church building and other types of building structures adopted this similar system for their construction in Freetown (Herbert, 1978).

The Manning Portable colonial cottage for emigrant (Figures 2.2 and 2.3) was the subsequent evolution of prefabricated houses. These structures were designed and developed by a carpenter from Great Britain called John H. Manning. The earliest archetype of the manning cottage that was an entirely prefabricated house that was built around 1830 for his son whom was immigrating to Australia (Ryan E Smith, 2009).

Figure 2.2: Typical Manning portable cottage (Abraham, Kim, & Lu, 2012)

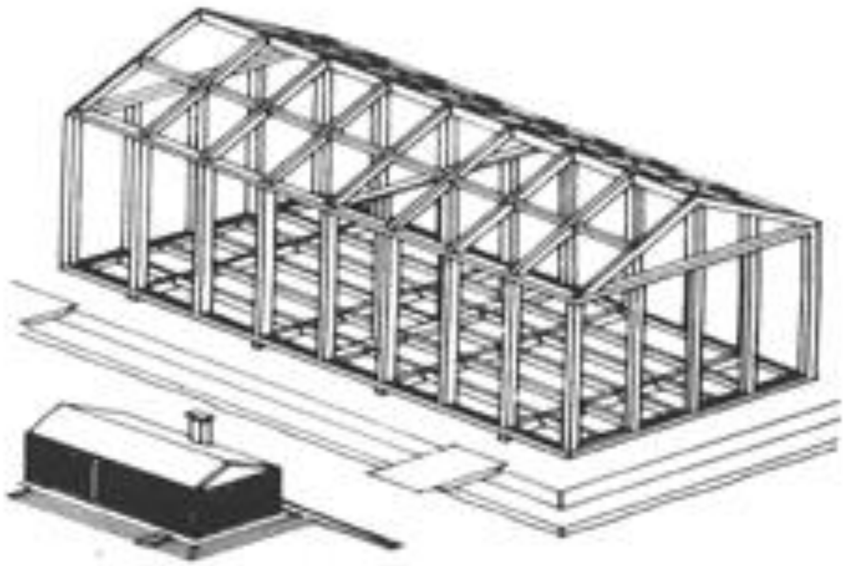


Figure 2.3: Framing of the Manning portable colonial Cottage produced in Great Britain (Smith, 2009)

During the Crimean war in 1855, the Renkoi Army hospital made from wood (Figures 2.4 and 2.5) was designed and developed by Brunel in England before being shipped to Crimea. The hospital was built using entirely prefabricated components and can be built on any site using unskilled labour. This military hospital was instrumental in lessening the death rate of wounded British soldiers to the barest minimal and by March 1856 more than 2,200 patients have been treated inside it ("Renkioi Hospital," 2000).

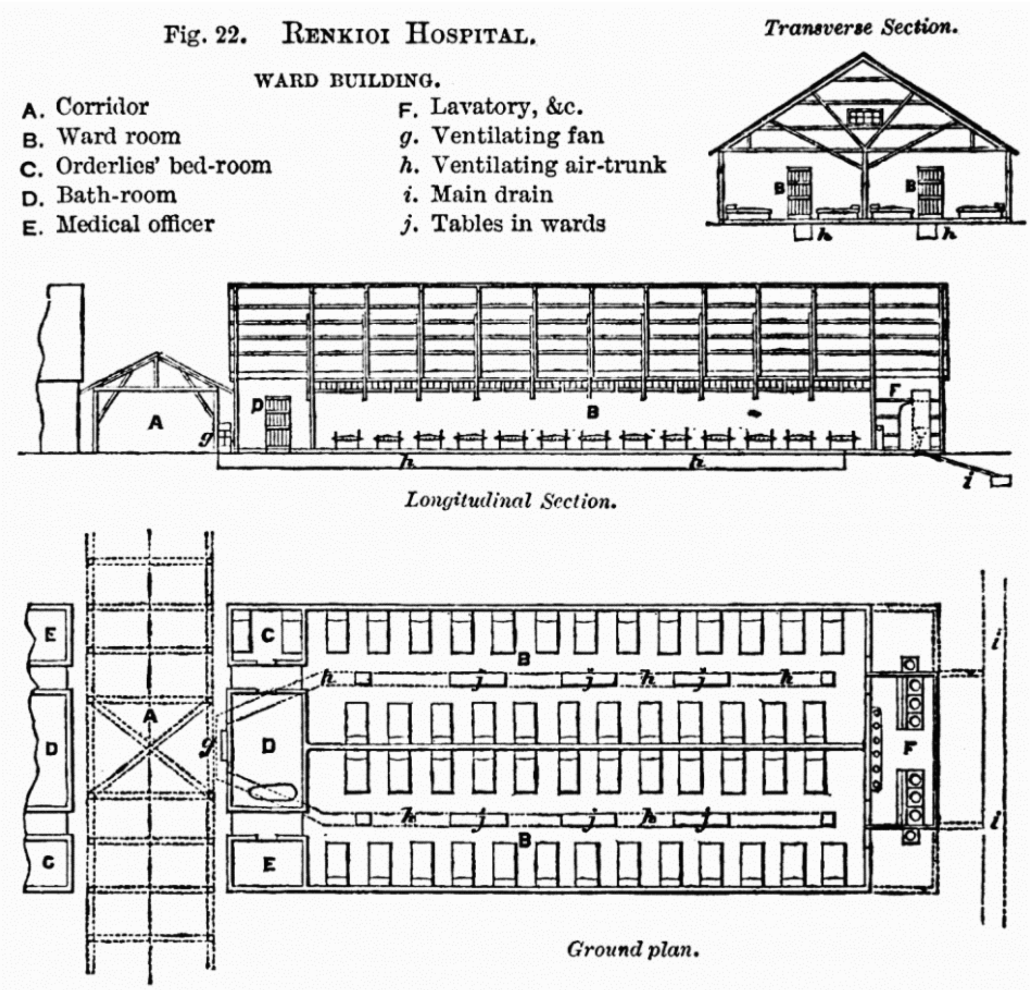


Figure 2.4: Plan and section of the Renkioi hospital (McDonagh, 2017)

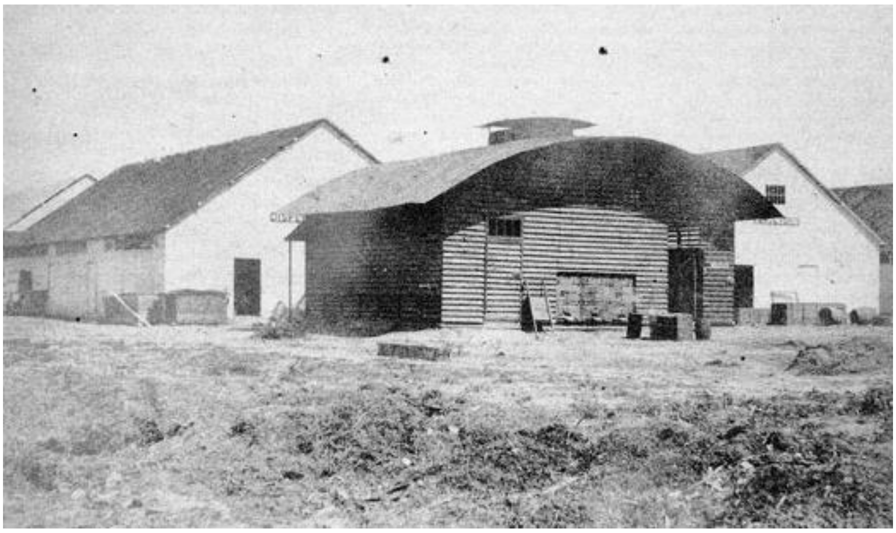


Figure 2.5: Exterior of the Renkioi hospital, Crimea (1857) made from prefabricated timber ("Brunel Photographs - Isambard Kingdom Brunel," n.d.)

Between 1920 and 1940, Sears Roebuck Company built many prefabricated structures most of which were houses (Figures 2.6 and 2.7). Its acceptance grew largely amongst the American populace around 1920. The idea behind the Sears prefabricated homes was gotten from the Aladdin's home concept which built kit homes out of pre-cut timber. These timbers are then used to construct light frame structures for Americans on the move resulting from the California Gold Rush enticement. After being purchased, these buildings are delivered by trains together with an explicit installation guide, full kits including nails and bucket of paints (Ryan E Smith, 2010).

Figure 2.6: Typical Sear Roebuck (Sheridan) bungalow (The Arts and Crafts Society, n.d.)

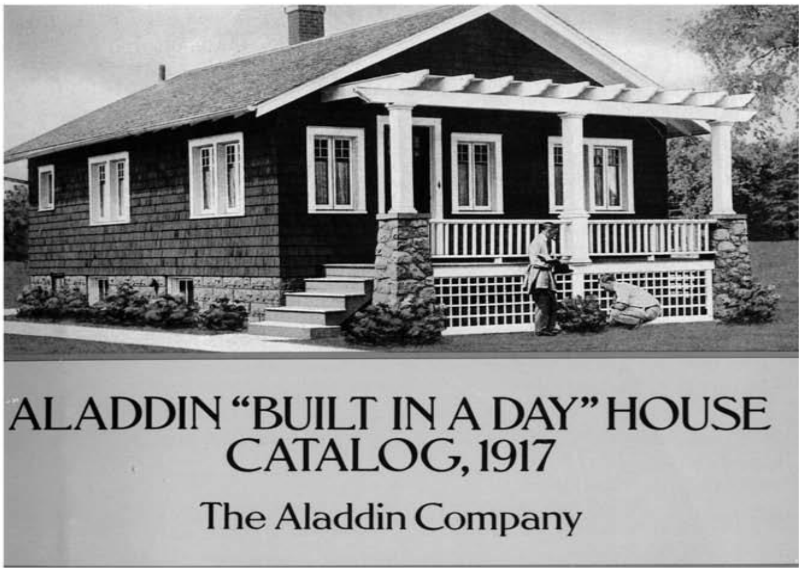


Fig. 2.7: Typical Aladdin built house between using pre-cut timber (Smith, 2010)

Prefabrication took a massive boost during the World War II due to the increasing necessity for multipurpose buildings for the U.S. military personnel. The army and navy needed mass produced lightweight structures for different uses which led to the development of the Quonset hut (Figure 2.8). The semi-circular latitudinal section structure which is made from either galvanized or corrugated iron sheets. Due to the fact that these structures can easily be assembled by unskilled personnel, it was easily adopted to reconstruct areas that were severely wrecked during the war buy the Japanese and Europeans ("Benefits and Applications of the Quonset Hut Design," 2016).

Figure 2.8: Typical Quonset huts built during WW.II (Winding Waters, n.d.)

Construction technique using concrete modular elements for the construction of high-rise buildings were introduced to the United States construction industry. A major milestone for the modular construction industry in the U.S. is the construction of the Hilton Palacio del Rio Hotel in San Antonio, Texas (Figure 2.9) during 1968 by H. B. Zachry Company and it took about 202 working days to complete. The modules which were made from pre-cast light-weight structural concrete. Having the first four of the 21 storeys built using on-site method while modules were stacked from the fifth to the twentieth.

Figure 2.9: Construction of the Hilton palacio Del Rio hotel (1968) (Walker & Fierro, 2015)

Figure 2.10: A crane hauling a module in place during construction of the Hilton Palacio Del Rio Hotel (1968) (Zachry Construction, n.d.)

The complete haulage of all the modular components (Figure 2.10) took 46 days, each weighs almost 35 tonnes. All modules were preinstalled with MEP, interior finishes and with furniture.

2.3 Definition of Terms

2.3.1 Pre-assembly

Pre-assembly can be described as the assembling of different building materials, components or elements and equipment together at a different location other than its final place of installation. This is simply because the main focus is not just to create a product but a system (Tatum & Vanegas, 1986). Haas and Fagerlund (2002) described Pre-assembly as the joining of prefabricated elements to make up a whole structure or system at a site aside its permanent installation site. In his option pre-assembly can be carried out on-site or off-site thus encouraging analogous fabrication operations. Pre-assembly as mentioned by Schoenborn (2012) involves employing diverse building trades during construction and also the utilization of a crane in the positioning of pre-assembled elements.

2.3.2 Modularization

The term "Modularization" is described by (Schoenborn, 2012) as a series of activities that results to the partitioning of a complete building structure into series of smaller modules. Usually these modules are constructed off-site while the only work done on-site is limited to just foundation works and assembling of modules. He further stated that the manufacturer of the modules has a better control over the productivity and quality of finished products. Transporting the modules could prove really costly hence it remains the most crucial drawback of this process.

Modularization would prove to be a very effective tool in cutting down on cost, decreasing schedule and minimizing risks when used appropriately but can turn out to be chaotic and complex when handled wrongly but irrespective of the of how fascinating a modularized project looks, an economical advantage over on-site construction much be achieved (Jameson, 2007).

2.3.3 Modular Coordination

According to Farhana, Pitroda, Bhavsar, & Dave (2015), modular coordination can be simply defined as a concept that involves the use of dimension and space in measuring and positioning components of a building in terms of basic module or unit. They further explained that it is nearly impossible to achieve effective building standardization without the use of modular coordination. Hence the basic module is recognised as 1M which is equivalent to 100 mm and it is internationally accepted by the International Standard Organization and some other countries.

Modular coordination has a clear aim of improving construction productivity through standardization hence promoting industrialization by manufacturing components in the factory which ultimately reduces the amount of work executed on-site. With modular coordination there will be less modification on construction sites and also less need for unskilled labour.

2.3.4 Industrialization

Industrialization is seen as a construction process whereby building components or elements are produced in a regulated location (on or off site). These components are then transported and assembled at their final location (Hamid, Kamar, & Alshawi, 2011) (Kamar, Alshawi, & Hamid, 2009). Thanoon et al. (2003) sees the process of industrialization as a technological investment in facilities and machineries with the aim of improving production and quality and reducing labour resources.

Roger-Bruno Richard who conducted one of the most significant studies about the concept of industrialization in construction explained that the extent of adoption of industrialized construction can be evaluated based on the level of industrialization. In the figure below, the extent of industrialization that was analysed in the research of Roger-Bruno Richard is presented (Kamaruddin, Mohammad, Mahbub, & Ahmad, 2013) (Musa, Yusof, Mohammad, & Mahbub, 2014); (Richard, 2005).

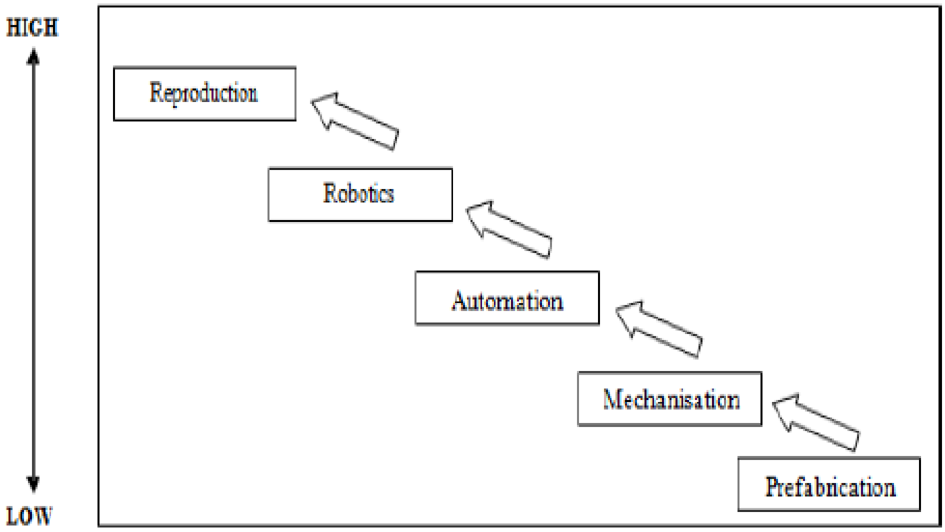


Figure 2.11: Degree of industrialisation (Richard, 2005)

Industrialization can be categorized into five different stages and they are Prefabrication, Mechanization, Automation, Robotic and Reproduction. Figure 2.11 describes the degree of industrialization at each stage. The first four stages still adopts the typical traditional construction process. The aim of prefabrication is generally directed towards the production environ whereas mechanization, automation and robotics aims at replacing human labour with machineries (Richard, 2005). The fifth stage (reproduction) is a borrowed concept which was adopted from the printing industry aiming at streamlining the multiplier of intricate goods thus supplying majority of the populace with quality and affordable buildings (CIB, 2010).

2.3.5 Lean Construction

Lean construction was created in 1993 by the International Group for Lean Construction during their first meeting (Gleeson & Townend, 2007). It refers to the design of production systems which tends to reduce effort, time and material wastage so as to increase production and maximum possible output (Koskela, Howell, Ballard, & Tommelein, 2002). Lean construction considers the needs of clients by managing, enhancing and developing the entire construction processes with maximum value at a reduced cost (Koskela et al., 2002). Lean production philosophy's main objective is to avoid or reduce waste (Shingo, 1988). Lean Construction Institute (LCI, 2013), reiterated that waste reduction and better value which are delivered to clients are achievable by the reliable release of work between assembly, design and supply specialist.

Javkhedkar (2006) explained that the thoughts of adopting manufacturing in the construction industry was scrapped by the construction industry. This is because of the complexity and uniqueness of project which are executed in an extremely unpredictable environ under severe pressure and timing that is totally distinct from manufacturing. But Howell (1999) argued that it is high time the construction industry reconsiders the Lean Production theory being that manufacturing and construction wastes occurs from similar activity-centred theory.

CHAPTER 3
THEORETICAL FRAMEWORK

3.1 Overview

This chapter mainly concentrates on the systematic study of some existing literatures relevant to this research. An in-depth review about off-site construction and its very important types would be provided. The processes involved in off-site construction would also be explained together with the major materials being used such as steel, reinforced concrete, timber and composite materials. The benefits and constraints of off-site construction would be highlighted while comparing the difference between off-site and on-site construction methods. A background of the leading countries using off-site method of construction would also be featured in this chapter while taking a close look at several case studies in each region. At the end of this chapter, a summary of the literature review would be presented and the necessary insight gained would be explained as it relates with the research objectives of this thesis.

3.2 Types of Off-site Construction

Here the various types of off-site construction would be discussed individually, they include prefabricated construction, panelised construction, modular/volumetric construction, precast/pre-stressed concrete construction and manufactured whole building (home).

3.2.1 Prefabricated construction

Prefabricated construction, Prefab or Prefabrication is categorized as an aspect of off-site construction or manufacturing. This owes to the fact that the operations in joining various building materials to generate components of a larger structures are carried out in a regulated factory condition (Haas, O'Connor, Tucker, Eickmann, & Fagerland, 2000). It was explained by Tatum & Vanegas (1986) as the transfer of on-site construction activities to an off-site manufacturing location. In the construction industry, prefabrication is seen as the primary level of industrialization which precedes mechanization, automation, robotics and (Richard, 2005). Prefabricated construction as described by Tam, Tam, Zeng, & Ng (2007) refers to a system whereby components used for construction are manufactured in a factory. Upon completion, these components are then transported and installed at a final location thus creating a complete building structure. Gibb et al., (1999) explained that prefabrication involves constructing building components and elements that constitutes a bigger final assemblage.

Prefabricated construction can be considered as a valuable substitute to on-site (conventional) construction. There are various improvements achievable in areas such as productivity, life cycle performance and construction predictability which tends to benefits all construction stakeholders (Pan, Gibb, & Dainty, 2012). When pitched with traditional construction, Li, Shen, & Alshawi (2014) explained that prefabricated construction reduces wastage, presents a more regulated condition for weather and quality not forgetting its ability to compress projects schedules.

As reported by Gibb (1999) prefabricated construction can be classified into four areas based on the level of prefabrication adopted and they include; "*(a) component manufacturing and subassembly that are always done in a factory and not considered for onsite production, (b) non-volumetric pre-assembly that refers to pre-assembled units not enclosing usable space, such as timber roof trusses, (c) volumetric pre-assembly that refers to pre-assembled units enclosing usable space and usually being manufactured inside factories but do not form a part of the building structure, such as the toilet and bathroom, and (d) entire buildings that refer to pre-assembled volumetric units forming the actual structure and fabric of the building, such as motel rooms.*"

Prefabricated construction collaborates with various strategies for the formation of a sustainable urban environment comprising improvement in the management of waste, reduction of on-site work and environmental disturbance while aiding the reuse and recycling of products at the expiry of a building's lifecycle (Sev, 2009). It is judged by Hsieh (1997) to be the most logical and productive approach in reducing and minimizing waste.

3.2.2 Precast and pre-stressed concrete construction

Precast construction refers to the use of precast concrete during construction. Recently, this method has been widely used in the building sector due to its numerous benefits as regards the control of quality and safety, environmental protection and construction optimization (Chiang, Chan, & Lok, 2006; Tam, Fung, Sing, & Ogunlana, 2015). Precast concrete is carried out off-site in a regulated factory condition using moulds that are reusable. It involves the preparation, casting and curing of concrete at a location other than its final location of installation. Typically, precast concrete can be connected with other components and element which makes up a whole structure. Generally precast concrete can be useful for the construction of building's structural elements including beams, columns, floors, wall panels and so on ("Precast concrete - Designing Buildings Wiki," 2018). Lawson, Ogden, & Goodier (2014) explained that the elements of precast concrete includes beams and columns (linear elements), walls (Figure 3.1) and slabs (planar elements). It is also possible to combine these elements to produce volumetric units that can either be joined together either at the construction site or casted in the factory.

Figure 3.1: Precast concrete walls being craned to position (Superior Walls, 2016)

On the other hand, Pre-stressed concrete construction (Figure 3.2) is a form of construction that involves the use of a structural material. This form of concrete allows for engineering stresses that have been pre-decided to be positioned in its members. This enables the concrete to resist tension that arises when loads act upon it. Pre-stressed concrete fuses the high tensile strength of steel and the high compressive properties of concrete. It was said that pre-stressed concrete seems to be more economical when there is a span above 9 meters. P. H.

Jackson an engineer from San Francisco patented in 1886 but was really accepted during the shortage of steel 50 years later. Pre-stressed concrete involves a process which can either be through pre-tensioning or post-tensioning ("Prestressed concrete - Designing Buildings Wiki," 2018).

Fig. 3.2: Pre-stressed concrete elements (The Constructor, n.d.)

3.2.3 Panelised construction

Panelised construction (Figure 3.3 and 3.4) is an aspect of off-site construction which is sometimes classified under Permanent Modular Construction (PMC). This form of construction employs the use of units which seems like a typical cassette arrangement and is often used in the construction industry.

Figure 3.3: Constituents of a typical panelised construction (Janzen, 2011).

Fig. 3.4: Wall panel of a panelised construction (McGregor, 2017).

3.2.4 Modular/volumetric construction

Modular construction (MC) is regarded to as a type of prefabricated construction technology that is also classified under off-site construction or production. Here three-dimensional or volumetric units also referred to as modules (Figure 3.5) are utilized in the construction of different types and sizes of buildings (Lawson et al., 2014). The definition of MC according to researchers from various regions around the world can be seen in Table 3.1 below;

Table 3.1: The Definitions of Modular Construction (Musa et al., 2014)

Countries	Authors	Definition of Modular Construction
USA	(MBI, 2008, 2013), (Lu & Bausman, 2009)	Modular construction is a process that constructs a building off site, under controlled plant conditions using the same materials and designed to the same codes and standards as conventionally built facilities but in about half the time. Buildings produce in "modules" and when put together on site, reflect the identical design intent and specifications of the most sophisticated traditionally built facility without compromise.
UK and Europe	(R. Mark Lawson, Ogden, & Bergin, 2012), (Vernikos, Goodier, Broyd, Robery, & Gibb, 2014)	Modular construction is a fully fitted out in a manufacturing facility comprises of prefabricated room size volumetric units. This room sized units as load bearing "building block" will be install on site.
Australia	(Blismas & Wakefield, 2009)	Modular construction is an inspirational unconstrained building design combined with highly efficient industrialised production in a control manufacturing facility. Once modular units are complete, it will be transport to the site and combine together to a completed building.

Asia	(Japan Modular Construction, n.d.)	Modular construction is produced out of the site and refers to as an off-site construction method. It is produce in the factory into modular units. Then, the modular units are transport to the building site.
	(Lee, Kim, & Lim, 2014)	Won-hak Lee Modular construction is from USA and Europe, an architectural system whose fundamentals technologies that are already been developed where this method is a production and construction method of buildings in a way that combines each box- type module produced from the factory and laminates them.

Gibb & Pendlebury (2006) defined modular construction in their build off-site glossary of terms as units that can be three-dimensional or volumetric which are manufactured in a controlled location after which it is then transported its final location to form the principal structural constituent of a building.

Modular construction aim is to produce a manufactured edifice whereby most of its construction processes are carried out inside a controlled location before being conveyed to site. This allows for both on-site (foundations and base construction) and off-site works (factory fabrication of modules) to be carried out simultaneously (Egege, 2017).

Figure 3.5: Stacking of a modules of a modular structure (WM Modular, 2017)

As reported by a published article by MB1 “Why Build Modular” (MBI, 2013), it was deducted that modular buildings are structurally resilient when compared to buildings built traditionally. This happens because modular structures are produced to individually resist both the rigour of haulage to site and stacking (Figure 3.6) thereby producing a secured integrated system once connected together.

Fig. 3.6: Stacking of a modules at a modular site (Littman, 2017)

The re-emergence of modular construction in Asia, USA, Europe, Great Britain and other part of the world resulted from the necessity of building sustainable structures with very high standards. Lawson et al. (2014) stated that this method of construction can be considered the most exceptionally developed aspect of off-site production. MBI 2011 annual report (MBI, 2011) revealed that 60-90% of modular construction works are produced and assembled are done in a regulated factory and then transported to site afterwards. Modular construction is usually carried out in phases and would be ideal for urban infill sites (Hartley & Blagden, 2007). In most cases modular structures comes with complete interior finishes preinstalled which also includes MEPs (Hartley & Blagden, 2007).

3.2.4.1 Classification of modular construction

The modular construction industry can be categorized into two distinguished sectors which are Permanent Modular Construction (PMC) (Figure 3.7) and Re-locatable Modular (RM) (Figure 3.8). RM which is also referred to as temporary building is a kind of structure which main purpose is to fulfil the needs for temporary spaces such as communication pods, show rooms, classrooms, site trailers, site offices etc. PMC can be used in the construction of multi-story family dwelling, schools, dormitories, hotels and health care facilities because it meets the International Building Code which is similar to buildings built using traditional construction methods but the major difference is the uptake of the process of factory production (Ryan E Smith, 2014).

Figure 3.7: Permanent Modular Structure (MBI, n.d.).

Fig. 3.8: Re-locatable or Temporary Modular building (Design Space Modular, 2018)

3.2.4.2 Modular construction stages

Modular Building Institute (MBI) explains that the process of off-site modular construction can be broken down into four stages which is quite similar to that of an automobile assembly line. These stages includes;

- ➢ Stage 1: Design development and subsequent approval by the client and other regulatory bodies.
- ➢ Stage 2: Production and assemblage of the modules (units) which is always carried out under a well supervised and controlled factory environment (Figure 3.9).

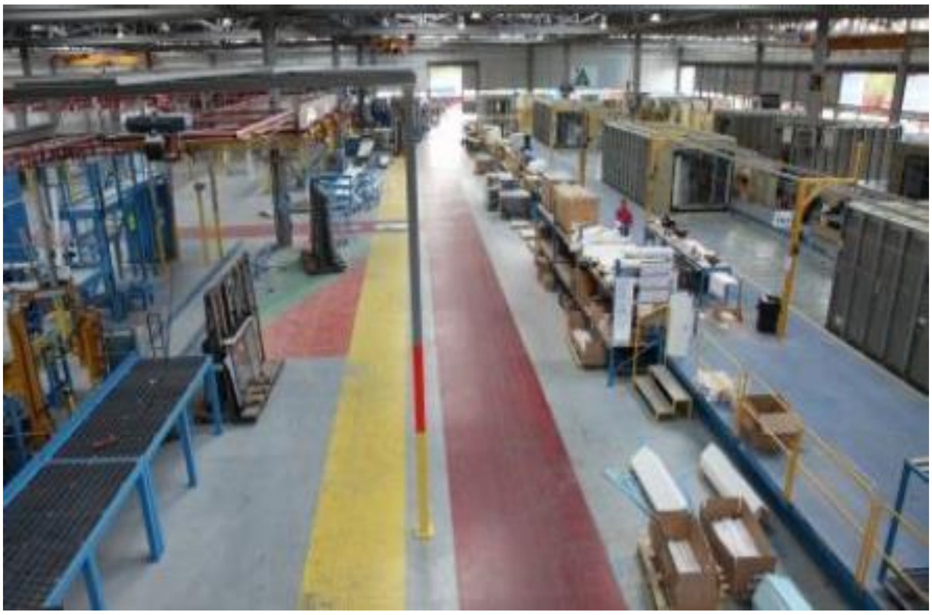


Figure 3.9: Typical manufacturing line in a modular factory**.** (Velamati, 2012)

➢ Stage 3: This involves the transportation of the completed modules with large trucks to the final installation site (Figure 3.10).

Fig. 3.10: Typical completed volumetric module ready to be transported to site from the factory (Velamati, 2012)

➢ Stage 4: This is the point where the modules are lifted by cranes into their respective position and then coupled together to produce a complete building structure (Figure 3.11).

Figure 3.11: Typical completed volumetric module being hoisted into place. (Velamati, 2012)

The most unique aspect of this construction method is the possibility of simultaneously carrying out site works when fabrication and manufacturing of modular units are being done in the factory.

3.2.4.3 Modules in modular construction

Modules used for modular construction each has its peculiar uses and application. According to Lawson (2007) these modules can be grouped into three major types namely; structural modules, non-structural modules and shutter modules. The first two would be discussed.

Structural modules acts as load-bearing frame, stressed skin box or the combination of both functions and they include four sided modules, partially open-sided modules, modules having corner support system, modules supported by primary structure and mixed modular and planar cassettes.

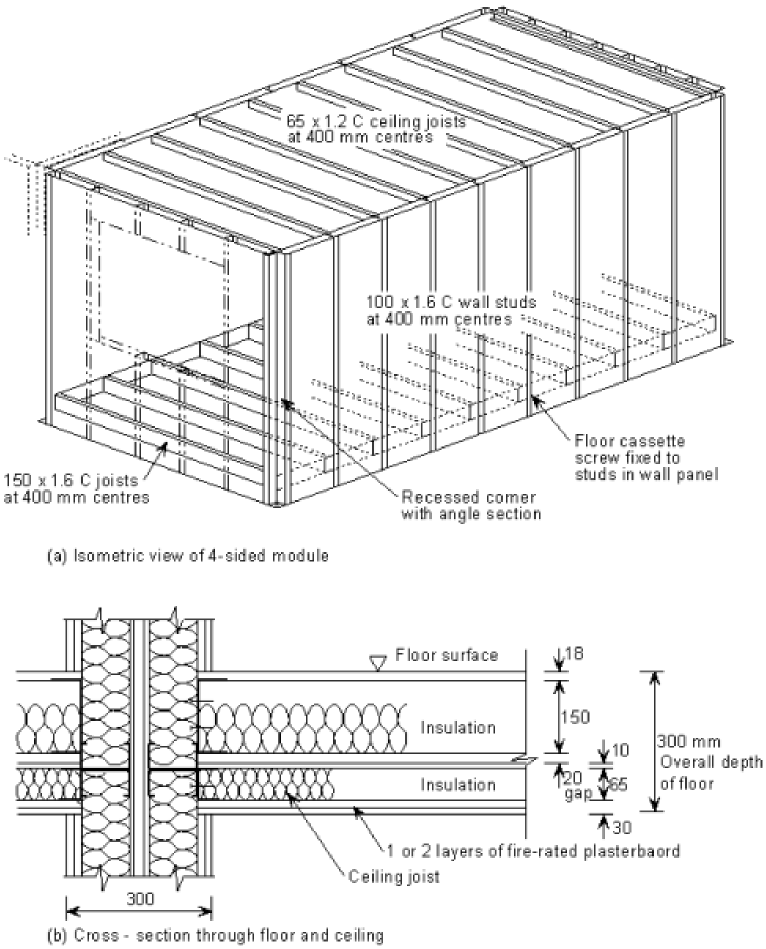


Figure 3.12: Typical details of 4-sided load-bearing module which shows recessed corners plus additional angle section (Steel Construction Info, n.d.)

Four sided modules are modules that are designed to continuously allow its vertical walls bear its loads (Figure 3.12) above and (Figure 3.13) below. Typically, these types of modules are manufactured as cellular-typed-spaces because their four sides are closed. They can be used in the construction of student housing, employee accommodation, hotels and residential buildings.

Due to wind consideration and stability system, the maximum height of buildings using only 4-sided modules should be between 3 – 12 storeys in respect to its location. These kind of modules are produced from panelised or 2D components starting with the floor panel before erecting the four walls panels on it and the attaching the ceiling panel.

Figure 3.13: Typical 4-sided load-bearing module, (Steel Construction Info, n.d.)

Open sided (corner-supported) modules are usually designed to have fully opened sides. The loads in this type of module are transferred to the corner posts which results from bending the longitudinal edge beams (Figure 3.14).

Figure 3.14: Primary steel frame used in open-sided module (Steel Construction Info, n.d.)

These sort of modules are frequently used in buildings that requires larger open plan spaces such as schools and hospitals by placing the modules/units side by side. The building's stability largely depends on a different type of bracing support in an X form in the demarcating walls thus the maximum height of a structure using this sort of module is about 3 storeys. Typically, the portioning walls within these modules are non-load bearing but it is recommended that lighter wall studs be used at the points where the columns and the walls intersect which provides and in-plane bracing.

Partially open-sided modules are four-sided modules that are designed to have partially open side with the use of stiff continuous edge beams on the floor panel while adding a corner and intermediate posts to the module (Figure 3.15). The module's edge member's stiffness and its resistance to bending limits the opening's maximum width. Square hollow sections of smaller cross-section acts as the extra intermediate post to enable it fit inside the wall width.

Figure 3.15: Partially open-sided module, (Lawson & Ogden, 2008)

These type of modules allows for the creation of bigger spaces by adding two or more modules together. A complete modular structure using this type of modules can achieve a building height of about 6 – 8 meters whereby the maximum building height is controlled by the compressional resistance of both the internal and corner posts. When wider openings are required, it is important to add additional edge beams which can be bolted to the posts. The section of this type of module is presented in Figures 3.16 and 3.17.

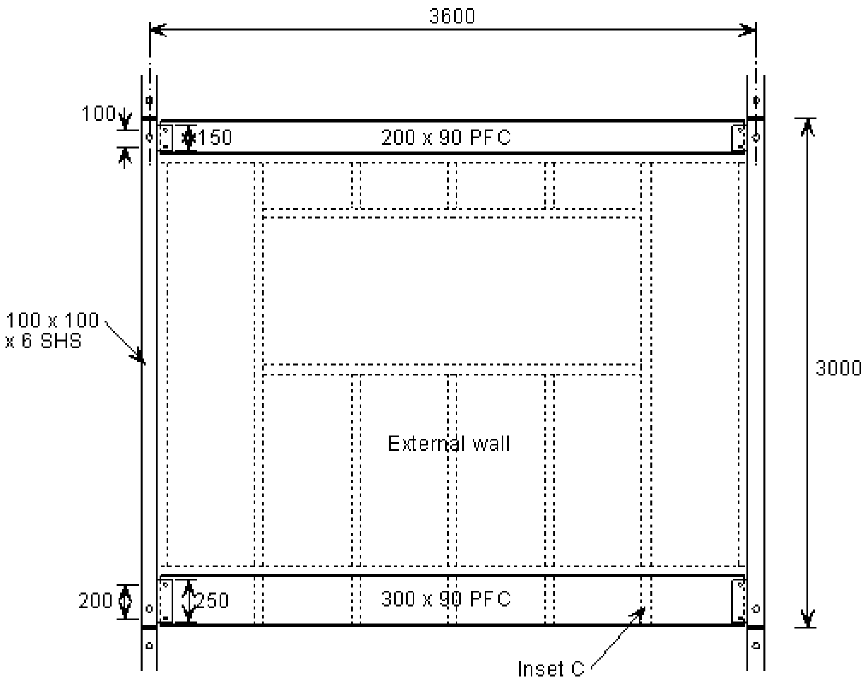


Figure 3.16: End view of a corner supported modules structural frame (Lawson, 2007)

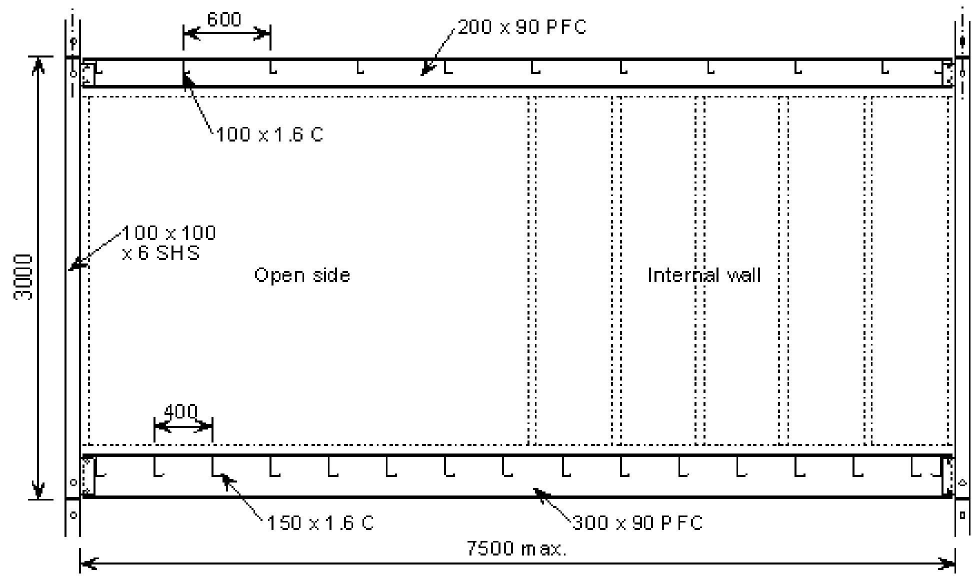


Fig. 3.17: Longitudinal edge beams of a corner supported module (Lawson, 2007)

Mixed modules and floor cassettes are generally used for terraced residential structures which are restricted to a maximum of 4 – 6 storeys. This type of construction involves the assembling of long units/modules whose service core is typically load-bearing. The span of the floor cassette is between the load-bearing walls and the unit/modules (3.18).

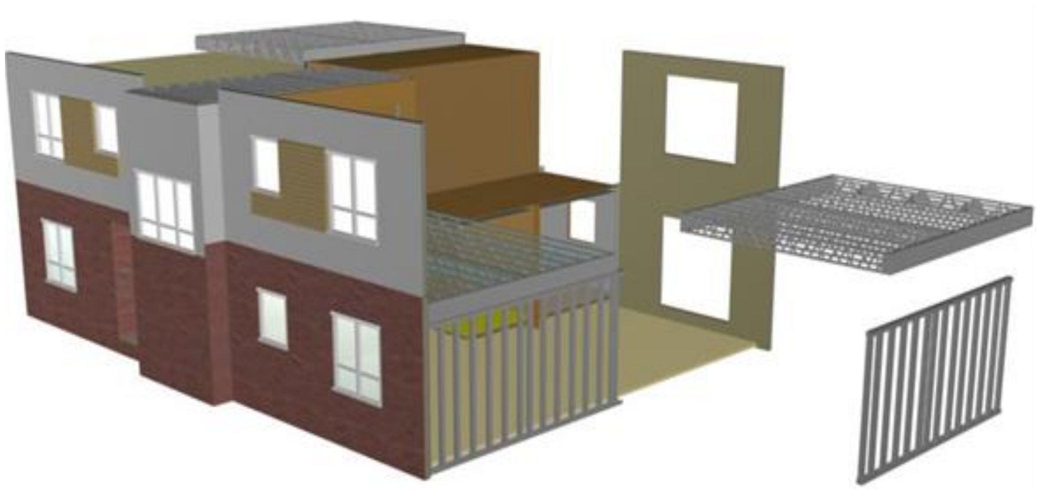


Figure 3.18: Mixed modular and panelised structure illustrating the attachment of the panelised components and the modules (Pods) (Lawson & Ogden, 2008)

Modules supported by primary structure is a form of construction where the modules are supported by a primary structure which can either be at a framework (Figure 3.19) or platform/podium level (Figure 3.20). The design of the beams are done such that it can support the total loads of the upper modules which shouldn’t exceed 6 storeys. The columns supports can spaced at multiple distance of two or three modules which is the module’s width.

Figure 3.19: Installation of modules supported by a primary steel structural framework at MoHo, Manchester (Steel Construction Info, n.d.)

Figure 3.20: Typical modular structure supported by a primary concrete podium (Lawson & Ogden, 2008)

Non-load bearing module are designed not to bear any form of external loads aside its own weight and that which is applied during hoisting. Typical examples include; toilet and bathroom units (Figure 3.21), special lifts and stairs modules, service units and plants rooms.

Non-structural modules are generally called Pods and they usually have a structural frame support system. Non-structural modules can also be supported by a concrete floor system.

Figure 3.21: Typical non-load bearing module (Pods) (Bath System, n.d.)

Special Stair Module (Figure 3.22) basically relies on a base and a top for its stability leading to the adoption and usage of a false landing. At the landings (half and full) positions, additional strengthening members is usually needed. For the transfer of the plane loads to the landing, it is necessary to strength the wall's open top and base.

Figure 3.22: Stair module with corner posts (Steel Construction Info, n.d.)

Other types of modules

Shipping container modules (Figure 3.23) ideally were designed for the transportation of various types of goods by sea and road using both ships and large trucks. They are manufactured from steel frames which constitutes corrugated steel walls that are welded together with hollow C-sections.

Figure 3.23: Typical building structure made from series of modular shipping containers (Belogolovsky, 2018)

The standard point for lifting the shipping containers are located at their corners. Because of their structural properties and dimensions, this special type of modules can be transformed for many permanent or temporary use quite easily because they are readily available (Lawson et al., 2014, pp. 49).

3.2.4.4 Sustainability in modular construction

With modular construction, the sustainability of a building structure during the construction phase can be greatly improved together with its performance after completion. This is due to the fact that structures that are constructed using this technique proffers considerable amount of possibilities in areas such as cost-effective construction, environmental stewardship, market penetration and LEED certification which is achievable through excellent construction (working) environment, adequate environmental control and material handling during construction (Kobet, 2009).

Hartley & Blagden (2007) cited that the reduction of construction waste in modular construction due to its factory manufacturing is about 5% compared to the 10 – 15% of on-site construction. Modular construction was also reported of having the highest level of waste curtailment amongst other forms of modern method of construction (MMC) and traditional construction.

According to Baldwin, Poon, Shen, Austin, & Wong (2009) the highest level of construction waste in on-site construction is as a result of concrete construction works and related trades which amounts to about 80%. These occurs as a result of direct concreting work and steel works (cutting of steel bars). Construction wastes also occurs through construction reworks whereby previously done works needs replacement, adjustment and correction. Baldwin further expressed that an efficient method of streamlining construction waste is to adopt precast construction method or the creation of duplicated forms in the factory.

During construction period, the impact of noise disturbance from the site is greatly reduced by almost 30 – 50% ensuring that the neighbouring structures aren't affected by site works compared to traditional on-site construction. Movement of heavy duty trucks to site for material delivery is also reduced by almost 70% with the use of modular construction thereby transferring the major part of material delivery to the factory. The reduced construction waste together with the use of lightweight construction materials tend to also help reduce the construction materials embodied energy.

3.2.4.5 Attributes of modular construction

According to an article by (SCI, n.d.), it was reported that the attributes of modular construction includes but not limited to;

- Suitability for structures that have numerous repeated units.
- Transportable unit/module size is restricted to 3.6 m by 8 m dimension.
- Units/modules can be assemble without support from another structure.
- Modular structures provides fire resistance of about 30 to 60 minutes.
- Acoustic insulation of the structure is achieve because of the double layers of walls and floors provided.
- A structure built entirely of modular units can rise to 10 floors, ideally six floors is advice.

Others includes:

- Greater reliability and quality of finished product.
- Greater certainty of scheduled completion.
- Quicker return on investment while increased profits is achievable.
- Coordination of activities can be achieve with much ease.
- It has a reduced construction cost and low maintenance cost.
- Possibility of reduced construction time (40% to 50%)
- Possibility of increased productivity (up to 50%).

3.2.5 Manufactured whole building

This in a broad term refers to a singlewide or doublewide building for residential purpose (Figure 3.24) and not a large residential project. Most times, it comes with an integrated chassis designed for mobility and is to be erect without the recommended standards (Schoenborn, 2012).

Alternatively, known as Manufactured Home, this method of construction can simply be likened to the manufacturing process of an automobile assembly it they also takes up factory production. The construction of manufactured homes in most instances takes place on demountable foundations and can be re-located to another site. An example of this kind of building is the M-House of architect Tim Pyne (Figure 3.24). This house originally designed as a vacation home can moved at sited at temporary locations such as a sky scrapper’s rooftop, on an open field and on water. It too some hours for the house which is separated into two to be assembled (Herbers, 2004), 76-78).

Fig. 3.24: Silvercrest Kingsbrook manufactured home, model KB-65 SP (Silver Crest, n.d.)

Figure 3.25: Architect Tim Pyne's M-House (Tree Hugger, 2004).

3.2.6 Hybrid Modular System

This type of system as explained by Salama, Salah, & Moselhi (2017) describes hybrid modular construction as a system adopting the use of two or more types of modular components in the construction of a building structure. In most cases, it is possible to combine volumetric (3D) modules with panelized (2D) units in an effort to reduce construction activities on-site.

Lawson & Ogden (2005) argued that the benefits of the 2D and 3D components together with that of the principal steel frame is what hybrid modular system aims at adopting. The essence of the principal steel frame structure is to help the designer plan interior spaces with much more flexibility and furthermore to help stabilize the entire structure. One can adopt volumetric (3D) modules for essentially important and serviced spaces such as the bathrooms while the open areas uses the panelized (2D) modules.

Hybrid modular system makes use of two general forms according to Lawson & Ogden (2005) and they are skeletal and podium structures.

Skeletal Structure – employs the use of both load bearing and non-load bearing modules for it designed (Figure 3.26). These modules attached to a steel skeletal frame for the construction of a building's superstructure and other required open areas. The essence of the steel skeletal frame is to allow for flexibility during planning (Jellen & Memari, 2013).

Figure 3.26: Hybrid modular system using skeletal structure (MBI, 2013)

Podium Structure - refers to buildings, which are generally for residential and commercial purposes (figure 3.20). The construction of the first two floors of such buildings are done using either reinforced concrete frame or steel and serves as the commercial spaces for the building. After which the main residential accommodation comes upon the podium by the assembling of load-bearing modules together (Jellen & Memari, 2013).

3.3 Structural Materials used for Off-site Modular Construction

3.3.1 Steel

The use of steel as a building material was discovered when countries that were extremely affected by the damages of the WW I sort out new cost effective and time saving methods at rebuilding their nations. Experimentations using steel was conducted by some of Europe finest architects such as Walter Gropius. Mies van der Rohe and Le Corbusier. They experimented using steel as the building's primary structure and also for design beautification. Henceforth, construction using steel has been adopted all over the industry worldwide. Steel evidently became very popular in Europe and America due to the numerous advantages it has over the timber such as the ability of building longer spans, taller building structures and bigger openings as compare with brick or timber construction (Anderson & Anderson, 2007).

It is very possible to mould steel into various types of shapes due to its flexibility and can be used in the production of numerous building materials (Ngoenchuklin, 2014). Lawson et al. (2014) explained that the conventional form of steel construction comprises of skeletal frames, columns and beams and has been in use for a very long time in the construction of multi-storey commercial buildings.

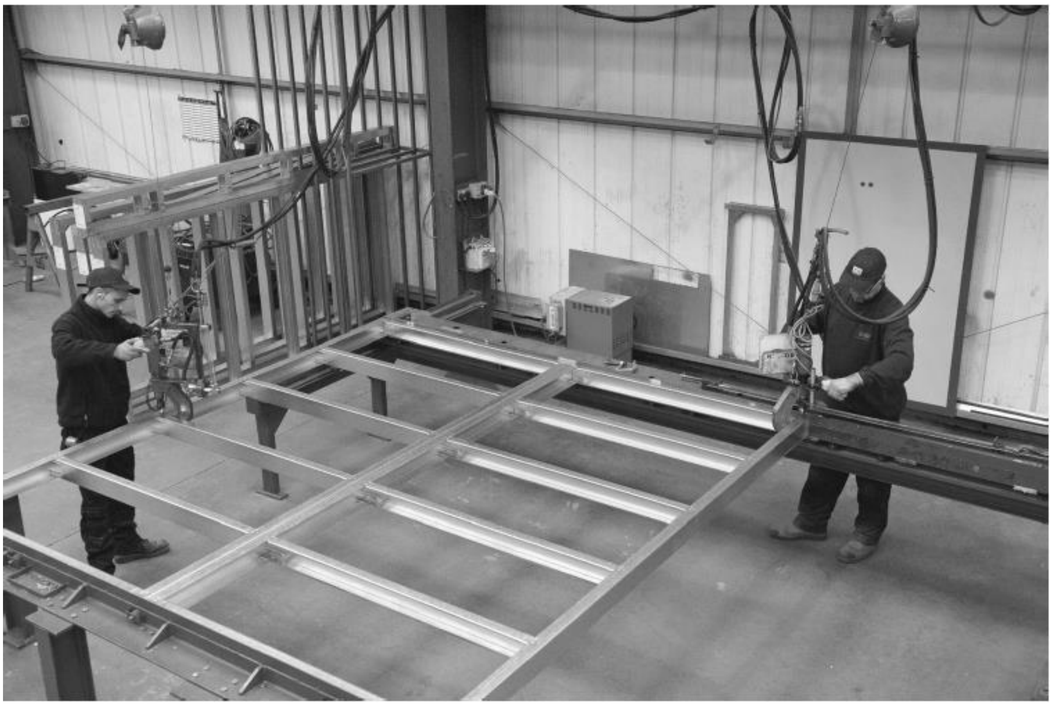


Figure 3.27: Manufacture of Light Steel Panel (Lawson et al., 2014)

A quite different type of steel (galvanised steel strip) that is cold rolled into C-sections are used in producing most steel-based modules. These C-sections are manufactured or fabricated into walls, floors and ceiling panels as shown in Figure 3.28 below (Lawson et al., 2014).

Adopting prefabricated steel for construction has its own merits but it is noticed that the cost of a project can increase using this material because it is more expensive when compared with brick and timber. In most cases these cost can be monitored and controlled by a more detailed architectural or engineering design which has a lesser amount of custom-design steel members (Ngoenchuklin, 2014).

Steel modules have been discussed more elaborately in section 3.2.4.3 of this thesis.

3.3.2 Precast concrete

Concrete is described as one of the most widely used construction material around the globe which was previously used only by cast in-situ method. This method typically easily allows for concrete mix in it liquid state to be pour in mould or cast of different shapes and sizes. Concrete is a mixture of cement, fine aggregates, coarse aggregates and water in a predetermined ration or proportion. Due to its flexibility and strength, it’s commonly used for the construction of structural elements such as beams, columns and floor slabs (Ngoenchuklin, 2014).

Precast concrete construction is reported as one of the most widely used concrete construction technique used and it also quite common in the United States construction industry. Smith (2010) expressed that "*precast construction is the casting of concrete components off-site in a plant and shipping to site for assembly*".

Precast concrete is a very renowned and efficient manufacturing industry whose products ranges from slabs (hollow-core) to columns and beams in structural frames. There re evidently two different methods of production for concrete modules – either as precast panelised components (Figure 3.28) for ceilings, floors and walls (2D) or as a volumetric/modular/3D units (Figure 3.29) that are usually cast using an open base technique. Their high resistance to damage makes its application a good choice when high security is required (Lawson et al., 2014).

Figure 3.28: Precast concrete wall panel (Choma, 2017)

Figure 3.29: Precast concrete volumetric/ modular/3d unit (Green Precast Modular, 2010)

The use of precast concrete tends to reduce the total cost and time of construction "*because precast concrete is made in the factory, its process may include adding heat to accelerate the hardening of the concrete and adding moisture for full hydration of the Portland cement and water. Recasting plants are able to produce fully cured elements from laying of pre-stressing or reinforcing strands to removal of finished elements from the bed in a 24-hour cycle*". This method tends to reduce cost of labour and shortening the concrete curing duration (Ryan E Smith, 2010).

Due to the weight and sizes of precast concrete panels or modules during use, there seems to be some agitation about the difficulty in transporting this material. Considering the fact that precast concrete seems lighter than cast in-situ concrete, it still weighs more than timber and steel. This extra weight of precast concrete eventually adds to the overall construction cost of the project. As earlier expressed, weight seems to be the greatest concern of using this material which led to the invention of fibre-reinforced concrete which was developed to reduce the weight of precast concrete. The system uses short stands of carbon, fibre or steel fibre suspension in the concrete mixtures rather than the conventional steel rebar thereby producing a light weight precast concrete (Ngoenchuklin, 2014).

Anderson & Anderson (2007) described that "*advances in concrete technology offers potential for much lighter, smaller section panels that can accommodate far more complex shapes and curves* *and will allow for more mobile and less costly off-site concrete construction*". There are more positives to be seen in precast concrete technology system which will be significant in its rapid growth in future.

3.3.3 Timber

Timber remains one of the most commonly used construction materials and it can be harvested easily. People around Europe still reside in a typical medieval and Tudor timber post and beam kind of dwellings which goes a long way to proof how durable and resilient timber frame structures are. The availability, sustainability and thermal properties of timber has made timber frame construction to remain indestructible in regions with extreme climatic conditions such as Canada, Germany, Scandinavia or the USA (Haas et al., 2000)

According to Lawson et al., (2014), pp. 20), the use of timber framing in the residential building sector has been adopted as far back as 1960 and it is a material commonly used in the construction of modular houses in the United States. They further pointed out that the use of timber frames were employed historically for the construction of relocatable or temporary modular buildings. Typically, these construction technique uses prefabricated timber wall panels (Figure 3.30) having a top and bottom track. The wall panels which are in most cases sheathed with the use of Oriented Strand Board (OSB) or plywood comes with the addition of a single or double layer of plasterboard internally.

Smith (2010) explained that timber (wood) is an environmentally sustainable and adaptable material and is also categorised as one of the very few structural materials that are renewable. Presently, timber frames that are manufactured also includes metal fasteners because of the custom joints they are manufactured with.

Since the nineteenth century, the American construction industry has mostly adopted the use of timber frames for the construction of most residential buildings. This according to Anderson & Anderson (2007) has made most American architects and contractors to be very conversant with the material.

It was suggested that the use of timber frames are quite easy for construction but architects and contractors should mindful when applying it. There are also some design limitations with the use of timber frames hence architects such be very cautious about this during design stages (Anderson & Anderson, 2007).

In general, the adoption of prefabricated timber frames can be beneficial on many projects in terms of construction cost and speed of completion. These prefabricated timber frames are quite easy to incorporate in the standard construction processes hence it is widely used in the construction of various building types. These building types include residential (single family houses, multi-family and mixed-used buildings) and commercial buildings or office structures (Anderson & Anderson, 2007).

Fig. 3.30: Timber panel being manufactured in a factory (Brinkley, 2016)

According to W.R.A.P., there are three assemblies that make up timber frame market; stick build, panelised walls and floor/roof cassettes. The first deals with on-site construction while the last two are connected to off-site construction.

The panelised walls are typically manufactured at the factory and comes with thermal insulation, services, doors, windows, exterior and interior finishes (Figure 3.31). Basically they are assembled to form both the load bearing walls and non-load bearing partitions of a building.

Figure 3.31: Assemblage of a timber panelised wall on site (Jacks New Zealand, n.d.)

The floor/ceiling cassettes (Figure 3.32) employ the same idea as the panelised walls but they seem a bit larger in size than the wall system. In most cases, insulation, services, lining, joists, beams and floor boards are also included in these element prior to them being shipped out to site.

Figure 3.32: Timber floor/ceiling panel (Colli Timber & Hardware, n.d.)

Figure 3.33 shows the production of a timber volumetric mode in a factory which are constructed by putting together floors, walls and ceiling panels together.

Figure 3.33: Factory fabrication of timber volumetric modules (Wölfl, 2016)

3.4 Benefits (Advantages) of Off-site Modular Construction

Off-site (modular) construction has series of benefits and advantages over conventional construction which generally spreads over a broad scope. These benefits include; construction cost reduction, positive social and environmental impact, improved construction feasibility, improved quality of construction, reduced construction time and severe improvement in construction health and safety practices (Tan, Kumar, & Kuilanoff, 1984). A summarized benefits of off-site construction is presented in Figure 3.34.

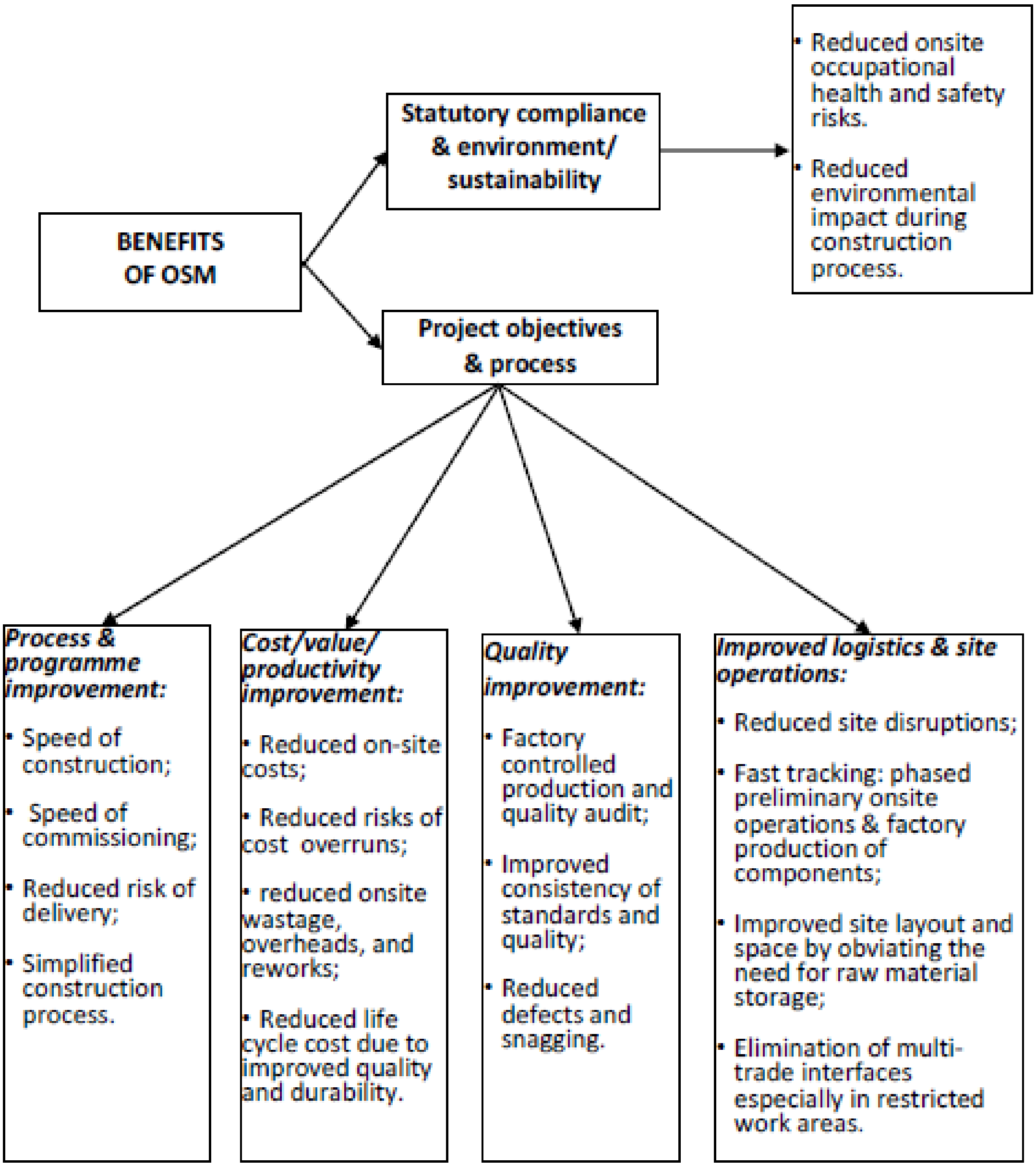


Figure 3.34: Summarized benefits of off-site (modular) construction (CRC, 2007)

Reduced cost: should off-site modular construction be adopted on a construction project, it is more than certain such project would be executed at a reduced cost. This cost reduction on the project could be between 5 – 10% as indicated by construction professionals in the sector (Tan et al., 1984). Shelley (1990) reported that the reduction in capital cost of construction projects adopting this method could reach almost 20%.

Time saving: seems to be yet another significant benefit of this construction technique. The transfer of considerable amount of activities to a factory environment tends to reduce the amount of time spent on-site. Construction deadlines are easily and effectively met using this technique because of the economies of scale that are generated in the predictable factory environment when compared with conventional construction (Alazzaz & Whyte, 2014).

Improved construction feasibility: the realization of construction projects in remote areas can proof gruelling with the application of conventional (on-site) construction. The utilization of off-site construction can prove to be the solution to the many challenges of erecting structures in these location which is another plus for this method. Some of the challenges which contractors and builders tend to encounter in these terrain as described by Tatum & Vanegas (1986) are manpower availability, state of the environment, limitations resulting from the site's condition and overall project constraint.

Improved construction quality: Shelley (1990) expressed that one crucial benefits of modular off-site construction happens to be the quality of construction which results from adopting this method. The fact that construction is done in a suitable environment leads to improved quality. Tan et al. (1984) pointed that improved quality control exists with the adoption of this method leading to optimized module.

Reduced construction schedule: reduction in schedule with the adoption of off-site modular construction is as a result of a well organised handling of both design and procurement simultaneously, improving the control schedule effectively, optimizing factory efficiency, ensuring activities are executed simultaneously and lastly operators should be trained while in the factory as oppose to the construction site (Wells, 1979).

Increased construction health & safety: with the adoption of off-site modular construction, the general health and safety of workers and increased due to the fact that are activities are carried out on a level plane in a regulated and controlled facility. In such factories, the health and safety regulations are strictly adhered to and closely monitored too.

Improved productivity: some other reports suggests that this benefit of Off-site modular construction supersedes the rest. Increased productivity comes with reduced cost and time and increased quality which ultimately translates the process to a more productive one in terms of per unit of input as opposed to conventional on-site (Alazzaz & Whyte, 2014). Gibb & Isack (2003) cited that improved productivity as a clear-cut category. A study of construction clients conducted by them, it was reported that productivity is perceived as the fourth most crucial benefit of off-site construction.

Other benefits of off-site modular construction includes;

- Increased profit margins
- Bridging skill and labour shortages
- Reduced change order
- Quick return on investment
- Avoidable weather disruptions
- Process predictability

3.5 Challenges (Disadvantages) of Off-site Modular Construction

Notwithstanding the numerous benefits and advantages of off-site modular construction, this construction technique still faces its own distinctive limitations. These constraints and limitation would be discussed below.

Additional coordination of activities: one vital limitation of this construction technique is the need for additional coordination of construction activities that are interdependent. This owes to the fact that activities are not performed in sequence but rather simultaneously therefore clearly boosting the needed amount of activity coordination (Tatum & Vanegas, 1986).

Additional construction effort: this perhaps should be another important limitation of off-site modular construction. These additional construction efforts described by Tatum & Vanegas (1986) results from the design and engineering of the project, planning and scheduling of the project, materials procurement, fabrication of modules, project assessment and transportation, handling and assemblage of modules.

Increased design cost: there is unavoidably an increment in the design and engineering cost for projects adopting off-site construction technique. The estimated increment which was reported by reported by Glaser & Causey (1979) stands at about 10% more than what is usually required for conventional construction resulting from the additional man-hour required for design and engineering. Glazer et al. went further in indicating that there is also a possibility of having an additional cost of procurement of about 20% allowing for sub-contractors to be properly evaluated before selection.

Need for additional materials: during the transportation of modules, there is a likelihood of needing additional 30% of structural steel which are used in rigging modules while in transit from the factory to the site (Shelley, 1990). This limitation of this technique is reported by Kliewer (1983) as the most significant of all other limitations because it seemingly add 0.5% to the total construction cost.

Reduced adaptability to design changes: this simply points to the fact that it is generally impossible or exceptionally difficult to review or adjust project design once construction commences using this technique. The construction activities interdependency which seriously improves from using this technique guides against such modification which if implemented would severely disrupt a range of corresponding activities.

Improved risks: the establishment of an entirely different scope to the organisation of a project with the adoption of this technique initiates new risks. Some of the perceived risks as suggested by Hesler (1990) comprises the engagement of unqualified and inexperience engineering and construction firms, exactness during module transportation (which if absent handled could lead to loss or damage of the module), project manager's incompetency and being faced with issues of procurement.

3.6 Comparing Off-site (Modular) Construction and Conventional Construction

It was reported by Goodier & Gibb (2007) that the speed of construction seems to be the most acknowledged benefit of using off-site construction. Goodier & Gibb (2007) further highlighted that another key decision in choosing between OSC and conventional construction greatly lies on the cost of development and not the project's life cycle.

Tab 3.2: Comparison between off-site construction and conventional construction (Wilson et al. 1999); Tam et al., 2007).

	Off-Site Construction	Conventional Construction
Construction Cost	Cost saving due to repetitive and standard modular production	Low initial cost of construction
Quality Control	High (better quality is achievable at the factory production)	Low (difficult to control the quality as the condition of sites varies)
Site Workers	Low (most of the construction elements are prefabricated in the factory hence the need for few workers)	Labour intensive (involves the use of timber formworks, in-situ concreting, wet trades and bamboo scaffolding)
Construction Time	Shorter (as few construction activities are required on site thereby improving productivity by 12%)	Relatively longer
Design Flexibility	Inflexible to changes in the design	Seemingly flexible to design changes
Construction Waste	Low (up to 84.7% can be saved on wastage reduction)	Quite high
Site Safety	Easy to manage (site tidiness is obviously improved due to less work trades on site which translates to fewer site accidents)	Difficult to manage (because it involves lots of crews on site)

Table 3.2 above gives the major comparisons between off-site construction and conventional (on-site) construction method.

In further comparison with conventional construction method, the performance of OSC in terms of greenhouse gas emission as described by Barrett & Wiedmann (2007 indicates that the later surpasses the former which proofs that OSC is more environmental friendly when adopted for construction.

The M.B.I. permanent modular construction annual report of 2011 (MBI, 2011) stated that in terms of time saving attributes, modular off-site construction has a better advantage over conventional (on-site) construction. This owes to the fact that works that were scheduled for both factory and site can be carried out simultaneously which leads to quicker return on investment for clients and investors (Figure 3.35).

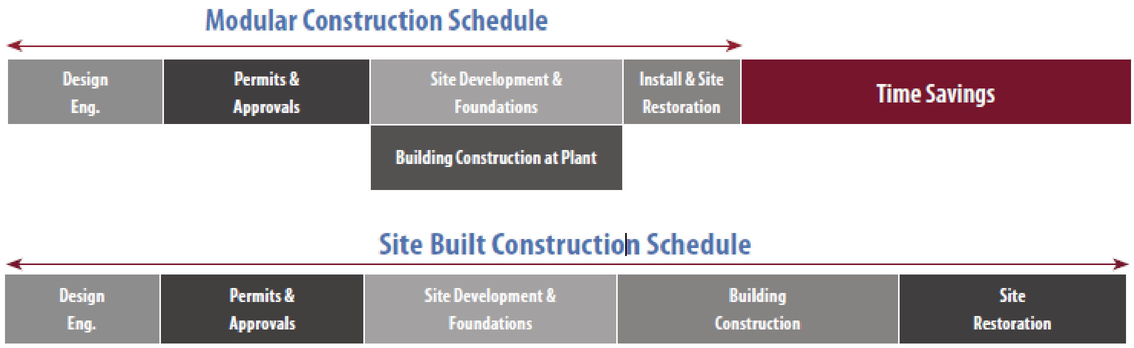


Figure 3.35: Schedule of works comparison between off-site (modular) construction and conventional (on-site) construction (MBI, 2011)

3.7 Case Studies of Off-site Modular Construction around the World

Off-site modular construction is growing worldwide. This thesis examined some of the most recent case studies of construction executed using off-site methods in some key regions around the world encompassing the United Kingdom, the North America, Australia, Europe (Norway and France), China, Turkey and of course North Cyprus. The reason why these regions were selected is simply because the emergence of off-site construction which includes prefabrication, modular (volumetric) and precast construction began in the first three regions and over time the construction industry in those regions have advanced technologically in the adoption and usage of off-site construction globally. The off-site techniques have been adopted in European for a while now but not as compare as the previous regions. Due to the optimal technological advancement in China, off-site construction is being adopted on a whole new dimension as never been seen before hence the need to examine case studies in this region was added to the list as a big sister nation to North Cyprus and being one of the emerging economies of the world. Then North Cyprus which happens to be our research location.

3.7.1 United Kingdom

3.7.1.1. Case study 1: Dalston works, London – United Kingdom

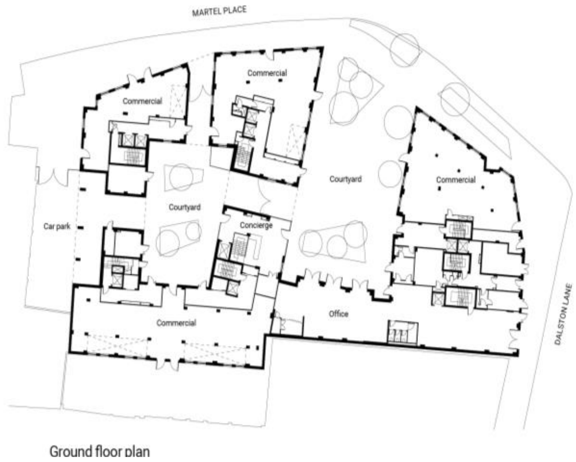
Figure 3.36: Dalson works building (Ramboll UK, 2015)

Table 3.3: Case study 1 information (Binderholz GmbH, n.d.; Waugh Thistleton Architects, n.d.).

OFFICIAL NAME **Dalston Works**	*LOCATION* **London, UK**	*OWNER/CLIENT* **Regal Homes**
ARCHITECTURE FIRM **Waugh Thistleton**	*STRUCTURAL ENGR.* **Ramboll & Pringuer-James Consulting Engr.**	*MAIN CONTRACTOR* **B & K Structures & Binderholz.**
STRUCTURAL MAT. **Cross Laminated Timber (CLT) & Steel**	*BUILDING SYSTEM* **Prefabricated Panels**	*BUILDING FUCNTION* **Mixed Use**
GROUND FLR. AREA **16,000sq. m**	*PROJECT VALUE* **Undisclosed**	*NUMBER OF UNITS* **121**
No. OF FLOORS/HEIGHT **10 (33m)**	*CONSTRUCTION START* **June 2015**	*COMPLETION* **March 2017**

Dalston works or Dalston lane (figure 3:36) is the world's largest Cross Laminated Timber (CLT) building and it is cladded externally with a non-load bearing brick façade. Figures 3.37 and 3.38 shows the ground floor plan and typical floor plan of the building while figure

3.39 presents the section A-A of the structure which shows the building having a concrete basement and ground floor.



(L-R) Figure 3.37: Ground floor plan of the Dalston works building; **Figure 3.38:** Typical floor plan of the Dalston works building (Merrick, 2017)

Figure 3.39: Section A-A of the Dalston works building (Merrick, 2017)

Some of the benefits attained from using both prefabricated CLT component which happens to be an environmentally friendly material includes (a) sustainable construction by reducing the amount of CO2 gases being emitted to the environment, (b) reduced risk of structural error since the panels where manufactured off-site, (c) the project avoided weather disruption (d) quicker and faster construction time which also led to quick return of investment (e) reduced environmental impact such as noise and dust.

3.7.1.2. Case Study 2: Apex House, London – United Kingdom

Figure 3.40: Apex house (The Skyscraper Center, n.d.-b)

Table 3.4: Case study 2 information (The Skyscraper Center, n.d.-b)

OFFICIAL NAME **Apex House**	*LOCATION* **London, UK**	*OWNER/CLIENT* **SCAPE**
ARCHITECTURE FIRM **HTA Design LLP**	*STRUCTURAL ENGR.* ***NA***	*MAIN CONTRACTOR* **Tide Construction & Vision Modular Syst.**
STRUCTURAL MAT. **Steel & R. Concrete**	*BUILDING SYSTEM* **Modular (Volumetric)**	*BUILDING FUCNTION* **Students Residence**
GROUND FLR. AREA **17,000 sq. m.**	*PROJECT VALUE* ***Undisclosed***	*NUMBER OF UNITS* ***580***
No. OF FLOORS/HEIGHT **29 (83 m)**	*CONSTRUCTION START* **October 2016**	*YEAR OF COMPLETION* **October 2017**

The Apex House (figure 3.40) is Europe's tallest modular structure. The building is made from steel frames and concrete floor modules which rests on a concrete core thus forming an L shape floor plan (figure 3.41). The project took 12 months to execute and the 679 modules used were stacked in just 13 weeks. Each module (figure 3.42) has a maximum width of about 4.5 meters, length reaching 12m and height of 2.8 meters. These modules were stacked on a concrete base.

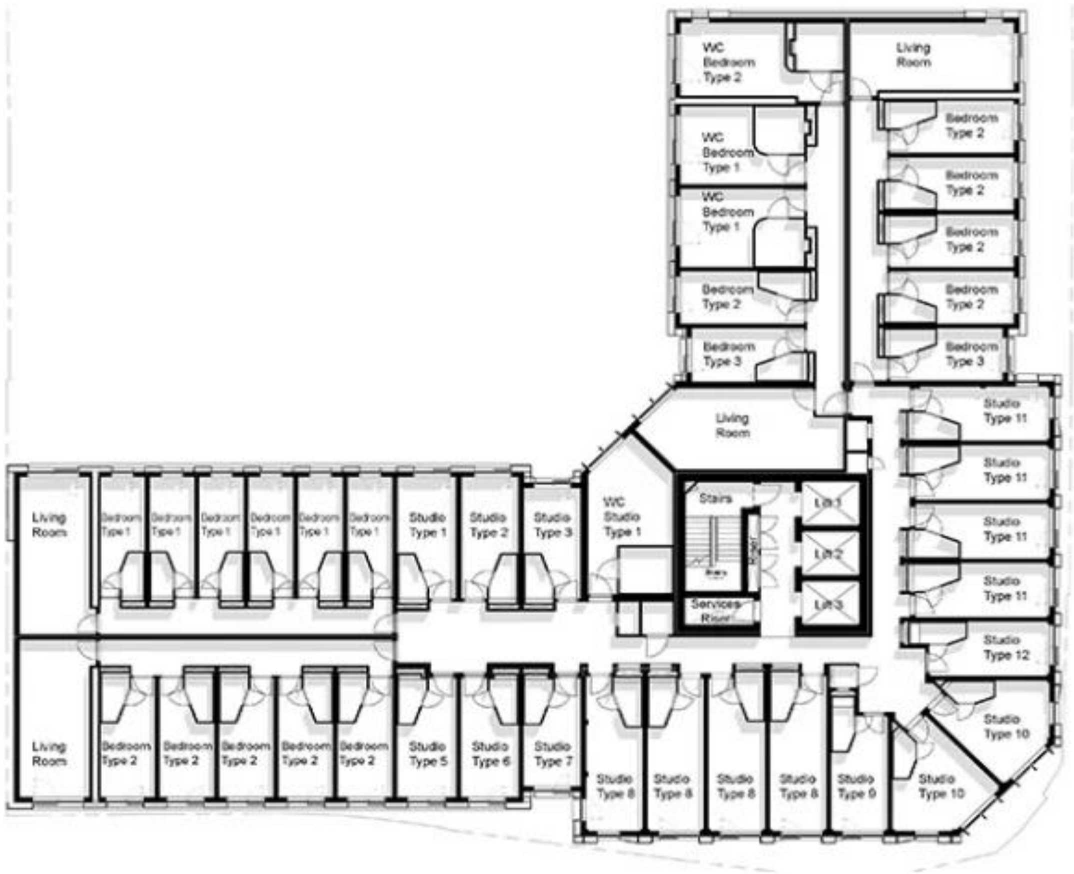


Figure 3.41: Typical floor plan of the Apex house, London (Construction Manager, 2017)

Figure 3.42: Modules for the Apex house being hoisted into position with a crane (Digital Construction News, 2017)

The advantages of using modular elements for this project as described by the developer and architect includes (a) it was a faster alternative to conventional construction (b) it brings about better quality of finished structure (c) versatility of design (d) there was 80% less waste © fewer on-site hours (f) fewer site men (g) certainty of actual project time and cost (h) better health and safety of workers without the use of scaffolds.

3.7.2 North America

3.7.2.1. Case Study 3: Brock Commons Tallwood House, Vancouver – Canada

Figure 3.43: Brock commons tallwood house (UBC, n.d.)

Table 3.5: Case study 3 information (The Skyscraper Center, n.d.-c)

OFFICIAL NAME **Brock Commons Tallwood House**	*LOCATION* **Vancouver, Canada**	*OWNER/CLIENT* **University of British Columbia**
ARCHITECTURE FIRM **Acton Ostry Architects**	*STRUCTURAL & MEP ENGR.* **Fast + Epp & Stantec Ltd.**	*MAIN CONTRACTOR* **Centura Building Syst. Ltd.** **Whitewater Concrete Ltd.** **Seagate Structures Ltd.** **Urban One Builders**
STRUCTURAL MAT. **Mass Timber Hybrid, R. Concrete**	*BUILDING SYSTEM* **Prefabricated Panels**	*BUILDING FUCNTION* **Students Residence**
GROSS FLOOR AREA **15.115 sq. m**	*PROJECT VALUE* **$51,500,000**	*NUMBER OF UNITS* **305**
No. OF FLOORS/HEIGHT **18 (53 m)**	*CONSTRUCTION START* **November 2015**	*YEAR OF COMPLETION* **May 2017**

The Brock commons tallwood house (figure 3.43) is the world's tallest mass wood tower. The project took 19 months to completer, 7 months lesser when compared with using on-site construction. The first 7 months were used in constructing the concrete elements such as the concrete base and core. Made from prefabricated mass timber such as CLT and glued laminated timber (glulam) panels each with a height of 2.8 meters. The timber was later encapsulated with gypsum board (figure 3.45) after the encapsulation, the floors are covered with concrete topping. It took 66 days to complete the timber structure going 2 months ahead of schedule. The building design (figure 3.44) was left simple to ease the approval process and for economic viability.

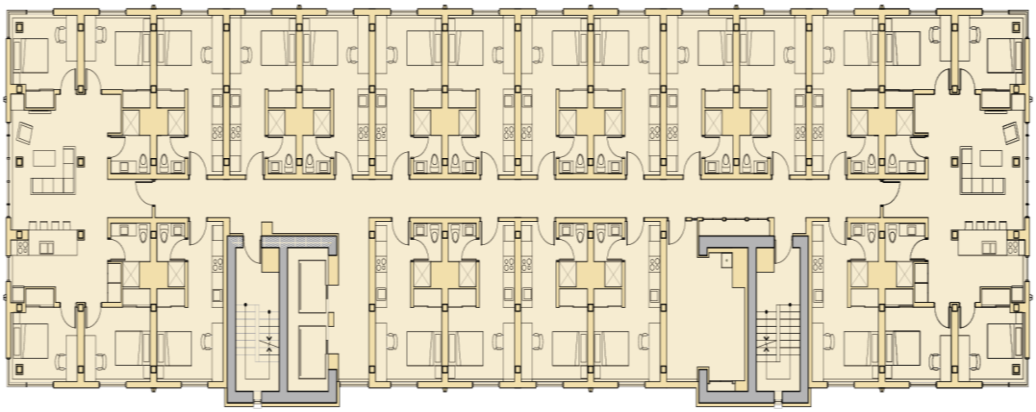


Figure 3.44: Typical floor plan of the Brock Commons Tallwood house (SAB Magazine, 2017)

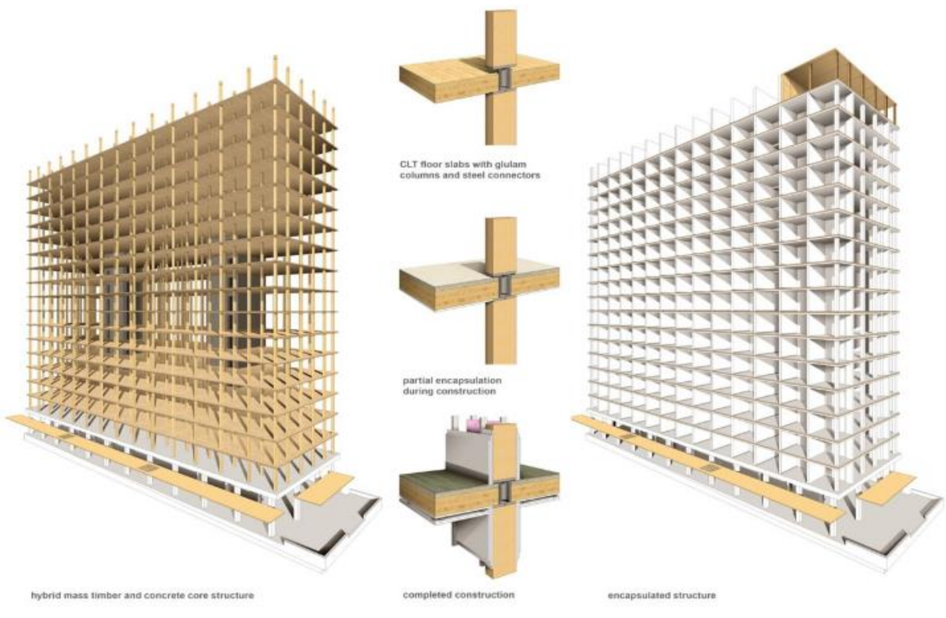


Figure 3.45: Details of the mass wood structure and encapsulation of the Brock Commons Tallwood house (Acton Ostry Architects, n.d.)

Advantages of using this material and building system includes (a) environmental sustainability with the use of timber and prefabrication (b) structural safety, strength and performance with the use of mass timber (c) economic viable structural system (d) cut down construction time due to preplanning © less traffic from trucks delivering construction materials (f) reduced construction waste (g) cleaner, quieter and smaller site (h) high level of precision (i) collaborating with designers, engineers, construction manager, and key trades during design led to quicker realization of the project.

3.7.2.2. Case Study 4: 461 Dean (Atlantic yard – B2), New York City – USA

Figure 3.46: 461 Dean building (Horseley, n.d.)

Table 3.6: Case study 4 information (The Skyscraper Center, n.d.-a)

OFFICIAL NAME **461 Dean**	*LOCATION* **New York, USA**	*OWNER/CLIENT* **Forest City Ratner**
ARCHITECTURE FIRM **ShoP Architects**	*STRUCTURAL & MEP ENGR.* **Arup Engineers**	*MAIN CONTRACTOR* **Turner Construction**
STRUCTURAL MAT. **Steel**	*BUILDING SYSTEM* **Modular (Volumetric)**	*BUILDING FUCNTION* **Residential**
GROSS FLOOR AREA **32,164 sq. m.**	*PROJECT VALUE* **$150,000,000**	*NUMBER OF UNITS* **363**
No. OF FLOORS/HEIGHT **32 (109. m)**	*CONSTRUCTION START* **2013**	*YEAR OF COMPLETION* **2017**

461 Dean or Atlantic Yard B2 (figure 3.46) as it was called is the tallest modular building in the world. It took 930 modules to build this 32 floors edifice, the longest modules are about 15 meters in length while all modules have a width of 4.5 meters and a height of 2.8 meters. The shape of the structure as seen in the typical floor plan (figure 3.47) was one of the greatest obstacle of the development thus leading to the building having over 225 unique modules. Figure 3.48 explains the structural system of the building. This system consists of a reinforced concrete basement slabs, a plinth which provides a level platform for the modules to be stacked on while the welded steel framed chassis forms the main building block for the system. The braced frames which are covered with prefabricated curtain wall panels supports the modules laterally and vertically.

Figure 3.47: Typical floor layout of 461 Dean showing 36 modules per floor (Farnsworth, 2014)

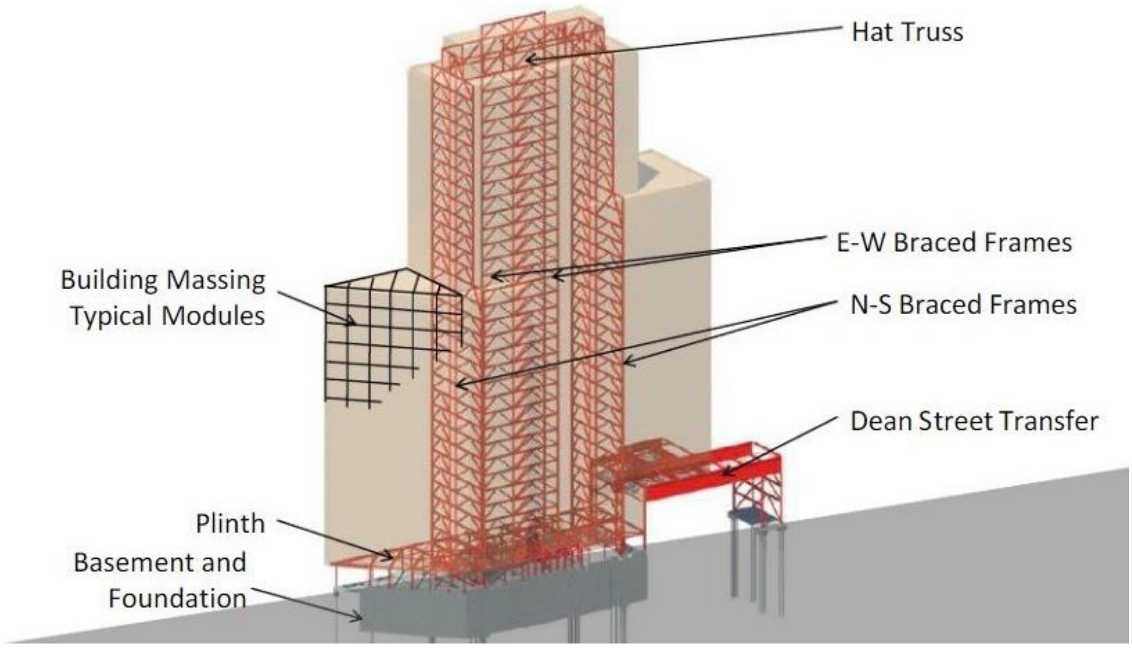


Figure 3.48: Modular structural scheme of 461 Dean building (Nonko, 2012)

The complexity of the project gave rise to a dispute between the developer Forest City Ratner and module manufacturer Sanska lasting over 2 years which delayed the date of completion. The Forest City sued Sanska for mismanaging the construction process while Sanska claimed Forest City and ShoP Architect's design were faulty and difficult to manufacture.

3.7.2.3. Case study 5: Caramel place, New York City – USA

Figure 3.49: Caramel place building (Hurley & Volner, 2017)

Table 3.7: Case study 5 information (The Skyscraper Center, n.d.-d)

OFFICIAL NAME **Caramel Place**	*LOCATION* **New York, USA**	*OWNER/CLIENT* **Monadnock Development**
ARCHITECTURE FIRM **nArchitect**	*STRUCTURAL & MEP ENGR.* **De Nardis Engineering & A. Joselow**	*MAIN CONTRACTOR* **Monadnock Construction & Capsys Corp.**
STRUCTURAL MAT. **Steel & Precast Concrete**	*BUILDING SYSTEM* **Modular (Volumetric)**	*BUILDING FUCNTION* **Residential/Retail**
GROSS FLOOR AREA **3,250 sq. m**	*PROJECT VALUE* **NA**	*NUMBER OF UNITS* **55**
No OF FLOORS/HEIGHT **9 (33.2 m)**	*CONSTRUCTION START* **May 2014**	*YEAR OF COMPLETION* **April 2016**

Caramel place (figure 3.49) a micro-unit apartment building is the tallest modular structure in Manhattan, New York. The tall narrow structure has four thin stepped volumes covered with different shades of grey bricks has 65 self-supporting steel framed modules with concrete slabs. 55 of these modules served as residential units while 10 served as the building core. Sizes of each micro-unit as can be seen from the typical floor plan (figure 3.50) ranges from 22.3 meters to 34.3 meters. Figure 3.51 shows the vertical section of the building which has its foundation and ground floor constructed from reinforced concrete on-site with ceiling height of 2.7 meters.

Figure 3.50: Typical upper floor plan of the Caramel place (Brake, 2016)

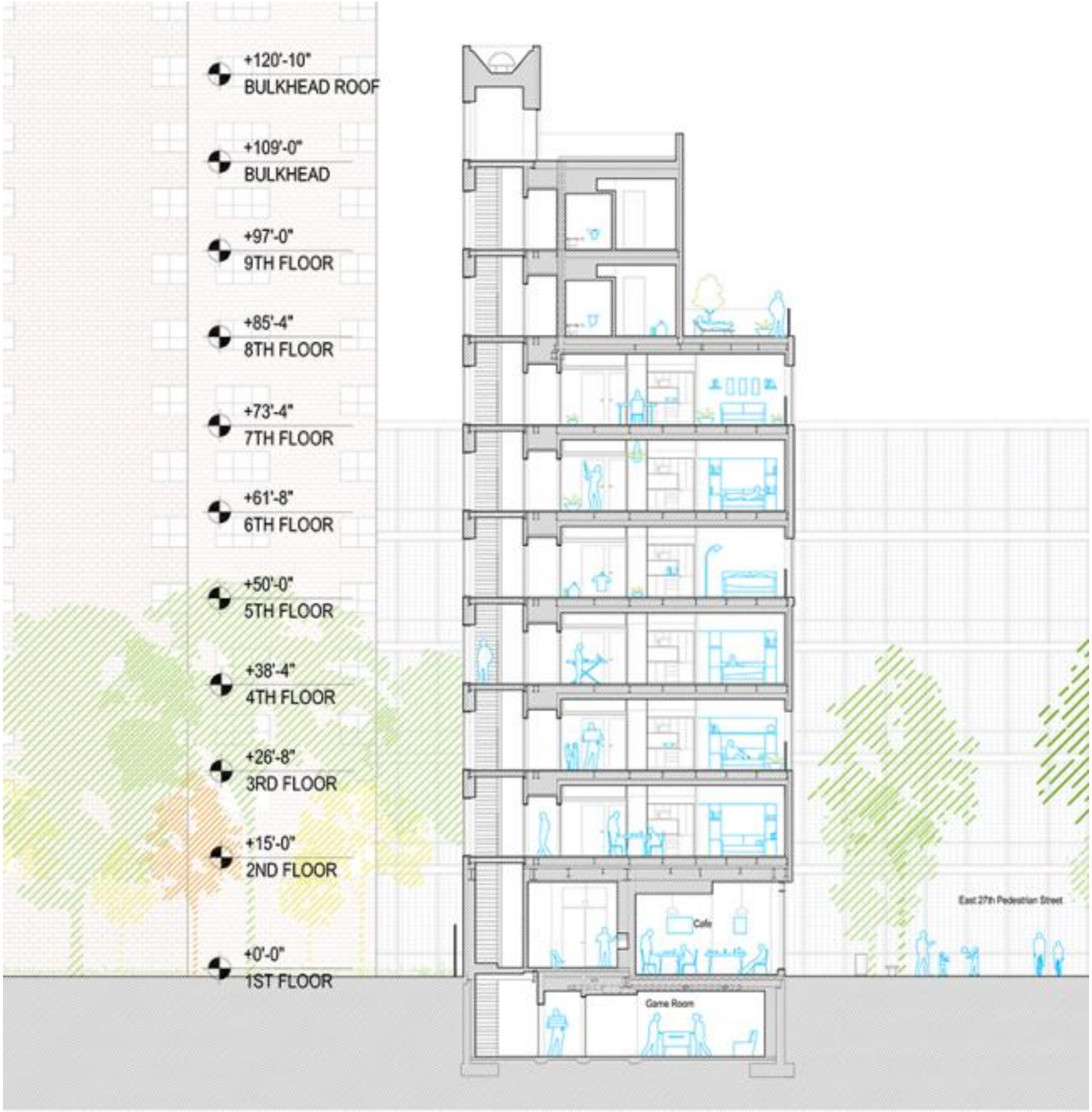


Figure 3.51: Caramel place building E-W section (World-Architects, 2016)

Advantage of using modular techniques resulted in (a) reduced construction noise and neighbourhood disruption since modules were fabricated off-site (b) better quality control and precise interior dimension resulting from the teams working in a controlled working environment.

3.7.3 Australia

3.7.3.1. Case Study 6: La-Trobe tower, Melbourne – Australia

Figure 3.52: La-Trobe tower: (The Skyscraper Center, n.d.-f)

Table 3.8: Case study 6 information (The Skyscraper Center, n.d.-f)

OFFICIAL NAME **La Trobe Tower**	*LOCATION* **Melbourne, Australia**	*OWNER/CLIENT* **Longriver Investment**
ARCHITECTURE FIRM **Rothelowman**	*STRUCTURAL & MEP ENGR.* **Hickory Building Systems**	*MAIN CONTRACTOR* **Hickory Group**
STRUCTURAL MAT. **Steel & Precast Concrete**	*BUILDING SYSTEM* **Prefabricated 3d Modules, PODs**	*BUILDING FUCNTION* **Residential**
GROSS FLOOR AREA **13,345 sq. m.**	*PROJECT VALUE* **NA**	*NUMBER OF UNITS* **206**
No OF FLOORS/HEIGHT **44 (133 m)**	*CONSTRUCTION START* **June 2015**	*YEAR OF COMPLETION* **December 2016**

The La-Trobe tower (figure 3.52) is the tallest prefabricated building in Australia. The structure which was completed in 18 months, 7 months faster than using conventional construction method. The building system made use of the Hickory's HBS system (figure 3.53) which is a new skeletal form of volumetric prefabrication. These prefab modules are typically designed in large components. The ceiling height for each residential floor according to information from the section of the building (figure 3.54) is about 3 meters.

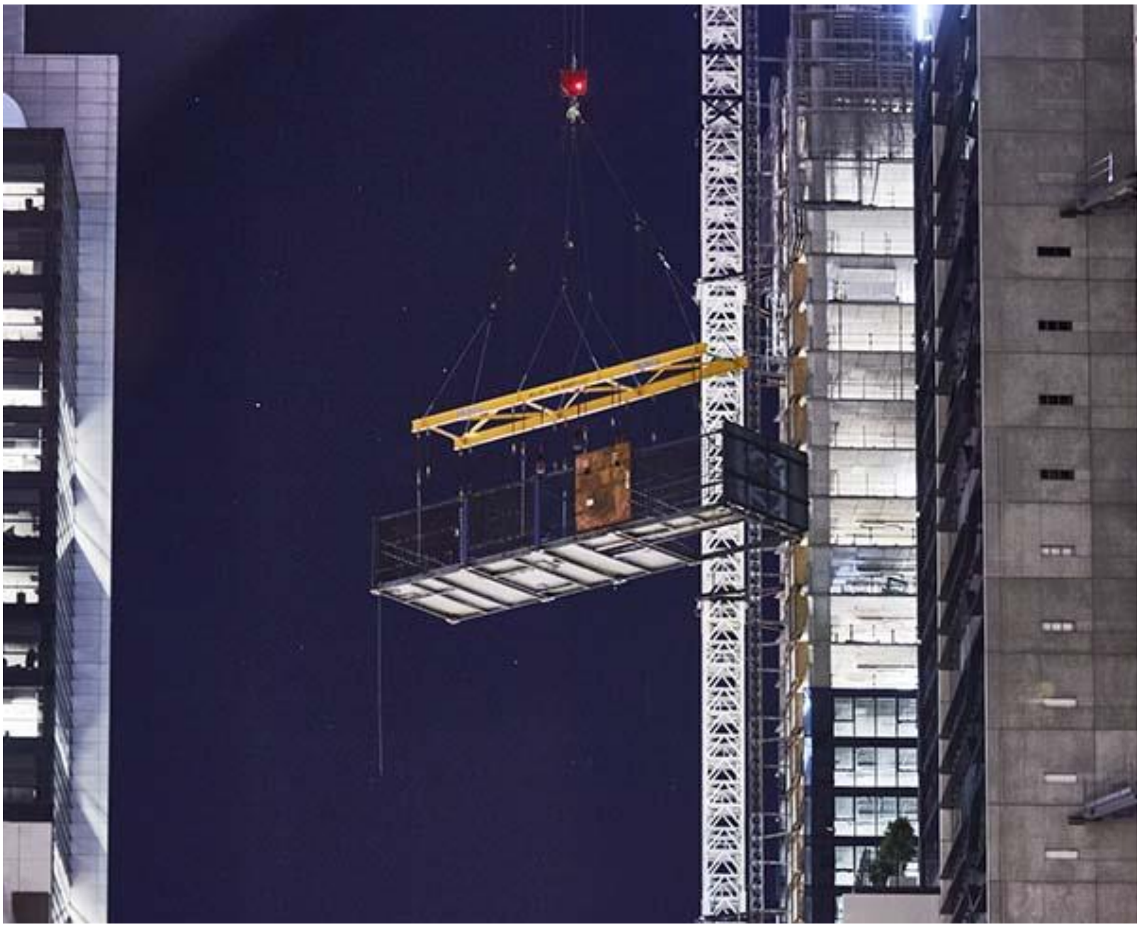


Figure 3.53: Crane hoisting the Hickory's HBS Module in place
(Hickory Group, n.d.-a)

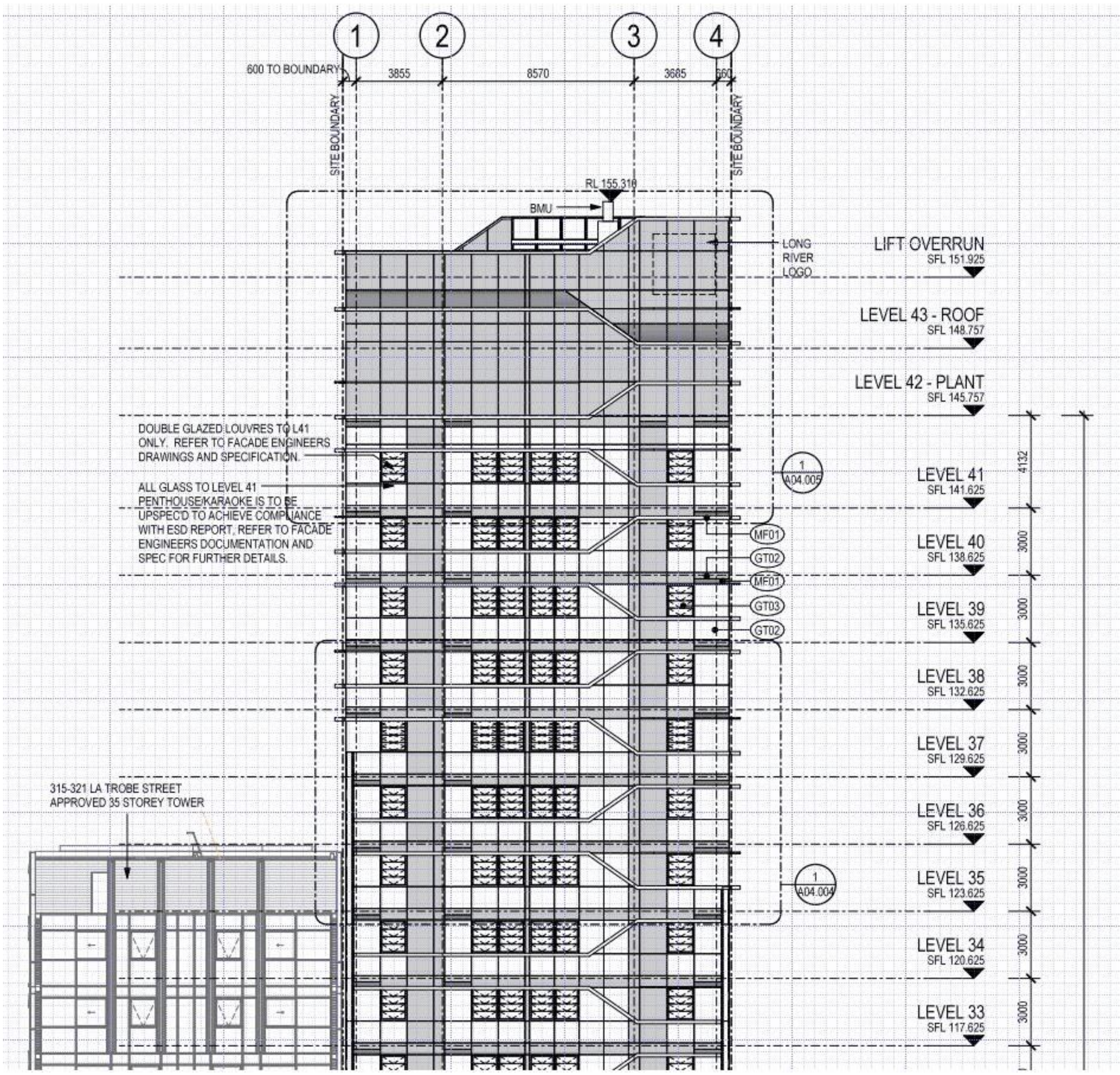


Figure 3.54: Section view of the La-Trobe towers showing top floors
(Urban Forum, 2014)

Advantages of using this building system are (a) compressed construction timeline was achieved using integrated structural prefabrication leading to a faster project completion time (b) sustainability was achieved as a result of reducing waste by 90% (c) safety of workers and road users was achieved (d) there was less disruption to the community as less amount of noisy works were carried out onsite with fewer truck deliveries also.

3.7.3.2. Case study 7: Pepper Kings Square Hotel, Perth – Australia

Figure 3.55: Pepper Kings Square Hotel (Austral Precast, n.d.)

Table 3.9: Case study 7 information (Hickory Group, n.d.-b)

OFFICIAL NAME **Pepper Kings Square**	*LOCATION* **Perth, Australia**	*OWNER/CLIENT* **Mantra Group**
ARCHITECTURE FIRM **Project Tourism Int'l Arch.**	*STRUCTURAL & MEP ENGR.* **Hickory Building Systems**	*MAIN CONTRACTOR* **Mode Modular Dev.**
STRUCTURAL MAT. **Steel & Precast Concrete**	*BUILDING SYSTEM* **Prefabricated 3d Modules,**	*BUILDING FUCNTION* **Hotel**
GROSS FLOOR AREA **NA**	*PROJECT VALUE* **AUD$40,000,000**	*NUMBER OF UNITS* **120**
No OF FLOORS/HEIGHT **17 (53 m)**	*CONSTRUCTION START* **December 2015**	*YEAR OF COMPLETION* **November 2016**

Pepper Kings Square Hotel (figure 3.55) is another building which adopted the Hickory's prefabricated building systems which comprises of integrated structural steel prefabricated 3d modules, pre-attached façade systems, precast concrete panels and bathroom Pods. The prefabricated elements were installed in as little as 11 weeks.

3.7.4 Europe

3.7.4.1. Case study 8: Treet or the Tree, Bergen – Norway

Figure 3.56: Treet or The Tree building (Panels and Furniture Asia, 2015)

Table 3.10: Case study 8 information (The Skyscraper Center, n.d.-h)

OFFICIAL NAME **Treet or The Tree**	*LOCATION* **Bergen, Norway**	*OWNER/CLIENT* **Bergen & Omegn Bldg. Soc.**
ARCHITECTURE FIRM **ARTEC AS**	*STRUCTURAL & MEP ENGR* **SWECO AS**	*MAIN CONTRACTOR* **FM Gruppen Strand AS** **Kodumaja. Moelven**
STRUCTURAL MAT. **Timber (CLT & Glulam)**	*BUILDING SYSTEM* **Modular & Prefab. Panels**	*BUILDING FUCNTION* **Residential**
GROSS FLOOR AREA **5,830 sq. m.**	*PROJECT VALUE* **€22,000,000**	*NUMBER OF UNITS* **62**
No OF FLOORS/HEIGHT **14 (49.9 m)**	*CONSTRUCTION START* **April 2014**	*YEAR OF COMPLETION* **November 2015**

Treet or The Tree building (figure 3.56) is a luxurious apartment and the tallest modular timber framed structure in the world. The building system comprises of glulam load bearing structures and modular flats made from solid CLT. The arrangement of the various types of modules used can be viewed from the typical floor plan in figure 3.57. The ceiling levels of each building floor can be noticed in the vertical section showing the load bearing structure (figure 5.78). The building's load bearing structure supports the CLT elements while modules are stacked four floors high, with two platforms which are above the 4th and 9th floors anchored to the glulam frame. These platforms are supported and reinforced by 3 meters high lattice beams.

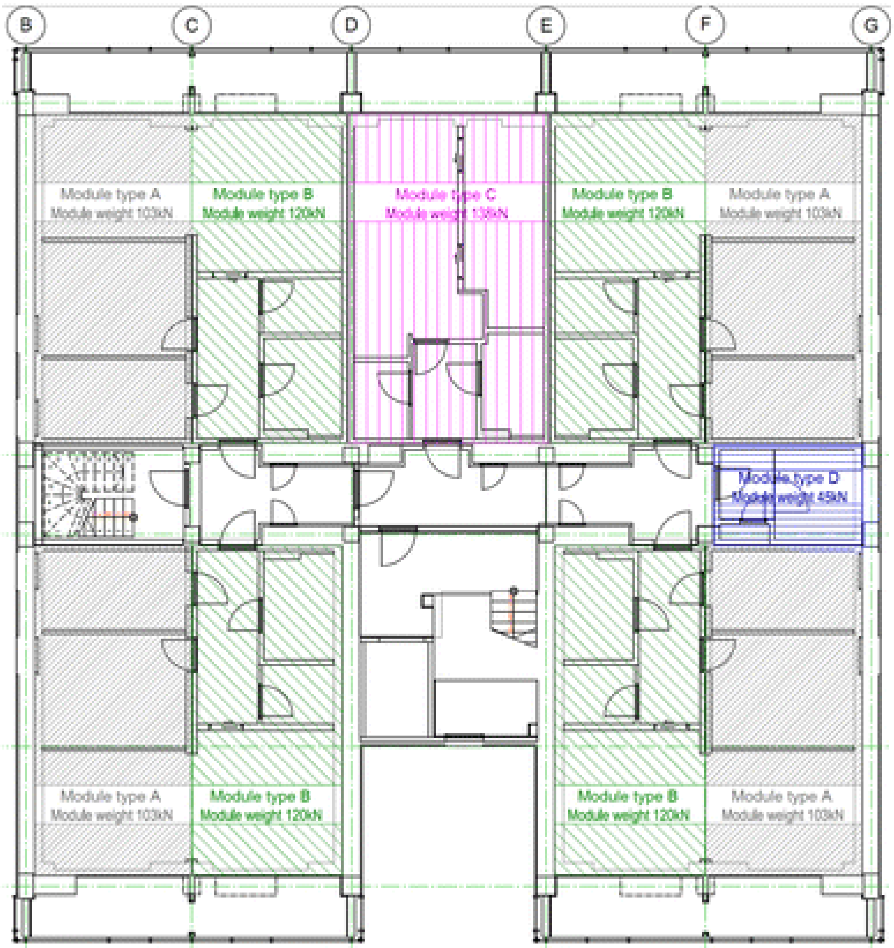


Figure 3.57: Typical Floor plan of Treet building (Malo, Abrahamsen, & Bjertnæs, 2016)

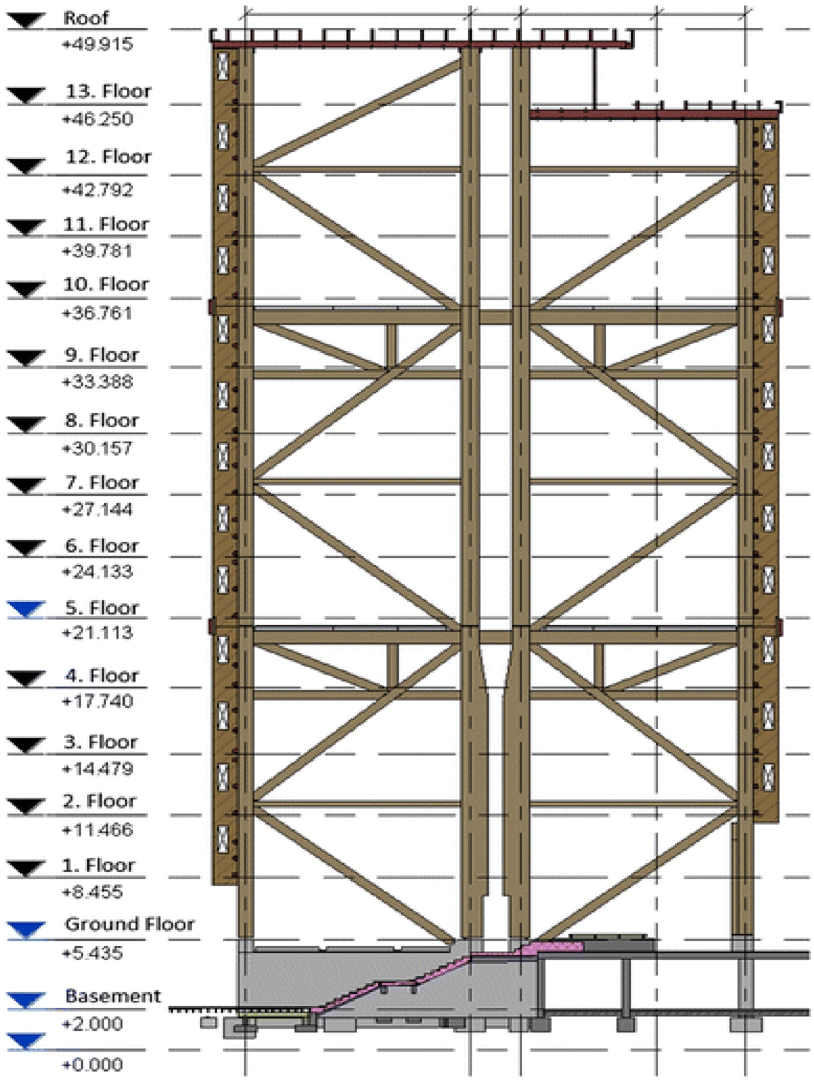


Figure 3.58: Vertical section of load bearing structure of Treet building (Malo et al., 2016)

The positives derived from the use of prefabricated timber modules and panels for the (b) cash savings as a result of quicker installation and quicker building time (c) reduced humidity and moisture of building components during construction which happens to be a major challenge in Norway (d) Sustainability – the structure was built as a Passive Haus which translates to little energy usage and emission © the ability to integrate Building Information Modelling (BIM) in simulating assembly before carrying out the main construction.

3.7.4.2. Case Study 9: Reims Student Housing, Reims – France

Figure 3.59: Container Student Housing in Reims
(XCUBE Engr & Prefab, 2015)

Table 3.11: Case study 11 information (Prefab Market, n.d.)

OFFICIAL NAME	*LOCATION* **Reims, France**	*OWNER/CLIENT* **Akerys**
ARCHITECTURE FIRM **NA**	*STRUCTURAL & MEP ENGR.* **NA**	*MAIN CONTRACTOR* **NA**
STRUCTURAL MAT. **Steel**	*BUILDING SYSTEM* **Shipping Container Modules**	*BUILDING FUCNTION* **Student Residence**
GROUND FLR. AREA **4,256 sq. m.**	*PROJECT VALUE* **$5,000,000**	*NUMBER OF UNITS* **131**
No OF FLOORS/HEIGHT **4 (13 m)**	*CONSTRUCTION START* **February 2014**	*YEAR OF COMPLETION* **August 2014**

This container student housing in Reims – France (Figure 3.59) was developed by Akerys for students of the University of Reims. The building was constructed from 152 containers measuring about 27 sq. m. (figure 3.60) to make studio apartments. It took just about 78 days to manufacture all the modules which were fabricated in a factory in China by a prefab manufacturer who carried out designing, manufacturing, shipping and constructing the entire structure within 6 months. Figure 3.61 shows a 3D rendering of a typical studio apartment which comes fully furnished including interior, kitchen and bathroom fittings.

Figure 3.60: Module of the Container Student Housing being stacked (XCUBE Engr & Prefab, 2015)

Figure 3.61: 3D interior rendering of the Container Student Housing (Living Spaces, 2016)

3.7.5 China

3.7.5.1: Case Study 10: T30 Hotel – Changsha

Figure 3.62: The T30 Hotel building (The Skyscraper Center, n.d.-g)

Table 3.12: Case study 10 information (The Skyscraper Center, n.d.-g)

OFFICIAL NAME **T30 Hotel**	*LOCATION* **Changsha, China**	*OWNER/CLIENT* **Broad Group**
ARCHITECTURE FIRM **Broad Sustainable Bldg. Co. Ltd.**	*STRUCTURAL & MEP ENGR.* **B.U.T. & Broad Sustainable**	*MAIN CONTRACTOR* **Sky City Inv. Co. Ltd.**
***S**TRUCTURAL MAT.* **Steel**	*BUILDING SYSTEM* **Prefabricated Modules.**	*BUILDING FUCNTION* ***Hotel***
GROSS FLOOR AREA **17,602 sq. m.**	*PROJECT VALUE* **$17,000,000**	*NUMBER OF UNITS* **330**
NUMBER OF FLOORS **30 (100 m)**	*CONSTRUCTION START* **December 2011**	*YEAR OF COMPLETION* **January 2012**

The T30 hotel (Figure 3.62) was erected in a record 15days by Broad Sustainable Building Company. The T30 hotel is only the 2nd project executed by the company at that time. The other being the Ark Hotel, a 15 storeys structure which constructed in as little as 15 days. The ground floor of the hotel (Figure 3.63) has a large reception area attached to the main building.

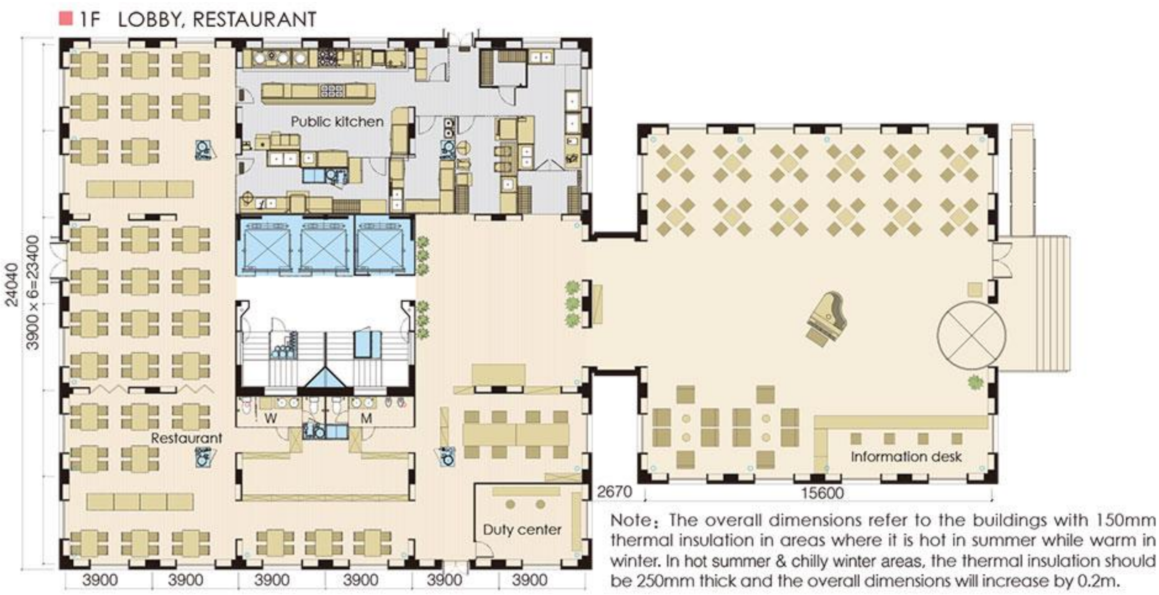


Figure 3.63: Ground floor plan of the T30 Hotel (Broad Sustainable Building, n.d.)

The building was constructed using several identical modules (Figure 3.64) that were fabricated or manufactured in the factory and comes installed in each one of them various pipes for air-conditioners, waste, hot and cold water. Each of these modules were basically used for just floors and ceilings and they measure 15.4 meters in length by 3.9 meters in width and 0.45 meters in thickness. The building’s floor to ceiling height is 2.75 meters.

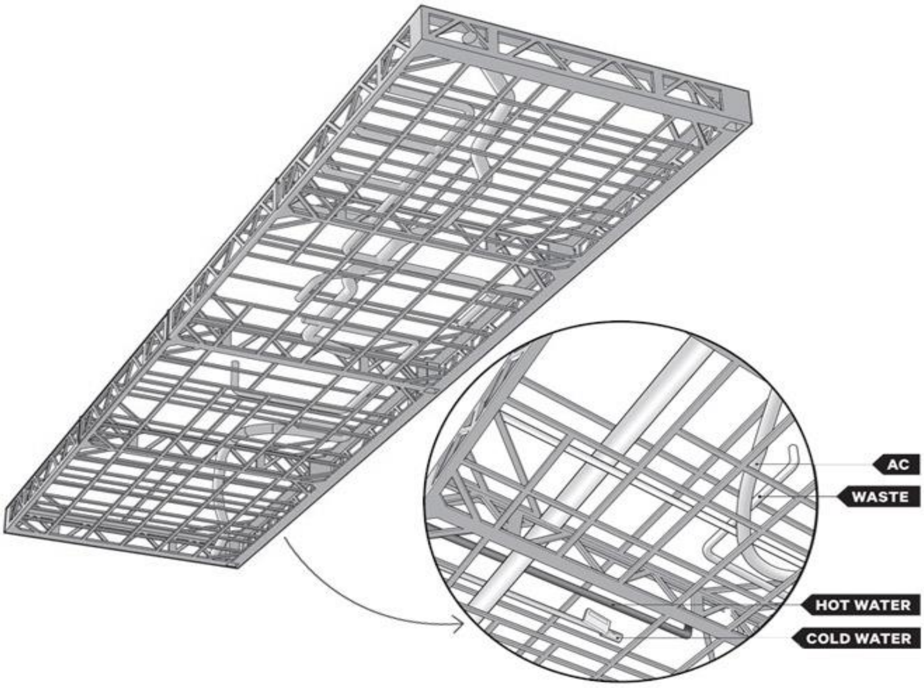


Figure 3.64: Typical module of the T30 Hotel (Higers, 2012)

After fabrication at the factory, a truck transports these complete modules together with other building components such as exhaust ducts, wall panels, columns and box of bolts required for each module to site for installation (Figure 3.65).

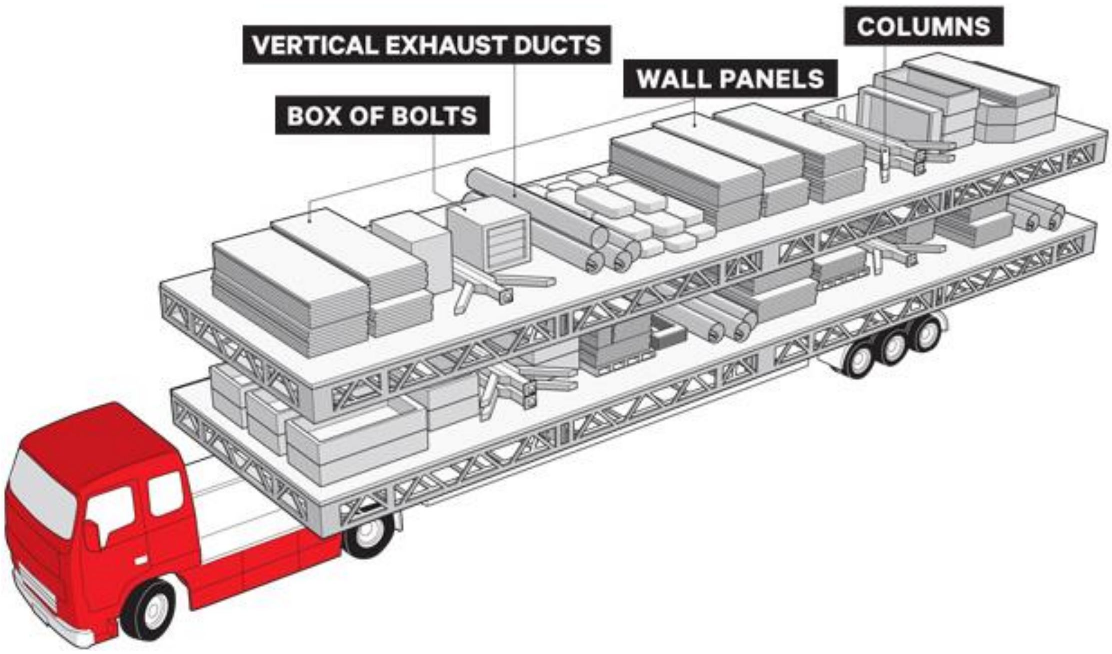


Figure 3.65: Truck transporting modules and other components to site (Higers, 2012)

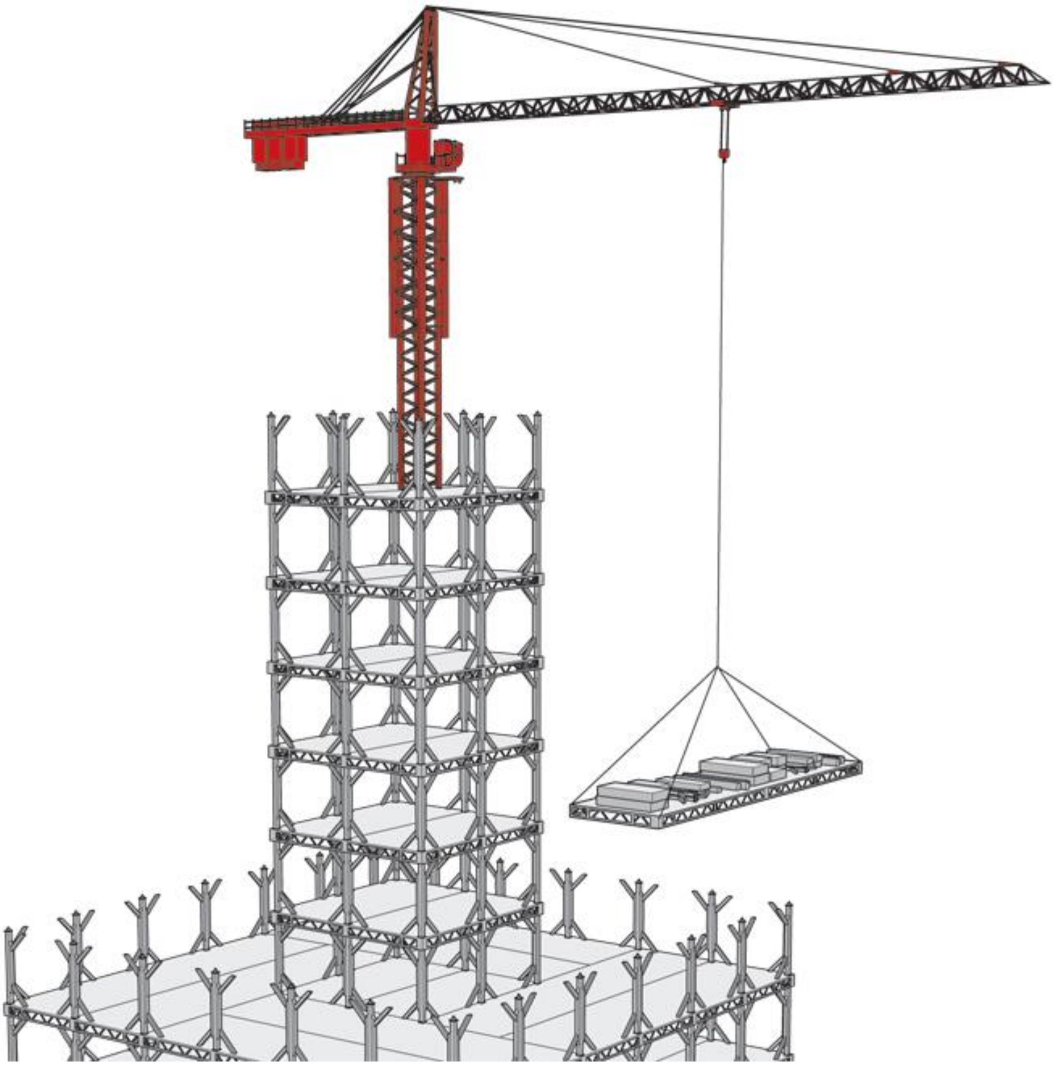


Figure 3.66: Lifting of modules and other components into place by a crane (Higers, 2012)

The use of this building system ensured that (a) the building can resist a 9.0 magnitude earthquake (b) the indoor fresh air in 100% cleaner than the outdoor (c) there was less wastage onsite since 90% of works were carried out in the factory (d) construction process was safer © the building weight much lesser by cutting down on the use on concrete.

3.7.5.2: Case Study 11: J57 Mini Sky City – Changsha

Figure 3.67: The J57 mini sky city building (The Skyscraper Center, n.d.-e)

Table 3.13: case study 11 information (The Skyscraper Center, n.d.-e)

OFFICIAL NAME **J57 Mini Sky City**	*LOCATION* **Changsha, China**	*OWNER/CLIENT* **Sky City Inv. Co. Ltd.**
ARCHITECTURE FIRM **Broad Sustainable Bldg. Co. Ltd.**	*STRUCTURAL & MEP ENGR.* **Sky City Inv. Co. Ltd.**	*MAIN CONTRACTOR* **Sky City Inv. Co. Ltd.**
STRUCTURAL MAT. **Steel**	*BUILDING SYSTEM* **Prefabricated Modules.**	*BUILDING FUCNTION* ***Mixed Use***
GROUND FLR. AREA **179,600 sq. m.**	*PROJECT VALUE* **$700/sq. m**	*NUMBER OF UNITS* **800**
NUMBER OF FLOORS **57 (207.8 m)**	*CONSTRUCTION START* **January 2014**	*YEAR OF COMPLETION* **February 2015**

The J57 Mini Sky City (figure 3.67) is a 90% factory made state of the art mixed used building that was constructed Broad Sustainable Building Company. The rectangular glass and steel building was constructed two burst within a space of 13 months. Fabrication of the 2,736 ceiling and floor modules used was done in 4 ½ months. It took 7 working days to construct the first 20 floors in 2014 and then construction was halted for about a year due to disputes as regards the building height which was initially for 97 floors. After several considerations especially the fact that construction site was 15km away from the airport, the building height was then reduced to 57 floors. The construction of the remaining 37 floors commenced on 31st January 2015 and was completed by 17th February 2015 where about two to three floors were constructed daily.

The construction process of the J57 Mini Sky City is a replica of the T30 Hotel (cast study 10). Some of the advantages of using these building systems, processes and materials include (a) Early completion time of close to 12 months when compared with conventional method (b) Construction cost was reduced by as much as 20 – 40% (c) Low Carbon Emission from the building (d) 80% more energy efficient than similar buildings.

3.7.6 Turkey

3.7.6.1: Case Study 12: Republika Academic Aparts – Florya

Figure 3.68: Republika Academic Aparts, Florya (Arkiv, n.d.)

Table 3.14: Case study 12 information (Arkiv, n.d.)

OFFICIAL NAME **Republika Academic Aparts**	*LOCATION* **Bakırköy, Istanbul**	*OWNER/CLIENT* **Bilgili Holding**
ARCHITECTURE FIRM **Autoban**	*STRUCTURAL & MEP ENGR.* **NA**	*MAIN CONTRACTOR* **NA.**
STRUCTURAL MAT. **Steel**	*BUILDING SYSTEM* **Modular units**	*BUILDING FUCNTION* **Students Residence**
GROUND FLR. AREA **3,400 sq. m.**	*PROJECT VALUE* **NA**	*NUMBER OF UNITS* **83**
NUMBER OF FLRS/HEIGHT **6 / 18 m**	*CONSTRUCTION START* **2014**	*YEAR OF COMPLETION* **2014**

Figure 3.69: Typical Plan of the Republika Academic Aparts, Florya (Arkiv, n.d.)

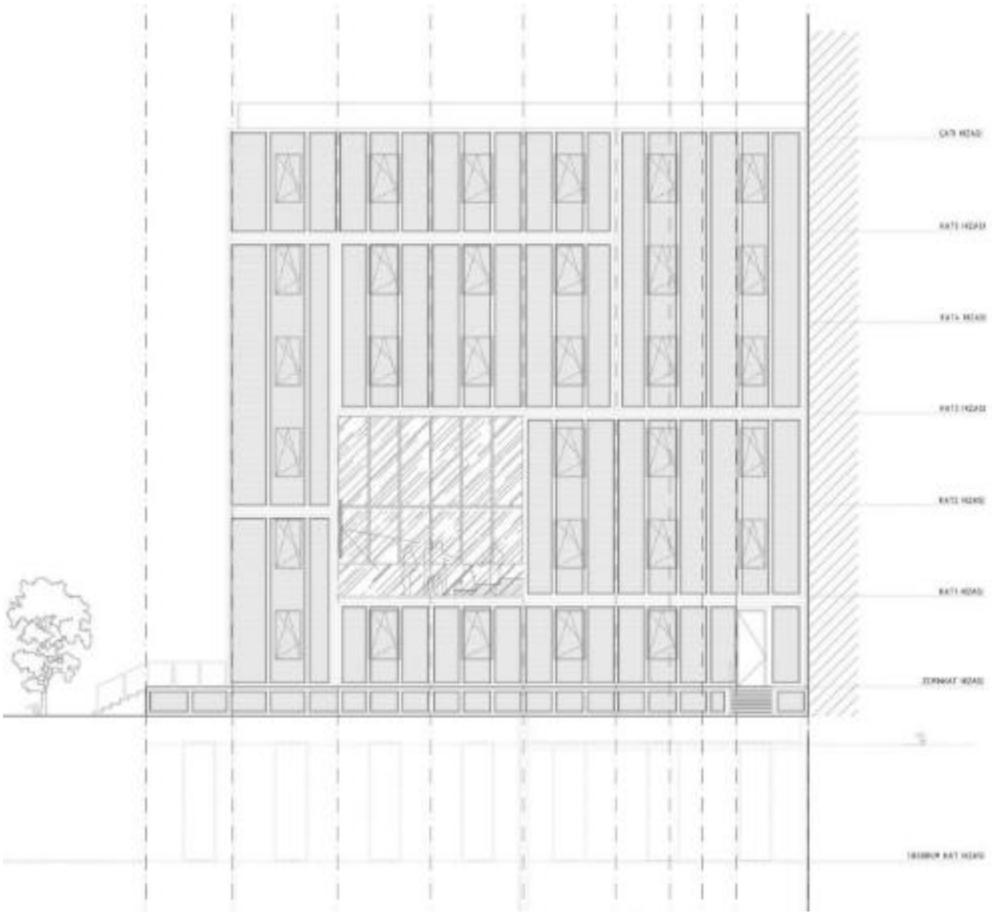


Figure 3.70: Latitudinal Section of the Republika Academic Aparts, Florya (Arkiv, n.d.)

The Republika Academic Aparts was built with an architectural plan of integrating modules having basic repetitive geometric forms into the building’s grid system. The interior design of this student residence was done to provide the occupants with maximum comfort possible in this little space which has a well-planned living spaces. The arrangement of the modules that constitutes the structural frame of this building was carried out so as to use the top level of each unit for daylighting.

The advantages of using modular units for the construction of the building includes (a) the ability to use low cost durable materials which automatically translates to low building cost (b) the small room spaces was able to contain all the functions needed in each room due to prefabrication of components (c) the project was completed quicker that it would have taken using conventional construction method (d) the quality of finished work was exceptional.

3.7.6.2: Case Study 13: Kilis Oncüpınar Accommodation Facility, Kilis

Figure 3.71: The Kilis Öncüpınar Accommodation Facility (McClelland, 2014)

Table 3.15: Case study 13 information (McClelland, 2014)

OFFICIAL NAME **Kilis Öncüpınar Accommodation Facility**	*LOCATION* **Kilis - Turkey**	*OWNER/CLIENT* **Turkish Government**
ARCHITECTURE FIRM **NA**	*STRUCTURAL & MEP ENGR.* **NA**	*MAIN CONTRACTOR* **NA.**
STRUCTURAL MAT. **Steel**	*BUILDING SYSTEM* **Shipping Container Modules**	*BUILDING FUCNTION* **Refugee Camp**
GROUND FLR. AREA **NA**	*PROJECT VALUE* **NA**	*NUMBER OF UNITS* **2053**
NUMBER OF FLRS/HEIGHT **1 / 2.7 m**	*CONSTRUCTION START* **2012**	*YEAR OF COMPLETION* **2012**

Kilis Öncüpınar Accommodation Facility is one of the many camps in Turkey for refugees fleeing from the Civil War in Syria. This camp is located in Öncüpınar which is next to the border between Turkey and Syria. The camp opened 8 years ago in 2012 and by February 2014 it has hosted over 14,000 refugee. The camp which has about 2053 shipping containers is linked with pathways made from bricks. Each container is 6.9 m by 3 m and it is divided into 3 rooms and accommodates one family. Within the same premises there are several schools, playgrounds and kindergarten for 2000 school children.

Figure 3.72: Entrance of the Kilis Oncupinar Accommodation Facility (McClelland, 2014)

The advantages of using shipping container modules for the refugee camp includes (a) quick response to providing housing for refugees (b) provision of quality and comfortable housing

Figure 3.73: Interior view of the Kilis Oncupinar Accommodation Facility (McClelland, 2014)

Figure 3.74: Bedroom view of the Kilis Oncupinar Accommodation Facility (McClelland, 2014)

3.7.7 North Cyprus

3.7.7.1: Case Study 14: Private Residential Duplex - Mağusa

Figure 3.75: Exterior view of a prefab private residence in Iskele (North Steel Homes, n.d.)

The construction of this 164 sq. m. prefab private residence commenced on the 1st of September 2012 and was completed in a space of 8 weeks (October 30th, 2012) and the occupants moved in around November 2012.

The main structural material for the building was steel which was manufactured at the factory and installed on the site. Because of this, the construction period was very fast and came with a trouble-free workflow.

The occupants of the building mentioned that the building was well insulated against sound and most importantly heat. Because of this the occupants reported that it wasn't really a necessity for them to install air conditioners in the building during summer while at winter the living room is only cold for a maximum period of about two hours in the day due to its orientation. They also mentioned that the prefabricated steel building guided against heat loss during the winter period thereby keep the house warm.

It was reported that with the use of prefabricated steel structure for the construction of the building, the client paid less when compared to using traditional construction making the building more economical and also helping occupants conserve much more energy.

The occupants stressed that steel house structures are more modern, convenient, comfortable and environmentally friendly both at the construction stages and during uses.

3.7.7.2: Case Study 15: Private Residential Duplex - Nicosia

Figure 3.76: Exterior view of a prefab private residence in Dikmen (North Steel Homes, n.d.)

This 200 sq. m. prefabricated steel private residence was constructed in the Dikmen area of Nicosia was completed in January 2013. It was constructed by North Steel Homes, a leading manufacturer of prefabricated steel in North Cyprus.

This building attracted a lot of attention around its environment due to the method of construction used and was completed in almost 4 months.

The prefabricated steel frame structure of the building was erected on a concrete base and comes who more advantages when compared with the use of reinforced concrete all through.

Some of the advantages from using prefabricated steel includes, better thermal insulation, cost efficiency and better quality of finished product.

3.7.7.3: Case Study 16: Private Residential Duplex - Nicosia

Figure 3.77: Exterior view of a prefab private residence in Hamitköy (North Steel Homes, n.d.)

North Steel Homes again built this prefabricated steel home in the Hamitköy area of the Nicosia. The structure has a floor area of about 157 sq. m. and construction started from August 2012 and was completed mid-September 2012.

Major advantages of using prefabrication on this project includes faster construction process, higher quality of works which translates to less faulty construction and lesser environmental disturbance and discomfort during construction.

The occupants of the building hinted that the structure is better when compared with the use of concrete during both winter and summer periods because the use of prefabricated steel carcasses allowed for better thermal insulation of the building and there was no need to use air conditioners during the summer periods.

3.8 Case Studies Comparison

Table 3.18: Case studies comparison (Author)

NAME OF BUILDING	*LOCATION*	*AREA (m2)*	*HEIGHT (m)*	*BUILDING SYSTEM*	*STRUCTURAL MATERIAL*
Dalston Works	England	16,000	33	Prefabricated Panels	CLT & Steel
Apex House	England	17,000	83	Modular (Volumetric)	Steel & R. Concrete
Brock Commons Tallwood House	Canada	15,115	53	Prefabricated Panels	Mass Timber Hybrid & R. Conc.
461 Dean (Atlantic Yard – B2)	U.S.A.	32.164	110	Modular (Volumetric)	Steel
Caramel Place	U.S.A.	3,250	33.2	Modular (Volumetric)	Steel & Precast Concrete
La Trobe Tower	Australia	13.345	133	Prefabricated 3d Modules	Steel & Precast Concrete
Pepper King Square	Australia	NA	53	Prefabricated 3d Modules	Steel & Precast Concrete
Treet	Norway	5,830	49.9	Modular & Prefab. Panels	Timber (CLT & Glulam)
Reims Student Housing	France	4,256	13	Shipping Container	Steel
T30 Hotel	China	17,600	100	Prefabricated 3d Modules	Steel
J57 Mini Sky City	China	179,600	207.8	Prefabricated 3d Modules	Steel
Republika Academic Aparts	Turkey	3,400	18	Modular (Volumetric)	Steel
Kilis Oncupinar Accomm. Facility	Turkey	NA	2.7	Shipping Container	Steel
Private Single Residence	North Cyprus	168	2.7	Prefabricated Panels	Steel
Private Single Residence	North Cyprus	200	2.7	Prefabricated Panels	Steel

From the case study examples steel seem to be the most widely used material for off-site construction. The tallest buildings which are the J57 Mini Sky City (207.8 metres), La Trobe Towers (133 metres), 461 Dean/Atlantic Yard B2 (110 metres) and the T30 hotel (100 metres) all adopted steel as their main structural materials. This allowed the buildings to rise to such magnificent heights. Most of these buildings were also constructed using modular units or prefabricated 3d modules which can either be built with or without concrete cores.

The highest height for buildings constructed using timber (mass timber, cross laminated timber and glued laminated timber) from the case studies presented is about 53 metres which is the Brock Commons Tallwood house in Vancouver. The next is the Treet building in Norway which is 49.9 metres tall and then followed by the Dalston works building in London which is about 33 metres in height.

From the case studies examples, steel seems to be the best structural materials choice when you are looking at going really high in the sky a feat that timber construction really looks up to. Considering the sustainability advantages of using prefabricated timber for construction more studies would be carried to see how buildings more than a 100 metres in height can be built using prefabricated timber (mass timber, CLT and Glulam).

In general, it would be advisable to make use of steel as a structural material when constructing high-rise or multi-story structures because of the advantages it possesses.

CHAPTER 4
RESEARCH MATERIALS AND METHODS

Generally, this research aims at critically examining and evaluating the North Cypriot building industry's level of adoption and usage of off-site modular construction. This research adopted the use of survey instrument (questionnaire) to obtain data from some building industry professionals such as architects, engineers, contractors/construction managers. The data to be obtained includes but not limited to the current construction method being used on building projects, the professional's knowledge of off-site modular construction and also the level of adoption and usage of off-site modular construction in the building industry. This section will cover details of research techniques and methodologies that would be used in obtaining and analysing the acquired data so as to achieve a meaningful and accurate result of the research.

4.1 Research Method

The aim of this thesis as earlier stated is to evaluate the adoption and usage of off-site modular construction on building projects in North Cyprus.

For the purpose of this study, the data to be used would be gathered from the use of survey method. The survey is the most appropriate approach when primary data is gotten through feedback from administered or self-administered questionnaires. The self-administered structured questionnaire would be distributed amongst building industry professionals actively practicing in North Cyprus.

The reason for evaluating the North Cypriot building industry is to understand if off-site modular construction which is an innovative and sustainable construction method is currently being utilized in the building industry and to what level.

4.2 Area of the Study

The geographical location covered by this study is the island of **North Cyprus** or **Northern Cyprus** or **Turkish Republic of Northern Cyprus (TRNC).**

The island of Cyprus is the third largest island by area in the Mediterranean region after Sicily and Sardinia. North Cyprus or TRNC as it is often called makes up about one third of the entire island which covers an area of about 3,355 square kilometre (1,295 sq. mi.). The neighbouring countries close to North Cyprus are Turkey, Syria, Egypt, Israel, Lebanon, Greece and Republic of Cyprus. Due to its specific location, the island holds and important political and geographical situation (Cansel, Bavik, & Ekiz, 2006).

North Cyprus, is a ***de facto*** independent republic which is located at the northern portion of the Cypriot Island and is only diplomatically recognised by Turkey. North Cyprus is dependent on Turkey for supports including political, economic and military (Balkiz & Therese, 2014). As at 2014, the population of North Cyprus stood at 313,626 ("T.R.N.C: Economic and Social Indicators," 2014).

Figure 4.1: Map of Cyprus (Parikiaki Cyprus, 2012)

4.2.1. North Cypriot Construction Industry

According to Celikag & Ozbilen (2007) the North Cypriot construction industry is highly individual and extremely intricate. It is principally a service industry that is responsible for converting architectural plans and specifications into finished products (buildings). The industry has witnessed serious boom in the last few years which it was not ready for because it has led to increased demands for buildings. This boom as reported by Yorucu & Keles (2007) engendered social costs as well as the destruction of historical places and generated environmental pollution to mention a few.

The construction industry impact on the North Cypriot's economy is quite excessive (Çelikağ & Özbilen, 2007). The sector plays an important part in the country's socio economic developments and some researchers have stressed the significance of the construction sector in the whole economy of a nation (Su, Lin, & Wang, 2003). Firms of various sizes including small proprietorship which employs one or two staffs to huge design & build firms which employs tens of staffs have been recorded handling projects costing millions of US dollars (Çelikağ & Özbilen, 2007).

The North Cypriot construction industry faces so many challenges just like most construction sectors around the globe. Some challenges such as poor site supervision, use of unqualified contractors and inexperience labour force all contributes to the reduced quality of the building structures produced (Çelikağ & Özbilen, 2007). It was also reported by Çelikağ & Özbilen (2008) that workers safety is another worrisome issue in North Cypriot's construction industry. These workers are frequently exposed to various hazards such as radiation, dust, toxic materials, noise and severe weather conditions. Workers are hardly seen wearing protective clothing while works plans are carried out without considering health and safety rules and regulation. The researchers further stressed that one of the vital safety barrier in North Cyprus is the usage of scaffolding system that is very unsafe. Being hit by falling materials from above, falling from scaffolds or high places and being crushed by equipment are described as the main causes of construction site accidents.

North Cyprus's Labour Department possesses a Work Act and a Health and Safety regulations for workers on construction sites. It's the responsibility of the Labour Department to enforce these Health and Safety regulations by visiting construction sites frequently. Unfortunately in practice, health and safety matters attract little or no importance in the construction industry. It can be said that the current regulations which hasn't been enforced to the latter has certainly led to construction being carried out in unsafe conditions using unsafe methods (Çelikağ & Özbilen, 2008).

In the construction section in North Cyprus, there are challenges in the supply of building materials which is as a result of increase in demand. This has caused material producers to supply contractors with low grade or sub-standard building materials which will in turn lead to the construction of building structures of lesser quality (Çelikağ & Özbilen, 2008).

The issue of low productivity is another challenge being faced in North Cyprus. This is caused by the high production cost and mobilization of unregistered or unqualified contractors and sub-contractors. Others includes weak financial and institutional structures of contractors combined with other negative factors which can have a negative toll on the construction sector (Şafakli, 2011).

There has been a significant development in technology globally which has also made available a wide range of new construction materials and methods. Most of the countries around the world are adopting these new material and methods while researching on newer ones. This is not to say all countries are following this trend, countries like North Cyprus are still lacking being in this regards (Celikag & Naimi, 2011).

4.3 Research Strategy

The research strategy employed for this thesis comprises of a comprehensive and systematic review of literatures relevant to this study, data collection and analysis as regards both the current construction method in use and also the level of adoption and usage of off-site modular construction on building projects in North Cyprus.

4.3.1. Secondary Data Sources

A systematic and comprehensive review of literature relevant to this study was performed to gain understanding of previous work in areas such as off-site construction and its historical background, types of off-site construction, structural materials used for off-site construction, benefits of off-site construction, challenges of off-site construction, comparison between off-site and on-site construction and case studies of off-site construction around the world.

4.3.2. Primary Data Sources

The primary data for this research was obtained by carrying out an industry survey on some building industry stakeholders within the three major regions of North Cyprus (Nicosia, Famagusta and Kyrenia). The self-administered questionnaire will then be used to collect the required data for quantitative analysis.

4.4 Sampling Method and Participants

This research was initially proposed to adopt a proportionate stratified random sampling method where an equal percentage of architects, engineers (civil, structural and building), City Planners, main contractors and construction/project managers would be selected for sampling or data collection. But it was impossible to retrieve the data f all registered members of the various professional bodies from their directories stating that those data are classified. Hence, a random sampling was adopted. These respondents were be gotten randomly from the invitation sent out to the Chamber of Architects, Chamber of Civil Engineers and Turkish Cyprus Building Contractors Association. The respondents were both male and female professional without age restriction who are actively in practice.

4.5 Questionnaire Layout

The questionnaire that would be utilized in providing empirical data for this thesis constitutes four sections: the introduction section, the demographic section, questions assessing construction methods in North Cyprus and questions assessing knowledge and adoption of off-site construction in North Cyprus. A brief introduction precedes the demographic section stating the purpose of the study. The remaining two sections comprises of 24 questions in other to assess both the current construction method being adopted for building construction as well as the knowledge and adoption of off-site modular construction in North Cyprus.

4.6 Ethical Approval

In other to fulfil the ethical requirements that were laid down by the ethics committee of Near East University, ethical approval was requested and gotten for this research. The survey questionnaire that was developed to gather data and other supporting documents including a duly completed ethical approval application form, participants' information sheet and participants' consent form were all submitted to the Near East University Ethics Committee.

4.7 Data Collection Tools

The proposed self-administered structured questionnaire consists of multiple choice questions (single and multiple answers) and scaled questions (Likert and Likert-type). The questionnaire has also been grouped into four parts which include; introduction section, personal information section, assessment of the construction methods being used on building projects in North Cyprus and, assessment of the knowledge, adoption and usage of off-site modular construction in North Cyprus. The data collection would be carried out from April 2018 to May 2018 by office visits (face to face), via email and web based online survey (Survey Monkey).

4.8 Industry Survey

In consideration of the participants' preferences, the survey questionnaire was made available in two different formats;

1. Paper based questionnaire: four page questionnaire to be completed, scanned and returned by email to chrislynegege@gmail.com (See **Appendix**).
2. Online format: online version of this survey was hosted on the website, Survey Monkey; a portal strictly for research based surveys. The website also provides for the researcher the statistics of the survey's responses and response rate.

A covering letter was attached to the questionnaire which will provide basic information pertaining the researcher, aim of the study, importance of findings, reason why participants should take part, approximate completion time for the questionnaire, how to return the questionnaire and a note of appreciation.

The questionnaire was circulated amongst the professional and trade associations associated with building construction in North Cyprus.

4.9 Data Analysis

To analyse the data gathered from respondents, a normal frequency distribution and percentage analysis was done to evaluate the personal data of respondents which also includes some demographic details (gender and age), occupation, educational qualification, years of experience and professional affiliation. After which the IBM SPSS version 25 statistical tool was used to analyse feedbacks from respondents.

4.10 Research Questions

The research evaluates the adoption and usage of off-site modular construction on building projects in North Cyprus and led to answer the following questions:

1. What is the current construction methods using on building projects in North Cyprus?
2. What are the major challenges being faced with the current construction method in North Cyprus?
3. What is your opinion about off-site construction?
4. What aspect of off-site construction would you be willing to adopt in your next project?
5. Who is responsible for the decision of use off-site construction on a building project?
6. At what point should the contractor performing off-site work be contacted?
7. Which benefits of off-site construction will you seek to take advantage of?
8. What are the major constraint restricting the adoption of off-site construction on building projects in North Cyprus?
9. What areas of support can professional bodies offer as regards adopting off-site construction?
10. How best can awareness be increased for the use of off-site construction?

CHAPTER 5

DATA PRESENTATION AND ANALYSIS OF RESULTS

Altogether, 39 responses were gathered from respondents of the survey questionnaire out of which there were only 31 usable data and they formed the basis for the analysis of the research.

5.1 Section A: Personal Information

Question 1:

Table 5.1: Occupation of respondents

Occupation of Respondents			
	Frequency	Percent	Valid Percent
Architect	27	87.1	87.1
Engineer (Civil/Structural)	1	3.2	3.2
General Contractor	1	3.2	3.2
University Teacher	2	6.5	6.5
Total	31	100.0	100.0

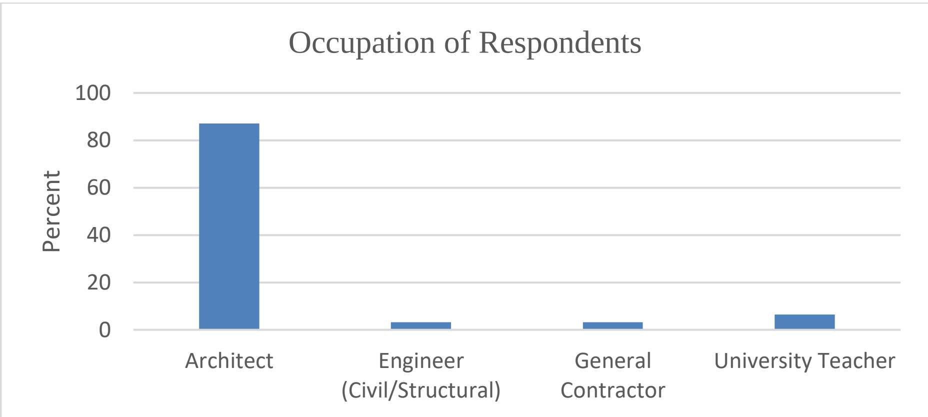


Figure 5.1: Occupation of respondents

The Table 5.1 and Figure 5.1 presents the occupation of respondents. Out of the 31 respondents, 27 (87.1%) are architects, about 2 (6.5%) of respondents were university teachers while engineers and general contractors were represent by 1 (3.2%) respondents each.

Question 2:

Table 5.2: Age of respondents

Age			
	Frequency	Percent	Valid Percent
22 - 25	1	3.2	3.2
26 - 30	8	25.8	25.8
31 - 35	10	32.3	32.3
36 - 40	3	9.7	9.7
41 - 45	3	9.7	9.7
46 - 50	3	9.7	9.7
50+	3	9.7	9.7
Total	31	100.0	100.0

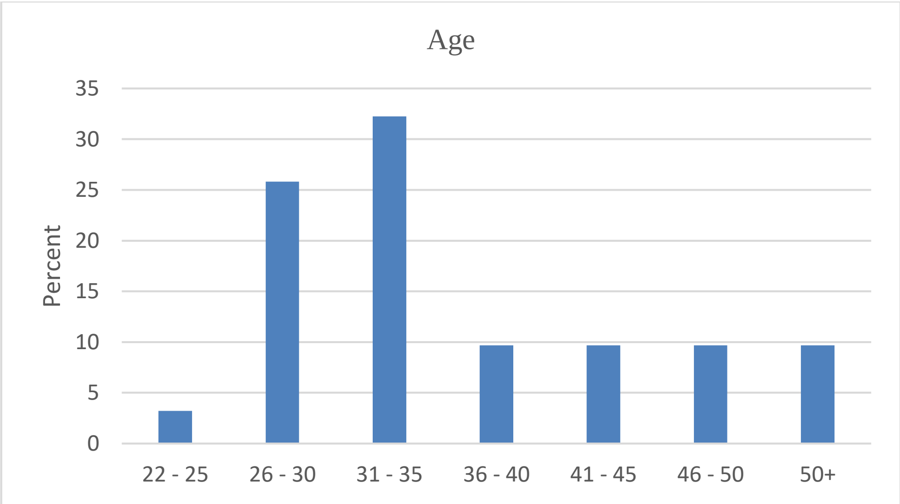


Figure 5.2: Age of respondents

The Table 5.2 and Figure 5.2 presents the age of respondents. The highest amount of respondents 10 (32.3%) were between the ages of 31 - 35 years closely followed by those between the age bracket of 26 - 30 with 8 (25.8%) respondents. Respondents between 36 - 40, 41 - 45, 40 – 50 and 50+ had 3 (9.7%) each while 1 (3.2%) respondent was between the age of 22 – 25.

QUESTION 3:

Table 5.3: Gender of respondents

Gender			
	Frequency	Percent	Valid Percent
Male	15	48.4	48.4
Female	16	51.6	51.6
Total	31	100.0	100.0

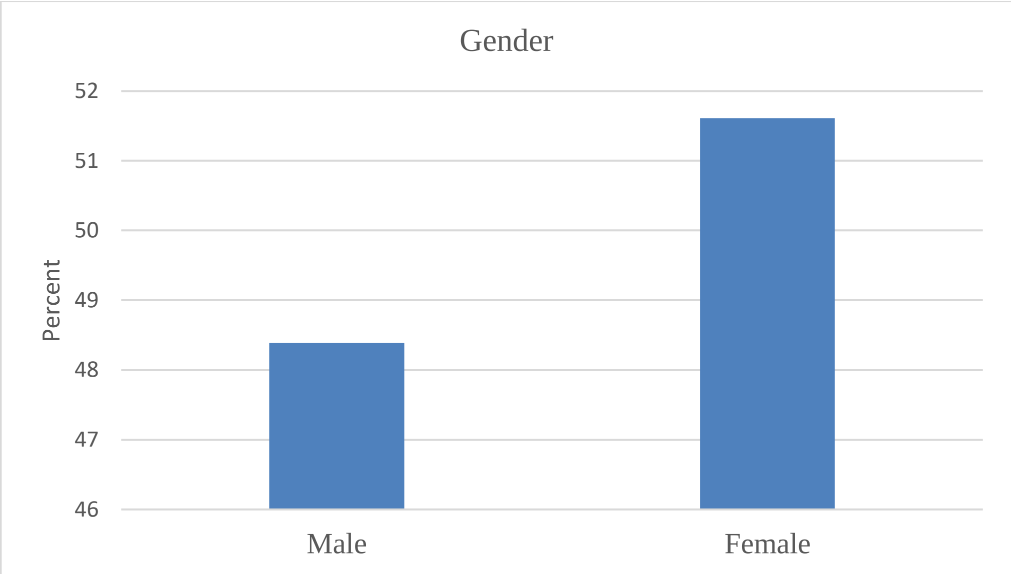


Figure 5.3.: Gender of respondents

From Table 5.3 and Figure 5.3, there seems to be a closeness between the amount of respondents from both gender with the female respondents 16 (51.6%) having one respondent more than the male counterpart at 15 (48.4%) respondents.

QUESTION 4:

Table 5.4: Education qualification of respondents

Educational Qualification			
	Frequency	Percent	Valid Percent
Bachelors'	19	61.3	61.3
Masters'	8	25.8	25.8
Doctorate	4	12.9	12.9
Total	31	100.0	100.0

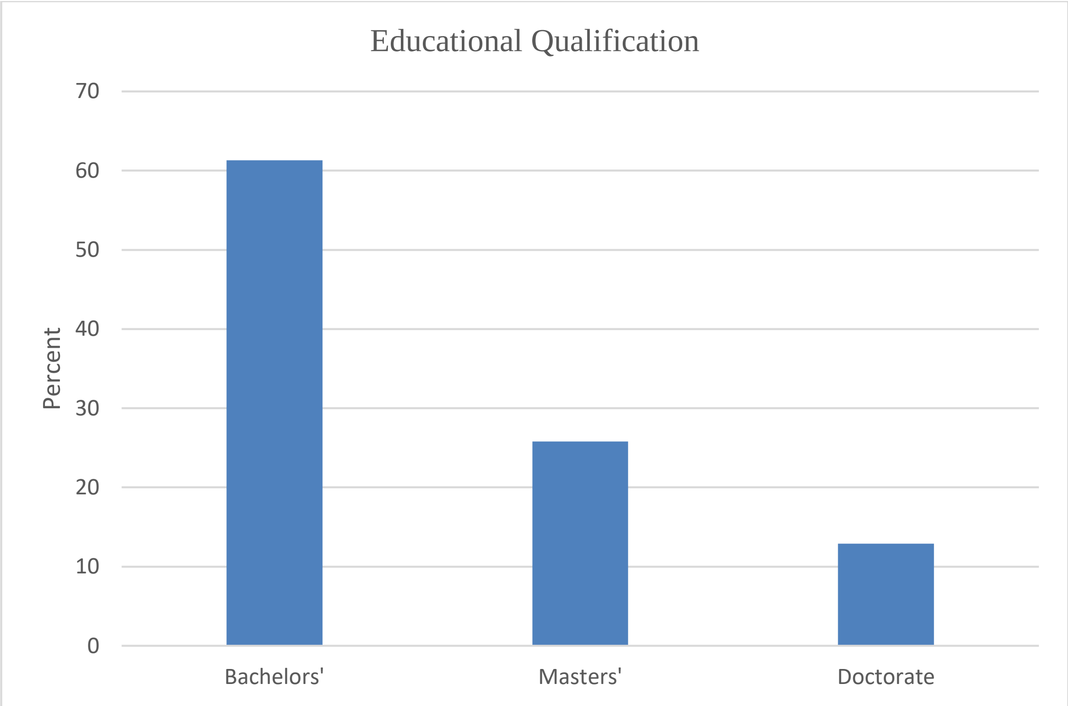


Figure 5.4.: Educational qualification of respondents

From Table 5.4 and Figure 5.4, it is gathered that 19 respondent (61.3%) to the survey have a bachelors' degree, 8 respondents (25.8%) have a masters' degree while the remaining 4 respondents (12.9%) have a doctorate degree.

QUESTION 5:

Table 5.5: Respondents years of experience

Years of Experience			
	Frequency	Percent	Valid Percent
Less than 5 years	7	22.6	22.6
5 – 10	11	35.5	35.5
11 – 15	3	9.7	9.7
16 – 20	3	9.7	9.7
21 – 25	4	12.9	12.9
More than 25 years	3	9.7	9.7
Total	31	100.0	100.0

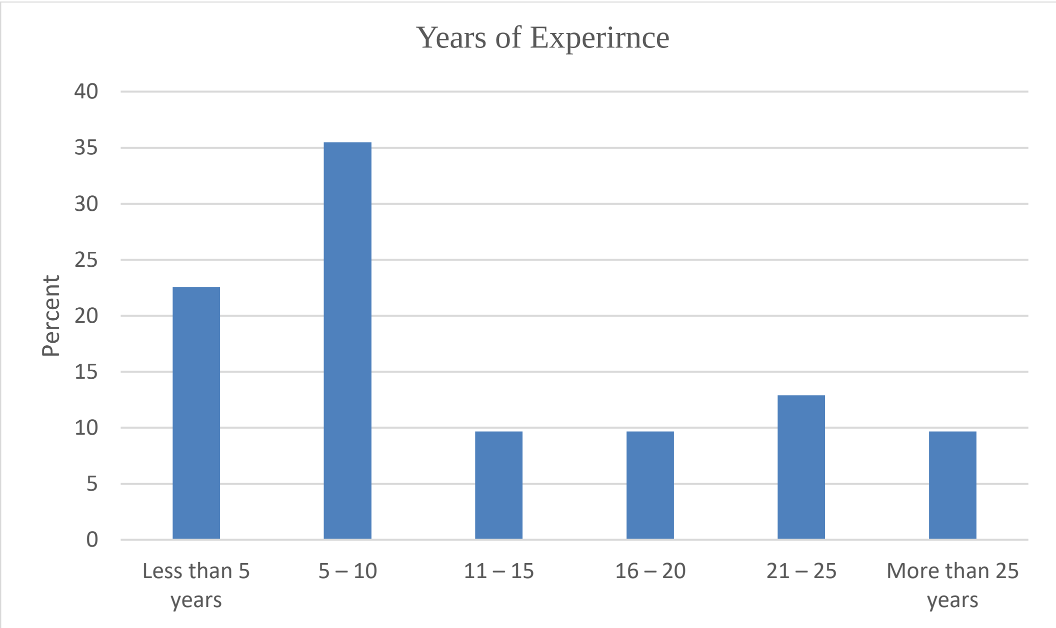


Figure 5.5: Respondents Years of Experience

Table 5.5 and Figure 5.5 reveals that most respondents 11 (35.5%) have years of experience between 5 – 10 years. Closely followed by respondents with less than 5 years of experience with 7 (22.6%) respondents. There were 4 (12.9%) who have 21 – 25 years of experience while professionals with 11 – 15 years, 16 – 20 year and more than 25 years all have 3 respondents (9.7%) each.

QUESTION 6:

Table 5.6: Respondents' organization

Organization			
	Frequency	Percent	Valid Percent
Architectural firm	17	54.8	54.8
Engineering firm (Civil/Structural)	3	9.7	9.7
Construction/Project Management firm	5	16.1	16.1
Government Agency	1	3.2	3.2
University	3	9.7	9.7
Other (please specify)	2	6.5	6.5
Total	31	100.0	100.0

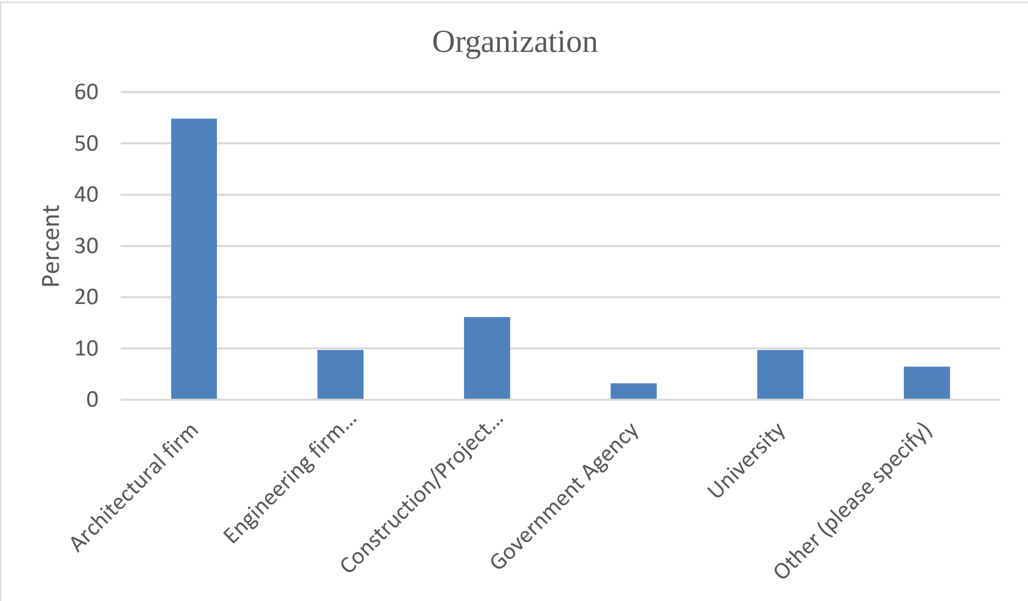


Figure 5.6: Respondents' organization

Table 5.6 and Figure 5.6 reveals that 17 respondents (54.8%) works with architectural firms distantly followed by respondents who work at construction and project management firms 5 (16.1%). Respondents who work with engineering firm and at the universities are 3 (9.7%) each while only 1 respondent (3.2%) works with a government agency. 2 respondents (6.5%) works with other organization not listed in the option.

QUESTION 7:

Table 5.7: Population size at respondents' organization

What is the size (population) of permanent staffs at your organization?			
	Frequency	Percent	Valid Percent
Less than 10	15	48.4	48.4
11 – 20	11	35.5	35.5
31 – 40	1	3.2	3.2
More than 40	4	12.9	12.9
Total	31	100.0	100.0

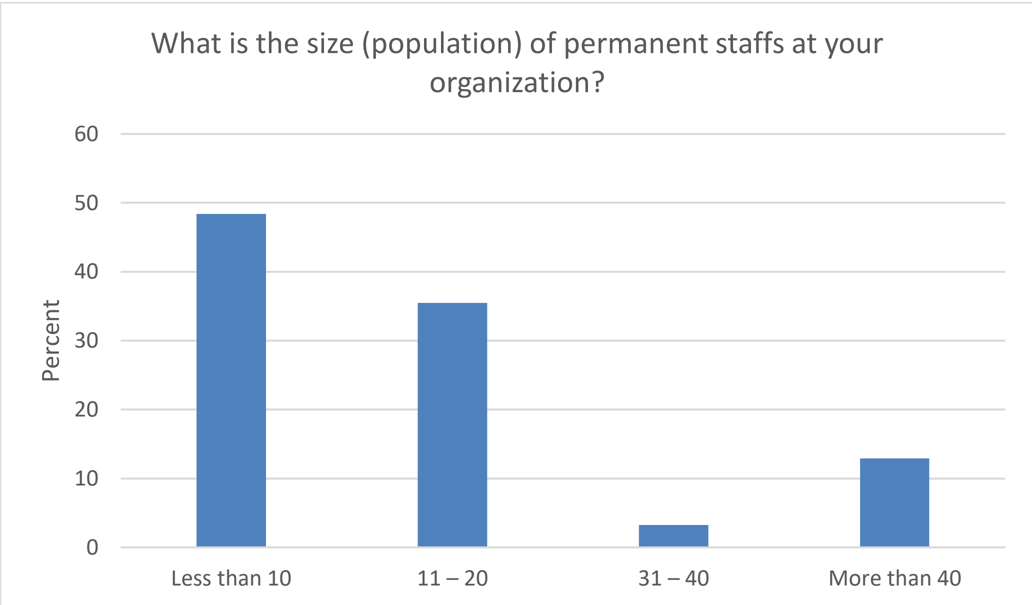


Figure 5.7: Population size at respondents' organization

From Table 5.7 and Figure 5.7, it is shown that most respondent 15 (48.4%) works in organization with a size of less than 10. 11 respondents (35.5%) work at organization with 11 – 20 staffs while 4 respondent (12.9%) have more than 40 staffs working at their organization. the data presented further deduced that only 1 respondent (3.2%) work at an organization with 31- 40 permanent staffs.

QUESTION 8:

Table 5.8: Amount of construction executed yearly

What amount of construction (sq. m) does your organization execute yearly?			
	Frequency	Percent	Valid Percent
Less than1000	7	22.6	22.6
1000 – 5000	12	38.7	38.7
5001 – 10000	2	6.5	6.5
10001 – 25000	2	6.5	6.5
25001 – 50000	5	16.1	16.1
More than 50000	3	9.7	9.7
Total	31	100.0	100.0

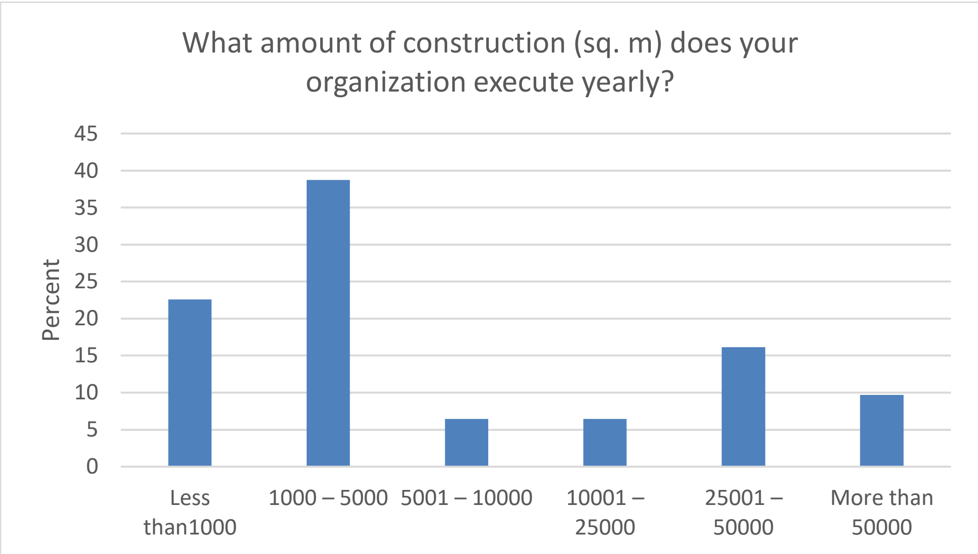


Table 5.8: Amount of construction executed yearly

From Table 5.8 and Figure 5.8, it was deduced that 12 respondents (38.7%) works in organization who executes between 1000 – 5000 m2 of construction yearly. 7 respondents (22.6%) work with organization who execute less than 1000 m2 construction project yearly. 5 respondents (16.1%) work at organization wo executes between 25001 – 50000 m2 of construction projects on a yearly basis while 3 respondents organizations executes more than 50000 m2 of construction yearly. 2 respondents (6.5%) each works with organizations that executes 5001 – 10000 m2 and 10001 and 25000 m2 construction projects yearly.

5.2 Section B: Assessment of the Construction Method/s Being Used on Building Projects in North Cyprus.

QUESTION 9:

Table 5.9: Current construction method used in TRNC

What is/are the current construction method/s commonly used on building projects in North Cyprus?			
	Frequency	Percent	Valid Percent
On-site (conventional) construction only	14	45.2	45.2
Both on-site and off-site construction	16	51.6	51.6
Others	1	3.2	3.2
Total	31	100.0	100.0

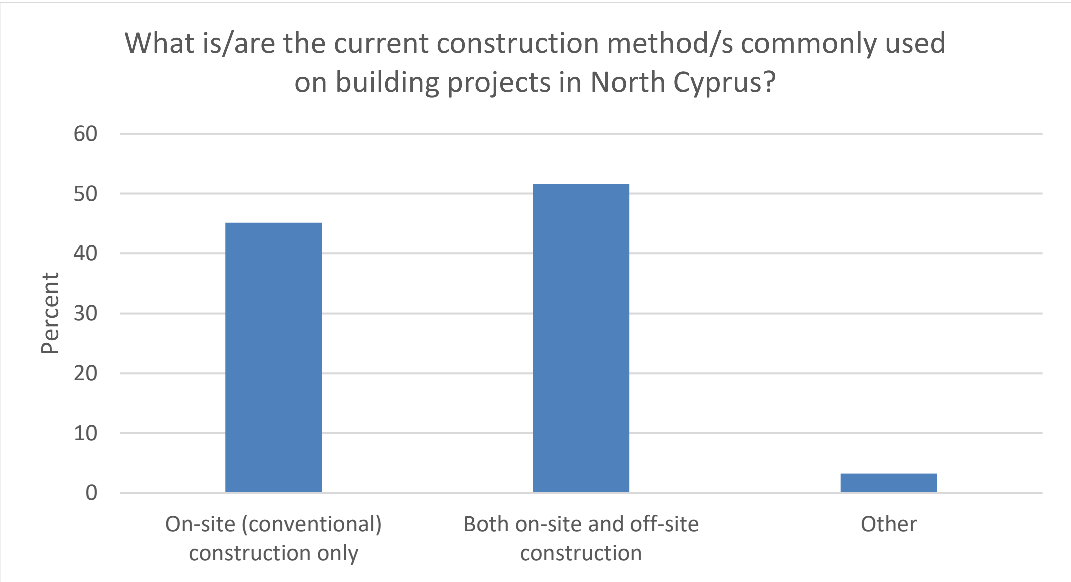


Figure 5.9: Current construction method used in TRNC

The Table 5.9 and Figure 5.9 reveals that the combination of both on-site and off-site construction with 16 responses (51.6%) are the current construction methods used in the building industry in TRNC. 14 respondents (45.2%) revealed that just on-site construction is being using.1 respondent (3.2%) said the current construction method is mostly conventional construction technique.

QUESTION 10:

Table 5.10: Percentage of on-site construction used in TRNC

What percentage of on-site (conventional) construction is being used on building projects in North Cyprus?			
	Frequency	Percent	Valid Percent
Less than 50	3	9.7	9.7
51 – 60	2	6.5	6.5
61 – 70	4	12.9	12.9
71 – 80	6	19.4	19.4
81 – 90	5	16.1	16.1
More than 91	11	35.5	35.5
Total	31	100.0	100.0

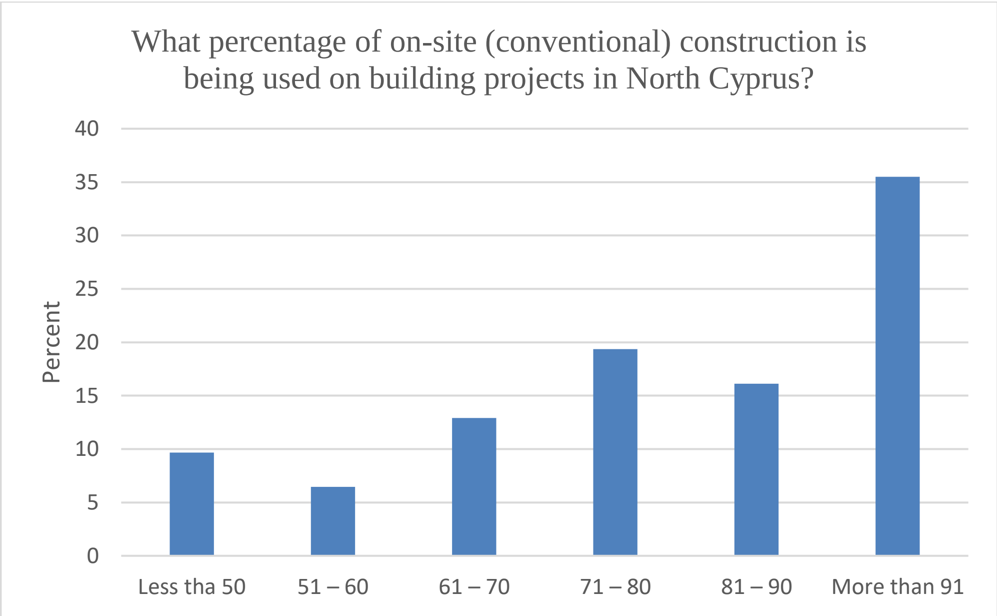


Figure 5.10: Percentage of on-site construction used in TRNC

As reported by Table 5.10 and Figure 5.10, 11 respondents (35.5%) believes the percentage of on-site construction used in TRNC is more than 91%, about 6 respondents (19.4%) went with between 71 – 80% and 5 respondents (16.1%) chose 81 - 90%. The remaining responses were distributed amongst respondents who believed the percentage to be between 61 – 70% with 4 respondents (12.9%), less than 50% with 3 respondents (9.7%) while 51 - 60% had 2 respondents (6.5%).

QUESTION 11:

Table 5.11: Percentage of off-site construction used in TRNC

What percentage of off-site construction is being used on building projects in North Cyprus?

	Frequency	Percent	Valid Percent
Less than 5	13	41.9	41.9
5 – 10	6	19.4	19.4
11 – 20	5	16.1	16.1
21 – 30	5	16.1	16.1
31 – 40	1	3.2	3.2
More than 41	1	3.2	3.2
Total	31	100.0	100.0

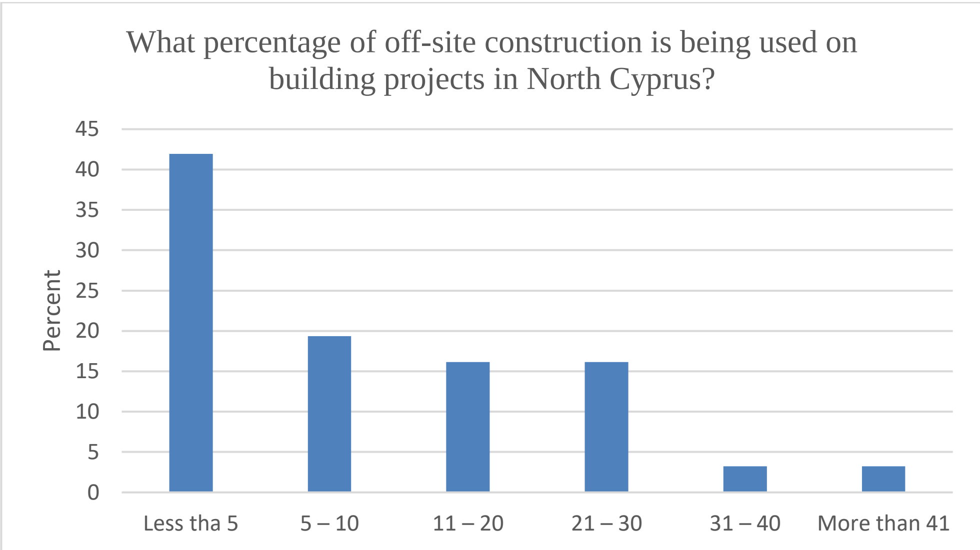


Figure 5.11: Percentage of off-site construction used in TRNC

As reported by Table 5.11 and Figure 5.11, 13 respondents (41.5%) believes the percentage of off-site construction used in TRNC is less than 5%, about 6 respondents (19.4%) went with between 5 – 10% and 5 respondents each (16.1%) selected both 11 - 20% and 21 – 30%. The remaining responses were distributed amongst respondents who believed the percentage to be between 31 – 40% and more than 40% with 1 respondents (3.2%) each.

QUESTION 12:

Table 5.12: Stakeholders satisfaction with the current construction method/s

Construction Stakeholders are satisfied with the current construction method/s being used in North Cyprus?			
	Frequency	Percent	Valid Percent
Strongly Disagree	2	6.5	6.5
Somewhat Disagree	12	38.7	38.7
Neutral / No opinion	2	6.5	6.5
Somewhat Agree	13	41.9	41.9
Strongly Agree	2	6.5	6.5
Total	31	100.0	100.0
		Mean	3.0323
		Std. Deviation	1.16859

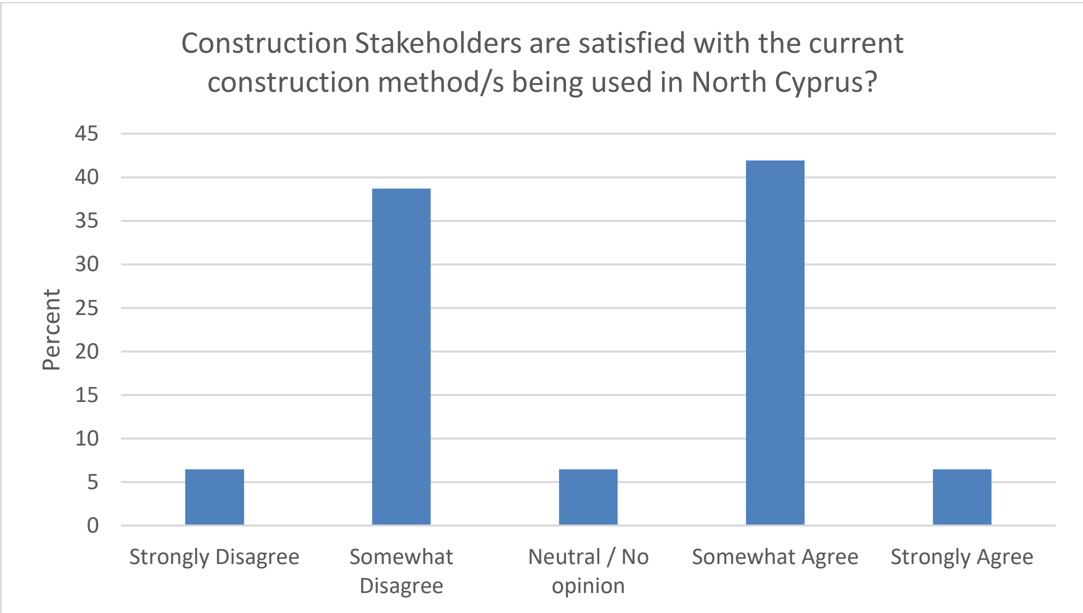


Figure 5.12: Stakeholders satisfaction with the current construction method/s

From Table 5.12 and Figure 5.12, it is evident to note that it was a close call between those respondents 13 (41.9%) who somewhat agree and respondents 12 (38.7%) who somewhat disagrees with the statement that construction stakeholders are satisfied with the current construction method/s. Those respondent 2 (6.5%) each had neutral or no opinion, strongly disagree and strongly agree with the statement.

QUESTION 13:

Table 5.13: Mostly used structural material/s in TRNC

What structural material/s is/are mostly used on building projects in North Cyprus?			
	Frequency	Percent	Valid Percent
Reinforced concrete only	9	29.0	29.0
Steel and reinforced concrete	16	51.6	51.6
Reinforced concrete and timber	2	6.5	6.5
Steel, reinforced concrete and timber	3	9.7	9.7
Others	1	3.2	3.2
Total	31	100.0	100.0

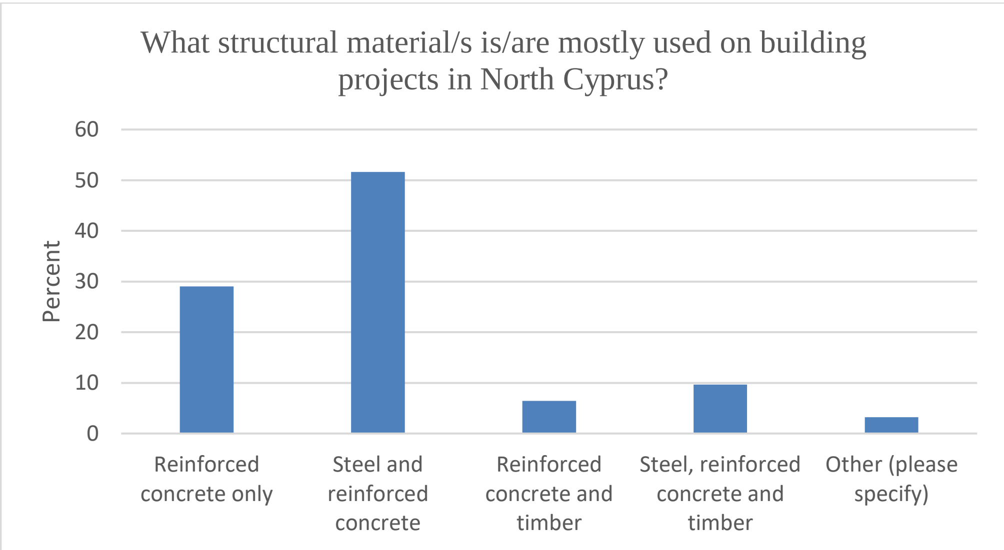


Figure 5.13: Mostly used structural material/s in TRNC

From Table 5.13 and Figure 5.13, it clearly shows than the combination of both steel and reinforced concrete seems to be the predominantly used materials in TRNC with 16 (51.6%) responses. 9 respondents (29.0%) selected only reinforced concrete to be the mostly used material. The combination of steel, reinforced concrete and timber was selected by 3 respondents (9.7%) to be the most used materials while reinforced concrete and timber was picked by 1 respondent (3.2%). 1 respondent (3.2%) also indicated that steel and reinforced concrete are major used for larger structures with large roofs.

QUESTION 14:

Table 5.14: Challenges with the current construction method/s in TRNC

What is the major challenge being faced with the current construction method/s in North Cyprus?			
	Frequency	Percent	Valid Percent
High construction cost	11	35.5	35.5
Low worker's safety	6	19.4	19.4
High wastage	1	3.2	3.2
Low quality of works	4	12.9	12.9
Use of unskilled personnel	4	12.9	12.9
Design problems	2	6.5	6.5
Use of unqualified supervision personnel	1	3.2	3.2
Others	2	6.5	6.5
Total	31	100.0	100.0

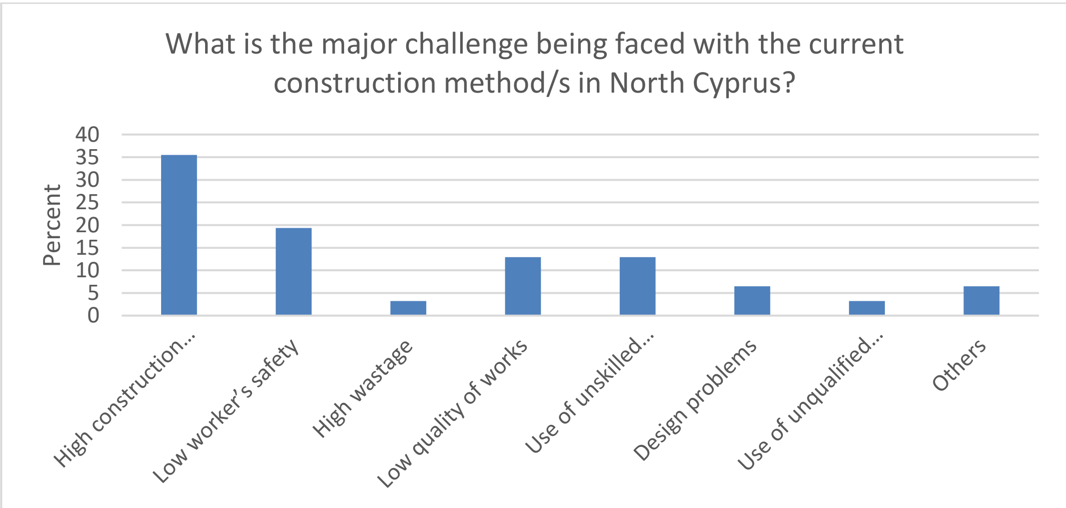


Figure 5.14: Challenges with the current construction method/s in TRNC

From Table 5.14 and Figure 5.14, the major challenge with the current construction method in TRNC is the high construction cost as reported by 11 respondents (35.5%) closely followed by low worker's safety reported by 6 respondents (19.4%). 4 respondents (12.9%) each cited the challenges to be low quality of works and the use of unskilled personnel's respectively. 2 respondent (6.5%) selects design problems while 1 respondent (3.2%) each selected high waste and use of unqualified supervision personnel. 1 respondent (3.2%) has no issue with the current construction method/s.

QUESTION 15:

Table 5.15: MMC can address challenges with the current construction method/s in TRNC

Modern Methods of Construction (MMC) such as off-site construction would appropriately address the challenges being faced with the current construction method/s in North Cyprus?			
	Frequency	Percent	Valid Percent
Strongly Disagree	2	6.5	6.5
Somewhat Disagree	5	16.1	16.1
Neutral / No opinion	3	9.7	9.7
Somewhat Agree	16	51.6	51.6
Strongly Agree	5	16.1	16.1
Total	31	100.0	100.0

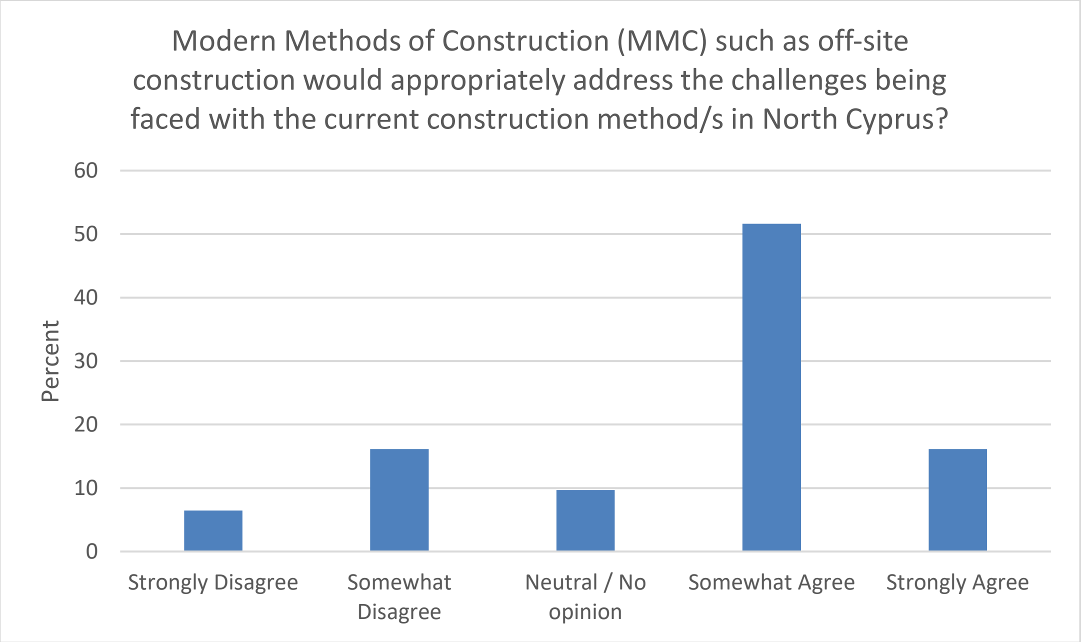


Figure 5.15: MMC can address challenges with the current construction method/s in TRNC

From Table 5.15 and Figure 5.15, it is evident to note that most respondents 16 (51.6%) somewhat agrees that MMC can address challenges with the current construction method/s in TRNC. 5 Respondents (16.1%) somewhat disagrees and 5 Respondents (16.1%) strongly agrees with the statement. 2 respondents (6.5%) strongly disagree with the statement while 3 (9.7%) were neutral or had no opinion.

5.3 Section C: Assessment of Knowledge, Adoption and Usage of Off-site Modular Construction on Building Projects in North Cyprus.

QUESTION 16:

Table 5.16: Perception about off-site construction

I have a positive perception about off-site construction.						
		Frequency	Percent	Valid Percent		
	Strongly Disagree	5	16.1	16.7		
	Somewhat Disagree	6	19.4	20.0		
	Neutral / No opinion	6	19.4	20.0		
	Somewhat Agree	8	25.8	26.7		
	Strongly Agree	5	16.1	16.7		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	3.3667
Total		31	100.0		Std. Deviation	1.27261

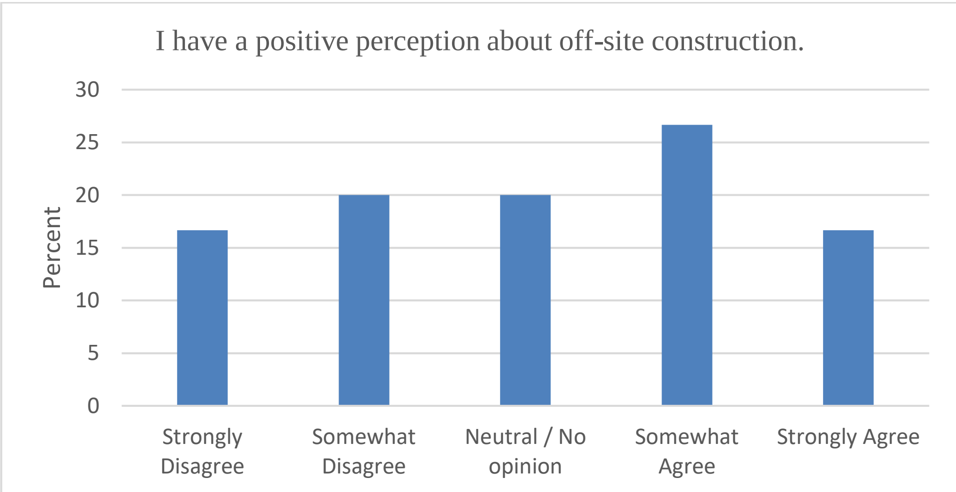


Figure 5.16: Perception about off-site construction

From Table 5.16 and Figure 5.16, it is reported that most respondents 8 (25.8%) somewhat agree to having a positive perspective about off-site construction. 6 respondents (19.4%) somewhat disagree with the statement while 6 respondents (19.4%) were neutral or had no opinion. 5 respondents (16.1%) strongly disagrees with the statement while 5 respondent (16.1%) strongly agreed to having a positive perception about off-site construction. There was an invalid response to this question.

QUESTION 17:

Table 5.17: Knowledge about off-site construction

I consider myself quite knowledgeable about off-site construction.						
		Frequency	Percent	Valid Percent		
	Strongly Disagree	3	9.7	10.0		
	Somewhat Disagree	5	16.1	16.7		
	Neutral / No opinion	6	19.4	20.0		
	Somewhat Agree	10	32.3	33.3		
	Strongly Agree	6	19.4	20.0		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	3.3667
Total		31	100.0		Std. Deviation	1.27261

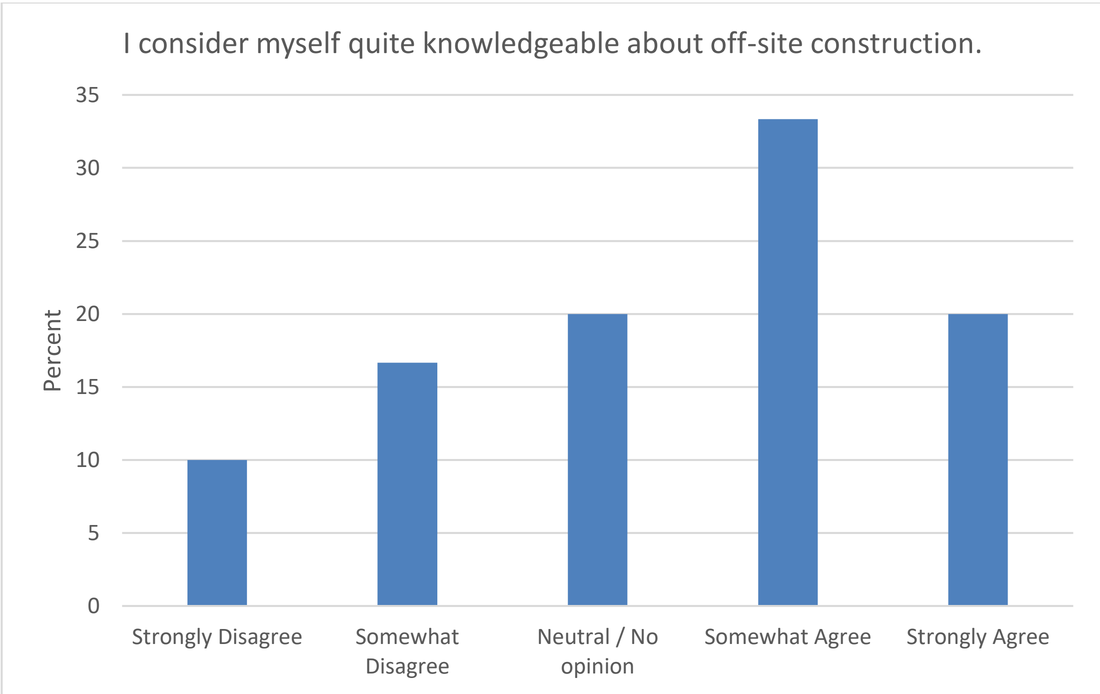


Figure 5.17: Knowledge about off-site construction

From Table 5.17 and Figure 5.17, it is reported that most respondents 10 (32.2%) somewhat agree to being knowledgeable about off-site construction. 6 respondents (19.4%) strongly agree with the statement while 6 respondents (19.4%) were neutral or had no opinion. 5 respondents (16.1%) somewhat disagrees with the statement while 3 respondent (9.7%) strongly disagreed being knowledgeable about off-site construction. There was an invalid response to this question

QUESTION 18:

Table 5.18: Interest in learning about off-site construction

I am interested in learning more about off-site construction.						
		Frequency	Percent	Valid Percent		
	Strongly Disagree	2	6.5	6.7		
	Somewhat Disagree	1	3.2	3.3		
	Neutral / No opinion	1	3.2	3.3		
	Somewhat Agree	11	35.5	36.7		
	Strongly Agree	15	48.4	50.0		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	4.2000
Total		31	100.0		Std. Deviation	1.12648

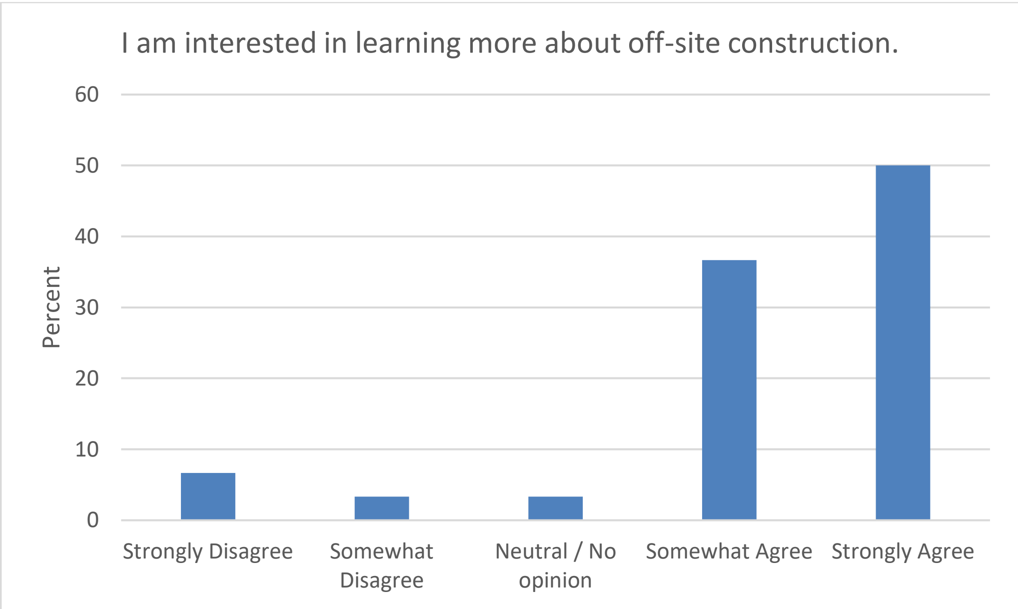


Figure 5.18: Interest in learning about off-site construction

From Table 5.18 and Figure 5.18 it is reported that most respondents 15 (48.4%) strongly agree to being interested in learning more about off-site construction. 11 respondents (35.5%) strongly agree with the statement while 2 respondents (6.5%) strongly disagrees with the statement. 1 respondent (3.2%) somewhat disagrees with the statement while 1 respondent (3.2%) was neutral or had no opinion.. There was an invalid response to this question

QUESTION 19:

Table 5.19: Frequency in the use of off-site construction

How frequent do/does you or your organization adopt off-site construction on any project?						
		Frequency	Percent	Valid Percent		
	Never	2	6.5	6.7		
	Rarely	11	35.5	36.7		
	Sometimes	13	41.9	43.3		
	Often	2	6.5	6.7		
	Always	2	6.5	6.7		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	2.7000
Total		31	100.0		Std. Deviation	.95231

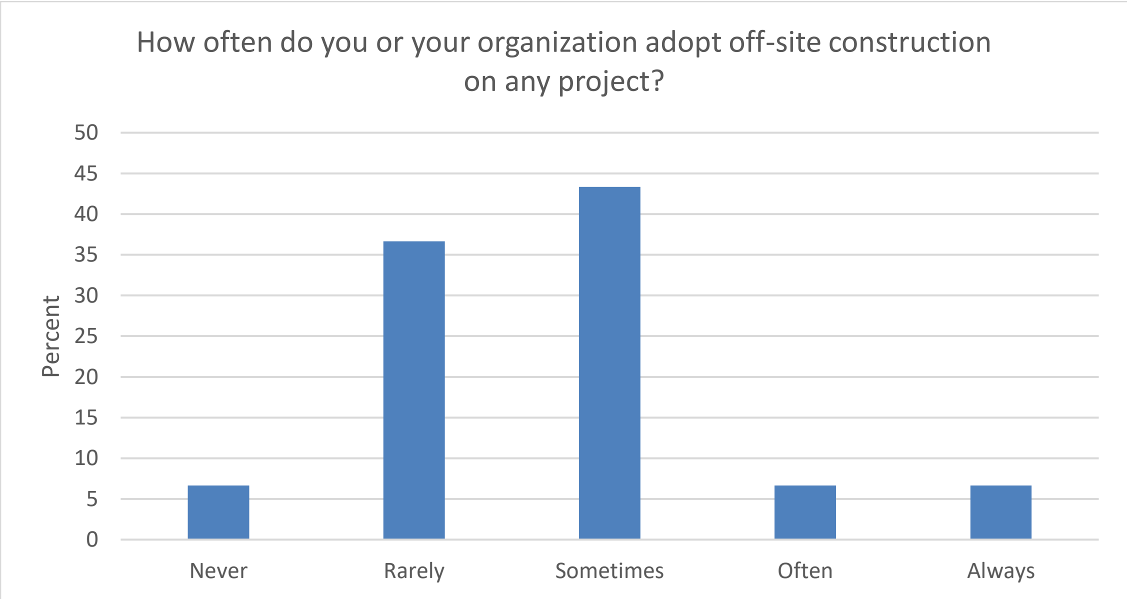


Figure 5.19: Frequency in the use of off-site construction

When asked how frequent they or their organizations uses off-site construction, most respondents 13 (41.9%) says they often adopt off-site construction. 11 respondents (35.5%) hinted that they rarely make use of it while 2 respondents (6.5%) says they sometimes adopt it, 2 respondents (6.5%) says they often adopt it and 2 respondents (6.5%) also said they always adopt off-site construction. There was an invalid response to this question

QUESTION 20:

Table 5.20: Total size of building constructed using off-site construction

What is the total building size of structures built by you/your organization adopting off-site construction?						
		Frequency	Percent	Valid Percent		
	0	7	22.6	23.3		
	Less than 100 m2	4	12.9	13.3		
	100 – 500 m2	10	32.3	33.3		
	501 – 1000 m2	2	6.5	6.7		
	1001 – 2500 m2	2	6.5	6.7		
	2501 – 5000 m2	3	9.7	10.0		
	More than 5000 m2	2	6.5	6.7		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	3.1667
Total		31	100.0		Std. Deviation	1.85850

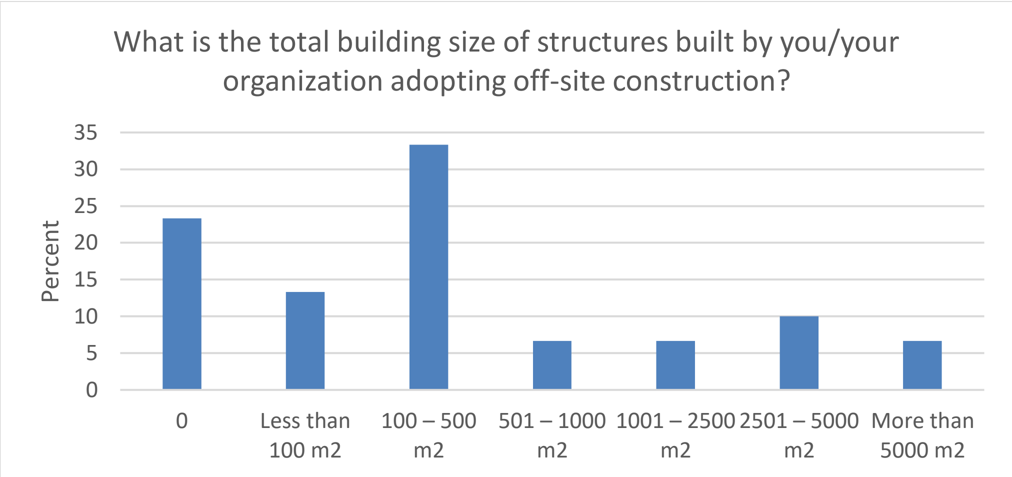


Figure 5.20: Total size of building constructed using off-site construction

From Table 5.20 and Figure 5.20, which shows that 10 respondents (32.3%) complete between 100 – 500 m2 of construction projects using off-site construction. 7 respondents (22.6%) haven't carried out any project using offsite construction. 4 respondents (12.9%) have completed projects of less than 100 m2 using off-site construction. Also 3 respondents (9.7%) have completed projects with sizes between 2501 – 5000 m2 while 2 respondents each have completed projects of sizes between 501 – 1000 m2 and 1001 and 2500 m2 respectively. There was an invalid response to this question.

QUESTION 21:

Table 5.21: Interest in adopting off-site construction on future projects

I am interested in adopting off-site construction on future projects.						
		Frequency	Percent	Valid Percent		
	Strongly Disagree	2	6.5	6.7		
	Somewhat Disagree	2	6.5	6.7		
	Neutral / No opinion	3	9.7	10.0		
	Somewhat Agree	14	45.2	46.7		
	Strongly Agree	9	29.0	30.0		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	3.8667
Total		31	100.0		Std. Deviation	1.13664

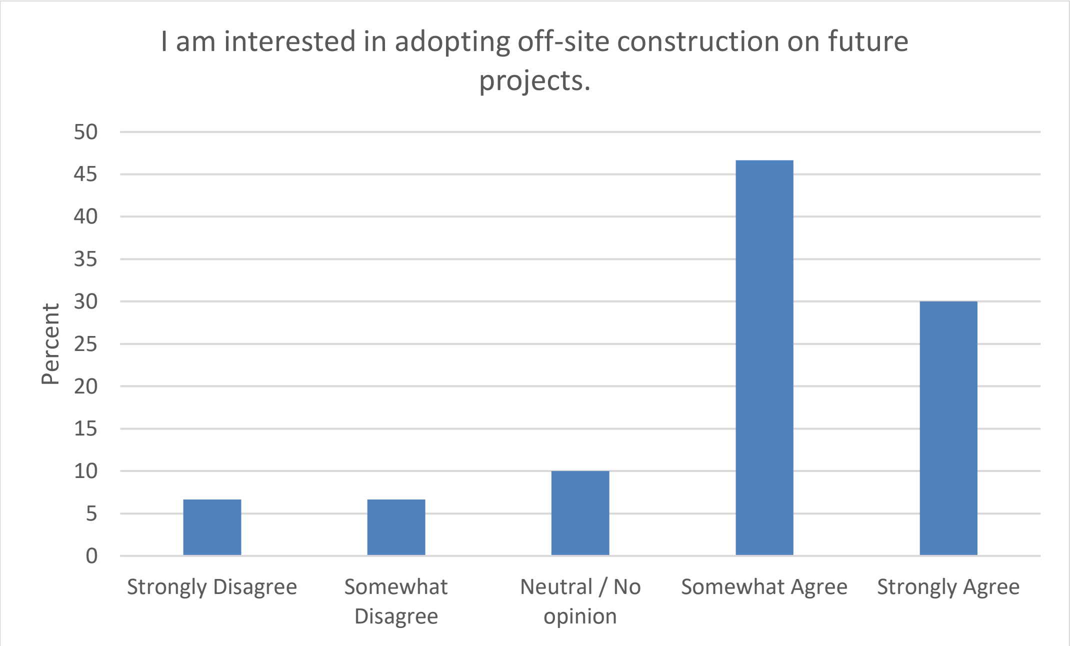


Figure 5.21: Interest in adopting off-site

From Table 5.21 and Figure 5.21, it is reported that most respondents 14 (45.2%) somewhat agree to being interested adopting off-site construction on future project. 9 respondents (29%) strongly agree to being interested while 3 respondents (9.7%) was neutral or had no opinion. 2 respondents (6.5%) each somewhat disagrees and strongly disagrees with being interested respectively. There was an invalid response to this question.

QUESTION 22:

Table 5.22: Preferred aspect of off-site respondents would want to adopt

What aspect of off-site construction has your organization adopted or would your organization be will to adopt		Responses		
		N	Percent	Percent of Cases
Aspect of off-site construction	Prefabrication	14	18.2%	46.7%
	Panelised Construction	14	18.2%	46.7%
	Modular/Volumetric Construction	17	22.1%	56.7%
	Precast/Pre-stressed Construction	21	27.3%	70.0%
	Manufactured Home	11	14.3%	36.7%
Total		77	100.0%	256.7%

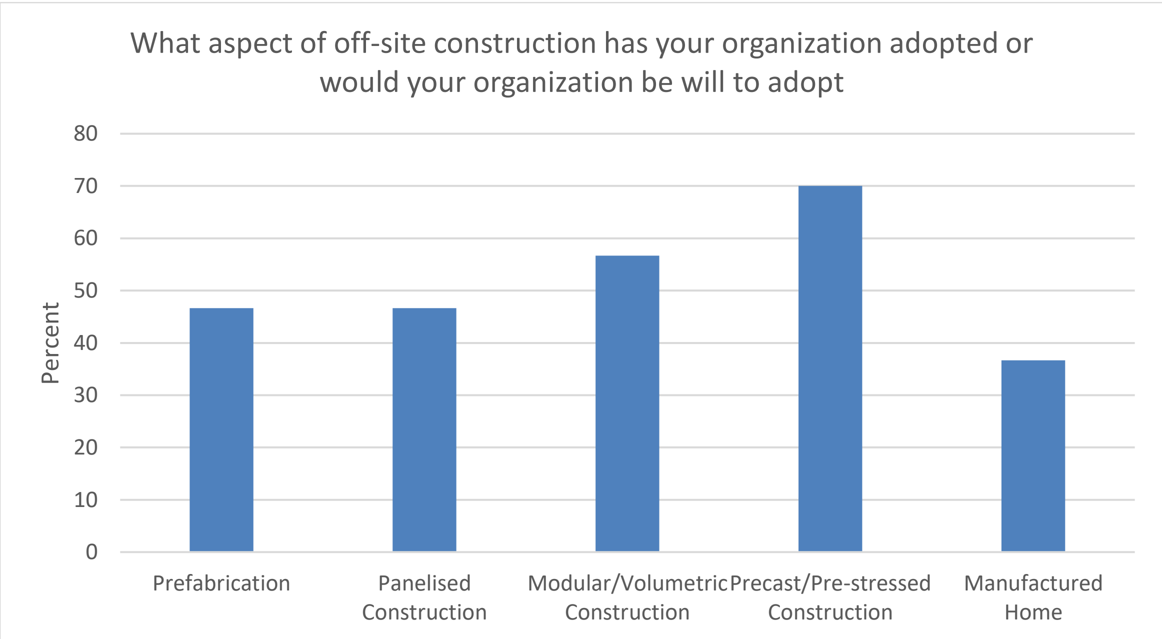


Figure 5.22: Preferred aspect of off-site respondents would want to adopt

From Table 5.22 and Figure 5.22, which clearly stated that more respondents 21 (27.3%) would be willing to adopt precast/pre-stressed concrete construction. 17 respondents (22.1%) selected modular/volumetric construction as one of their choices while 14 respondents each selected prefabricated and panelised construction respectively. The least choice was the manufactured home with 11 respondent (11.4%). There was an invalid response to this question

QUESTION 23:

Table 5.23: Preferred building projects to adopt off-site construction on

What type of building project has your organization executed or would be willing to execute using off-site construction.				
		Responses		
		N	Percent	Percent of Cases
	Single family housing	13	20.3%	46.4%
	Multiple family housing	9	14.1%	32.1%
	Commercial building	7	10.9%	25.0%
	Educational building	4	6.3%	14.3%
	Healthcare building	2	3.1%	7.1%
	Industrial building	10	15.6%	35.7%
	Hospitality building	10	15.6%	35.7%
	Retail outlets	9	14.1%	32.1%
Total		64	100.0%	228.6%

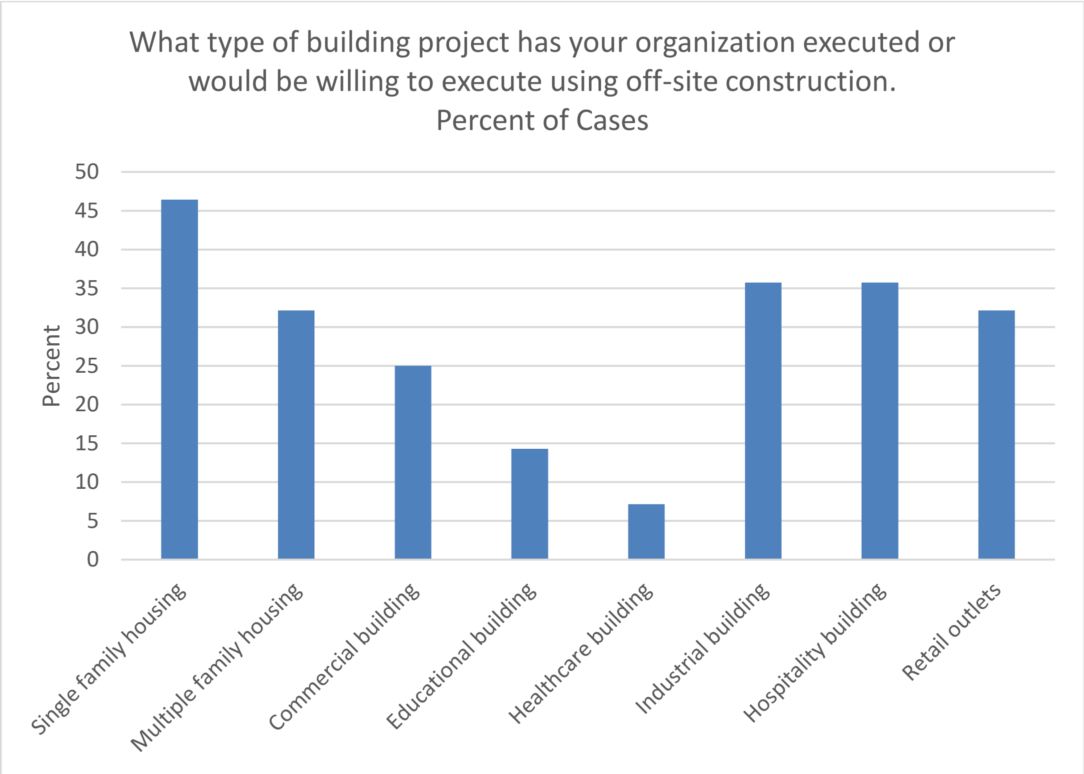


Figure 5.23: Preferred building projects to adopt off-site construction on

From Table 5.23 and Figure 5.23, it was gathered that most respondent 13 (20.3%) would be willing to execute single family housing using off-site construction. 10 respondents (15.6%) each chose industrial building and hospitality building respectively as the building type they would be willing to adopt off-site construction on. 9 respondent (14.1%) each opted for multiple-family housing and retail outlets respectively while 7 (10.9%) chose commercial building. Educational building had 4 respondents while healthcare building had 2 respondents (3.1%).

QUESTION 24:

Table 5.24: Who's responsible for selecting off-site construction on a project?

In your opinion, who is responsible for the decision to use off-site construction on building projects?				
		Frequency	Percent	Valid Percent
	Other (please specify)	3	9.7	10.0
	Clients	12	38.7	40.0
	Architects	7	22.6	23.3
	Engineers (Civil/Structural)	2	6.5	6.7
	City/Urban Planners	1	3.2	3.3
	Construction/Project Managers	5	16.1	16.7
	Total	30	96.8	100.0
Missing	System	1	3.2	
Total		31	100.0	

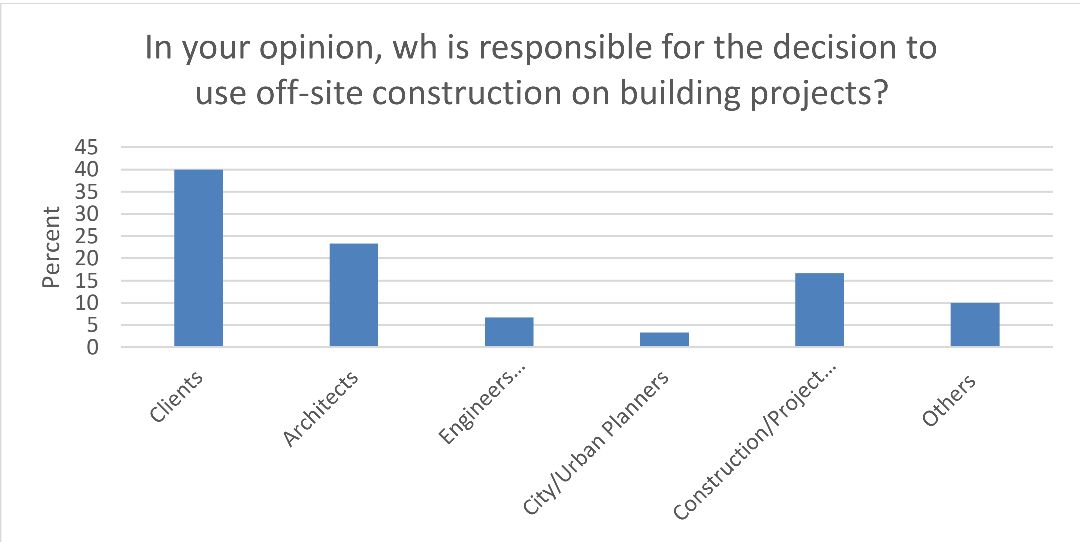


Figure 5.24: Who's responsible for selecting off-site construction on a project?

From Table 5.24 and Figure 5.24, it is obtained than most respondents 12 (38.7%) believed the clients to be responsible for the decision to use off-site construction and it is closely followed by 7 respondents (22.6%) who believed that it is the architect's responsibility to make the decision. 5 respondents (16.1%) went for construction/project managers while 2 respondents (6.5%) went for civil or structural engineers. Only 1 respondent (3.2%) felt it was the reasonability of the city/urban planner. Other respondents 3 (9.7%) hinted that any one of the listed professional is qualified enough to make that decision.

QUESTION 25:

Table 5.25: Importance of involving manufacturer and general contractor

It is important to involve the manufacturer and general contractor during the design stages of a project adopting off-site construction.						
		Frequency	Percent	Valid Percent		
	Strongly Disagree	1	3.2	3.3		
	Somewhat Disagree	1	3.2	3.3		
	Neutral / No opinion	1	3.2	3.3		
	Somewhat Agree	8	25.8	26.7		
	Strongly Agree	19	61.3	63.3		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	4.4333
Total		31	100.0		Std. Deviation	.97143

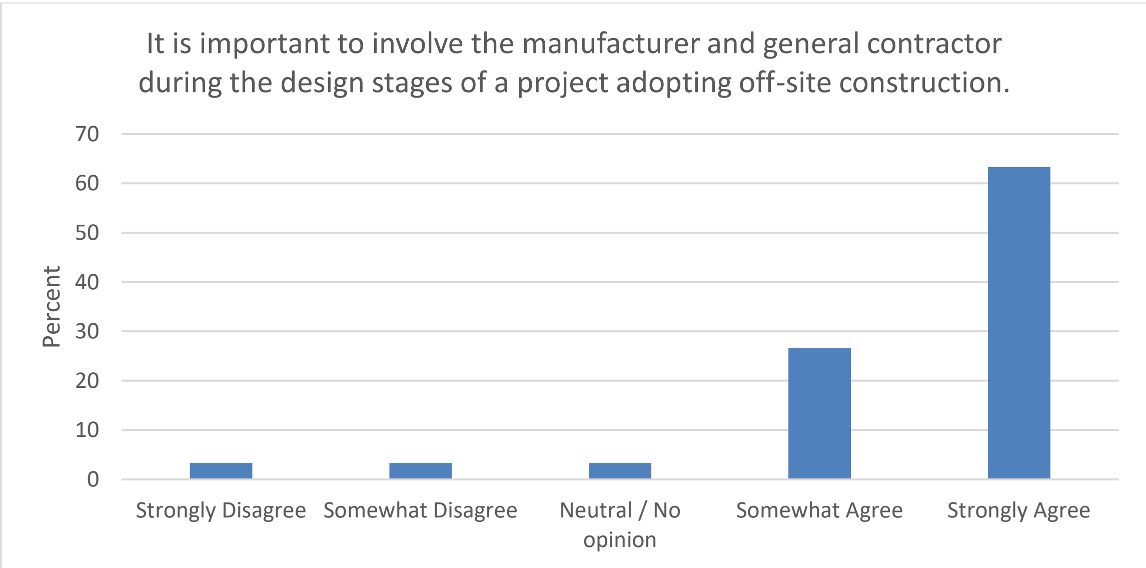


Figure 5.25: Importance of involving manufacturer and general contractor

As can be deduced from Table 5.25 and Figure 5.25, majority of respondents 19 (61.3%) strongly agree that it is indeed important to involve manufacturer and general contractors at the design stage of a project adopting off-site construction while 8 respondents (25.8%) somewhat agrees with the statement. 1 respondent (3.2%) each strongly and somewhat disagree with the statement respectively. 1 respondent (3.2%) was neutral or had no opinion. There was an invalid response to this question.

QUESTION 26:

Table 5.26: Consulting the general contractor on an off-site construction project

At what point during a project should the contractor performing the off-site work be consulted?				
		Frequency	Percent	Valid Percent
Valid	Conceptual stage	6	19.4	20.0
	During the schematic design stage	5	16.1	16.7
	After the completion of schematic design	3	9.7	10.0
	During design development	9	29.0	30.0
	After the completion of the design	5	16.1	16.7
	While preparing construction documents	1	3.2	3.3
	After the preparation of construction documents	1	3.2	3.3
	Total	30	96.8	100.0
Missing	System	1	3.2	
Total		31	100.0	

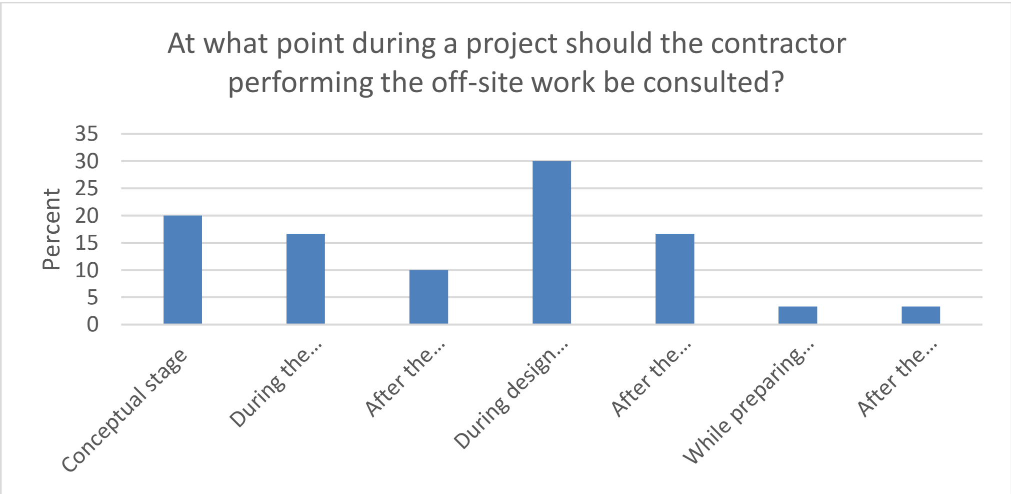


Figure 5.26: Consulting the general contractor on an off-site construction project

From Table 5.26 and Figure 5.26, 9 respondents (29%) says contractor performing the off-site works should be consulted during the design development stage which 6 respondents (19.4%) opted for at the conceptual stage. 5 respondents (16.1%) each selected during the schematic design stage and after the completion of design respectively. 3 respondents (9.7%) selected after the completion of schematic design while 1 respondent (3.2%) each chose while preparing construction documents (bidding) and after the preparation of construction documents. There was an invalid response to this question.

QUESTION 27:

Table 5.27: Knowledge about the benefits of off-site construction

I consider myself to be well inform about the benefits of off-site construction.						
		Frequency	Percent	Valid Percent		
Valid	Strongly Disagree	8	25.8	26.7		
	Somewhat Disagree	4	12.9	13.3		
	Neutral / No opinion	5	16.1	16.7		
	Somewhat Agree	10	32.3	33.3		
	Strongly Agree	3	9.7	10.0		
	Total	30	96.8	100.0		
Missing	System	1	3.2	Mean		2.8667
Total		31	100.0	Std. Deviation		1.40770

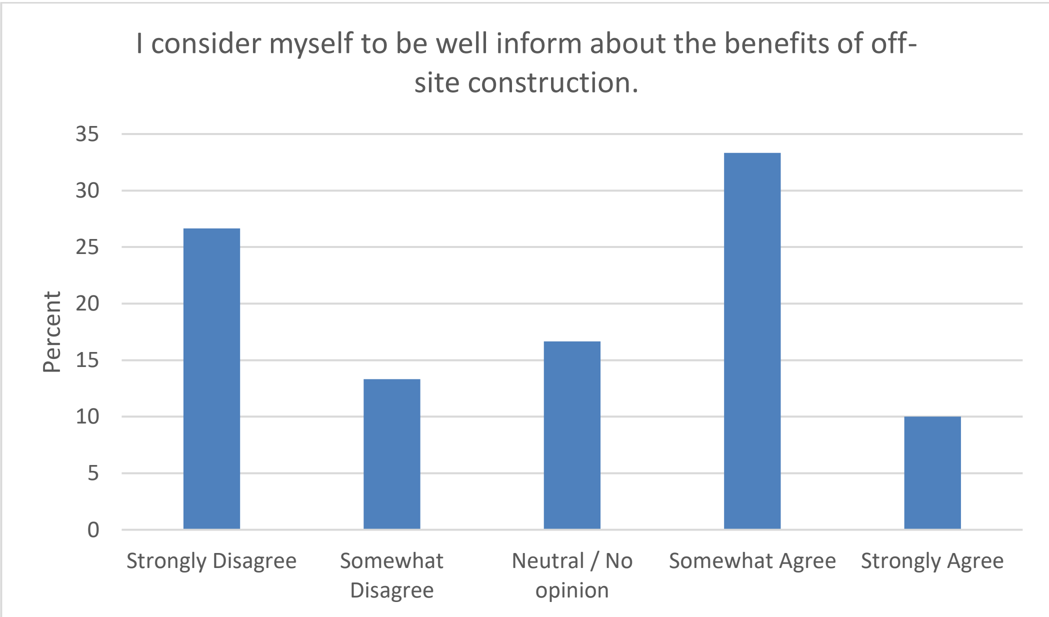


Figure 5.27: Knowledge about the benefits of off-site construction

From Table 5.27 and Figure 5.27, 10 respondents (32.3%) somewhat agree to be well informed about the benefits of off-site construction while 8 respondents (25.8%) strongly disagree to being well informed about its benefits. 5 respondents (16.1%) were neutral or had no opinion about the statement. 4 respondents (12.9%) strongly disagree to the statement while 3 respondents (9.7%) strongly agree to being well knowledgeable about the benefits.

QUESTION 28:

Table 5.28: Preferred benefits of off-site construction

Which of the benefits of off-site construction did or would your organization think to take advantage of?	Responses		
	N	Percent	Percent of Cases
Reduction in schedule/Time	27	17.1%	90.0%
Cost control	25	15.8%	83.3%
Increased productivity	11	7.0%	36.7%
Increased profit margins	16	10.1%	53.3%
Increase in worker's safety	19	12.0%	63.3%
Waste reduction	15	9.5%	50.0%
Increased quality of finished product/quality assurance	13	8.2%	43.3%
Addressing skill and labour shortages	2	1.3%	6.7%
Reduced change order	11	7.0%	36.7%
Quick return on investment	14	8.9%	46.7%
Avoidable weather disruptions	5	3.2%	16.7%
Total	158	100.0%	526.7%

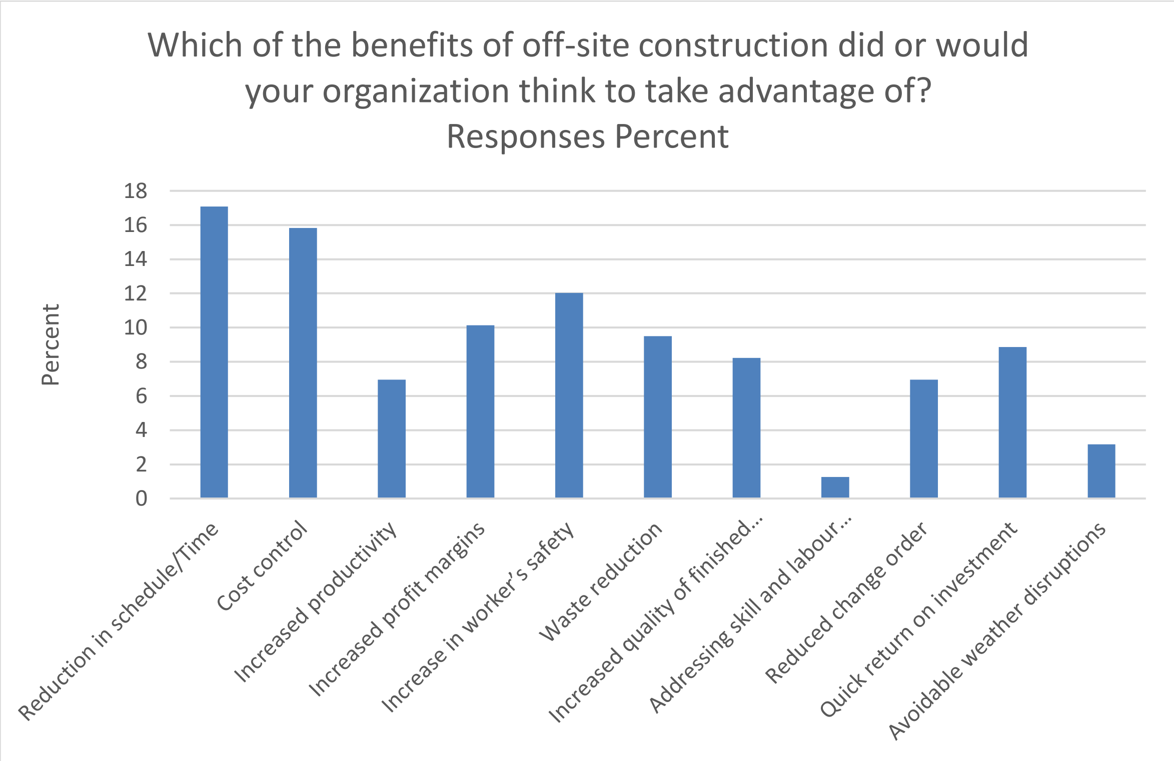


Figure 5.28: Preferred benefits of off-site construction

From Table 5.28 and Figure 5.28, 27 respondents (17.1%) would take advantage of reduction in schedule and time benefits of off-site construction and it is closely followed by 25 respondents (15.8%) who will seize the advantage of cost control. 19 respondents (12%) opted for increase in worker's safety and 16 respondents (10.1%) going for increased profit margins. Some 15 respondents (9.5%) will like of take advantage of the waste reduction benefit while 14 respondents (8.9%) picked the benefit of quick return on investment. Increased productivity and reduced change order had 11 respondents (7%) each with 5 respondents (3.2%) selecting avoidable weather disruptions. The lower amount of responses was 2 (1.3%) going to addressing skill and labour shortages benefit.

QUESTION 29:

Table 5.29: Constraints and barriers of off-site construction

What are the major constraints and barriers restricting the full adoption of off-site construction on building projects in North Cyprus?	Responses		
	N	Percent	Percent of Cases
Historical stigma	21	12.3%	70.0%
Building inspectors and regulatory agencies	11	6.4%	36.7%
Project finance	8	4.7%	26.7%
Client's perception and knowledge	27	15.8%	90.0%
BIM integration	4	2.3%	13.3%
Logistics (transportation)	8	4.7%	26.7%
Design restriction	12	7.0%	40.0%
Designer's knowledge about off-site construction	18	10.5%	60.0%
Cost estimating and budget	13	7.6%	43.3%
Scheduling and sequencing	5	2.9%	16.7%
Bidding and procurement	3	1.8%	10.0%
Availability of manufacturers	17	9.9%	56.7%
Availability of skilled labour	14	8.2%	46.7%
Quality control and assurance	10	5.8%	33.3%
Total	171	100.0%	570.0%

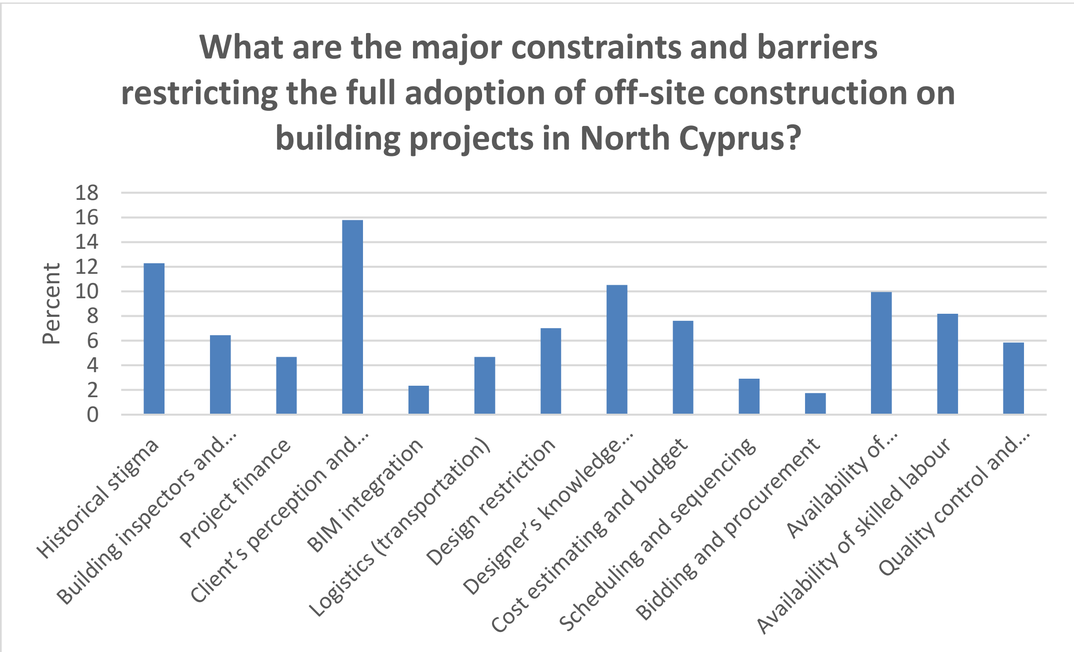


Figure 5.29: Constraints and barriers of off-site construction

From Table 5.29 and Figure 5.29, the major constraints and barriers to the full adoption of off-site construction in TRNC as report by 27 (15.8%) of the responses is the client's perception and knowledge of off-site construction. 21 (12.3%) of responses also saw historical stigma as s major constraints and barriers. The designer's knowledge about off-site construction was chosen by 18 respondents (10.5%) as the major constraint and barrier which is closely followed by availability or of manufacturers with 17 responses (9.9%). 14 respondents (8.2%) cited availability of skilled personnel as a major constraints with cost estimating and budgeting getting 13 responses (7.6%). Design restriction has 12 respondents (7.0%) while quality control and assurance had 10 responses (5.8%). Both project finance and logistics (transportation) has 8 responses (4.7%) with 5 respondents selecting scheduling and sequence as a major constraint to them. BIM integration together with bidding and procurement had the lowest amounts of response 4 (2.3%) and 3 (1.8%) respectively.

QUESTION 30:

Table 5.30: Area of support from professional regulatory agencies

What areas of support could professional regulatory agencies in North Cyprus offer that would be beneficial to your organization's utilization of off-site construction?					
		Responses			
		N	Percent	Percent of Cases
Support	Design standards, details and specification	27	34.2%	90.0%
	Case studies	19	24.1%	63.3%
	Industry data (construction performance)	20	25.3%	66.7%
	Networking	3	3.8%	10.0%
	Academic research partnership	8	10.1%	26.7%
	Glossary of terms	2	2.5%	6.7%
Total		79	100.0%	263.3%

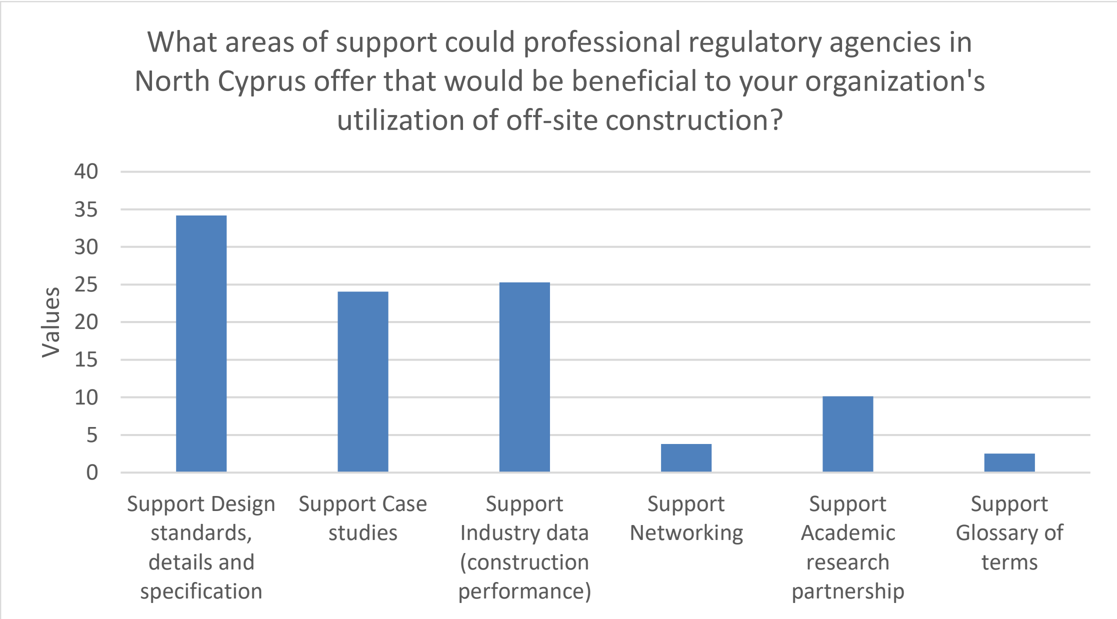


Table 5.30: Area of support from professional regulatory agencies

From Table 5.30 and Figure 5.30, most respondents 27 (34.2%) suggested that design standards, details and specification will beneficial to their organizations adoption of off-site construction. 20 respondents (25.3%) went for industry data (construction performance) which was closely followed by 19 respondents (24.1%) choosing real life case studies. Some 8 respondents (10.1%) selected academic research partnership while 2 respondent (2.5%) selecting glossary of terms. There was an invalid response to this question.

QUESTION 31:

Table 5.31: Raising off-site construction awareness in TRNC

It is important to raise awareness about off-site construction within the building industry in North Cyprus.						
		Frequency	Percent	Valid Percent		
Valid	Strongly Disagree	2	6.5	6.7		
	Somewhat Disagree	4	12.9	13.3		
	Neutral / No opinion	1	3.2	3.3		
	Somewhat Agree	12	38.7	40.0		
	Strongly Agree	11	35.5	36.7		
	Total	30	96.8	100.0		
Missing	System	1	3.2		Mean	3.8667
Total		31	100.0		Std. Deviation	1.25212

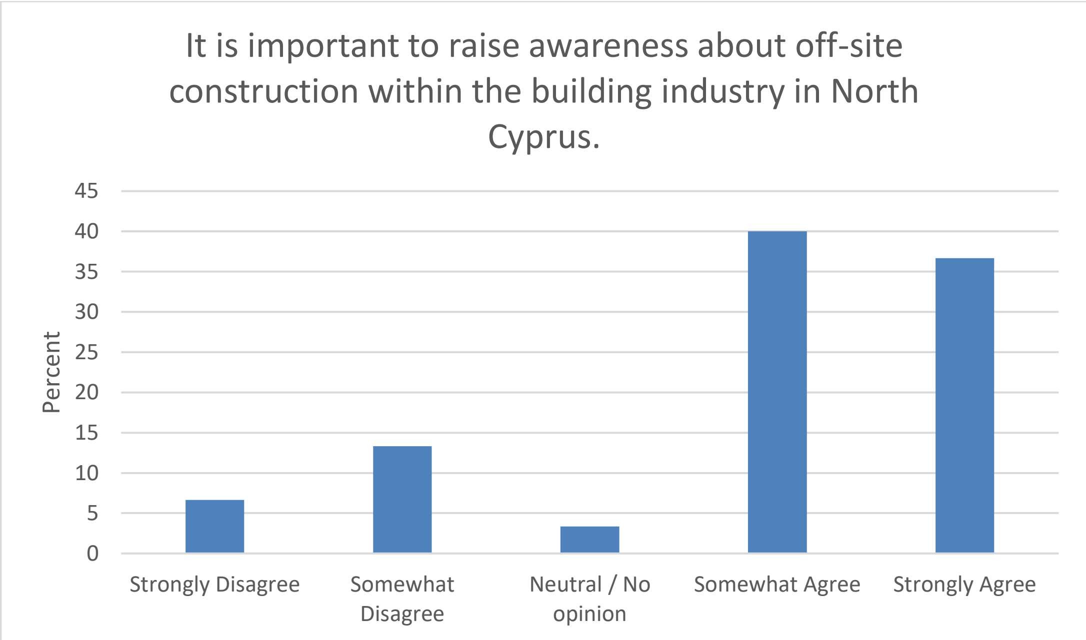


Figure 5.31: Raising off-site construction awareness in TRNC

Table 5.31 and Figure 5.31 shows that most respondents 12 (38.7%) somewhat agree that awareness about off-site construction should be raised in the TRNC building industry which is closely followed by 11 respondents (35.5%) who strongly agree with the statement. Only 4 respondents (12.9%) somewhat disagree with raising the awareness level with 2 other respondents (6.5%) strongly disagreeing with the statement. One respondent remained neutral or had no opinion. There was also an invalid response to this question.

QUESTION 32:

Table 5.32: Ways of raising off-site construction awareness in TRNC

What is/are the best way of increasing the awareness level for the use of off-site construction in North Cyprus?	Responses		
	N	Percent	Percent of Cases
Organizing of conferences, workshops and seminars	25	30.9%	83.3%
Education and training of construction professionals	22	27.2%	73.3%
The provision of articles and research studies	5	6.2%	16.7%
The provision of books, newsletters and magazines	3	3.7%	10.0%
The provision of real life case studies	26	32.1%	86.7%
Total	81	100.0%	270.0%

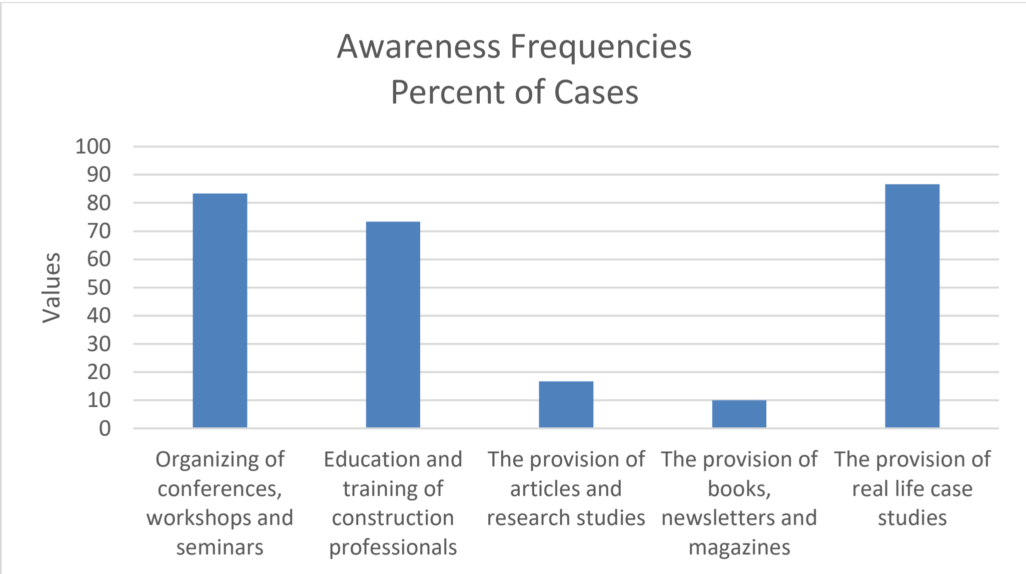


Figure 5.32: Ways of raising off-site construction awareness in TRNC

From Table 5.32 and Figure 5.32, 26 respondents (32.1%) pointed out that the best way of raising awareness about off-site construction in TRNC is by the provision of real life case studies which was closely followed by 25 respondents (30.9%) who selected organising conferences, workshops and seminars. 22 respondents (27.2%) also picked educating and training construction professional on the adoption of off-site construction. Provision of articles and research studies had 5 respondents (6.2%) with the lowest responses of 3 (3.7%) going for the provision of books, newsletters and magazine. There was also an invalid response.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The data from the survey collected from construction stakeholders (mostly professionals) in North Cyprus proved that both on-site (conventional) construction and off-site construction remains the most widely used construction method here in North Cyprus. Even though most respondents agreed that building projects are completed to more than 91% using on-site conventional construction, others suggested that the percentage of off-site construction used is less than 5%.

It was also reported that construction stakeholders to a large extent aren't satisfied with the current construction method which is largely with the use of conventional construction technique. The construction material that is predominantly used in North Cyprus are the combination of steel and reinforced concrete. This is why most professionals would opt for precast/pre-stressed off-site construction on building projects in the future. The major problems faced with the current construction methods as reported by survey are high cost of construction, low workers' safety, low quality of works and the use of unskilled personnel's. Most respondents somewhat agree that MMC such as off-site construction would appropriately address the challenges faced by the current methods.

From the survey it was also gathered that most professionals somewhat agree that modern method of construction such as off-site construction can address the challenges being faced with the current construction method. Most professionals were also reported to somewhat agreeing to having a positive perception and knowledge about off-site techniques. It is also of great importance to note that from the survey most professionals are open to learning more about off-site construction since the difference between those who sometimes makes use of it and that of those who rarely adopt it is quite close. In addition, because of this, the survey reported that most respondent hinted that they complete between 100 – 500 m^2 of construction adopting off-site construction methods annual. Most respondents are somewhat interested in adopting off-site construction on future projects with most going for the adoption of precast/pre-stressed concrete construction and modular construction. In addition, single-family housing, industrial and hospitality buildings remains the favourite structures these professionals would want to use off-site construction for.

The survey further hinted that it is in fact the responsibility of the client (individual or corporate) in the selection of off-site construction on projects and most respondents strongly agree that the general contractor and manufacturer should be involved early on (during design development stage) in a project adopting off-site construction technique.

It was also reported by the survey that most respondent somewhat agree to be well informed about the benefits of off-site construction with most of the responses choosing reduction in schedule/time, cost control, increase in workers' safety, increase in profit margins, waste reduction and quick return on investment as the major benefits of off-site construction they would like to take advantage of.

Clients' perception and knowledge of off-site, historical stigma of off-site construction, designer's knowledge of off-site construction, availability of manufacturers and skilled labour remains the major constraints and barriers towards the full adoption of off-site modular construction on building projects in North Cyprus. Hence, the provision of design standards, details and specification, industry data consisting of construction performance and real life case studies are the top supports professionals in North Cyprus want from professional regulatory agencies and organizations.

Most respondents somewhat and strongly agree that awareness about off-site construction should be raised with in the building industry in North Cyprus with most suggesting that the provision of real life case studies, organizing of conferences, workshops and seminars and educating/training of construction professionals are the best ways of raising the awareness level.

Off-site construction hasn't been used extensively in North Cyprus as was reported from the survey. The North Cyprus case study examples goes a long way in showing that most projects carried out using off-site construction are mostly single family housing which were made from prefabricated steel frames.

Off-site construction is ideal for urban infill where it is necessary to build multi-story structures due to the presence of very large population. But considering the case of North Cyprus with its small size population of less than 500,000 people and its small economy, it wouldn't be cost effective and necessary to fully adopt this method of construction here. This sole reason might be why building professionals to a very large extent still stick to on-site (traditional) construction.

Though there are reports of off-site methods currently being used on some projects, the full adoption might be considered later in the future when the island has been completely built up and there are reasons to construct high-rise buildings. The potentials in the future use of off-site construction would have a positive impact on its socio-economy status as a nation in three possible positive ways (1) it would increase its manufacturing power which would also increase job availability (2) it would ultimately increase the standardization of the building sector thereby increasing productivity and quality (3) it would generally address all challenges being faced in the building sector.

Construction is taking a new leap worldwide and it is important that the North Cyprus construction industry are equipped with the right information about current construction techniques so they are not left behind. We have also seen the importance and advantages of using off-site construction from the case studies presented in this thesis. Off-site construction is a sustainable construction method which would be beneficial to any country's economy by increasing the level of manufacturing which takes place as well as an increased level of building standardization.

With all of these, would anyone still think construction is supposed to be rigorous, cumbersome, dirty and unsafe?

6.2 Recommendation

This study clearly shows that off-site construction is being used to some degree in the building industry in North Cyprus but hasn't gained much momentum as expected amongst construction stakeholders. Hence, it would be important to recommend that more seminars and workshops be carried out in North Cyprus to train professionals and enlighten clients and the public at large about its usage.

It would also be recommended that off-site construction be incorporated into the university curriculum for studies under the built environment departments and faculties such as architecture and civil engineering. This way the students most of whom are aspiring built environment professionals are being introduced to this innovative and sustainable construction method which is gradually growing worldwide.

More studies should also be carried in comparing both off-site and on-site construction in terms of construction cost, construction time & schedule, construction quality and safety.

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APPENDIXES

APPENDIX A
ETHICAL APPROVAL

YAKIN DOĞU ÜNİVERSİTESİ

BİLİMSEL ARAŞTIRMALAR ETİK KURULU

10.04.2018

Dear Chrislyn Omochiere Egege

Your application titled **"Evaluating The Adoption And Usage Of Off-Site Modular Construction On Building Projects In North Cyprus"** with the application number YDÜ/FB/2018/25 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

Assoc. Prof. Dr. Direnç Kanol

Rapporteur of the Scientific Research Ethics Committee

Direnç Kanol

Note: If you need to provide an official letter to an institution with the signature of the Head of NEU Scientific Research Ethics Committee, please apply to the secretariat of the ethics committee by showing this document.

APPENDIX B

PARTICIPANT INFORMATION SHEET AND INFORMED CONSENT FORM

"Evaluating the Adoption and Usage of Off-Site Modular Construction on Building Projects in North Cyprus"

PARTICIPANT INFORMATION SHEET AND INFORMED CONSENT FORM

Dear Participant,

This survey is part of a research that is being carried out to in other to critically examine and evaluate the North Cypriot building industry. This is to ascertain the level of adoption and usage of Off-site Modular Construction on building projects on the Island. The data gathered from the questionnaire which comprises of series of questions will be used to determine the current construction method being adopted in the building industry as well as the level of knowledge and exposure of building professional in North Cyprus to off-site modular construction.

Please it is important to note that you participating in this study is strictly voluntary and you should also be informed that your identity or that of your organization will not be disclosed to a third party. All data which would be collected in the course of this study will solely be used for academic purposes only and may be presented at national/international conferences, academic meetings and/or for publication. You have the right to quit from participating in this study at any point in time by getting in touch with us via the contact information provided. When you choose to opt out of this study, all data of you and/or your organization will be erased from our database and will be excluded in any further part of this study.

By proceeding to answer the survey questionnaire you have agreed to participate in this survey and your consent have been given to the researchers to use your data. Should you have any concern or question, please contact the researchers using the below information or Hayriye Kocacan, Ethics Review Board, Near East University Ethics Committee, on 0392675100 / 3044 or email baek@neu.edu.tr.

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APPENDIX C
INVITATION TO THE SURVEY QUESTIONNAIRE

MASTER'S THESIS QUESTIONNAIRE

Dear Participant,

Research Survey: Evaluating the Adoption and Usage of Off-site Modular Construction on Building Projects in North Cyprus.

I am a master's research student from the Graduate School of Applied Sciences of Near East University. I am carrying out the above research as my master's thesis/dissertation. The aim of this research is to evaluate the level of adoption of off-site construction on building projects in North Cyprus. The outcome of this study would help the construction industry recognise its stance on the use of innovative and sustainable modern methods of construction.

Relevant registered members of **Chamber of Architects, Chamber of Civil Engineers, Turkish Cypriot Building Contractors Association and T.R.N.C. Building Construction Council** are invited to take part in this research by completing a survey questionnaire. I would be glad if you can help in making this research a success. Completing this questionnaire only takes about 10mins of your time. Your participation in this research will contribute to further development of the North Cypriot building industry. Please be assured that all response would be treated with strict confidence and will be used solely for academic purposes.

This survey questionnaire has been evaluated and approved by the Scientific Research Ethics Committee of Near East University dated 10th of April, 2018.

Participation in the survey is voluntary with no obligation to participate. Please kindly complete the survey online via the link that would be provided before **18th of May, 2018** or simply return a softcopy of the questionnaire to chrislyegege@gmail.com.

Thank very much for your time and anticipated help in making this research a success.

Yours sincerely,

Chrislyn Omochiere Egege
(Master's Student in Architecture)

APPENDIX D

THE SURVEY QUESTIONNAIRE (ENGLISH)

MASTER'S THESIS QUESTIONNAIRE

Dear Participant,

Research Survey: Evaluating the Adoption and Usage of Off-site Modular Construction on Building Projects in North Cyprus

SECTION A: PERSONAL INFORMATION

(**NOTE**: Please kindly indicate at the appropriate columns with either (√) or (•) as affirmative)

1. Occupation of Respondent: Estate Developer ( ) Architect ( ) Construction/Project Manager ( ) City/Urban Planner ( ) Engineer (Civil/Structural) ( ) General Contractor ( ) University Teacher ( ) Others………………
   ……………………………………………………
2. Age: 22 - 25yrs ( ) 26 - 30yrs ( ) 31 - 35yrs ( ) 36 – 40yrs ( ) 41 - 45yrs ( ) 46 – 50yrs ( ) 50yrs+ ( )
3. Sex: Male ( ) Female ( )
4. Educational Qualification: Bachelor's ( ) Master's ( ) Doctorate ( ) Others …………
   ……………………………………………………
5. Years of experience: less than 5yrs ( ) 5 – 10yrs ( ) 11 – 15yrs ( ) 16 – 20yrs ( ) 21 – 25yrs ( ) more than 25yrs ( )
6. Organization: Estate Develop. Firm ( ) Architectural firm ( ) Planning firm (City/Urban) ( ) Engineering firm (Civil/Structural) ( ) Construction/Project Mgt. firm ( ) General Contractor ( ) Govt. Agency ( ) University ( ) others …………..
   ……………………………………………………
7. What is the size (population) of permanent staffs at your firm? Less than 10 ( ) 11 – 20 ( ) 21 – 30 ( ) 31 – 40 ( ) more than 40 ( )
8. What amount of construction (Sq. M.) does your organization execute yearly? Less than 1000 ( ) 1000 – 5000 ( ) 5001 – 10000 ( ) 10001 – 25000 ( ) 25001 – 50000 ( ) more than 50000 ( )

SECTION B: ASSESSMENT OF THE CONSTRUCTION METHODS BEING USED ON BUILDING PROJECTS IN NORTH CYPRUS

(**NOTE**: Please kindly indicate your response with either (√) or (•) at the appropriate columns)

Question 9

What is/are the current construction method/s commonly used on building projects in North Cyprus?

- On-site (conventional) construction only
- Off-site construction only
- Both on-site and off-site construction
- Others (Please Specify) ……………………
  ……………………………………………………

Question 10

What percentage of on-site (conventional) construction is being used on building projects in North Cyprus?

- Less than 50
- 51 – 60
- 61 – 70
- 71 – 80
- 81 – 90
- More than 91

Question 11

What percentage of off-site construction is being used on building projects in North Cyprus?

- Less than 5
- 5 – 10
- 11 – 20
- 21 – 30
- 31 – 40
- More than 41

Question 12

Construction stakeholders are satisfied with the current construction method/s being used in North Cyprus?

- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 13

Which structural material/s is/are mostly used on building projects in North Cyprus?

- Steel only

- Reinforced concrete only
- Timber only
- Steel and reinforced concrete
- Reinforced concrete and timber
- Steel and timber
- Steel, reinforced concrete and timber

Question 14
What is the major challenge being faced with the current construction method/s in North Cyprus?
- High construction cost
- Low productivity
- Low profit margins
- Low worker's safety
- High wastage
- Low quality of works
- Use of unskilled personnel
- Weather disruptions
- Design problems
- Use of unqualified supervision personnel
- Others (Kindly specify)……………………… ………………………………………………

Question 15
Modern Methods of Construction (MMC) such as off-site construction would appropriately address the challenges being faced with the current construction method/s in North Cyprus?
- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

SECTION C: ASSESSMENT OF KNOWLEDGE, ADOPTION AND USAGE OF OFF-SITE MODULAR CONSTRUCTION ON BUILDING PROJECT IN NORTH CYPRUS
(**NOTE**: Please kindly note that the Likert and Likert-type questions are scaled from 1 – 5. Also kindly indicate your response with either (√) or (ˣ) at the appropriate columns).

Question 16
I have a positive perception about off-site construction?
- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 17
I consider myself quite knowledgeable you about off-site construction?
- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 18
I am interested in learning more about off-site construction?
- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 19
How often does your organization adopt off-site construction on any of its projects?
- Never
- Rarely
- Sometimes
- Often
- Always

Question 20
What is the total building size of structures built by your organization adopting off-site construction?
- 0
- Less than 100 Sq. M
- 100 – 500 Sq. M
- 501 – 1000 Sq. M
- 1001 – 2500 Sq. M
- 2501 – 5000 Sq. M
- More than 5000 Sq. M

Question 21
I am interested in adopting off-site construction on future projects?
- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 22
What aspect of off-site construction has your organization adopted or would your

organization be willing to adopt? (Please select the most important 3)

- Prefabrication
- Panelised construction
- Modular/Volumetric construction
- Precast/Pre-stressed concrete construction
- Manufactured home
- Others (Kindly specify) ……………………… ……………………………………………………

Question 23

What type of building project has your organization executed or would your organization be willing to execute using off-site construction? (Please select the most important 3)

- Single family housing
- Multi-family housing
- Commercial building
- Educational building
- Healthcare building
- Industrial building
- Hospitality building
- Retail outlets
- None

Question 24

In your opinion, who is responsible for the decision to use off-site construction on building projects?

- Clients
- Architects
- Engineers (Civil/Structural)
- City/Urban Planners
- Construction/Project Managers
- General Contractors
- Others (Kindly specify) ……………………… ……………………………………………………

Question 25

It is important to involve the manufacturer and general contractor during the design stages of a project adopting off-site construction.

- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 26

At what point during a project should the contractor performing the off-site work be consulted?

- Conceptual stage
- During the schematic design stage
- After the completion of schematic design
- During design development
- After the completion of the design
- While preparing construction documents
- After the preparation of construction documents.

Question 27

I consider myself to be well inform about the benefits of off-site construction?

- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 28

Which of the benefits of off-site construction did or would your organization think to take advantage of? (Please select the most important 6)

- Reduction in schedule/Time
- Cost control
- Increased productivity
- Increased profit margins
- Increase in worker's safety
- Waste reduction
- Increased quality of finished product/quality assurance
- Addressing skill and labour shortages
- Reduced change order
- Quick return on investment
- Avoidable weather disruptions
- Others (Kindly specify) ……………………… ……………………………………………………

Question 29

What are the major constraints and barriers restricting the full adoption of off-site construction on building projects in North Cyprus? (Please select the most important 6)

- Historical stigma
- Building inspectors and regulatory agencies
- Project finance
- Client's perception and knowledge
- BIM integration
- Logistics (transportation)

- Design restriction
- Designer's knowledge about off-site construction
- Cost estimating and budget
- Scheduling and sequencing
- Bidding and procurement
- Availability of manufacturers
- Availability of skilled labour
- Quality control and assurance
- Others (Kindly specify……………………….. ……………………………………………………..

Question 30

What areas of support could professional regulatory agencies in North Cyprus offer that would be beneficial to your organization's utilization of off-site construction? (Please select the most important 3)

- Design standards, details and specification
- Case studies
- Industry data (construction performance)
- Networking
- Academic research partnership
- Glossary of terms
- Others (Kindly specify)……………………… ……………………………………………………..

Question 31

It is important to raise awareness about off-site construction within the building industry in North Cyprus?

- Strongly Disagree
- Somewhat Disagree
- Neutral / No opinion
- Somewhat Agree
- Strongly Agree

Question 32

What is/are the best way of increasing the awareness level for the use of off-site construction in North Cyprus? (Please select the most important 3)

- Organizing of conferences, workshops and seminars
- Education and training of construction professionals
- The provision of articles and research studies
- The provision of books, newsletters and magazines
- The provision of real life case studies
- Others (Kindly specify) ……………………… ……………………………………………………..

Thank you for taking time out to answer the questionnaire.

Best regards,
Chrislyn Omochiere Egege.

APPENDIX E

THE SURVEY QUESTIONNAIRE (TURKISH)

YÜKSEK LİSANS TEZİ ANKETİ

Sayın Katılımcı,

Araştırma Anketi: Kuzey Kıbrıs 'taki Bina Projelerinde Şantiye Dışı Modüler Yapımın Benimsenmesini ve Kullanımını Değerlendirmek.

BÖLÜM A: KIŞISEL BILGILER

(**Not**: Lütfen uygun sütunları (√) veya (•) pozitif olarak belirtiniz.)

1. Katılımcının Mesleği: Emlak Geliştirici ( ) Mimar ( ) İnşaat/Proje Yöneticisi ( ) Şehir/Kentsel Planlayıcı ( ) Mühendis (İnşaat/Yapısal) ( ) Genel Yüklenici ( ) Üniversite öğretim elemanı ( ) Diğerleri……………………………………

2. Katılımcı Yaşı: 22 - 25yrs ( ) 26 - 30yrs ( ) 31 - 35yrs ( ) 36 – 40yrs ( ) 41 - 45yrs ( ) 46 – 50yrs ( ) 50yrs+ ( )

3. Cinsiyet: Erkek ( ) Kadın ( )

4. Eğitim Düzeyi: Lisans ( ) Yüksek Lisans ( ) Doktora ( ) Diğer: ……………………………….

5. Meslek Deneyimi: 5 Yıldan az ( ) 5 – 10 ( ) 11 – 15 ( ) 16 – 20 ( ) 21 – 25 ( ) 25 yıl üzeri ( )

6. Bulunduğu Organizasyon: Emlak Geliştirme Firması ( ) Mimarlık Firması ( ) Planlama Firması (Şehir/Kentsel) ( ) Mühendislik Firması (İnşaat/Yapısal) ( ) İnşaat/Proje Yönetim Firması ( ) Genel Yüklenici ( ) Devlet Kurumu ( ) Üniversite ( ) Diğerleri……………………….

7. Kuruluşunuzda Daimi Personelin sayısı (nüfus) nedir? Küçük 10 ( ) 11 – 20 ( ) 21 – 30 ( ) 31 – 40 ( ) 40 'dan fazla ( )

8. Organizasyonunuzun yaptığı yıllık inşaat miktarı (m2)? Küçük 1000 ( ) 1000 – 5000 ( ) 5001 – 10000 ( ) 10001 – 25000 ( ) 25001 – 50000 ( ) 50000'den fazla ( )

BÖLÜM B: KUZEY KIBRIS'TA YAPI PROJELERİNDE KULLANILAN İNŞAAT YÖNTEMLERİNİN DEĞERLENDİRİLMESİ

(**Not**: Lütfen (√) ya da (•) ile cevabınızı belirtiniz.)

Soru 9
Size göre şu an Kuzey Kıbrıs'ta projeler inşa etmek için yaygın olarak kullanılan yapım yöntemi nedir?

- Sadece yerinde (konvansiyonel) inşaat
- Sadece şantiye dışı inşaatı (prefabrik üretim)
- Hem yerinde hem de şantiye dışı inşaat
- Diğerleri (lütfen belirtiniz) ……………... ……………………………………………..

Soru 10
Size göre Kuzey Kıbrıs'ta inşaat projelerinde şantiyede (konvansiyonel) yapım hangi yüzdelerde kullanılıyor?

- 50'den az
- 51 – 60
- 61 – 70
- 71 – 80
- 81 – 90
- 91'den fazla

Soru 11
Size göre Kuzey Kıbrıs'ta bina projelerinde şantiye dışı yapım yüzdesi ne kadar kullanılıyor?

- 5'den küçük
- 5 – 10
- 11 – 20
- 21 – 30
- 31 – 40
- 41'den fazla

Soru 12
Size göre inşaat paydaşları Kuzey Kıbrıs'ta kullanılmakta olan mevcut inşaat metotlarından memnun mu?

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 13

Hangi yapısal malzeme çoğunlukla Kuzey Kıbrıs 'ta projelerin inşaasında kullanılır?

- Sadece Çelik
- Sadece Betonarme
- Sadece Ahşap
- Çelik ve betonarme
- Betonarme ve ahşap
- Çelik ve ahşap
- Çelik, betonarme ve ahşap

Soru 14

Kuzey Kıbrıs'ta mevcut inşaat metodu kullanımında karşılaşılan önemli sorunlar nelerdir?

- Yüksek inşaat maliyeti
- Düşük verimlilik
- Düşük kâr marjları
- Düşük işçi güvenliği
- Yüksek israf
- Düşük kalitede çalışmalar
- Vasıfsız personel kullanımı
- Hava bozulmaları
- Tasarım sorunları
- Vasıfsız gözetim personelinin kullanımı
- Diğerleri (lütfen belirtiniz)...............
  ....

Soru 15

Şantiye dışı yapım gibi modern yapım yöntemleri, Kuzey Kıbrıs'ta mevcut inşaat yöntemleri ile karşılaşılan zorlukları uygun şekilde çözebilir.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

BÖLÜM C: KUZEY KIBRIS'TA BİNA PROJESİNDE ŞANTİYE DIŞI MODÜLER YAPIMIN BİLGİ BİRİKİMİ, KABULLENME VE KULLANIMININ DEĞERLENDİRİLMESİ

(Not: Lütfen (√) ya da (•) ile cevabınızı belirtiniz.)

Soru 16

Şantiye dışı yapım hakkında olumlu bir algı vardır.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 17

Şantiye dışı yapım hakkında kendimi oldukça bilgili görüyorum.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 18

Şantiye dışı yapım hakkında daha fazla bilgi edinmekle ilgileniyorum.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 19

Kuruluşunuz hangi sıklıkta şantiye dışı yapımı benimser?

- Asla
- Nadiren
- Bazen
- Sıklıkla
- Her Zaman

Soru 20

Kuruluşunuzun şantiye dışı yapımı benimseyerek yaptığı yapıların toplam alansal boyutu nedir?

- 0
- 100 m^2'den küçük
- 100 – 500 m^2
- 501 – 1000 m^2
- 1001 – 2500 m^2
- 2501 – 5000 m^2
- 5000 m^2'den fazla

Soru 21

Gelecekte yapılacak projelerde şantiye dışı yapımı destekliyorum.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok

- Biraz katılıyorum
- Oldukça katılıyorum

Soru 22

Şantiye dışı yapı üretimi söz konusu olduğunda, kuruluşunuz ne tür bir yapıda daha istekli olacaktır? (lütfen en önemli 3 tanesini seçiniz)

- Prefabrikasyon
- Panel yapım
- Modüler/Hacimsel yapım
- Prekast/Ön Gerilimli beton yapım
- Prefabrik Ev
- Diğerleri (lütfen belirtiniz)

Soru 23

Kuruluşunuz şantiye dışı yapım kullanarak ne tür bir yapı inşa etti veya inşa eder? (lütfen en önemli 3 tanesini seçiniz)

- Tekil konut
- Toplu konut projeleri
- Ticari binalar
- Eğitim binaları
- Sağlık binaları
- Sanayi binaları
- Konaklama binaları
- Perakende satış noktaları (büfe gibi)
- Hiçbiri

Soru 24

Sizce işyerinizde şantiye dışı üretim konusunda karar vermede kim sorumludur?

- Mal sahipleri
- Mimarlar
- İnşaat mühendisleri
- Şehir/kent planlamacıları
- İnşaat/Proje yöneticileri
- Genel müteahhitler/yükleniciler
- Diğerleri (lütfen belirtiniz)

Soru 25

Şantiye dışı üretim tekniğini benimsemek açısından bir projenin tasarım aşamalarında üretici ve genel yüklenicileri dahil etmek önemlidir.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 26

Sizce, şantiye dışı üretimin gerçekleşmesi için projenin hangi aşamasında yükleniciler dahil edimelidir?

- Konsept aşamasında
- Şematik tasarım aşamasında
- Şematik tasarımın tamamlanmasından sonra
- Tasarım geliştirme sırasında
- Tasarımın tamamlanmasından sonra
- İnşaat ihale dosyası hazırlarken
- İnşaat ihale dosyası hazırlandıktan sonra

Soru 27

Kendimi şantiye dışı yapı üretimi konusunda iyi bilgilenmiş görüyorum.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 28

Şantiye dışı yapı üretiminin faydaları göz önüne alındığında, kuruluşunuz bunların hangilerini kullandı veya kullanmak ister? (lütfen en önemli 6 tanesini seçiniz)

- İnşaat süresini azaltma
- Maliyet kontrolü
- Üretkenliğin artması
- Kar marjlarının artması
- Işçi güvenliğinde artış
- Atık azaltma
- Bitmiş ürün kalitesi/kalite güvencesinin artması
- Köprüleme beceri ve işgücü eksikliklerini giderme
- İş tekrarını azaltma
- Hızlı yatırım getirisi
- Hava koşullarından etkilenmeme
- Diğerleri (lütfen belirtiniz) ……………
  ………………………………………….....

Soru 29

Sizce, Kuzey Kıbrıs'taki projelerde şantiye dışı yapı üretiminin tamamen benimsenmesini kısıtlayan faktörler nelerdir? (lütfen en önemli 6 tanesini seçiniz)

- Tarihsel alışkanlık
- Yapı denetçileri ve yasal düzenleyici kurumlar

- Proje finansmanı
- Müşterinin algı ve bilgisi
- BIM entegrasyonu (bilgisayar yoğun entegrasyon)
- Lojistik (Taşımacılık)
- Tasarımın getirdiği kısıtlamalar
- Tasarımcının şantiye konusundaki bilgisi
- Maliyet keşifleri ve bütçe
- Planlama ve iş sırası
- İhale koşulları
- Üreticilerin uygunluğu
- Kalifiye işgücü uygunluğu
- Kalite kontrol ve güvence
- Diğerleri (lütfen belirtiniz) ……………. …………………………………………..

Soru 30
Kuruluşunuzun şantiye dışı yapımı kullanmasında, Kuzey Kıbrıs'taki (profesyonel düzenleyici kurumlar)ın hangi alanlarda destek vermesi yararlı olabilir? (lütfen en önemli 3 tanesini seçiniz)

- Tasarım standartları, detaylar ve şartname
- Örnek çalışmalar
- Endüstri verileri (İnşaat performansı)
- Ağ
- Akademik araştırma ortaklığı
- Terimler sözlüğü
- Diğerleri (lütfen belirtiniz) ……………. …………………………………………..

Soru 31
Kuzey Kıbrıs'ta inşaat sektöründe, şantiye dışı yapımla ilgili farkındalık yaratmak önemlidir.

- Kesinlikle katılmıyorum
- Biraz katılmıyorum
- Tarafsız/hiçbir fikrim yok
- Biraz katılıyorum
- Oldukça katılıyorum

Soru 32
Kuzey Kıbrıs'ta şantiye dışı yapım kullanımı konusunda farkındalık düzeyinin arttırılması için en iyi yol/yollar nelerdir? (lütfen en önemli 3 tanesini seçiniz))

- Konferans, atölye ve seminerlerin organize edilmesi
- İnşaat profesyonellerinin eğitimi
- Makale ve araştırma çalışmalarının desteklenmesi
- Kitap, bülten ve dergi temini
- Gerçek örneklerin inşa edilmesi
- Diğerleri (lütfen belirtiniz)

Ankete cevap verdiğiniz için teşekkür ederim.

Chrislyn Omochiere Egege