Off-site Modular Construction as a Method of Improving Construction Quality and Safety

Chrislyn O. Egege
Near East University/Architecture, Nicosia, Northern Cyprus
Email: brauwneyez007@gmail.com

***Abstract*— Amongst others, Construction Quality and Safety are two very important factors to be considered on a construction site. A project can be deemed successful when it has an excellent quality (with no defects) and delivered in a very safe manner (with low construction fatality rate). Over time construction stakeholders have been in search of more innovative ways of delivering quality construction projects with the lowest fatality rate possible. Modular Construction which is an aspect of Off-site Construction proffers such innovation; this is owing to the fact that 60-90% of construction takes place in a regulated factory condition. Construction Safety is quite important in the sense that worker's health should be safeguarded in other to prevent insurance and liability claims. These claims in most cases add to the overall construction cost thereby reducing profits. Likewise, Construction Quality needs to meet and if possible exceeds a client's specification and expectations for project success. Off-site Construction as a method of increasing construction efficiency, Construction Quality and Safety of workers has not gained as much recognition as required hence this paper would analyze Modular Construction as an aspect of Off-site Construction and why it is the most innovative way of delivering quality and safety-oriented construction projects.**

***Index Terms*— Off-site Construction, Modular Construction, Innovative, Construction Quality, Construction Safety**

I. Introduction

The conventional construction practice in the building industry has over time turned out to be labor-intensive and comes with so many concerns such as health and safety, procurement cost, changing weather condition, quality etc.

Business wise, job-related injuries and illness in construction projects tend to affect the profitability of such projects. Costs that are directly associated with job-related injuries and sickness covers medical costs, workers premiums, liability, compensations and property losses [1].

From the angle of quality and productivity, the cost of labor is about 30% of the entire project cost [2]. Manpower mismanagement and delay in construction which was investigated by [3] expressed that the unproductive time of a typical construction worker's day is up to 40-60%. The cost related to construction rework (redoing an aspect of construction due to poor craftsmanship) as discovered by [4] is about 12% of the entire construction costs excluding losses which are as a result of delayed schedule, lawsuit and other impalpable cost of substandard quality.

Unsatisfactory quality of work and unsafe work environment and conditions have led to clients, companies and the general public to lose millions of dollars thereby causing severe hardship to the affected construction employees and their families [5].

Off-site Modular Construction as a sustainable construction method is taking a new leap worldwide in increasing and enhancing productivity level in the building and construction sector thus reducing the resulting social and environmental effects arising from the activities of conventional method of construction.

Construction site work is one of the most hazard based jobs worldwide presently and the construction fatality rate likewise is on the increase globally with Europe having the highest fatality rate of 23% with Germany, France, Spain, United Kingdom and Portugal leading the ranks [6].

The building industry receives series of regular checks for quality of work according to [5], these checks aim at minimizing construction errors, the use of defective and inferior construction materials.

Due to the complexity of construction, the need for innovation and the adoption of new technologies to ease construction process is required.

A. Problem Statement

Due to the intricate nature of construction, contractors sometimes find it arduous to deliver quality projects to clients, as a result some projects come with so many imprecision. The usage of substandard and defective materials in other to cut or reduce construction cost all contributes to substandard project delivery. The exposure of site workers to accidents on the construction sites might interfere with site work for some period of time which increases the contractor's liability to pay health and insurance premiums which adds to the overall cost of the project and unavoidably reduces profits.

B. Aim

This paper aims at critically scrutinizing the subject of discuss in order to fully grasp how Off-site Modular Construction can be adopted in achieving productivity increase, reducing site workforce, reducing site work

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hours and minimizing construction risk towards improving Construction Quality and Safety.

C. Methodology

This study adopted the systematic review of literatures relevant to this study which includes textbooks, conference papers, journals, articles and technical reports which were published by research bodies, individual authors and also governmental organization. Also Modular Building Institute's (MBI) award winning case studies were also examine in other to critically determine the level of impact Off-site Modular Construction has in increasing Construction Quality and Safety. The resulting insights which were gathered were discussed and used to draw up the conclusion.

II. Literature Review

A. Construction Quality and Safety

Construction Quality and Safety can be described as minimizing rework in other to achieve accident free construction which can be attained by complying with plans and designs thereby satisfying the client's expectations while effectively eliminating any form of injury.

In construction, quality is also described as; *"The totality of the attributes of a building that enables it to satisfy needs, including the way in which individual attributes (external attributes; performance attributes; and aesthetic & amenity attributes) are related, harmonized, and integrated in the whole building and its surroundings"* [7].

Quality has *over time been described as the "ability to satisfy needs"* [8], "*conformance to requirements"* [7], *and "fitness for purpose"* [9].

"Ref. [10]" in his research defined quality as the *"degree of excellence of the contractor's services and finished product as perceived by the customer".*

All the above definitions and descriptions about construction quality aim at expressing both the requirements and expectations of a quality project.

"Ref. [11]" defined safety as *"the control of recognized hazards to attain an acceptable level of risk".* Safety is also defined by [12] as the *"freedom from (unacceptable) risk of harm to persons which may also encompass environmental or asset damage/loss"*.

"Ref. [13]" pointed out that the major causes of recurrent injury and mishap on construction sites include falls, being hit by mobile plants, materials falls & cave-in, electrocution and lastly trips which are the most common causes of construction site injuries.

"Ref. [5]" reiterated that the characteristics of the working environment are actually responsible for the decrease in Construction Quality and Safety.

A large percentage of the associated challenges which conventional construction faces currently as regards to quality and safety can be resolved and managed (reduced) to a large degree if or when Off-site Construction is somehow adopted in practice.

B. Off-site Construction

"Ref. [14]" defined Off-site Construction as the designing, engineering, fabricating, and erection of building components at a site aside from its eventual established site which the principal purpose is to support the speedy and systematic construction of a relocate-able and permanent building. In most cases, these components could be prefabricated in a separate facility and delivered to the construction site or it can also be prefabricated within the construction site and later transported to their eventual location. The supply chain optimization and an integrated planning are the two major characteristics of Offsite Construction [14].

It is gathered that Off-site Construction outputs often includes modularized, panelized and componentized components or elements which are utilized to serve as systems for services, structural stability, enclosure, and interior portioning [15]. For this paper, the focus would be on modularized elements.

C. Modular Construction (MC)

Modular Construction is a form of prefabricated construction technology which is also an off-site method of construction where panelized or volumetric units known as modules are used for constructing various building types [16].

"Ref. [17]" in their glossary of terms for build off-site defined Modular Construction as units that are either volumetric or three-dimensional that are typically produced in a controlled factory facility then conveyed to site thus forming the major structural elements of the structure.

In an attempt to define Modular Construction, the Modular Building Institutes (MBI) in its 2011 annual report [18] defined it as a process or method of construction that permits for single individual modules to be built as a stand-alone structure or in combination with other modules which constitutes a larger building edifice.

The intent of Modular Construction is clear, to deliver a manufactured structure where most of the construction is performed in a regulated environment and transported to the site. This way the on-site works which include the construction of the foundation and base for the module can be ongoing while off-site prefabrication and manufacturing of the modules are carried out in the factory simultaneously.

According to the article published in [19] titled "Why Build Modular", it is gathered that buildings which were built using modular method are structurally stronger than those built with conventional construction and this is because each module is designed and manufactured to singularly resist the severity of transportation and lifting into position, making up an integrated entity once placed together and sealed.

It is the desideratum of constructing a sustainable structure with high standards that have led to the re-emergence of Modular Construction especially in Europe, Asia, USA, Great Britain and other parts of the globe.

"Ref. [20]" reiterated that Modular Construction has to be the most highly-developed off-site manufacturing

process. "Ref [18]" agreed with that because Modular Construction has about 60-90% of the total construction work manufactured and assembled in a controlled facility after which they are then delivered to the permanent site. According to [21], the Modular Construction idea would also be suitable for urban infill sites because the construction is typically carried out in phases.

D. Brief History of Off-site Construction

Off-site Construction history can be traced back to the prefabrication that commenced during Great Britain's efforts to colonize the globe. A rapid building initiative was required in other to help them settle in present-day Australia, Africa, Canada, India, Middle-East, New Zealand and the U.S. The challenges of being unfamiliar with the numerous materials that can be found in these regions led to them shipping in by boat components that were manufactured in England. The houses prepared in England and sent to Cape Anne (Massachusetts) were the earliest cases recorded around 1624 [22].

The earliest settlement that was reported inside New South Wales happens to be a hospital that was prefabricated and storehouses that were transported to Sydney around 1790. These buildings were completely made out of timber which was used as the frame, floors, walls, and roofs. Years later this same system was used in building a church and some other types of structures in Freetown [23].

"Ref. [24]" explained that next in line in the advancement of prefabricated houses was this structure subsequently known as the Manning Portable Colonial Cottage for emigrant (Figures 1 & 2) and it was designed and developed by H. John Manning, a London carpenter. The prototype which was developed for his immigrating son to Australia around 1830 became the first ever completely prefabricated house.

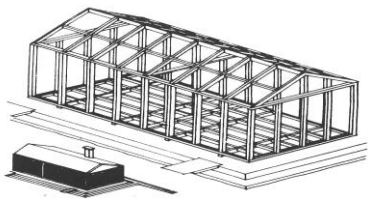

Figure 1. Framing of the Manning Portable Colonial Cottage produced in Great Britain and delivered to colonies around the globe; courtesy – (Smith, 2009)

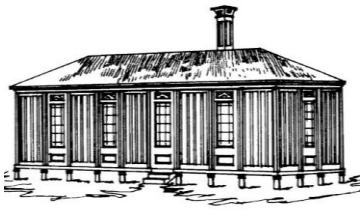

Figure 2. Typical Manning Portable cottage; courtesy - http://www.quonset-hut.blogspot.com

A prefabricated Army hospital known as Renkioi Hospital was built during the Crimean War in 1855 (Figures 3 & 4). The structure designed by Isambard Kingdom Brunel and was shipped to Crimea and helped reduce the death rate of wounded British soldiers [25].

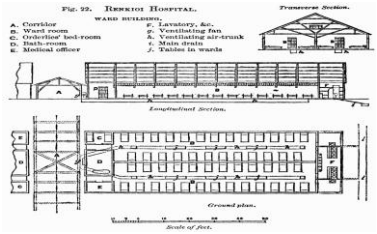

Figure 3. Plan and section of the Renkioi Hospital (courtesy - http://www.modularize.co.uk)

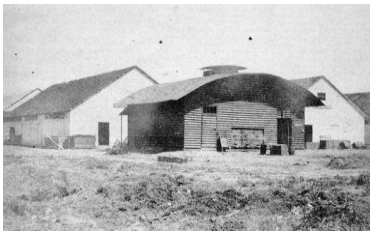

Figure 4. Exterior of the Renkioi Hospital, Crimea (1857) made from prefabricated timber; courtesy - http://www.ikbrunel.org.uk

Modular buildings which grew popular in America in 1940 were built by the Sears Roebuck Company (Figures 5 & 6); these fabricated homes were intended for the moving populace of America who were enticed by the California Gold Rush. It was transported by rail after being purchased and comes with detailed installation manual, complete kits, buckets of paint and even nails.

Figure 5. Typical Sears Roebuck (Sheridan) bungalow (1940); courtesy - http://www.arts-crafts.com

Figure 6. Sears Kit House - The Elsmore courtesy – http://www.arts-crafts.com

The need for mass accommodation by soldiers during the World War II gave rise to massive prefabrication. A typical example was the lightweight Quonset huts (Figure 7) which were made out of either corrugated or galvanized steel which exhibits a semi-circular cross-sectional form. It can be assembled by unskilled personnel and immediately the Europeans and Japanese adopted the method to reconstruct areas destroyed as a result of the war.

Concrete Modular Construction was proposed to the American construction industry around 1960 and 1970

for constructing high-rise structures. A hotel, Hilton Palacio del Rio was the first erected with this method (Figure 8). The modules were manufactured using precast light-weight structural concrete that were produced at a nearby factory, each weighs about 32,000kg and took 48days to erect all the modules which came complete with furniture, interior finishes and MEP [26].

Figure 7. Typical Quonset huts built during WW.II; courtesy - http://www.quonsethuts.org

Figure. 8. Construction of the Hilton Palacio del Rio Hotel (1968); courtesy - https://www.therivardreport.com

E. Classification of Modular Construction

"Ref. [15]" mentioned that two distinguish sectors make up the Modular Construction industry and they are Relocate-able Modular and Permanent Modular. The *Relocate-able Modular Construction* also called Temporary Modular as its name implies means a structure that was built to meet the temporary space need such as temporary classrooms, communication pods, site trailers and show rooms (Figure 9) while on the other hand *Permanent Modular Construction (PMC)* which meets the International Building Code (IBC) is akin to on-site structures but it is also different in the sense that it takes up a factory manufacturing process. PMC is ideal for the construction of schools, hotels, multi-story family dwelling, dormitories and health care facilities to mention just a few (figure 10).

Figure 9. Typical Relocate-able Modular building, courtesy - http://www.modular.org

Figure 10. Typical Permanent Modular building; courtesy - http://www.modular.org

F. Classification of Permanent Modular Construction

According to [19], Permanent Modular Construction (PMC) is a sustainable and innovative method of delivering construction projects which enables the prefabrication of single or multi-story structures while employing lean manufacturing off-site techniques. PMC structures are produced at a safe and well secured regulated environment and can typically be built using timber, steel framing (mostly light-gauge) and in some cases concrete whereby the structure is 60% to 90% finished at the factory before it is transported and assembled at the construction site.

PMC can be classified into two distinct groups which are Panelized Modular and Volumetric Modular.

"Ref. [27] reported that Panelized Modular Construction is often used in the building industry presently and it employs a type of assemblage which seems like a typical cassette arrangement. The type of assembly (unit) that can be manufactured for a Panelized Modular includes floor, wall and roof systems (Figure 11).

Figure 11. Typical Panelized Modular Construction, courtesy - http://www.grizzlylogbuilders.com

Figure 12. Volumetric (3D) Modular Construction; courtesy – http://www.theconstructioncentre.co.uk

Volumetric Modular Construction ideally refers to three-dimensional (box like) or cellular units in form of modules which in most cases are constructed from combining two-dimensional or panelized components. (Figure 12). The nature of this type of assembly is such that the prefabricated module's interior has been totally installed (with MEPs and PODs) at a controlled factory. These modules can either stand individually as a single unit or form a larger building structure in connection with other modules [27].

G. Types of Modules in Modular Construction

"Ref [28]" explained that there are about seven types of modules that can be applied in modular construction and they include; modules with 4-sides, modules that are partially open-sided, module with corner support (open-sided), modules that are supported by a primary structural frame, non-load bearing modules (pods), unique lift or stair modules, mixed modules and planar floor cassettes.

Each one of the above mention modules has its own particular application but for the purpose of this paper, we won't be going into details. Below are some major module types which can also be used in connection with each other to form a hybrid module.

Figure 13. Typical 4-sided Load-bearing Module, courtesy – (Lawson, 2014)

Figure. 14. Partially open-sided module; courtesy – (Lawson, 2014)

Figure 15. Typical Open-sided Module with corner post, courtesy – (Lawson, 2007)

Figure 16. Typical Non-load bearing Module (PODs); courtesy – (Lawson, 2014)

"Ref. [29]" further explained that 4-sided modules with load-bearing walls (Figure 13) are mainly used for cellular-types spaces while open-sided modules with corner support (Figures 14 & 15) are used for large open plan spaces and finally the non-load bearing modules (pods) are used as bathroom and balcony modules (Figure 16).

H. Stages of Modular Construction

Modular Building Institute (MBI) article on [30] disclosed that there are primarily four stages that make up a typical Off-site Construction and they are;

First Stage: The approval of the design by the end user and any other regulating authorities.

- Second Stage: The assembly of module components, this is usually carried out in a regulated or controlled factory environment.
- Third Stage: Transportation of the manufactured modules to the final location which is the construction site.
- Fourth Stage: Assembling of each modular unit to make up a complete and finished structure.

The uniqueness of Off-site Modular Construction is that site works can be on going while fabrication of the modules is being carried out at the manufacturing facility.

I. Attributes of Modular Construction

- Greater reliability and quality
- Reduced construction time (40% to 50%)
- Increased productivity (up to 50%)
- Reduced construction cost
- Reduction in wastage
- Increase in profits
- Greater certainty of scheduled completion
- Quicker return on investment
- Ease of coordination
- Low maintenance cost

J. Benefits and Limitation of Modular Construction

Using the Modular (Off-site) Construction method for the building of structures potentially has its merits and demerits anytime it is pitched with the conventional method of construction (on-site). "Ref. [31] were able to point out that Modular Construction approach ultimately provides economic values as compared to conventional construction.

"Ref. [32] points out the advantages of Modular Construction to include reduced construction cost in every area, improved productivity and quality, improved schedule and well testing and better constructability.

When adopting Modular Construction method for a project, it is important to be conscious of the available advantages that are found in broad areas such as reduction in construction cost, increased construction quality, reduction in construction time, improved health and safety, improvement in construction possibility and finally reduced social and environmental impact [33].

- Benefits

Increased Quality: one major advantageous aspect of using MC is the quality of construction which this method creates because of the appropriate working condition [34]. There is also an increase in quality control, availability of skilled labor and optimal module testing [33].

Improved Safety: Higher health and safety of workers are achieved while using MC due to the fact that all works are carried out on a level ground in a controlled

facility with adequate health and safety regulation which are applied for a safer and conducive facility

Reduced Cost: construction projects can have a reduced cost when Modular Construction is adopted. Professionals in the Modular Construction sector evidently believe that the cost of construction can be reduced by as much as 5% to 10% when MC is adopted in a project [33], while in some cases (projects) construction capital cost savings is almost 20% [34].

Reduced Schedule: some of the items that facilitates a cutback in the schedule while using MC include; efficiently carrying out both design and procurement concurrently, effectively improving the control schedule, increasing efficiency in the factory, ensuring work is done concurrently and the training of operators in the fabrication facility rather than on-site [35].

Increased Possibility of Construction: in construction, the task of executing construction projects in some remote locations can be utterly difficult when using conventional construction methods (on-site) while in contrast MC (off-site) can simply be used to solve such challenges on projects located in such terrains thus stressing another vital advantage of this method. Typical difficulties which builders and contractors might encounter in such locations according to [36] are; constraint as a result of the site's characteristics, availability of manpower, environmental condition and ultimately project constraint.

- Limitation

Despite having so many merits Modular (Off-site) Construction is also faced with its peculiar challenges which would be discussed below.

Extra Construction Effort: this unarguably is one of the very few major disadvantages of using MC method. Some of the disadvantages of increased construction efforts as listed by [36] are generated from project design and engineering, project planning and scheduling, procurement of materials, modules fabrication, project inspection and lastly module transportation, handling, and assembly.

Extra Coordination of Activities: the need for extra coordination of interdependent construction activities is another major disadvantage of MC. This is because most of these activities have to be performed simultaneously rather than sequentially thus increasing the amount of coordination of activities needed [36].

Need for Extra Material: "Ref [34]" pointed out the possibility of requiring about 30% additional structural steel when transporting the completed modules to the site from the factory which is basically for rigging the module. "Ref [37]" explains that this is the most serious of all MC demerits because it inevitably adds to the cost of construction by 0.5%.

Increased Design Cost: There is an increase in the cost of designing and engineering while using MC method for a project. "Ref [31]" estimated the increase to be about 10% more than design for conventional construction which is due to the fact that more man-hour is needed for the design and engineering. He further suggested the possibility of increased procurement cost might arise which can be up to 20% extra to enable the evaluation and selection of sub-contractors.

Reduced Adaptability to Design Changes: this refers to the fact that once construction starts using MC method, it's impossible or extremely difficult to have the design reviewed or adjusted due to the improved interdependency of construction operations and as such any little modification would disrupt a wide range of correlated activities.

Increased Risk: New risk blooms when MC method is used for a project because this method of construction establishes a different scope to project organization. "Ref [32]" accentuates the risks involved to include engaging the services of unqualified and inexperienced construction and engineering firms, rigor of module transportation that could lead to either damage or loss of the module, incompetence on the part of project managers and being confronted with procurement issues.

K. How Does Off-site Construction Increase Construction Quality and Safety

A myriad of contemporary examples uses prefabricated (off-site) construction not for its benefits in the efficiency of cost but in precision and the increase in quality of the product [38].

According to Sheryl Jackson's article on [39], Mark Konchar, the senior vice president of enterprise developments at Balfour Beatty Construction stated that another major benefit of using Off-site Construction is that of quality from the manufactured elements. "*We are meeting manufacturing standards with the production of modular units*," he said. The superior quality translates into further savings on construction cost. He went on to point out that "*with fewer defects per million joints welded, a team avoids wasted time in chasing issues during finish work phase*." Konchar believes that "*if a building construction is of high quality, you have fewer maintenance issues*."

Another aspect that contributes to quality project delivery using Modular Off-site Construction is the fact that manufacturing of the key components and elements are carried out in a controlled facility. According to Sheryl "*the controlled environment of a manufacturing plant lends itself to more thorough quality testing and traceability of components that enable the team to correct problems before the unit or system arrives at the work site*."

According to [19], Construction Quality is attained because construction occurs indoors away from the effect of harsh weather which positively prevents the building materials from damage while the builders work in more comfortable condition.

In a survey conducted by [40] in 2014, 63.5% of respondents anticipated achieving Construction Quality prior to construction using off-site method while 62.5% reported that Construction Quality was the actual benefit using this method of construction.

In another survey conducted by [41], respondent reported that there was no loss in Construction Quality compared to conventional construction methods and they were really impressed with the significant quality of

Permanent Modular Construction (Off-site) buildings. More than 60% of those who used Off-site Construction method in their current projects highlighted quality as an actual benefit.

"Ref. [42]" highlighted that all factory procedures must conform to audit trails under the ISO 9001:2000 quality standard and is bound to function under standard situation. This surely gives manufactured (Off-site) construction an edge over conventional construction.

"Ref. [43]" elucidated that there lies a connection between construction safety and prefabrication /modularization.

Redirecting most of the construction activities from an open site to a regulated factory condition streamlines the time spent by workers on-site and decreases the potential for on-site accidents and mishap [42].

"Ref. [43]" hinted that there seems to be a notable and remarkable increase in the level of adoption of nearly every safety practice which the survey measures when prefabrication (Off-site) is adopted. As much as 73% of prefabrication and modularization users disclose having totally observed safety program which is 25% more than those who don't use prefab method of construction.

The report further explicates that a key factor which improves Construction Safety is the ability of the contractor to be involved in the project before its commencement due to the use of prefabrication.

"Ref. [42]" hinted that adopting Off-site assembly helps to reduce the risks associated with health and safety in the sense that equipment are arranged with access to all four sides on modular base cassettes.

ConCA which is a research project at Loughborough examined accident causality in conventional construction. It was gathered from the research that many off-task accidents occur while personnel move around the site while not being associated with their duties. Off-site construction to a large extent avoids such situations by reducing the number of site based personnel which inevitably reduces the number of off-task accidents [42].

III. Case-study Examples

All of the case-studies examined in this paper are all winners in various categories of the MBI Awards of Distinction. The criteria for the award selection are; architectural excellence, technical innovation, sustainability and cost effectiveness.

- Case Study 1: **The Stack, Manhattan – New York**

Figure 17. Exterior View of The Stack building); courtesy – http://www.modular.org

TABLE I. Case Study Information

OFFICIAL NAME **4857 Broadway**	LOCATION **Manhattan, NY**	**DEVELOPER NYC Partnership**
CONTRACTOR **DeLuxe Bldg. Syst. PA**	ARCHITECT **GLUCK+**	PROJECT SIZE **27,000 SF**
PROJECT VALUE **$13,000,000**	DATE OF OPENING **Fall 2013**	DAYS TO COMPLETE **19**
NUMBER OF FLOORS **7**	NUMBER OF UNITS **28**	NUMBER OF MODULES **56**

The Stack (Figure 17) is the first ever Off-site Modular building built in Manhattan, New York. The method of construction used as reported by the developers makes for greater unit quality control. This project also received the Award for Outstanding Project "New Buildings $10-30m" from The National Council of Structural Engineers Association's Excellence in Structural Engineering Awards. Table I gives a brief overview of the structure.

Figure 18. Exterior Facade of The Stack building, courtesy – http://www.gluckplus.com

The Stack streamlined the complete development process in other to create a product with high-quality with minimal carbon footprint. The fabrication of the modules in a highly controlled environment allowed for precise engineering and better quality assurance (Figure 18).

The development also made use of minimal tradesmen on site, a total of about 15 crews were used which reduced the chances of accidents and injuries while increasing the overall safety on the project.

- Case Study 2: **Eviva Midtown Apartment, Sacramento – CA**

Figure 19. Exterior View of the Eviva Midtown Apt, courtesy – http://www.modular.org

TABLE II. CASE STUDY INFORMATION

OFFICIAL NAME **EVIVA Midtown**	LOCATION **Sacramento, CA**	DEVELOPER **Integral Group, LLC & LDK.**
CONTRACTOR **Tricorp Hearn Construction**	ARCHITECT **Devrouax & Purnell and LDA Arc.**	PROJECT SIZE **176,521 SF**
PROJECT VALUE **$37,500,000**	COMPLETION DATE **August, 2016**	DAYS TO COMPLETE **424**
NUMBER OF FLOORS **6**	NUMBER OF UNITS **118**	NUMBER OF MODULES **200**

Winning the award for first place in Permanent Commercial Housing at the MBI 2017 Awards of Distinction, the Eviva Midtown Apartments (Figures 19 & 20) is showing the strength of Off-site Modular Construction.

Figure 20. Eviva Midtown Courtyard view, courtesy – http://www.evivamidtown.com

Some of the benefits of using Modular construction on this project include; faster construction, increased quality and a quicker return of investment.

Because Modular Construction requires fewer tradesmen during construction the developer was able to cope just fine with the shortages of qualified tradesmen which would have been a serious concern if conventional construction was to be used. Using this construction method also enabled the developer to mitigate many of the unknown risks to be accounted for without the need to build in an overload of contingency pricing. Table II presents an overview of the building structure.

- Case Study 3: **Domain Apartment, San Diego – California**

Figure 21. Exterior View of the Domain Apartment, courtesy – http://www.equityapartments.com

TABLE III. CASE STUDY INFORMATION

OFFICIAL NAME **Domain Apt.**	LOCATION **San Diego, CA**	DEVELOPER **Equity Residential Development**
CONTRACTOR **Guerdon Modular Bldg.**	ARCHITECT **Humphreys & Partner Arch.**	PROJECT SIZE **450,000 SF**
PROJECT VALUE **$215,000,000**	DATE OF OPENING **November,2013**	DAYS TO COMPLETE **609**
NUMBER OF FLOORS **5**	NUMBER OF UNITS **444**	NUMBER OF MODULES **485**

Domain apartment (Figure 21 & 22) is the country's largest modularly constructed residential building in the west coast of USA. According to project contractor Guerdon Modular Building, the benefits of using Modular Construction on their projects include; speed of market, budget certainty, consistent quality, reduced risk, quiet construction, green design and lastly safety.

The director of Equity Residential Development Peter Solar hinted that the call for Modular Construction was more than just a matter of saving time he said *"the quality you get on the field is much better because units are built out of a factory where there is a better quality control,"* he said *"plus you don't have to worry about weather damage"*.

Table III reports a concise overview of the Domain apartment.

Figure 22. Courtyard view of the Domain Apartment, courtesy – http://www.equityapartments.com

IV. DISCUSSION

As seen from the case studies presented, construction can improve significantly from the adoption of Off-site Modular Construction. The level of perfection, precision, quality and aesthetics of the finished product cannot be over emphasized

The production line of Off-site Modular Construction is subjected to uncompromising quality check at every stage before a final inspection prior to transporting the finished modules to the site. It can be said that Off-site method of construction allows for zero defects thereby limiting the level of maintenance required.

The potential that exist using Off-site Modular Construction are numerous especially in the aspect of safety and quality project delivery. The manufacturing of

the building components off-site provides for more controlled indoor conditions which ultimately give room for workers safety, precision and improvement in the quality of the fabricated elements while necessitating thorough inspection at every step of production.

Off-site Modular Construction makes construction less cumbersome and tidier which enables better working environment and quality project delivery. An increase in the quality delivery of a project and safety of personnel all through the construction period will certainly increase the profits of contractors.

It is advisable and important for architects to enlighten their clients during the planning stage and before commencement of projects about the benefits of Off-site Modular Construction and why it is ideal for their project.

It would also be recommended that architects liaise with the contractors and engineering firms during the design stage of the project to give them an insight into what is required of them.

It is necessary to employ qualified supervisory personnel who have the required technical background on this method of construction all through the duration of the project to ensure proper supervisor of construction.

V. Conclusion

Prefabricating building components off-site always provide for more controlled conditions which invariably improve the quality and precision in these components.

Off-site construction is the future for an ultra-efficient way of building structures and it is important that all professionals and stakeholders in the building and construction sector be sensitized as often as possible about the potentials in the use of Modular Off-site Construction method.

Standardization of a country's building/construction industry can be improved through the adoption and use of Off-site Modular Construction.

Considering the technological advancement globally as of today, the writer closes by asking this question "is construction supposed to be difficult, dangerous, and dirty?"

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Chrislyn O. Egege was born in Lagos – Nigeria in May 1985. He recently bagged his Master of Science degree in Architecture from Near East University Nicosia - Cyprus with high honors. He obtained his Bachelor of Science in Architecture degree from Olabisi Onabanjo University, Ogun State - Nigeria.
He's currently a member (student) of the Chartered Institute of Building (C.I.O.B) U.K. Chrislyn is interested in pursuing a doctorate degree in Architecture & Construction while his research interests includes Modular Construction, Off-site Construction, Prefabricated Construction, Industrialized Building Systems and Automated Construction.