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Opportunities and Challenges of Modular Construction in a Hospitality Centric Environment

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OPPORTUNITIES AND CHALLENGES OF MODULAR CONSTRUCTION IN A HOSPITALITY CENTRIC ENVIRONMENT

By

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ABSTRACT

Modular construction techniques can substantially decrease project schedules and costs, effectively maintaining or increasing the quality of an end product by shifting a percentage of site-based work to an off-site fabrication shop. Modular construction can also significantly contribute to sustainability by reducing site disruption, reducing waste generated, creating better relocatability and reusability, causing less dust and noise pollution, and reducing the probability of loss, theft, and damage to equipment. The primary goal of this research is to identify the opportunities and challenges of implementing modular construction techniques in a hospitality-centric environment, by investigating the current situation and characteristics of modular construction in Las Vegas. In this study, the approach includes the formulation of a survey, which was shared with 63 industry professionals, followed by three personal interviews. The results suggested that 85% percent of survey participants expected an improvement in schedule, and 65% of those actually experienced an improved schedule. Sixty-two percent of the participants claimed that they would continue using modular methods in the next 12 months, whereas, 44% claimed a plan to increase their use of modularization in the next 5 years. Two of the top five expected benefits achieved included reduced waste and less site disruption (noise/traffic, dust, etc.), which contribute towards sustainable construction. The results also demonstrated that transportation/logistics was selected by industry professionals as a key barrier in the implementation of modular construction. To implement more sustainable modular construction, practitioners require additional research to improve/overcome the key barrier of transportation/logistics. The results from this research would provide valuable insights for implementing modular methods in hospitality-centric environments around the world, such as Paris, Macau, Singapore, Dubai, etc.

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TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1: Introduction

1.1 Background

The construction industry provides a significant contribution to the economy of any country. In 2007, around 8% of the total workforce of the United States, i.e. 11 million people, worked in the construction industry (U.S. Department of Labor, 2008). The total value of the built infrastructure was around $611 billion (U.S. Census Bureau, 2008a). There is a growing demand for the construction industry to provide improved quality and better-value projects. Modular methods can help the industry by building prefabricated modules in controlled environments, such as factories or fabrication shops, which are located away from the construction sites. Modular construction can prove to be beneficial in reducing the construction costs, duration, noise, waste and accidents. (Tatum, Vanegas, & Williams, 1987) (Song, Fagerlund, Haas, Tatum, & Vanegas, 2005) (O'Connor, O'Brien, & Choi, 2013) (Haas, O'Connor, Tucker, Eickmann, & Fagerlund, 2000); (Modular Building Institute (MBI) 2010); (McGraw Hill Construction 2011). After fabrication, the modules can be transported to a construction site and assembled like building blocks (Lawson, Ogden, & Bergin, 2012). In this way, modular construction might also be helpful in reducing the construction noise, which causes disturbance to the visitors. With modular construction, the construction process can be sped-up, by building the modules parallel to site preparation. This type of construction is best suitable for structures with repetitive elements such as hotels or dormitories. Moreover, temporary modular buildings can also be dismantled and reused, effectively maintaining their asset value. Mainly schools' benefit from temporary modular structures.

Modularization can help the industry in taking a leap towards sustainable construction by reducing the amount of material used and waste generated as compared to traditional stick-built methods. It also reduces the disruptions to sites and to their surroundings, by moving a large share of site-based work to an offsite facility. Additionally, modularization reduces the overall construction schedule, ultimately reducing the disruption to the neighborhoods. Modularization contributes to the economy, as the relocatable and reusable property of the modules increases their value. As most of the construction work is carried out in a contained facility, there is less dust and noise at the site. Further, modular construction reduces the chances of the theft of material or equipment from construction sites.

Las Vegas is a city that attracts a large number of tourists throughout the year. The hospitality industry could benefit from modular methods of construction. Las Vegas has the highest number of hotel rooms in the United States and in the world i.e. more than 160,000 (Statista, 2018). Notably, Las Vegas was ranked first in the world's top 10 cities with the most hotel rooms (Albawaba Business, 2017). According to the Los Angeles Times, Las Vegas had a record 42 million visitors in the year 2015 (Jones, 2015). This manuscript will potentially attempt to report the challenges and barriers for adopting modular construction to a greater extent in Las Vegas.

1.2 Research Needs

Previous studies focusing on the benefits and barriers of using modular methods in a hospitality centric environment are limited. (Choi, Chen, & Kim, 2017) researched using modular design and construction in the dense urban environment of Hong Kong, with a focus on both the

challenges and opportunities available. The characteristics of Las Vegas, as a city, differs substantially from a dense urban environment. Therefore, further research needs to be done to evaluate the opportunities and challenges of implementing modular methods in hospitality-centric cities, such as Las Vegas, Paris, Macau, Singapore, etc.

1.3 Research Objectives

The primary goal of this research is to learn the challenges and opportunities for using modular methods in the Las Vegas construction industry. Further, this research focuses on comparing the results to a similar study conducted by (Choi et al., 2017) for a dense urban environment. After establishing the barriers, the secondary goal of this research is to suggest measures that can be taken, and to determine future studies that needs to be conducted, in order to increase modularization in the Las Vegas construction industry.

1.4 Research Scope and Limitations

The understanding of the definition of modular construction might differ between individuals. The definition and the process of modular construction was provided on the first page of the survey. However, a difference in perception of definition between the respondents is possible. This research was conducted in the Las Vegas construction industry and the survey participants are practitioners/professionals working on construction projects in the Las Vegas Valley. The research has been conducted in 2018-2019, so there may be advancements or changes in the industry after this point.

1.5 Thesis Structure

The research is organized into four chapters, two appendices, and references. Chapter two summarizes the previous research on modularization and how it has helped the hospitality sector, both in and outside of the United States, to save time and money on hotel construction projects. It also proves how modular methods of construction can aid in achieving higher levels of sustainability in the construction sector. Chapter three focuses on the research methodology adopted for this study; the preliminary investigation conducted before the survey; the formulation of the main survey; the data analysis; the discussion of face-to-face interviews; and the description of the survey participants. Chapter 4 focuses on the findings of this study from the survey and interviews. Chapter 5 includes the conclusion and recommendations for future research. This is then followed by appendices, and the thesis concludes with references.

Chapter 2: Literature Review

2.1 Introduction

To understand and present the modular methods, a literature review on the advantages of modular construction was conducted, and hotel projects were investigated. The Las Vegas construction industry demands improvement in construction quality for the hospitality industry, as it is a prominent tourism attraction for the world. This manuscript will attempt to report the challenges and barriers in adopting modular construction to a greater extent in Las Vegas.

2.2 Modular construction

According to numerous studies conducted by the Construction Industry Institute, reduced project duration, improved labor productivity, and improved efficiency of job-site management are some of the benefits of implementing modular construction practices ("Prefabrication, preassembly, modularization, and offsite fabrication in industrial construction: A framework for decision-making," 2002). A study on the perception of general contractors of offsite construction also talks about the benefits of modular construction, which include reduced overall project schedule, increased product quality, increased labor productivity, increased onsite safety, reduced onsite disruption, and reduced negative impacts on the environment (Lu & Liska, 2008). Further, modular construction provides the ability to reduce the construction schedule substantially, by sidestepping the unavoidable delays in conventional construction methods such as weather (Velamati, 2012).

Taking the hospitality industry into consideration, more and more owners, contractors, and project managers are implementing modular methods in their hotel projects, both inside and

outside of the United States. In the US, The Canyons lodge and cabins in Yellowstone National Park is a $90 million project, which was fabricated by Guerdon Modular Buildings in their Boise, Idaho facility. Out of the total five structures, three were fabricated in the first six months. The estimated stick-built time was proposed to be 30 months. After adopting modular construction methods, the builder was able to finish the project in one-third of the proposed stick-built time. They also reported a reduction in construction waste by 85% ("Canyons Lodge, Yellowstone National Park, Wyoming," 2018). Another project, the Hampton Inn and Suites built in Harrison, New Jersey, saved approximately three to four months of schedule, which led to the earlier generation of revenue (Deluxe-Built, 2004). Further, the Folsom Fairfield Inn and Suites by Marriott, a 97-room hotel constructed in Folsom, California was also completed four to five months earlier, as compared to the projected stick-built time (Anderson, 2016) ("Folsom Fairfield Inn and Suites," 2016). Outside of the US, Kings Park Accommodations in Queensland, Australia saved 40% of the expected cost by adopting modular construction methods. The modules were prefabricated within 50 days in Shanghai, China, and assembled at the site in just one week ("How this Builder Saved 40% by Choosing Modular Container Construction," 2016).

2.3 Sustainable Construction

Sustainability is a process of avoiding the diminution of natural resources in order to maintain an ecological balance. It is a kind of progress that meets the need of the current generation without compromising the needs of the future generation (HEC Global Learning, 2014). Modular construction practices help in the reducing, reusing, and recycling of waste, as the materials left over from one project can be stored in the inventory to be reused on the next project. Additionally, modular construction promotes reusing by providing the ability to deconstruct a building, relocate

it and reconstruct it at a new site (NRB, 2014). For hotel projects, and other structures with substantial amounts of repetition involved, constructing the bathrooms or entire rooms, in the form of pods off-site, will reduce the waste at the construction site by 50%, and most of the waste generated in the off-site facility is either reused or recycled. (Mtech Consult Group, 2012).

Using prefabricated components, like sandwich exterior walls, can help in reducing the construction dust emissions by 30%. These components can also help in reducing construction noise by manufacturing off-site, and reducing construction waste by effectively calculating the material required, and reusing the material wasted (Wilkinson, Xia, & Chen, 2016). By adopting modular construction, the total construction period of a project is reduced, which leads to reduction in construction noise for the surroundings for that period of time. Building modular also provides opportunities to obtain Leadership in Energy and Environmental Design (LEED) certification of higher levels (Velamati, 2012).

Additional benefits to sustainability have been reported. A project with high levels of prefabrication will provide less traffic interruption at the site, as there will be a limited and planned number of trips to the site from the fabrication shop (Chen, Okudan, & Riley, 2010). Another research study, on the economic and financial performance of relocatable buildings by Sage Policy Group, suggests that the demand for the buildings in the current market shifts from one form of building to another. For instance, in recent years, the trends have changed from classroom units, to mobile offices and modular complex units have been observed. Thus, the relocatability and reusability of modular components can help in supplying these modular units where the demand is observed (Basu, 2012). Additionally, with modular construction, the chances of equipment getting stolen on site are greatly reduced, as costly elements of construction are finished in the factory and assembled on site (Velamati, 2012).

Modular construction can substantially contribute to sustainability aspects by reducing the impacts of construction on the environment. It also adds value to the construction industry by reducing the schedule, ultimately reducing the costs, and improving the quality of the end product.

2.4 Summary of Literature Review

Previous research suggests that modular methods are effective in providing cost and schedule benefits to a construction project. Studies have also proven that prefabrication can help in making a project sustainable, by reducing the construction waste, dust, and noise, as well as reducing the overall adverse effects of construction on the environment and the surroundings. The research on prefabrication in the hospitality industry is limited. However, (Choi et al., 2017) studied the opportunities and challenges of implementing modular methods in a dense urban environment with survey participants from the Hong Kong construction industry. Therefore, this study focuses on evaluating the opportunities and challenges of implementing modular methods in a hospitality-centric environment, with survey participants from Las Vegas, which is a prominent tourism destination.

Chapter 3: Research Methodology

3.1 Research Methodology Flow

After identifying the research problems and selecting a suitable research method, a literature review was conducted. A standard strategy used in the construction industry, wherein a target respondent is identified, is a survey and interviews. Subsequently, a questionnaire for the survey was prepared. After this stage, the data collection process was carried out in three stages: (1) Preliminary investigation to learn the willingness of industry professionals for survey participation, and to get feedback on the survey questionnaire; (2) Main survey, which includes sending the survey to the construction managers, superintendents, and owners in Las Vegas, who have substantial experience in the construction industry; (3) In-depth interviews were organized to gain detailed data from that gathered in the main survey stage. These three stages are explained in the sections below. To understand the current mindset of the players in the Las Vegas construction industry and to learn the potential barriers and challenges for implementing modular methods, a survey was conducted, followed by face-to-face interviews with the industry professionals, Figure 1.

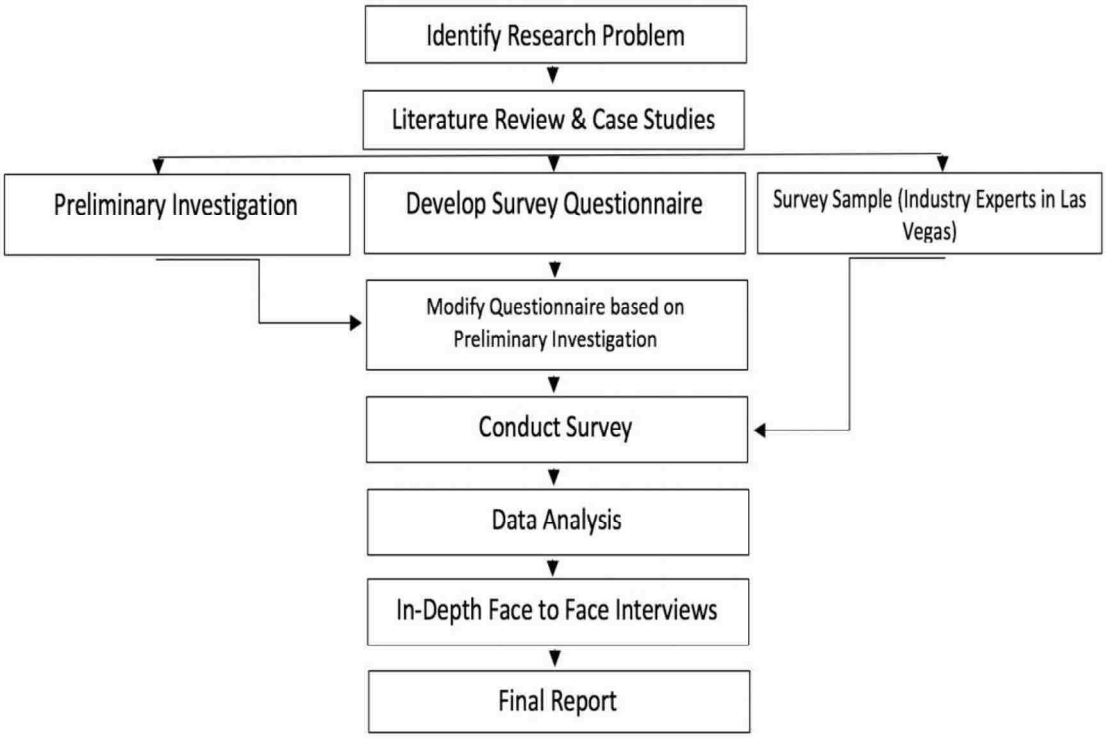

Figure 1: Research Methodology Flow Chart

3.2 Preliminary Investigation

The main aim of the preliminary investigation was to obtain feedback on the survey questionnaire, which was further improved for the main survey. Initial findings suggested that the hotel/resorts visitors face quite a bit of inconvenience due to construction noises around the hotels/resorts. Tourists often visit websites/forums such as TripAdvisor (www.tripadvisor.com) to discuss the current situation around the hotel at which they are planning to stay, Figure 2-4. Modular methods of construction might help in reducing the construction noise by building modules away from the location, and only assembling them on site.

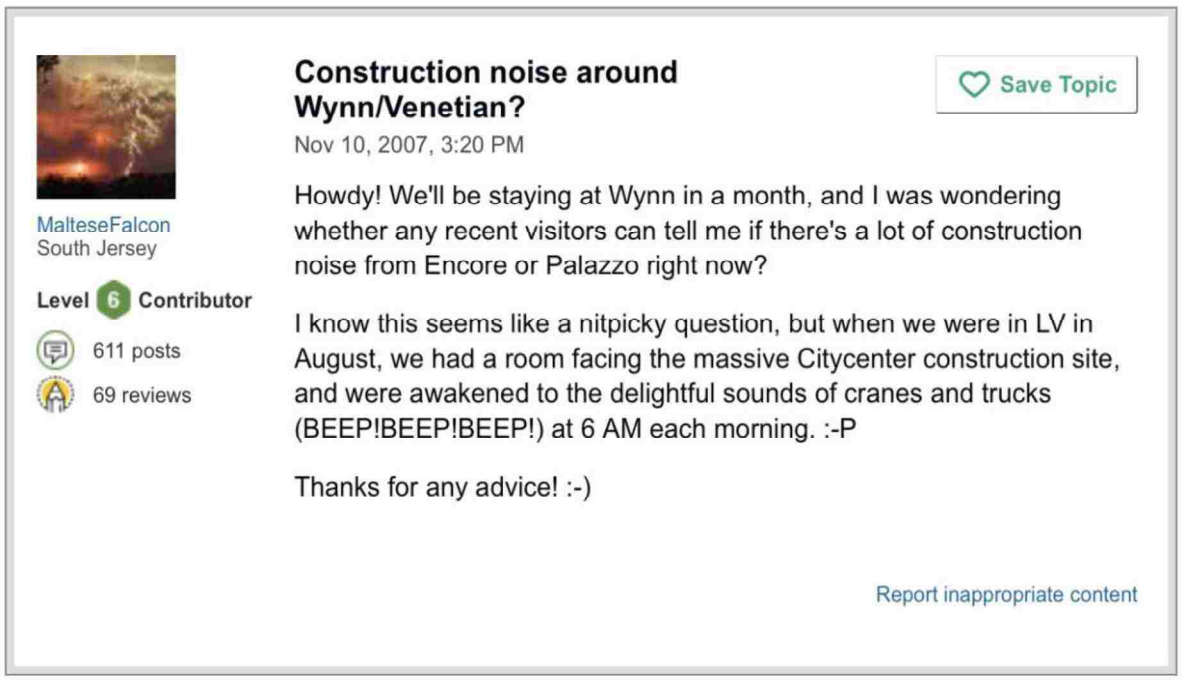

Figure 2: TripAdvisor Comments 1

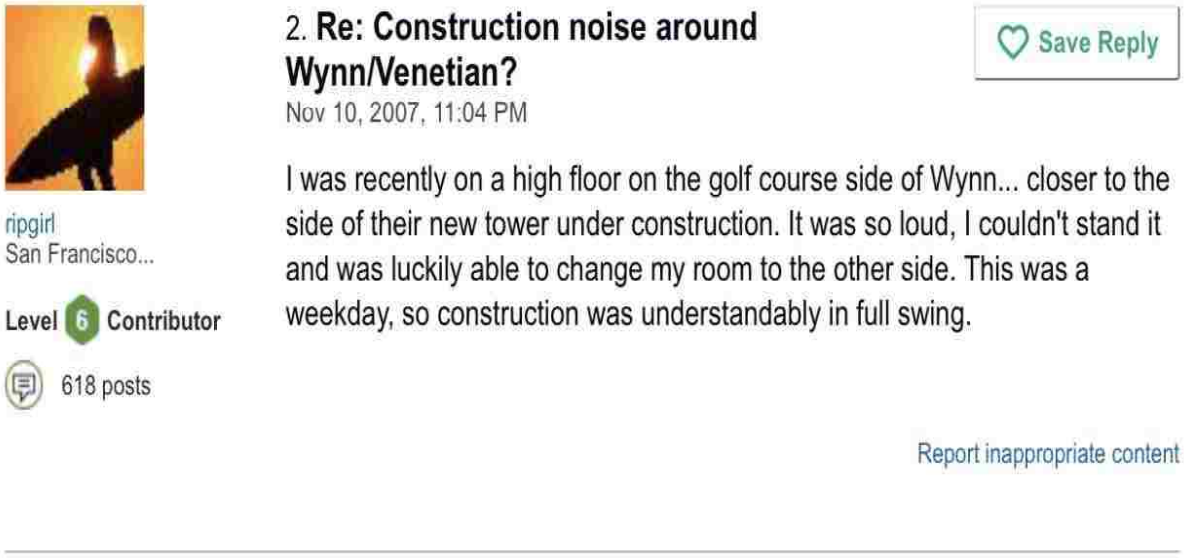

Figure 3: TripAdvisor Comments 2

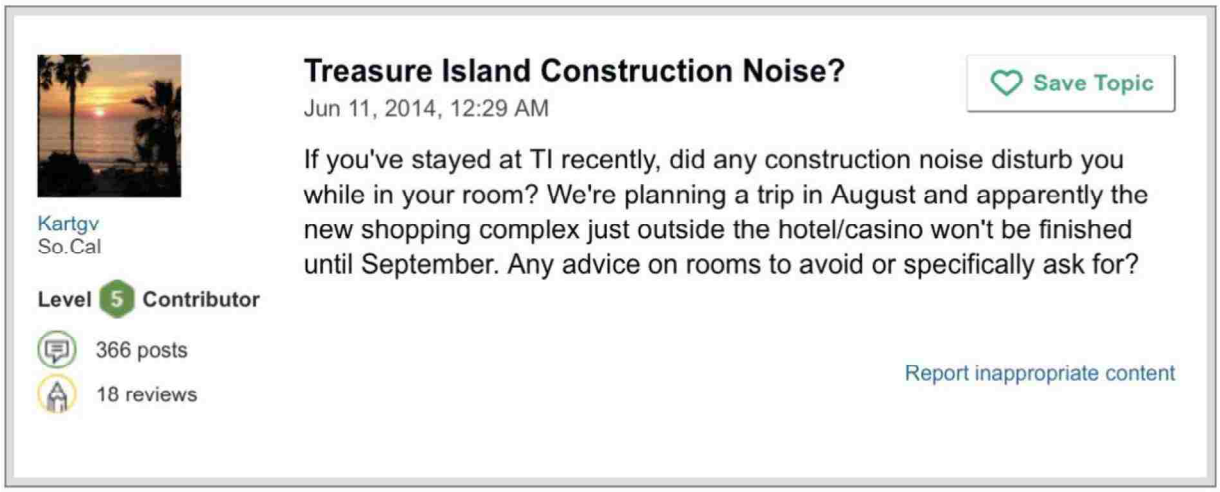

Figure 4: TripAdvisor Comments 3

3.3 Survey Design

The survey questionnaire was developed, using a well-established questionnaire i.e. "Opportunities and Challenges of modular methods in dense urban environment" (Choi et al., 2017), as the basis, with some changes made. To keep the survey simple, the descriptions and definitions were specified after each question, in order to avoid misinterpretation. The questionnaire consisted of 30 questions; twelve of them were open-ended; sixteen were close-ended; and two were matrix/rating-scale type. The survey was modified and finalized in July 2018. The data collection was conducted from August 2018 through November 2018. The data analysis was done in November and December 2018. A web-based survey platform Survey Monkey (https://www.surveymonkey.com) was used to distribute the survey to the participants. The aim of the research was explained in an email that was sent with the link to the survey.

The survey was distributed to 600 industry professionals in Las Vegas. Two reminder emails were sent to the participants after the original email, in the total span of six weeks. The survey collection was aimed for 50 individual responses from experts with varied industry experience, and no more than five participants working at the same company. A total of 63 survey responses from 38 different companies were received. The response rate from the construction professionals in Las Vegas was less than 10%. The respondents included eight owner/developers, 26 general contractors/construction managers, 27 Architect/Engineer's (A/E's) and one subcontractor. The average age of survey participants was 25 years, with five participants having experience of less than 10 years, and 26 participants with more than 30 years of experience. Forty-eight participants belonged to the companies working on projects valued below $100 million, 13 belonged to companies with projects between $100 million and $1 billion, and two belonged to companies with projects of more than $1 billion.

3.4 Data Analysis

Descriptive statistics were used to summarize the data collected from the survey. It was useful to find the patterns in the set of data and summarize them in a meaningful way. Statistical analysis was conducted for each question asked in the survey.

3.5 Face-to-Face Interviews

To get more detailed perspectives of the professionals in the Las Vegas construction industry, three face-to-face interviews were conducted after the survey. The interview participants were: one project manager of an engineering firm, and two project superintendents from two different construction firms. The interview with the project manager was held at the company's main office, while the interviews with the project superintendents were held at the construction trailers located at their construction sites. The face-to-face interviews aimed to discuss the benefits observed and barriers faced in adopting modular methods in any of their construction projects.

3.6 Description of Survey Participants

Company's Primary Service

The survey participants were asked about their company's primary service. Out of 63 participants, eight belonged to owner/developer category, 26 belonged to the contractor/construction manager category, four belonged to the architectural field, 23 belonged to engineering companies, one participant belonged to a subcontracting company, and one was from a company that deals with structural design and manufacturing of steel facades and signs, Figure 5.

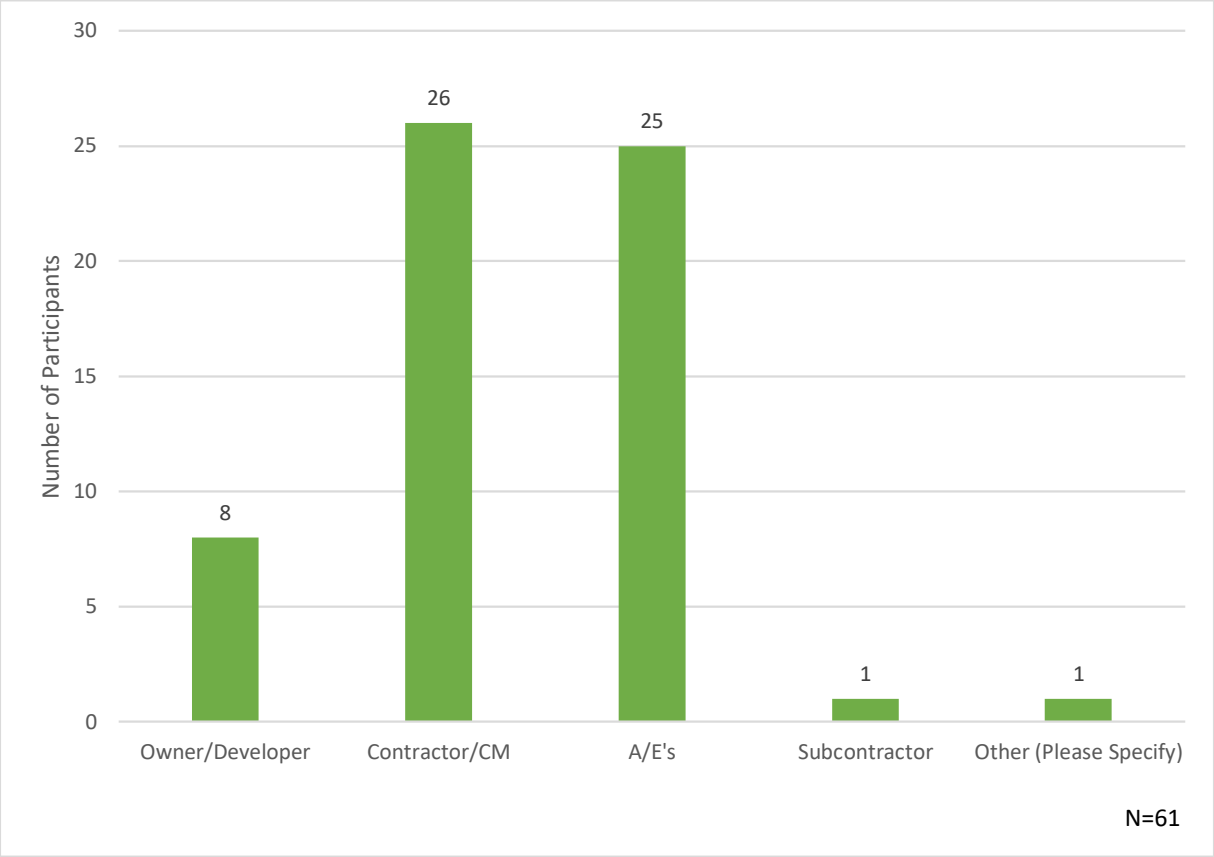

Figure 5: Company's Primary Service

Industry Experience

The survey participants were asked about the number of years they have served the construction industry. The responses show that 39 participants had an experience between 10 and 30 years, 18 participants had experienced of more than 30 years, and six participants had experience of less than 10 years, Figure 6.

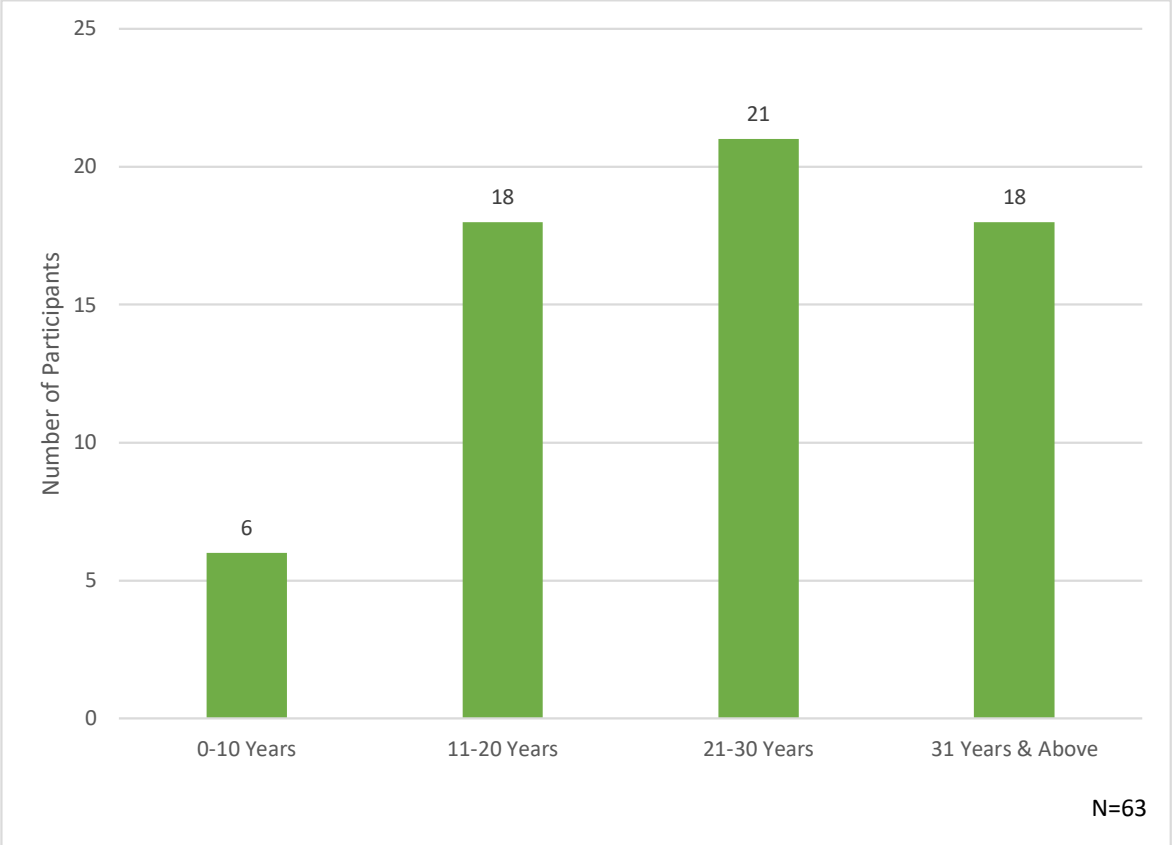

Figure 6: Survey Participants' Years of Industry Experience

Approximate Number of Modular projects worked on in the Career

The survey participants were asked about how many modular projects they had worked on in their careers. The results suggested that 38 participants had worked on less than 10 modular projects, 21 participants had worked on modular projects ranging from 11-100, and four participants had worked on 100 projects and above, Figure 7.

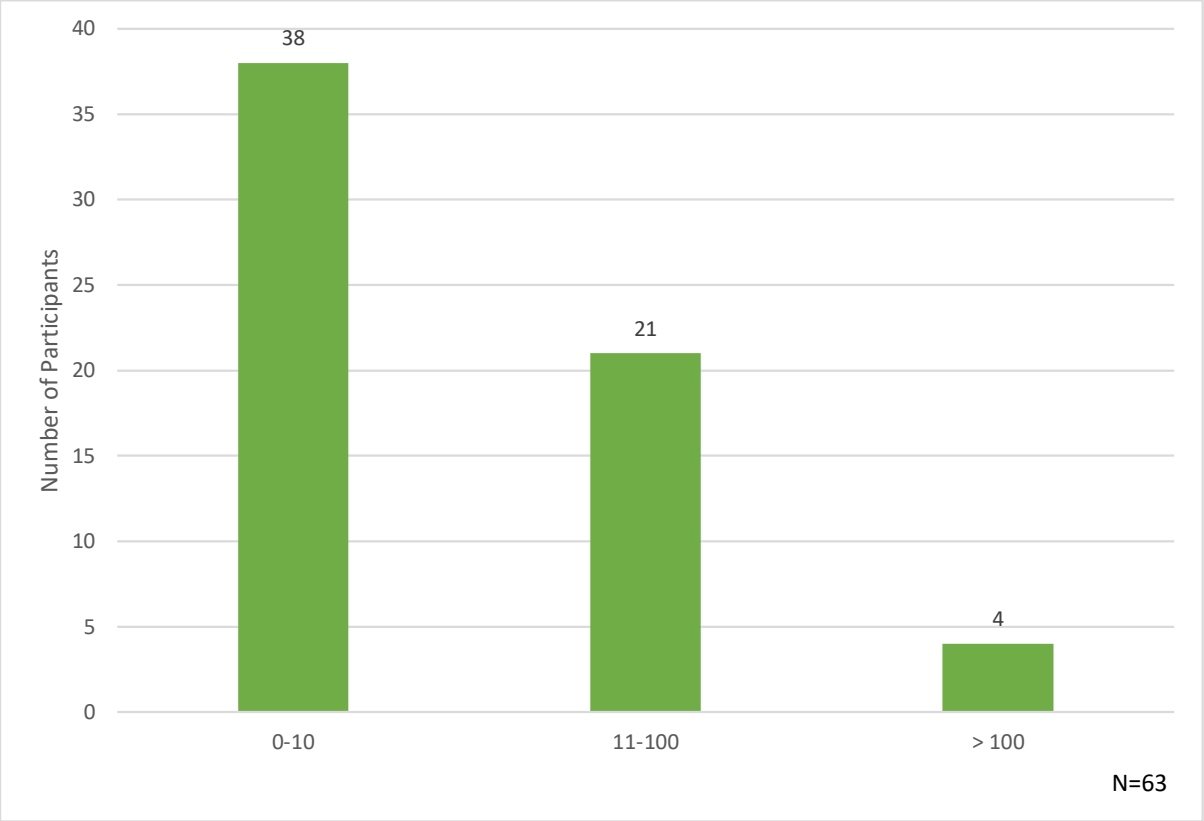

Figure 7: Approximate Number of Modular Projects worked on in career

Company's usual project size

The survey participants were asked about the sizes of the projects they generally undertake. The results indicate that 48 participants worked at companies with usual project sizes of less than $100 million, 13 participants worked at companies with usual project sizes between $100 million - $1 billion, and two participants worked at companies with usual project sizes of more than $1 billion, Figure 8.

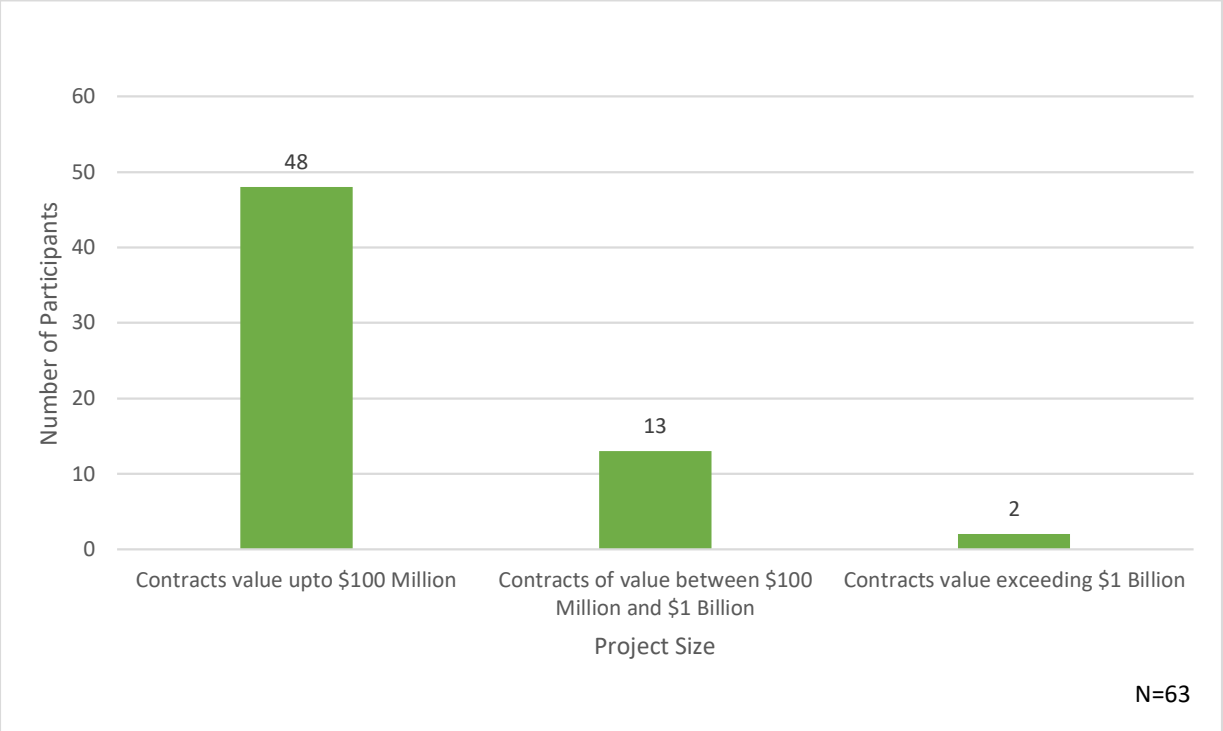

Figure 8: Company's Usual Project Size

Incorporated Modular Methods in the last 12 months

The survey participants were asked whether they had used modular methods in their construction projects in the last 12 months. Forty-two participants (66.67%) selected that they had used modular methods, while 21 participants (33.33%) selected that they had not incorporated modular methods in their construction projects in the past 12 months, Figure 9.

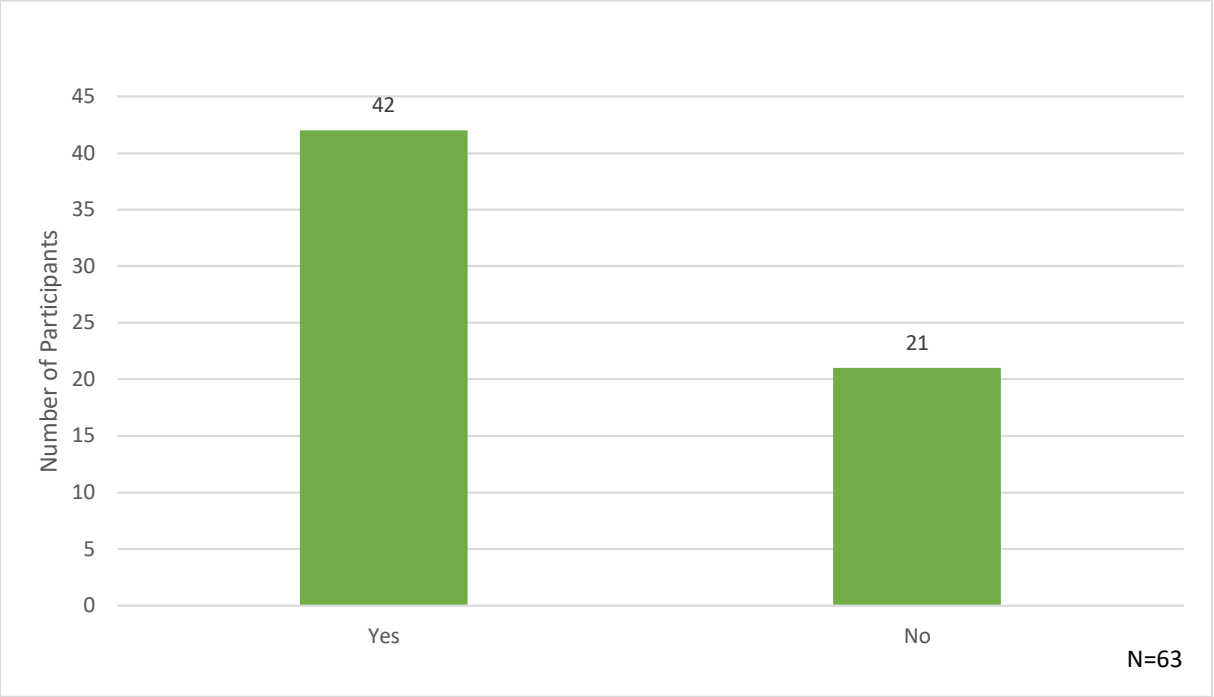

Figure 9: Incorporated modular methods in the last 12 months

Incorporated Modular Methods in the last 5 years

The survey participants were also asked whether they had used modular methods in their construction projects in the last five years. Fifty-one participants (80.95%) selected that they had used modular methods, while 12 participants (19.05%) selected that they had not incorporated modular methods in their construction projects in the past five years, Figure 10.

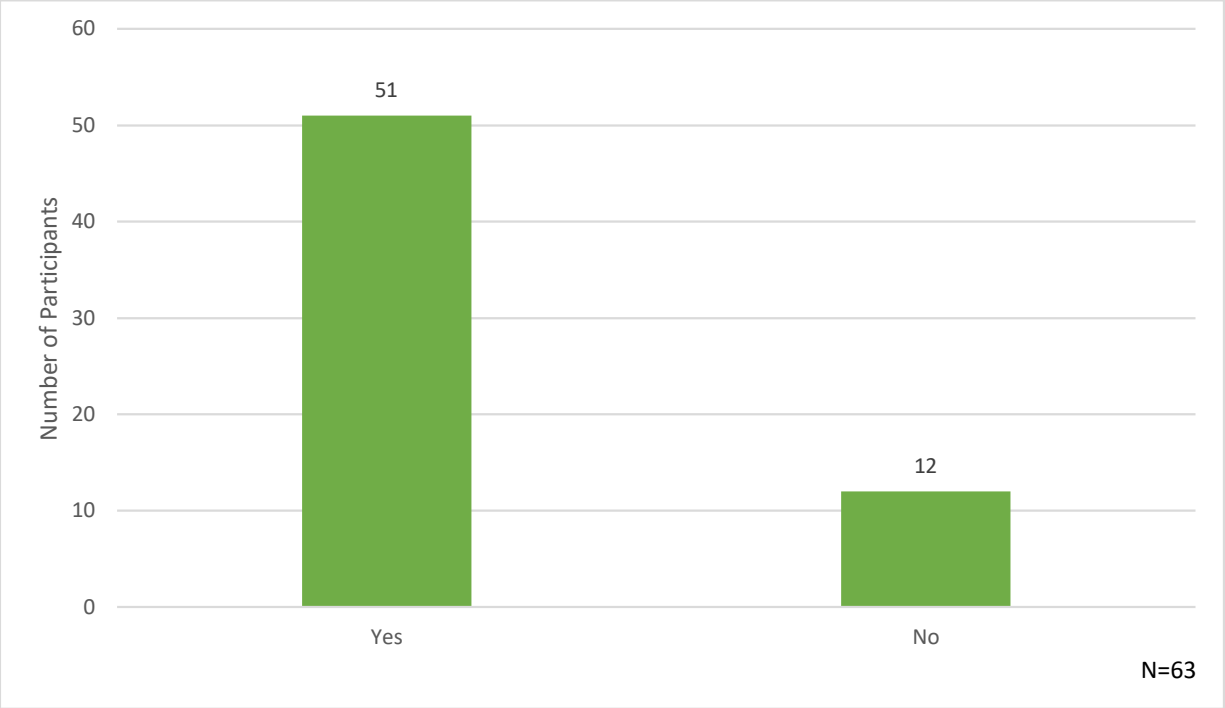

Figure 10: Incorporated Modular methods in the last 5 years

Chapter 4: Findings

4.1 Introduction

The primary goals of this research were to find out the current standpoints and awareness of using modular methods in the Las Vegas construction industry, and to evaluate the opportunities and challenges for modular construction in the Las Vegas construction industry. To achieve this, a 30-question survey was forwarded to the members of the construction industry. The findings of the survey are analyzed and are presented in this chapter. The following topics were investigated through the survey:

- modular elements incorporated in the last 12 months;
- expected and actual benefits of implementing modular methods;
- barriers in implementing modular methods;
- key decision makers to implement modular methods;
- laydown space available at the construction site;
- importance of building information modelling;
- schedule benefits after incorporating modular methods;
- cost benefits after incorporating modular methods;
- quality of labor where module shop/yard is located;
- quantity of labor where module shop/yard is located;
- productivity of labor market where module shop/yard is located;
- anticipated modularization in the next 12 months;
- anticipated modularization in the next 5 years;
- prefabrication opportunity for types of buildings in Las Vegas;
- use of modular methods for post-disaster reconstruction of facilities.

4.2 Modular Elements

Figure 11 below shows the modular elements that were incorporated in the respondents' construction projects in the last 12 months. The five modular elements that were most implemented were; (1) precast concrete elements, (2) prefabricated exterior wall assemblies, (3) steel assemblies (frame, roof truss, etc.), (4) concrete panel systems, and (5) headwall assemblies. These were followed by equipment skids, Heating Ventilation and Air-Conditioning (HVAC), plumbing and electrical racks, risers, etc. and precast concrete elements (piles and pad foundations). Compared to the projects completed in Hong Kong (Choi et al., 2017), the modular elements incorporated in Las Vegas were similar. The other precast elements specified by survey participants were box culverts, drop inlets, manholes, modular communication cabinets, electrical panel assemblies, and bridge girders for monorails. Interestingly, an industry expert working for a prominent home-builder in Las Vegas pointed out that residential construction is currently not utilizing prefabrication in this region. Further, an industry expert from a general contracting company mentioned "prefabricated wood assemblies failed miserably" in one of their projects. In the United States, approximately 90% of residential buildings are constructed using light-frame wood (Ellingwood, Rosowsky, Li, & Kim, 2004), and this area is facing challenges in fully implementing the modular methods.

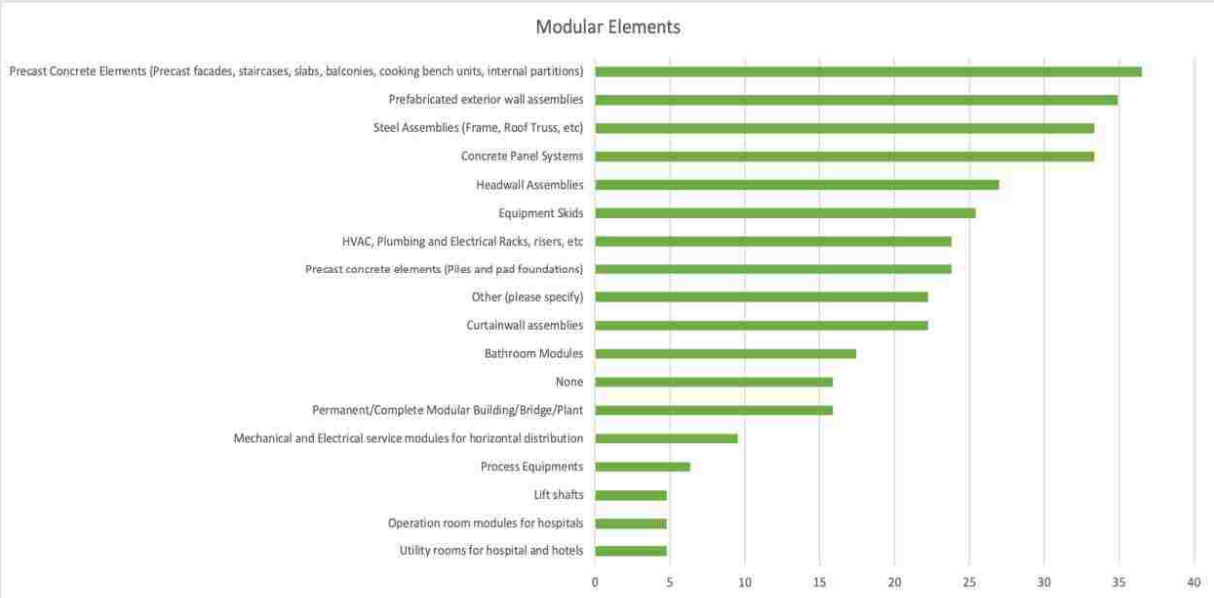

Figure 11: Modular Elements

4.3 Benefits

The study aimed to assess the expectations of the industry professionals who are willing to implement modular methods, and the actual benefits realized after the implementation of those modular methods. The experts were asked to select their expected benefits from preconstruction, as well as the realized actual benefits after using modular methods in their projects in the past five years. The responses were compared to the expectations and actual benefits found in the Hong Kong construction industry (Choi et al., 2017).

Figure 12 shows the expected benefits compared to the actual benefits in Las Vegas. The first four expected and actual benefits in the Las Vegas and Hong Kong construction industries were similar, i.e. improved schedule, lower cost, better quality and improved productivity. Improved schedule was selected as the biggest benefit of implementing modular methods in Las Vegas, as compared to better site operations in Hong Kong.

The survey results suggest the top five expected benefits which were achieved (variance < 5%) were: sufficient labor supply, reduced site-based permits, reduced waste, less site disruption (noise/traffic, dust, etc.), and increased safety.

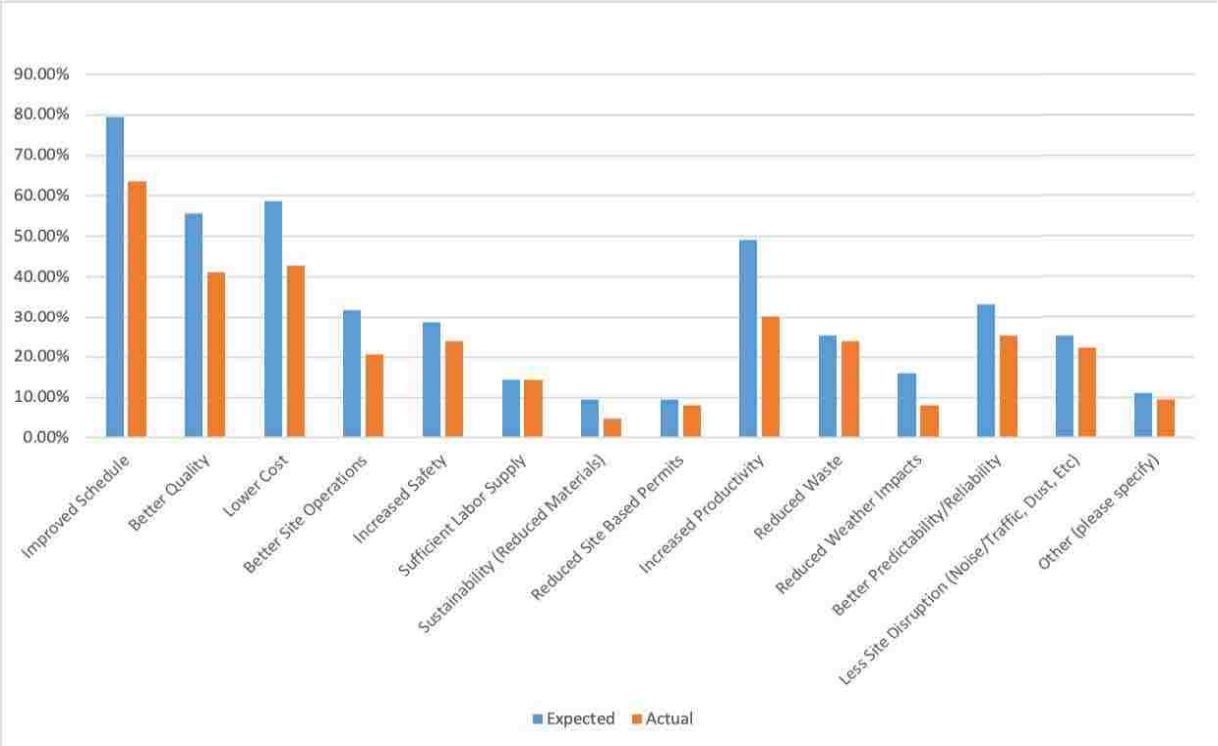

Figure 12: Benefits (Expected vs. Actual)

4.4 Barriers

The questionnaire asked the industry experts to rate the barriers for implementing modular methods in the Las Vegas construction industry on a scale of one to four (1 – no barrier, 2 – small barrier, 3 – moderate barrier, 4 – significant barrier). The list of barriers was obtained from the survey conducted in Hong Kong (Choi et al., 2017) and the question was asked using a matrix/rating scale.

The five barriers most recognized for implementing modular methods in Las Vegas were (1) contractor capability/leadership/experience, (2) program of the building, (3) Owner tendency, (4) Transportation/Logistics and (5) Distance from factory to site. The barrier of urban site (site access and on-site storage area)' ranked sixteenth in Las Vegas, as compared to ranking first in Hong Kong (a dense urban environment). The experts were also asked to rate the site laydown space for their projects as generous, tight, adequate, or inadequate. Approximately 16% of survey participants claimed the site laydown space was generous, and 32% claimed it to be adequate. The least identified barriers in Las Vegas were concern for quality (20) and financing and insurance (21), in Las Vegas which were ranked 13th and 18th in Hong Kong, respectively. A detailed breakdown of recognized barriers to modular construction in Las Vegas is presented below in Figure 13.

Rank	Barrier	Score
1	Contractor Capability/Leadership/Experience	2.65
2	Program of the building	2.65
3	Owner Tendency	2.64
4	Transportation/Logistics	2.61
5	Distance from factory to site	2.58
6	Industry Knowledge	2.55
7	A/E's Tendency	2.52
8	Cost vs. Value	2.52
9	Fabricator Capability/Leadership/Experience	2.51
10	Regulations + Codes + Approval from Authorities	2.48
11	Design + Construction Culture	2.43
12	Supply Chain + Procurement	2.41
13	Labor Union	2.39
14	Design Freeze	2.29
15	Coordination	2.29
16	Urban Site (Site Access and on-site storage area)	2.1
17	Initial Investment	2.1
18	Manufacturing Technology	1.97
19	Site Operations	1.97
20	Concern for Quality	1.92
21	Financing + Insurance	1.77

Figure 13: Barriers

4.5 Other Barriers

Below are the responses provided by the survey participants in the 'others' section, in which they were asked about the barriers for implementing modular construction in Las Vegas:

- trade coordination; for framing assemblies, Building Information Modeling (BIM) is a must;

- lack of information;
- quality of the construction; some modular is cheap, fabricated in china and is not durable;
- cost, coordination, knowledge;
- limited local suppliers;
- trade perception of the pre-fab;
- jurisdiction acceptance and code compliance;
- fabrication facilities that carry the correct certifications for local building officials;
- mainly centers on the building type and knowledgeable, competent fabricators, as well as installers;
- labor mindset;
- cost on locking in a subcontractor before design is complete;
- perhaps the available variety of existing modular units; getting them customized can be an increased cost;
- trade level skill level and training period;
- government approval delays;
- Las Vegas is an "urban island"...distance to other metropolitan areas is great.
- Las Vegas building codes are much stricter than other parts of the country. Something that is used in other parts may not meet code here, especially with multiple jurisdictions within the valley;
- Normal design progression in Las Vegas focuses along a linear path from core/shell to finish trades. Modular construction components like pre-fab bathrooms require more complete design and ownership decisions of finishes and amenities be made early on and NOT to Change - Las Vegas owners are famous for last minute changes in that regard.

4.6 Decision Makers

The survey respondents were asked to answer a question acquired from the (Choi et al., 2017) study: "During the project planning phase of your project, who was responsible for the decision to use modular methods?". The results of the survey in Las Vegas (Figure 14) reported that the decision is primarily made by the owner/client (35%), followed by the construction manager (24%). 'Other' responses in this survey were mainly integrated lean project delivery or engineer. In Hong Kong, the key decision makers were the architects/engineers (46.8%), which is totally opposite as compared to Las Vegas (11.06%).

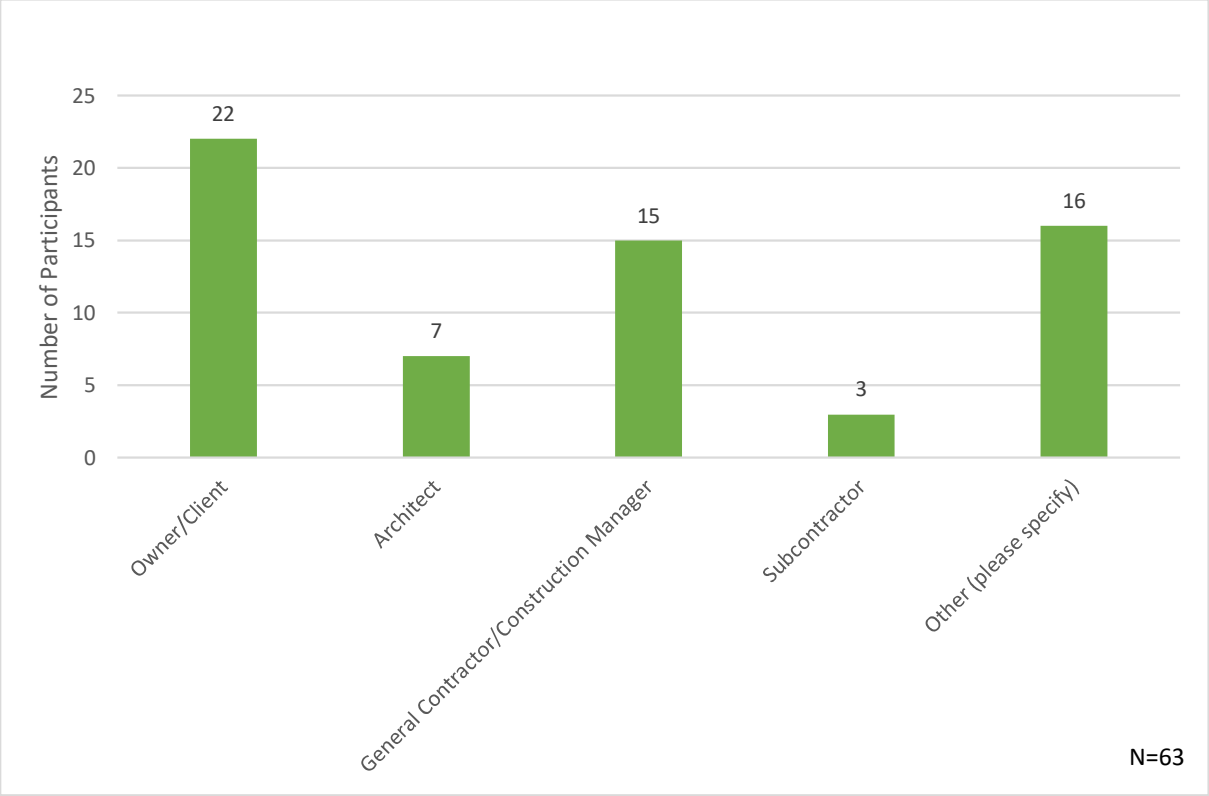

Figure 14: Decision Makers

4.7 Site-laydown Space

The survey participants were asked to state the laydown space available on their construction projects as generous, adequate, tight, inadequate, n/a, or other (please specify), Figure 15. The majority of the participants claimed that the laydown space was adequate. One of the 'other' responses stated that with good project planning, projects with tight site laydown space would have no problems with prefabricated components.

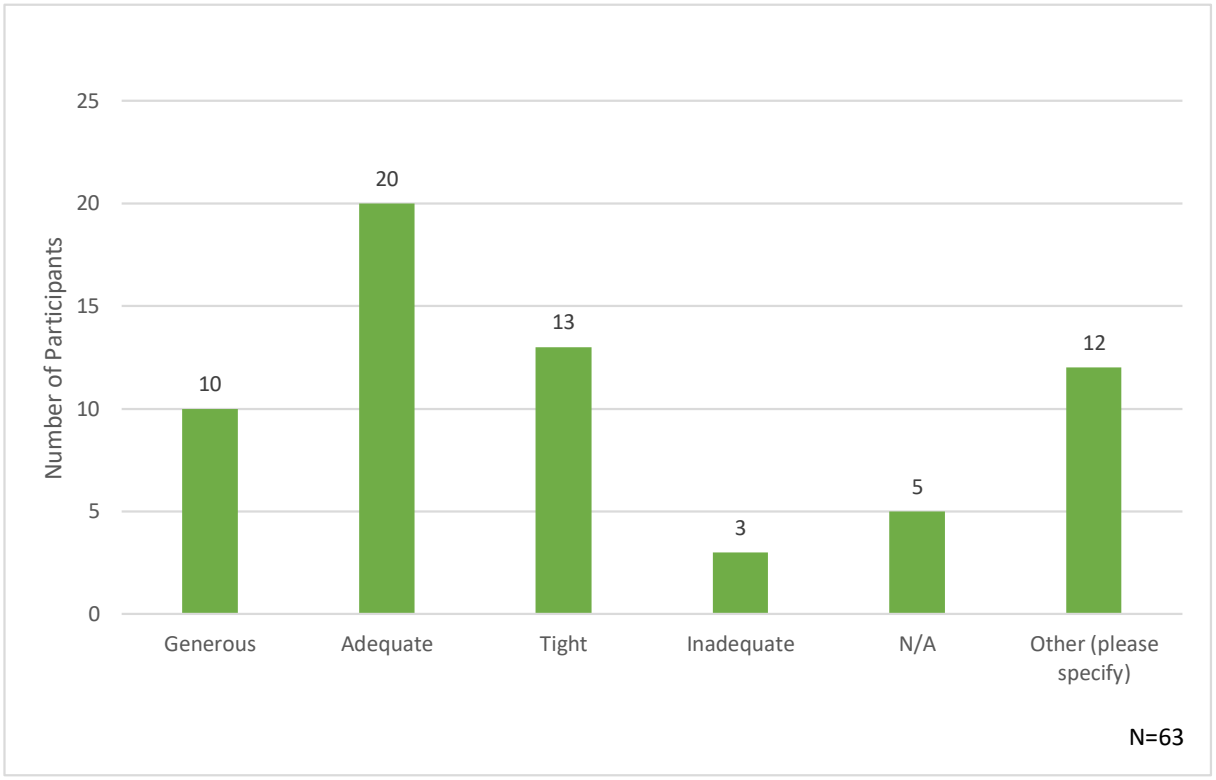

Figure 15: Site Laydown Space

4.8 Building Information Modelling

The survey participants were asked how crucial Building Information Modelling (BIM) is, according to them, for properly implementing modular construction methods. The majority of participants chose the option 'very critical', Figure 16.

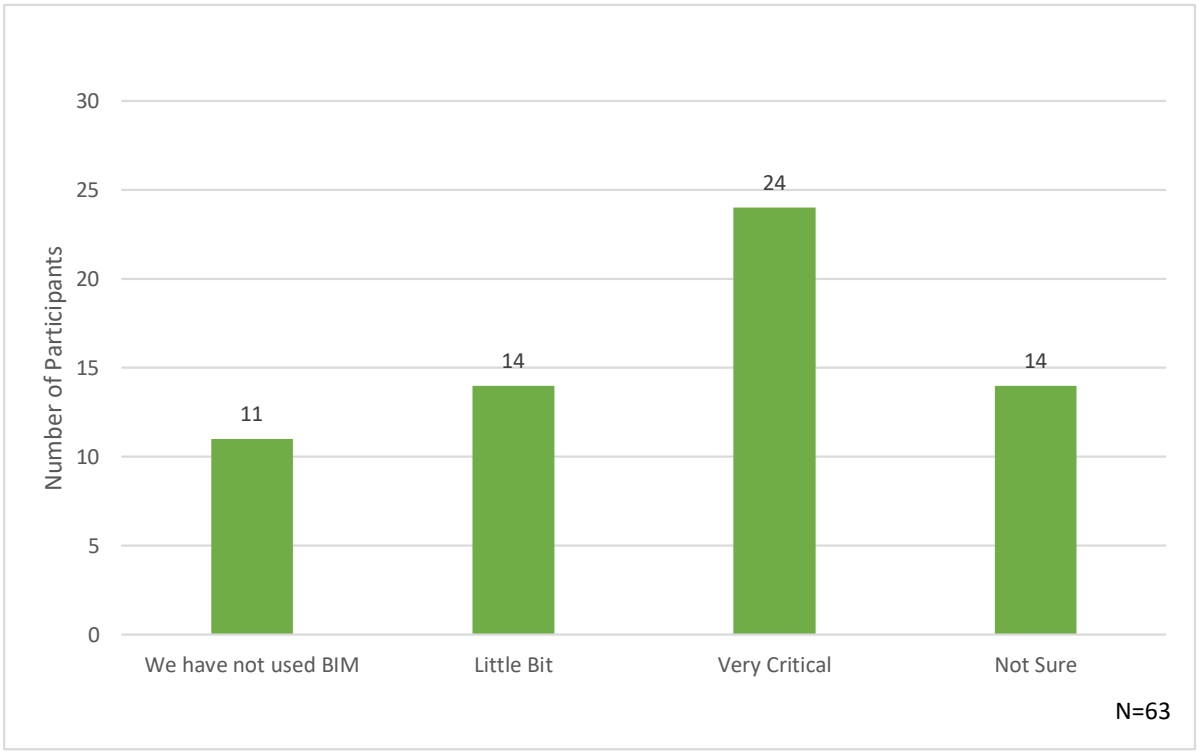

Figure 16: Importance of Building Information Modelling

4.9 Schedule Benefits

The survey participants were asked an open-ended question about the percentage of schedule benefits they had gained in their projects after using modular methods, Figure 17. The majority of respondents gained schedule benefits of between 1-15%. Around 17% of the participants had no knowledge about the schedule benefits, and 17% chose N/A, as they did not incorporate modular

methods in their projects. Nearly 15% of participants stated that they did not receive any schedule benefits.

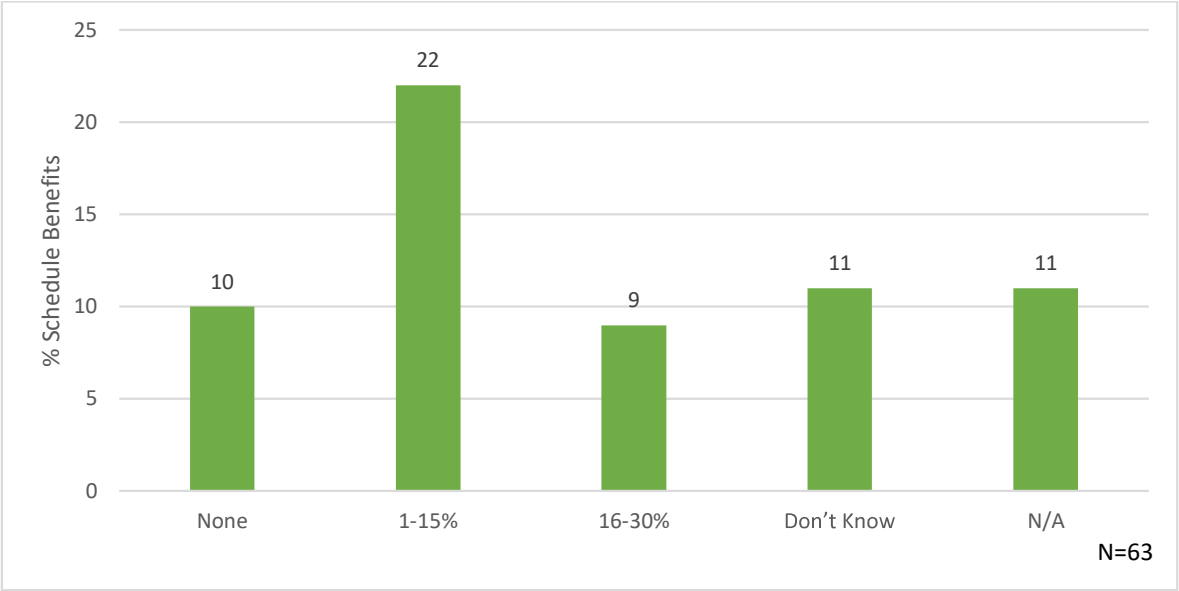

Figure 17: Schedule Benefits

4.10 Cost Benefits

The survey participants were asked an open-ended question about the percentage of cost benefits they had in their projects after using modular methods. Around twenty-five percent of participants reported that they received cost benefits between 1-15%; 15.3% of participants received cost benefits between 16-30%; 14.3% of participants received no cost benefits; 6.4% of participants claimed that using modular methods was more expensive; 27% of participants did not know about the cost savings for the project; and 12.7% of participants chose N/A as they did not adopt modular methods, Figure 18.

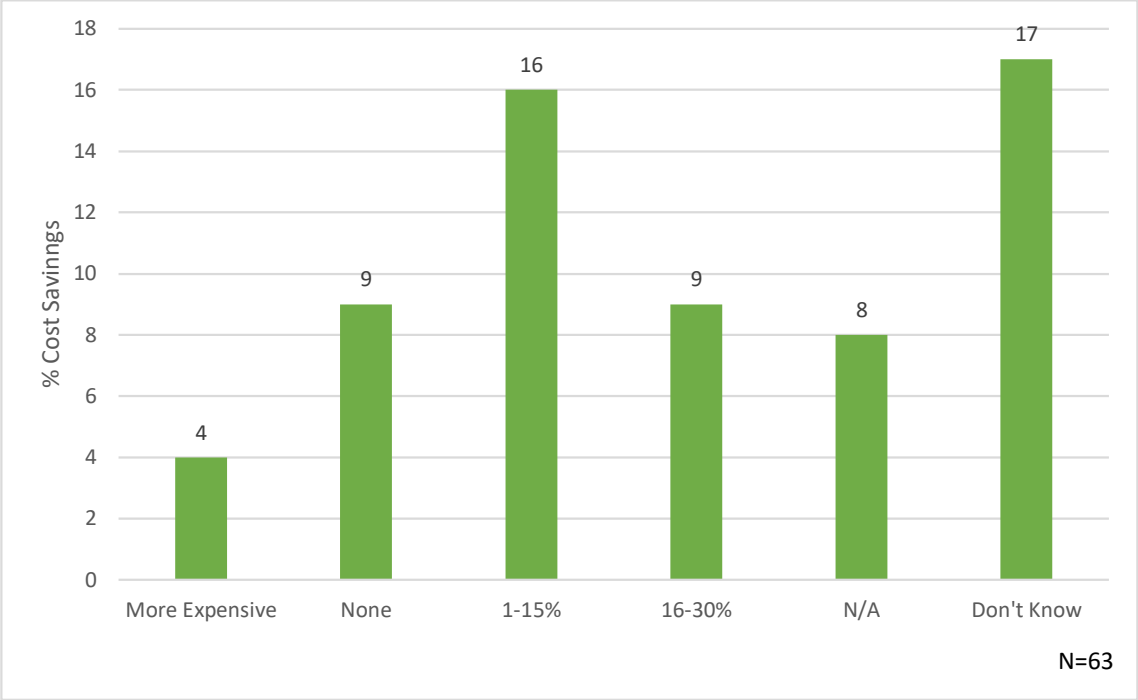

Figure 18: Cost Benefits

4.11 Quality of Labor

The survey participants were asked about the quality of labor present at the location of the modular shop/factory/yard they had used. The majority (46.03%) of survey participants selected the quality of labor to be medium, Figure 19.

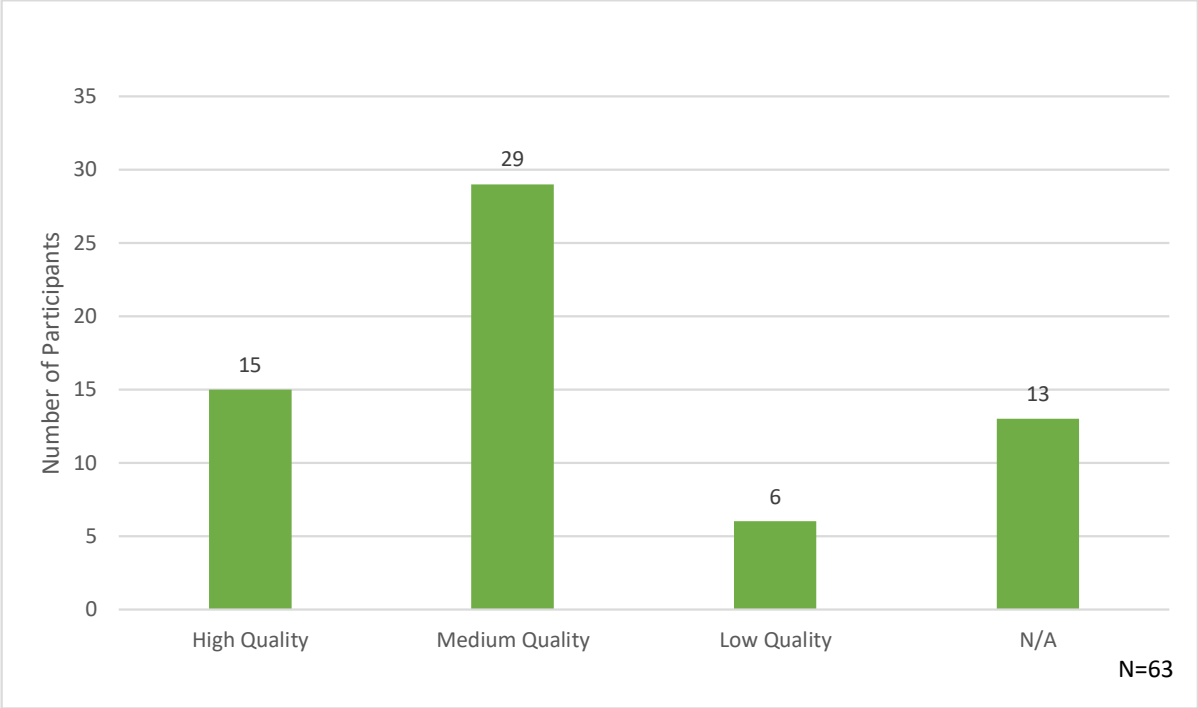

Figure 19: Quality of Labor

4.12 Quantity of Labor

The survey participants were asked about the quantity of labor present at the location of the modular shop/factory/yard they had used. The majority of survey participants (58.7%) selected the quality of labor to be adequate, Figure 20.

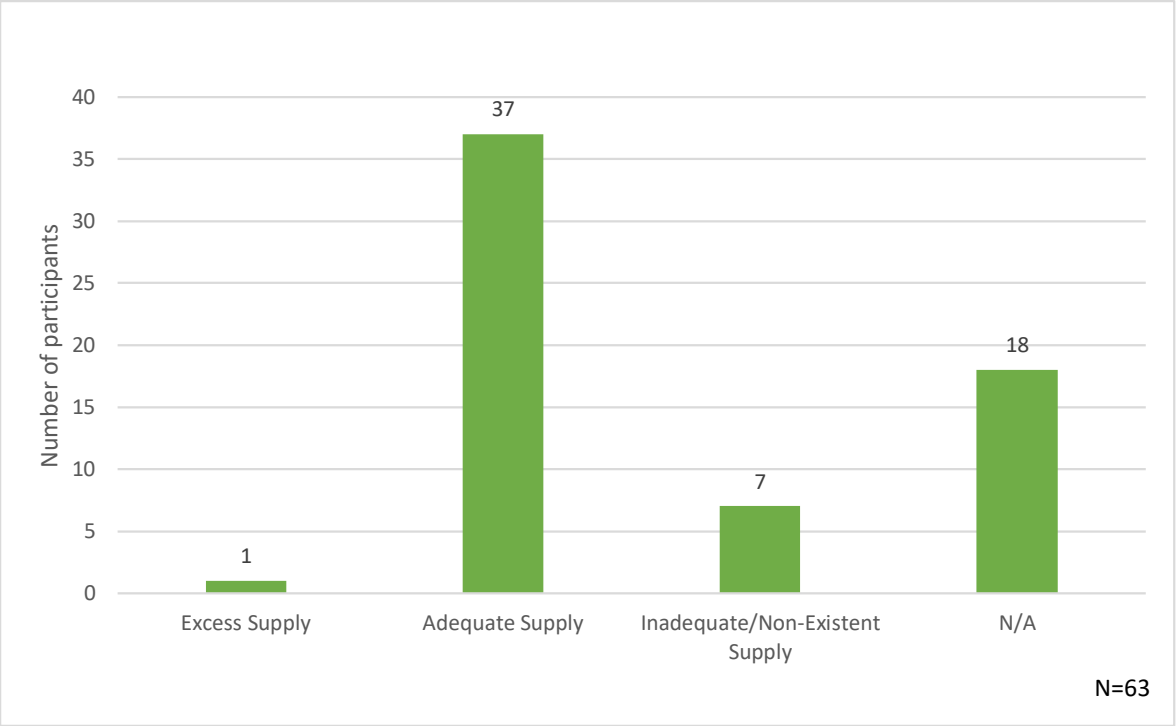

Figure 20: Quantity of Labor

4.13 Productivity of Labor Market

The survey participants were asked about their standpoints on the productivity of the labor market at the location of the modular shop/factory/yard they had used. Around 44 of the participants selected that the productivity of labor market met their expectations, whereas around 44% of participants were not aware about the productivity, Figure 21.

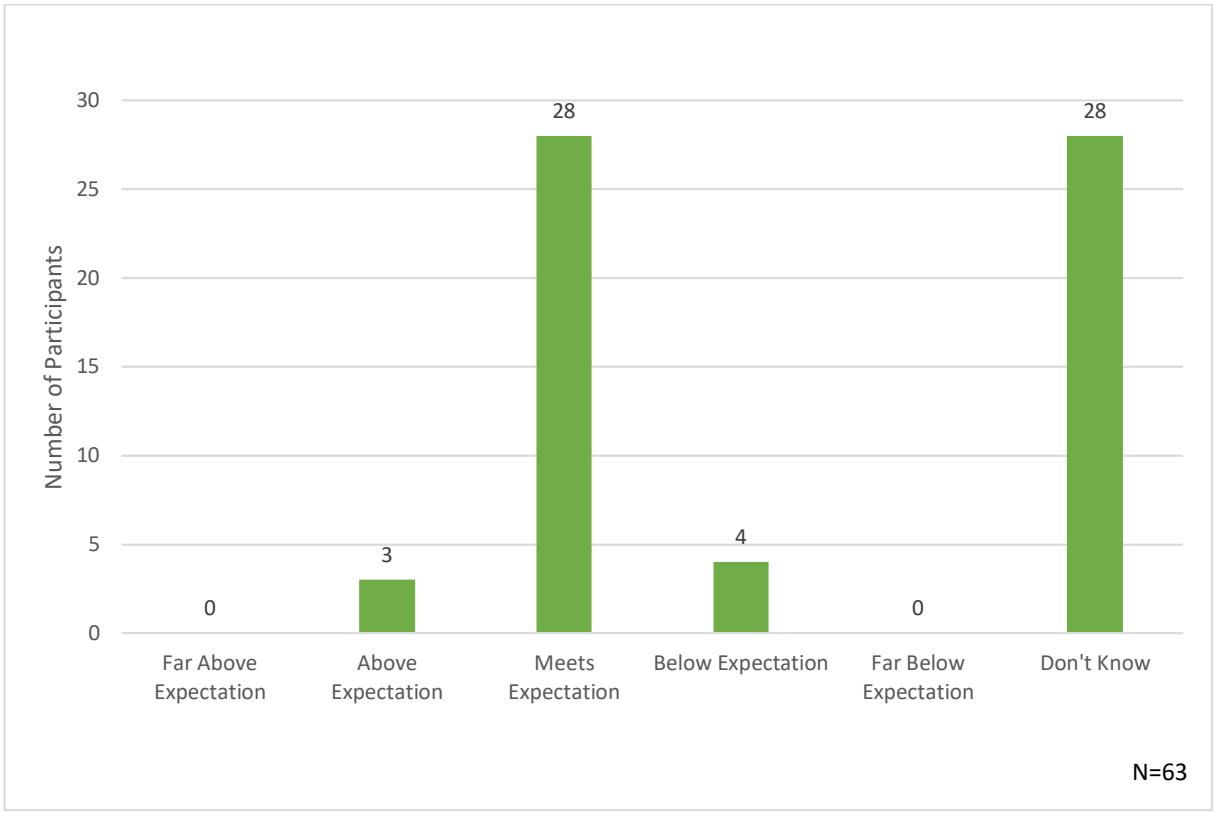

Figure 21: Productivity of Labor Market

4.14 Anticipated Modularization in the next 12 Months

The survey participants were asked about how often they anticipate using modular methods in the next 12 months. Around 60% of the participants said they would keep using the modular methods at the same level they are currently implementing them; 23.8% of participants said they would not use modular methods at all; and 11% of participants claimed they would use more modular methods in the next 12 months, Figure 22.

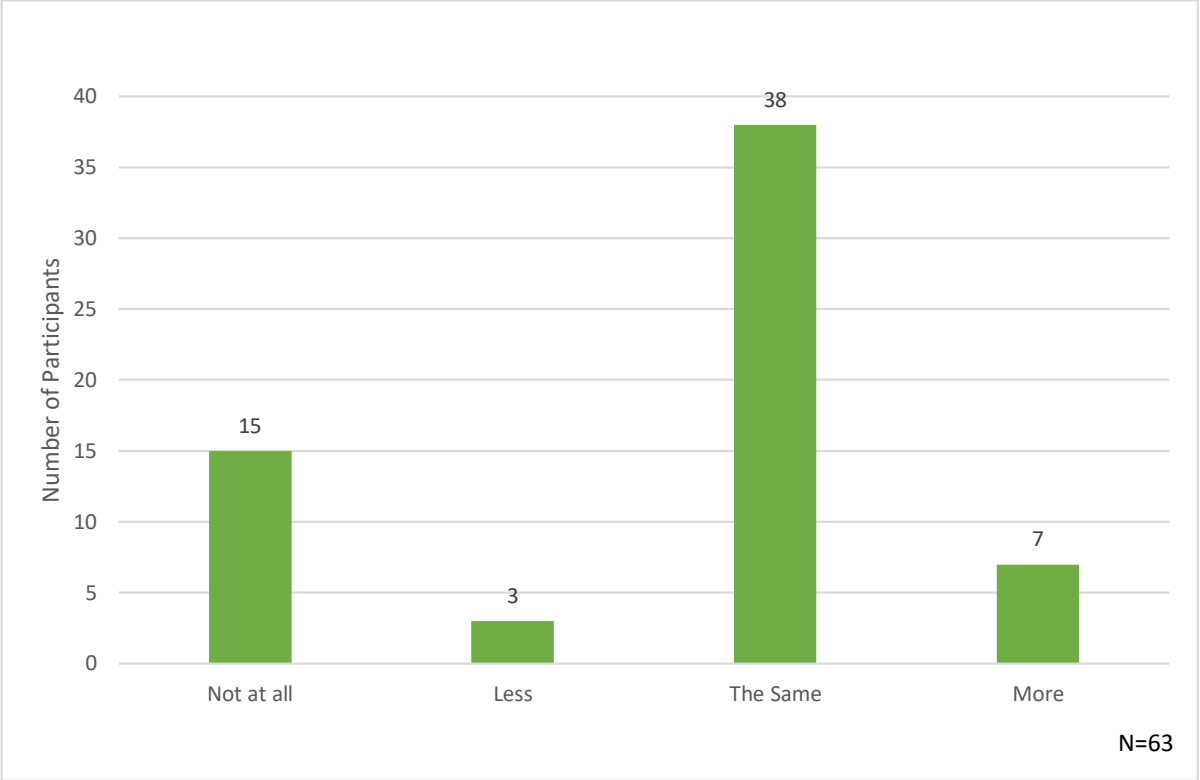

Figure 22: Anticipated Modularization in the next 12 months

4.15 Anticipated Modularization in the next 5 Years

The survey participants were asked about how often they anticipate using modular methods in the next five years. Around 44% of participants claimed they would use modular methods the same amount, whereas 36.5% of the participants said they would use modular methods more, Figure 23.

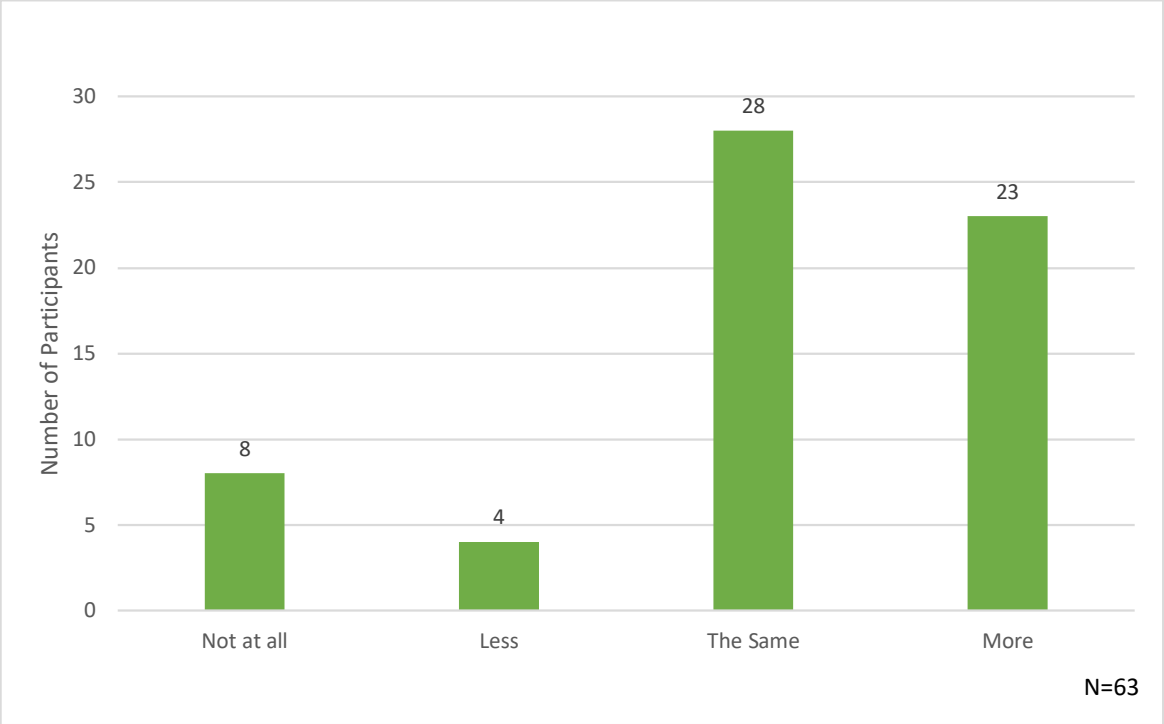

Figure 23: Anticipated Modularization in the next 5 years

4.16 Rank Buildings for prefabrication opportunity

The survey participants were asked to rank the buildings types according to their opportunity of prefabrication in the Las Vegas construction industry, Figure 24. Hotels were ranked sixth among 13 categories. Parking garages were ranked first in terms of prefabrication, followed by hospitals.

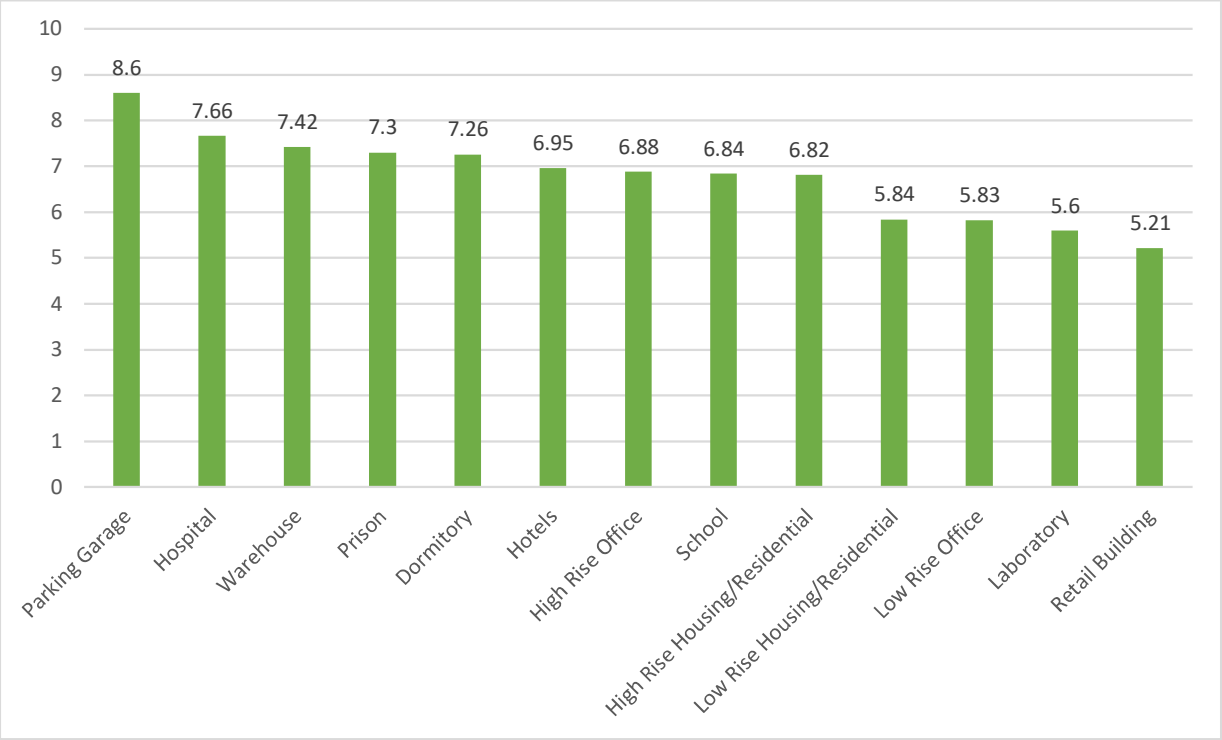

Figure 24: Rankings of types of building for prefabrication opportunity

4.17 Post Disaster Reconstruction of Facilities

The survey participants were asked about their standpoints on utilizing modular methods and the prefabrication of components at the location of a disaster, such as a wildfire, tsunami, earthquake, etc., Figure 25. Around 32% of participants strongly agreed with this idea, whereas 62.9% of participants agreed that modular methods could be used for post-disaster reconstruction of facilities. The respondent who strongly disagreed, claimed that the amount of preconstruction planning and coordination would not allow construction to begin as quickly as with traditional methods. This respondent also commented that it would be challenging to find an adequate and skilled workforce to take part in the specialized construction. However, an interesting solution to this issue, given by another respondent, was be that the prefabricators in the non-affected areas

could start working on the modules during the clean-up process in the affected disaster areas and deliver them as soon as the cleanup process was finished.

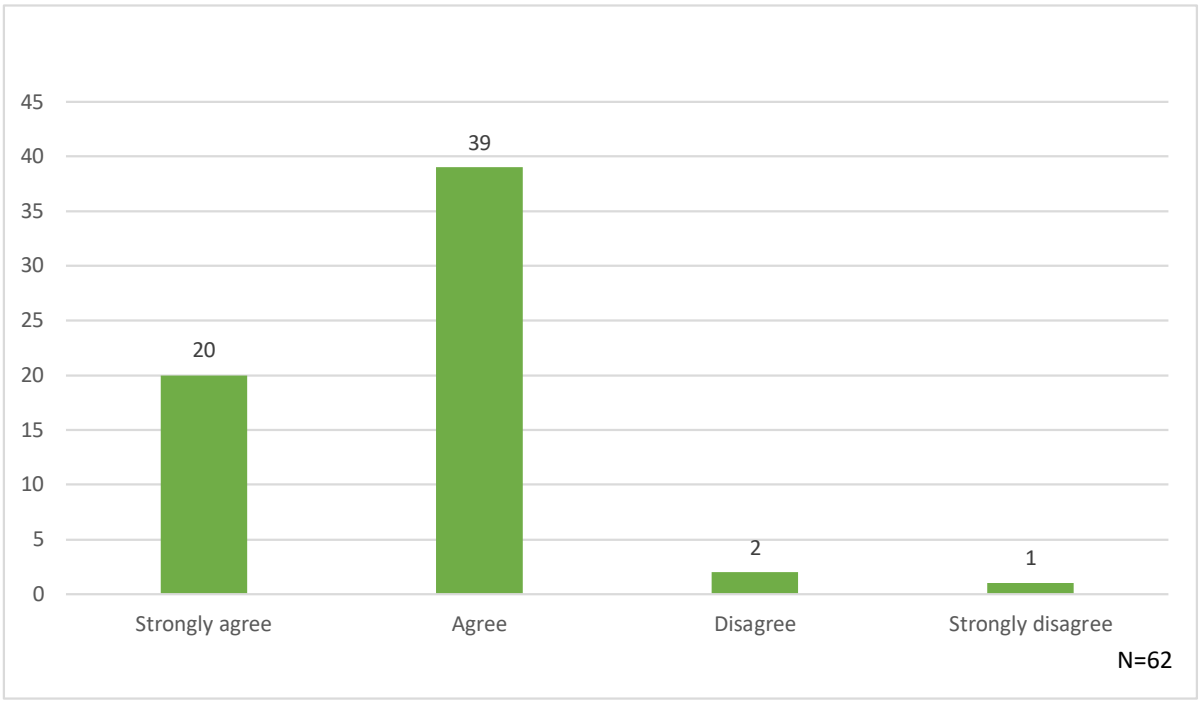

Figure 25: Post Disaster Reconstruction of Facilities

Chapter 5: Conclusion and Recommendations

5.1 Introduction

In order to assess the opportunities and challenges of implementing modular construction techniques in Las Vegas, a hospitality-centric environment, a survey was conducted with 63 participants from 38 different companies. No more than five participants were included from one company for the survey. The companies included owners/developers, general contractors, engineers, architects, home builders, and two government agencies. The scope of this study included learning about modular elements implemented in Las Vegas in the last 12 months, the industry's perspective and experience on the barriers of implementing modular methods in Las Vegas, and the decision makers responsible to implement these modular methods.

5.2 Summary of what was learned

The findings from this study are as follows: Firstly, the five mostly-implemented modular elements in Las Vegas are precast concrete elements, prefabricated exterior wall assemblies, steel assemblies (frame, roof truss, etc.), concrete panel systems and headwall assemblies. Secondly, the top four actual benefits of implementing modular methods in Las Vegas are improved schedule, lower cost, better quality, and improved productivity. Third, the five most recognized barriers in implementing modular methods are contractor capability/leadership/experience, program of the building, owner tendency, transportation/logistics and distance from factory to site. Further, the key decision makers for using modular methods in Las Vegas are owner/developers, followed by general contractors.

5.3 Contributions

Contributions to Practice

This manuscript helps in better understanding of the relationship between modularization and sustainable construction, and how implementing modular methods can improve the sustainability aspects of a construction project. Additionally, this study also presents the industry's standpoint on the expectations, benefits, and barriers for implementing modular methods.

5.4 Recommendation for Future Research

A prominent barrier to implement modular construction in the Las Vegas construction industry was identified to be the building code compliance and jurisdiction acceptance. One of the respondents stated that the compliance is more stringent due to multiple jurisdiction in the Las Vegas valley; Clark County Building Department, City of Las Vegas Building Department, City of Henderson Building Department, and Public Works Department. To overcome this barrier, further studies need to be conducted related to managing building code compliance and the acceptance of modules by the different jurisdictions.

Appendix A: Survey PDF

The purpose of this survey is to assess the opportunities and challenges for implementing the Modular Construction techniques in Las Vegas construction Industry.

Modular Construction is a process which includes shifting of fabrication of modules to be installed on the site to a safer and controlled environment. The manufacturing process generally takes place at a specialized facility, in which various components are joined together to form a final component or a part of final installation. Modularization can also include preconstruction of complete system away from the job site. The process of adopting modular construction method includes:

- Fabrication of components offsite.
- Shipping of components to module site.
- Assembling of components in a module shop.
- Shipping of modules to the construction site.
- Installation of modules.

Advantages of modular construction include:

- Lower Capital Costs.
- Improved Scheduled Performance.
- Increased Productivity.
- Higher Overall Quality.
- Increased Safety Performance.
- Reduced Waste and Better Environmental Performance.
- Reduced Site-based Permits.
- Improved Reliability.

Expected Benefits from the study?

The survey results will help in summarizing the challenges and barriers for implementing Modular Construction in Las Vegas.

You may complete the survey by manually marking up the document and return via pdf scan/email. Please return to Shreyansh Paliwal, via email: shreyansh.paliwal@unlv.edu

Q1. Your Name?

_____

Q2. Industry Experience (Years)?

_____

Q3. Approx. Number of Modular Projects worked on in career?

_____

Q4. Company Name?

_____

Q5. Company's Primary Service?

- Owner/Developer

- Contractor/CM
- Architecture
- Engineering
- Subcontractor
- Other: _____

Q6. Have you incorporated Modular methods (Prefabrication/Preassembly/Off-site fabrication/Permanent Modular Construction) in one or more projects in last 12 months?

- Yes
- No

Q7. Have you incorporated Modular methods in one or more projects in last 5 years?

- Yes
- No

Q8. Have you incorporated the following modular elements in one or more projects in the last 12 months (check all that apply).

Non-volumetric applications (items that do not enclose usable space

- Precast concrete elements (Precast facades, staircases, slabs, balconies, cooking bench units, internal partitions)
- Precast concrete elements (piled and pad foundations)
- Concrete panel system
- HVAC, Plumbing and Electrical racks, risers, etc. (non-volumetric)
- Steel assemblies (frame, roof trusses, etc.)
- Raised floor and suspended ceiling systems

- Equipment skids
- Curtainwall assemblies
- Prefabricated exterior wall assemblies

Volumetric applications (units that enclose usable space)

- Headwall assemblies
- Bathrooms module
- Utility (Plant) rooms for hospitals or hotels
- Operation room modules for hospitals
- Lift shafts
- Mechanical and Electrical service modules for horizontal distribution (building services riser shafts)
- Process equipment

Q8. In your experience, what were the **pre-construction expected benefits** in terms of using Modular Construction Method?

- Improved Schedule
- Better Quality
- Lower Cost
- Better Site Operations
- Increased Safety
- Sufficient Labor Supply
- Sustainability (Reduced Materials)

- Reduced Site Based Permits
- Increased Productivity
- Reduced Waste
- Reduced Weather Impacts
- Better Predictability/Reliability
- Less Site Disruption (Noise, Traffic Dust, etc.)
- Others:_____

  _____

  _____

  _____

  _____

  _____

Q9. What were the **actual benefits** realized after using Modular Construction method?

- Improved Schedule
- Better Quality
- Lower Cost
- Better Site Operations
- Increased Safety
- Sufficient Labor Supply
- Sustainability (Reduced Materials)
- Reduced Site Based Permits
- Increased Productivity

- Reduced Waste
- Reduced Weather Impacts
- Better Predictability/Reliability
- Less Site Disruption (Noise, Traffic Dust, etc.)
- Others:_____

_____

_____

_____

_____

_____

Q10. According to you, what are the **barriers for the implementation** of using Modular Construction by Hospitality Industry here in Las Vegas?

Barriers	**No Barrier**	**Small**	**Moderate**	**Significant**
Design+ Construction Culture				
Distance from Factory to Site				

Program of the Building				
Transportation / Logistics				
Industry Knowledge				
Supply Chain + Procurement				
Cost vs. Value				
Regulations + Codes + Approval from Authorities				
Site Operations				
Concern for Quality				
Owner Tendency				
Contractor Capability/Leadership/Experience				

Fabricator Capability/Leadership/Experience				
A/Es Tendency				
Design Freeze				
Manufacturing Technology				
Urban Site (Site access and on-site storage area)				
Financing + Insurance				
Initial Investment				
Coordination				
Labor Union				

Other Barriers for implementing modular construction in Las Vegas:

_____

_____

_____

Q11. What schedule benefits did you get after adopting Modular Construction? **(% Schedule Savings)**

_____

Q12. What cost benefits did you get after adopting modular construction? **(% Cost Savings)**

_____

Q13. During the planning phase for your project, who was **responsible for the decision** to use Modular Method?

_____

Q14. What is the approximated **% Modularization** of the project?

(Ref: % Modularization: Portion of original site-based work hours exported to fabrication and module shops)

_____

Q15. What is the **location of the site** of the project?

_____

Q16. What is the **location of Module shop**/ factory/ yard of the project?

Q18. How critical is Building Information Modeling (BIM) to your ability to prefabricate assemblies?

- We have not used BIM
- Little Bit
- Very Critical
- Not Sure

Q17. What is the **quality** of the labor market where the module shop/ factory/ yard is located?

- High Quality
- Medium Quality
- Low Quality

Q18. What is the **quality** of the labor market where the module shop/ factory/ yard is located?

- Excess Supply
- Adequate Supply
- Inadequate/Non-Existent Supply

Q19. In the next 12 months, how often do you anticipate using modular method**?**

- Not at all
- Less
- The Same
- More

Q20. In the next 5 years, how often do you anticipate using modular method?

- Not at all
- Less
- The Same
- More

Thank you for your prompt participation and for your time and effort in completing this survey.

Appendix B: Survey Monkey Screen Captures

Modularization is termed as a process of Prefabricating components of a building Off-Site, and assembling them On-Site.

University of Nevada, Las Vegas is conducting a study on the current status and industry standpoint for Modular Construction/Prefabrication in Las Vegas Valley.

Purpose: This research focuses on finding out the current expectations and barriers/challenges in achieving higher levels of prefabrication/modularization.

The survey includes **30 questions** and the estimated average time to finish is **11-12 minutes**.

If you have any questions, please reach out to

Shreyansh Paliwal, Masters' Student, University of Nevada, Las Vegas
paliwal@unlv.nevada.edu

Jin Ouk Choi, Ph.D., Assistant Professor, University of Nevada, Las Vegas
jinouk.choi@unlv.edu

* 1. Company's primary service?

- ◯ Owner/Developer
- ◯ Contractor/CM
- ◯ Architecture
- ◯ Other (please specify)
- ◯ Engineering
- ◯ Subcontractor

* 2. Company's Name?

3. Your Name?

* 4. Industry Experience? (Years)

* 5. An approximate number of Modular/Pre-Fabricated projects worked on in career?

* 6. Company's usual project size?

- ◯ Contracts of Value upto $100 Million
- ◯ Contracts of value between $100 Million and $1 Billion
- ◯ Contracts of value exceeding $1 Billion

* 7. Did you incorporate Modular Methods (Prefabrication/Pre-assembly/Off-site fabrication/Permanent Modular Construction) in one or more projects in last 12 months?

○ Yes ○ No

* 8. Did you incorporate Modular Methods/Pre-Fabrication in one or more projects in last 5 years?

○ Yes ○ No

* 9. Did you incorporate the following Modular/Pre-fabricated elements in the last 12 months? (Check all that apply)

- [ ] Precast Concrete Elements (Precast facades, staircases, slabs, balconies, cooking bench units, internal partitions)
- [ ] Precast concrete elements (Piles and pad foundations)
- [ ] Concrete Panel Systems
- [ ] HVAC, Plumbing and Electrical Racks, risers, etc
- [ ] Steel Assemblies (Frame, Roof Truss, etc)
- [ ] Equipment Skids
- [ ] Curtainwall assemblies
- [ ] Prefabricated exterior wall assemblies
- [ ] Headwall Assemblies
- [ ] Other (please specify)

- [ ] Bathroom Modules
- [ ] Utility rooms for hospital and hotels
- [ ] Operation room modules for hospitals
- [ ] Lift shafts
- [ ] Mechanical and Electrical service modules for horizontal distribution
- [ ] Process Equipments
- [ ] Permanent/Complete Modular Building/Bridge/Plant
- [ ] None

* 10. What were your **Pre-Construction Expected Benefits** in terms of using Modular Construction/Pre-Fabrication?

- [ ] Improved Schedule
- [ ] Better Quality
- [ ] Lower Cost
- [ ] Better Site Operations
- [ ] Increased Safety
- [ ] Sufficient Labor Supply
- [ ] Sustainability (Reduced Materials)
- [ ] Other (please specify)
- [ ] Reduced Site Based Permits
- [ ] Increased Productivity
- [ ] Reduced Waste
- [ ] Reduced Weather Impacts
- [ ] Better Predictability/Reliability
- [ ] Less Site Disruption (Noise/Traffic, Dust, Etc)

* 11. What were the **Actual Benefits** realized after adopting Modular/Pre-Fabricated Construction method?

- [ ] Improved Schedule
- [ ] Better Quality
- [ ] Lower Cost
- [ ] Better Site Operations
- [ ] Increased Safety
- [ ] Sufficient Labor Supply
- [ ] Sustainability (Reduced Materials)
- [ ] Other (please specify)
- [ ] Reduced Site Based Permits
- [ ] Increased Productivity
- [ ] Reduced Waste
- [ ] Reduced Weather Impacts
- [ ] Better Predictability/Reliability
- [ ] Less Site Disruption (Noise, Traffic, Dust, etc)
- [ ] N/A

* 12. According to you, what could be the **Barriers to the implementation** of Modular Construction in Las Vegas? (Please check 1 of 4 columns for each row)

	No Barrier	Small	Moderate	Significant
Design + Construction Culture	☐	☐	☐	☐
Distance from factory to site	☐	☐	☐	☐
Program of the building	☐	☐	☐	☐
Transportation/Logistics	☐	☐	☐	☐
Industry Knowledge	☐	☐	☐	☐
Supply Chain + Procurement	☐	☐	☐	☐
Cost vs. Value	☐	☐	☐	☐
Regulations + Codes + Approval from Authorities	☐	☐	☐	☐
Site Operations	☐	☐	☐	☐
Concern for Quality	☐	☐	☐	☐
Owner Tendency	☐	☐	☐	☐
Contractor Capability/Leadership/Experience	☐	☐	☐	☐
Fabricator Capability/Leadership/Experience	☐	☐	☐	☐
A/Es Tendency	☐	☐	☐	☐
Design Freeze	☐	☐	☐	☐
Manufacturing Technology	☐	☐	☐	☐
Urban Site (Site Access and on-site storage area)	☐	☐	☐	☐
Financing + Insurance	☐	☐	☐	☐
Initial Investment	☐	☐	☐	☐
Coordination	☐	☐	☐	☐
Labor Union	☐	☐	☐	☐

* 13. Are there any **Other Barriers** to implement Modular Construction in Las Vegas?

* 14. What **Schedule Benefits** did you get after adopting Modular Construction? (%Schedule Savings)

* 15. What **Cost Benefits** did you get after adopting Modular Construction? (% Cost Savings)

* 16. During the planning phase of your project, who was **responsible for the decision** to use Modular Methods?

- ◯ Owner/Client
- ◯ General Contractor/Construction Manager
- ◯ Architect
- ◯ Subcontractor
- ◯ Other (please specify)

* 17. What is the approximated **% Modularization** of the project? *(Ref %Modularization: Portion of the original site based work hours (excluding site preparation and demolition) exported to fabrication shops)*

* 18. What is the **location of the site** of the project in which prefabricated components were installed?

* 19. How adequate is the **Site Laydown Space? (Space which was available on site to store the prefabricated components)**

- ○ Generous
- ○ Adequate
- ○ Tight
- ○ Other (please specify)
- ○ Inadequate
- ○ N/A

* 20. What is the **location of the module shop/yard/factory** for the project in which Modular methods were implemented? (The location where the prefabricated components were manufactured) (If not, you may fill 'N/A')

* 21. According to you, how critical is Building Information Modelling (BIM) to ones' ability to prefabricate projects?

- ◯ We have not used BIM
- ◯ Little Bit
- ◯ Very Critical
- ◯ Not Sure

* 22. What is the **Quality of Labor** market where the modular shop/factory/yard is available?

- ◯ High Quality
- ◯ Medium Quality
- ◯ Low Quality
- ◯ N/A

* 23. What is the **Quantity of Labor** available where the module shop/factory/yard is located?

- ◯ Excess Supply
- ◯ Adequate Supply
- ◯ Inadequate/Non-Existent Supply
- ◯ N/A

* 24. What was the **actual productivity** of the labor market where the **module shop/factory/yard is located**?

- ◯ Far Above Expectation
- ◯ Above Expectation
- ◯ Meets Expectation
- ◯ Below Expectation
- ◯ Far Below Expectation
- ◯ Don't Know

* 25. In the next 12 Months, how often do you anticipate using Modular Construction method?

- ◯ Not at all
- ◯ Less
- ◯ The Same
- ◯ More

* 26. In the next 5 years, how often do you anticipate using Modular Construction method?

- ◯ Not at all
- ◯ Less
- ◯ The Same
- ◯ More

* 27. If you are not going to use modular methods or less within 5 years, what are **the reasons?**

28. Rank Building types for prefabrication/modularization opportunity in Las Vegas. (Please click one rank for each category)

	1	2	3	4	5	6	7	8	9	10	11	12	13
Dormitory	○	○	○	○	○	○	○	○	○	○	○	○	○
Hotels	○	○	○	○	○	○	○	○	○	○	○	○	○
Low Rise Housing/Residential	○	○	○	○	○	○	○	○	○	○	○	○	○
High Rise Housing/Residential	○	○	○	○	○	○	○	○	○	○	○	○	○
Low Rise Office	○	○	○	○	○	○	○	○	○	○	○	○	○
High Rise Office	○	○	○	○	○	○	○	○	○	○	○	○	○
Hospital	○	○	○	○	○	○	○	○	○	○	○	○	○
Laboratory	○	○	○	○	○	○	○	○	○	○	○	○	○
Parking Garage	○	○	○	○	○	○	○	○	○	○	○	○	○
Prison	○	○	○	○	○	○	○	○	○	○	○	○	○
Retail Building	○	○	○	○	○	○	○	○	○	○	○	○	○
School	○	○	○	○	○	○	○	○	○	○	○	○	○
Warehouse	○	○	○	○	○	○	○	○	○	○	○	○	○

29. Do you think that the Modular Construction/PreFabrication approach can be adopted for **mass post-disaster reconstruction** of facilities? (Wildfires, Hurricanes, etc.)

- Strongly agree
- Agree
- Disagree
- Strongly disagree

30. If you disagree with Question 29, why?

1 / 1 100%

Done

References

Albawaba Business. (2017). Dubai makes it to world's top 10 cities with most hotel rooms.

Anderson, M. (2016). Here's how a new Folsom hotel topped out in just four days.

Basu, A. (2012). The Economic & Financial Performance of Relocatable Buildings in the U.S. Modular Buillding Industry. *Sage Policy Group*, (January), 1–36.

Canyons Lodge, Yellowstone National Park, Wyoming. (2018). Retrieved from http://www.guerdonmodularbuildings.com/our-work/canyon-lodge/

Chen, Y., Okudan, G. E., & Riley, D. R. (2010). Sustainable performance criteria for construction method selection in concrete buildings. *Automation in Construction*, *19*(2), 235–244. https://doi.org/10.1016/j.autcon.2009.10.004

Choi, J. O., Chen, X. Bin, & Kim, T. W. (2017). Opportunities and challenges of modular methods in dense urban environment. *International Journal of Construction Management*, *0*(0), 1–13. https://doi.org/10.1080/15623599.2017.1382093

Deluxe-Built. (2004). Construction Simplified. *Deluxe-Built Deluxe Building Solutions LLC*. Retrieved from https://www.deluxe-built.com/project/hampton-inn-and-suites-harrison-nj/

Ellingwood, B. R., Rosowsky, D. V., Li, Y., & Kim, J. H. (2004). Fragility Assessment of Light-Frame Wood Construction Subjected to Wind and Earthquake Hazards. *Journal of Structural Engineering*, *130*(12), 1921–1930. https://doi.org/10.1061/(ASCE)0733-9445(2004)130:12(1921)

Folsom Fairfield Inn and Suites. (2016). Retrieved from http://www.guerdonmodularbuildings.com/our-work/folsom-fairfield-inn-suites/

Haas, C., O'Connor, J., Tucker, R., Eickmann, J., & Fagerlund, W. (2000). Prefabrication and preassembly trends and effects on the construction workforce. *Center for Construction Industry Studies, The University of Texas at Austin*.

HEC Global Learning. (2014). Retrieved from http://www.globalfootprints.org/sustainability/

How this Builder Saved 40% by Choosing Modular Container Construction. (2016).

Jones, J. (2015). Las Vegas hits record 42 million visitors in 2015, even before New Year's Eve crowds.

Lawson, R. M., Ogden, R. G., & Bergin, R. (2012). Application of Modular Construction in High-Rise Buildings. *Journal of Architectural Engineering*, *18*(2), 148–154. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000057

Lu, N., & Liska, R. W. (2008). Designers' and general contractors' perceptions of offsite construction techniques in the United State construction industry. *International Journal of Construction Education and Research*, *4*(3), 177–188. https://doi.org/10.1080/15578770802494565

Mtech Consult Group. (2012). Waste reduction potential of offsite manufactured pods, 1–10. Retrieved from www.wrap.org.uk

NRB. (2014). 7 Sustainable Building Benefits of Off-Site Construction | NRB Blog. *NRB*, *1*, 17–19. Retrieved from https://www.nrb-inc.com/modular-construction-blog/7-sustainable-

building-benefits-site-construction/

O'Connor, J., O'Brien, W., & Choi, J. (2013). Industrial modularization: How to optimize; How to maximize. *The University of Texas at Austin, Construction Industry Institute*.

Prefabrication, preassembly, modularization, and offsite fabrication in industrial construction: A framework for decision-making. (2002). *Construction Industry Institute*.

Song, J., Fagerlund, W. R., Haas, C. T., Tatum, C. B., & Vanegas, J. A. (2005). Cosidering Prework on Industrial Projects. *ASCE*, *131*(6).

Statista. (2018). Number of lodging rooms in Las Vegas in the United States from 2000 to 2017. Retrieved from https://www.statista.com/statistics/221045/room-inventory-in-las-vegas/

Tatum, C., Vanegas, J., & Williams, J. (1987). *Constructability improvement using prefabrication, preassembly, and modularization. Austin(TX): The University of Texas at Austin: Construction Industry Institute. (RR 83-3)*.

U.S. Department of Labor, B. of L. S. (2008). Employment Projections. Retrieved from http://www.bls.gov/emp/

Velamati, S. (2012). Feasibility, Benefits and Challenges of modular construction in high rise development in the united states: A developer's perspective, *Unknown*(Unknown), 1–102. Retrieved from http://www.dt.co.kr/contents.html?article_no=2012071302010531749001

Wilkinson, S. P., Xia, J., & Chen, B. (2016). *Sustainable Buildings and Structures*.

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