AMERICAN UNIVERSITY OF BEIRUT

PRECAST INDUSTRY IN LEBANON “ADVANTAGES VS SHORTCOMINGS”

by
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AN ABSTRACT OF THE THESIS OF

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The Construction field is one of the main business activities contributing for around 4.46 % of the overall Lebanese GDP in 2015(World Bank; Lebanon, 2015). Stakeholders and construction experts are always trying to enhance the construction industry in Lebanon through attaining improved values in terms of productivity, cost, time, environmental impacts and structural features. The adopted construction method plays a vital role in determining the outcomes of a project; there are two methods of construction, either the cast-in-situ process or the precast technology. Precast systems are dedicated to offer high promises to the construction industry regarding the former designated aspects. However, in Lebanon the precast process occupies only 7-10% of the construction projects, which indicates a deficiency in the utilization in Lebanon despite its high potentials. Thus, our research is directed to realize the literal precast advantages that attract construction projects versus the shortcomings which will help us determine why it's of a little participation in the Lebanese construction field. The results of our research contributed to major inferences through our adopted quantitative and qualitative approaches of data collection. We rigorously determined the precast potentials and the shortcomings by adequate obtained rating scales, and compared the attitudes of different Lebanese construction companies towards precast technology in the market.

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NOMENCLATURE

α	Cronbach's Alpha of the reliability test
R	Rate of Response
df	Degree of freedom by SPSS
$Sig.$	Probability of rejecting the null hypothesis by SPSS "P-value"
S	Set of the shortcomings
$S1$	Set of Advantages "Productivity and Cost"
$S2$	Set of Advantages "Environmental Impact"
$S3$	Set of Advantages "Time Reduction"
$S4$	Set of Advantages "Structural Factors"
n	Sample Size of the participants
μi	Hypothesized sample mean of the criteria according to the type of participants
$H0$	Null Hypothesis
$H1$	Alternative Hypothesis

CHAPTER I

INTRODUCTION

A. Motivation

It's been a long time since the construction industries adapted the traditional ways of building structures where every single work detail must be achieved on site specifically erecting concrete and building elements. Cast-in-situ method was the only technique to perform building procedures and construct structural elements in all projects. Cast-in-situ procedure means that concrete is batched, mixed and poured right at the site or it's brought as a ready mix concrete to be erected. In 1850, an innovative method of construction is widely introduced which occupied civil engineering projects and spread-out through many ventures. (Abedi et al, 2015). Precast concrete structures had gigantic modifications in the construction industry with a participation of about 6% in the US and about 20-25% in the northern European countries of the total share (Polat, 2010). So, in this research we aim to identify the advantages and disadvantages of precast concrete utilization, based on statistical based examination allowing us to determine the roots of the limitations of precast construction in Lebanon and signpost the high potentials that precast industry delivers.

The previous works that were concentrated on the precast industry spreading in the construction market all over the world was limited, in which no further discussions and actions engrossed the basic reasons behind the deficiency in Lebanon. So, our literature will include three parts; the first will give an overview concerning works and projects adopting precast concrete as their motivation and the consequent addressed development. The second part will embrace the works on the advantages in the construction field and its high capabilities of the superlative investment efficiency in all available resources. Finally, the third part will have the shortcomings as its basic argument, which will aid our work to better recognize the limitations of precast concrete tradition in Lebanon.

Our research will be organized as the following; first the background and the literature review will present a general overview about the precast industry from a worldwide point of view comprising the previous works on the potentials that precast technology offers to construction projects, as well as conversing the shortcomings that limit its usage in the markets. Then we'll present the adopted methodology of our research, reaching the results and the corresponding discussions about precast industry in Lebanon. Finally we'll present a conclusive paragraph that condenses the whole knowledge.

B. Overview and Background

An introduced term of precast concrete based buildings "Industrialized Building System IBS" was announced by Thanoon et al (2003).They defined IBS as structures to be jointed together composed of walls, slabs, columns, beam girders, stair cases, prefabricated in a factory or at sites under a level of quality control and minimum activities. For instance, the 7th Malaysia plan was to build 800,000 building units for its inhabitants, but only 20% of these houses were accomplished. So, the 8th plan was to build the others by a small period with the help of IBS. Note that if industry petition remains constant and the supply declines construction expenses will upsurge, this will appeal IBS more and more.

The literature continues in describing the importance of prefab construction in the market share and its predominance in outsized projects. It is consistent to signpost the South African revolution in the building industry that has been growing in the market. Precast industry would be the preeminent alternative to align the given demand. This would bring the infrastructure to meet the 2010 world cup requirements that was to take place in South Africa (“New Venture”, 2006) increasing the demand on housing, schools, clinics, shopping centers, and stadiums. Broadening the matching knowledge, (“Precast Concrete Elements”, 2008) declares that precast industry is spreading throughout the world and representing its adaptability and inherited value. For instance, Penny Ville project in Canada, which is a reasonable housing venture, was built with high percentages of precast elements.

Polat (2010) and Arditi et al (2000) indicated that the precast industry has improved for the last 11 years, and after World War II precast constructions were maintained in European countries, however the current average share is proceeding up to 40-50% in Northern European countries. Liu et al (2017) revealed that precast industry is getting broader in private and public sectors. For instance, in the Modernization Program for the Development of Chinese Architecture Industry of China, a parameter was issued by the Chinese government estimating precast construction to grow and secure 20% to 50% of the building industry in 2020 and 2025 respectively.

Astonishing results that had been indicated by Rogers (2007); she highlighted the significance of time reduction using precast concrete elements. In her article, she believed that the more the project enlarges the more economical to be via adopting precast industry. In the US, where the construction industry is vastly demanding, accompanied by the availability of high-tech criteria, precast erection has occupied around 42% of the constructed buildings (Kaner, 2007). In addition the US companies that are involved in Precast-Prestressed reported \$4.2 Billion in 2003, \$2.4 Billion in 1993 and \$1.9 Billion in 1983 (Peter, 2005).

CHAPTER II

LITERATURE REVIEW

The prior purpose of companies and entities integrated in the construction field is to be committed with projects delivering higher income, consuming fewer charges and demanding lower resources. Besides, the available and most applied two approaches of construction are the cast-in-situ & the precast. In particular, precast concrete industry promises the ventures with high efficiency, duration reduction, augmented productivity, amplified outputs, overall cost reduction, and boosted quality control. The following illustrations will present the scholar working who are seeking to display the vivacious consequences and compensations on the construction industry.

A. Advantages

1. Time Reduction and Productivity Enactment

The cited researches covering the advantages of precast concrete implementation is wide-spreading and adopted by many authors, since precast industry have shown throughout several studies, that it has high spiritual tendencies of construction industry boost and growth promising high pluses to clients. The business of building industry and its actions play a vital role in commercial and conservational progress, life eminence and facility (Polat, 2010).

Cho et al, (2017) have revealed that, precast concrete is a modernization playing a significant role of feature enhancement, time reducing and suitability. They argued that, most of the researches have taken the precast concrete system from a structural point of view, whereas very few have taken it from management aspects. Precast concrete is found to be highly productive in management, beneficial in waste management, reducing in costs, time saving, environmental considerate. After his research simulation Cho et al, (2017) grasped that constructing one floor, in terms of productivity, via cast-in-place method requires 174 working hours through all its phases, however precast technique require 103.3 working hours. Consequently the reduction of costs based on KPI (Korea Price Information), the reduction of cost may reach 178.4 $/cycle using precast instead of the conventional method (cast-in-place).

Thanoon et al (2003) indicated that his introduced designation, “Industrialized Building System IBS”, which is basically built with precast elements, has resulted from the demand increase on affordable building projects, since IBS minimize source wastage and improves durability, cost, time, indoor quality, labor productivity in addition to achieving architectural flexibility. For example “Condominium” in Singapore indicated that cast-in-situ methods of a single floor require 22 working days where as precast construction needs a maximum of 14 days (Thanoon et al, 2003).

It is important to present the significant results indicated by Rogers (2007) through the example of “Hills Boruough” in Florida. This project consisted of 256 security beds and was completed within 3 months in contrast with the 8 to 10 months estimation if conducted by conventional methods. An additional example stated by Gardiner (2018) is the GSU Piedmont Central Student housing project in the US of 23,583m2 that was accomplished in 1 year, considering that precast construction reduces time by an average of 15-25%. In the same route, but considering precast concrete structures in bridge construction civil engineering sector, which is considered to be largely reliant on prefab elements Gase et al (2010), showed that in order to accelerate the bridge construction we should adopt the precast elements, especially in highly congested zones, to benefit from reducing on-site construction time, minimizing traffic impacts, and improving work zone safety. Thus, precast concrete industry would be a vital option to recent projects in the markets around the world, promising the ventures with high efficiency, duration reduction, augmented productivity, amplified outputs, overall cost reduction, and boosted quality control.

2. Environmental Impact

Ensuring the former knowledge about the environmental impact Dong et al (2015) bring about that each $1m^3$ of precast concreted quantity will diminish a 10% of carbon discharges; illustrated by each $1m^2$ floor area the adoption of precast elements is capable of reducing a 2.1 kg of CO2 emissions. Stephen (2004) continues to note that precast method leads to waste reductions of concrete, since the specific volume will be batched occupying the mold exactly, and widens the recycling of the building panels by dismantling the ended economic life of claddings renovated or crushed or by using them as hard-cores. Site disturbances and noise also may be decreased while adapting precast expertise as signposted by Polat (2010) and VanGeem (2006). Therefore, precast concrete is assumed to be friendlier to the environment approaching the green building systems.

3. Structural Factors

Recently, there has been much interest in increasing the structural design abilities of concrete buildings contributing to more durable structures and extended lifespans. In the structural manner, Cho et al (2017) stated that precast-pre-stressed elements have better cracking deflection values than cast-in situ. This may be referred to the reason of that pre-stressing with high strength concrete and cables are considered as non-cracked sections. He also contributed that precast concrete manufacturing systems are mainly based on automation and high technological tools which enhance the quality features of the elements produced. However, inexact and inconsistent design and manufacturing may lead to low levels of user satisfaction (Polat, 2010; Arditi et al, 2000). Liu et al (2017) argued for a very significant structural dispute regarding the seismic response that construction stakeholders considers fragile. Yet, both the precast and the cast-in-situ methods have the same seismic resistance capability (Liu et al, 2017). In fact, some standards and studies have attained high levels of design and implementation for earthquake engineering.

B. Shortcomings

On contrast to what is identified before, scholars have recognized more critically the disadvantages and the full picture behind the precast shortage, in the industry market. Based on that, our research purpose also concentrates on revealing the main limitations of the precast industry and their perception in Lebanon. The available literature was concerned about an equivalent path of bestowing the disadvantages of the precast industry. However, research was limited to certain countries, as indicated by Yu et al (2008) that precast industry is definitely due to a decent financial atmosphere, which arouse the precast application. So our selected investigation is to rely on the past works and scholars signifying the precast detriments, discover additional shortcomings suggesting them as an analogous case for Lebanon and rely on our statistical method framework to signpost the reasons behind the precast utilization deficiency in Lebanon.

Some Studies had signified an imperative challenge that is usually occurring between architectural and structural engineers in which architectural designs require high values of decorations and aesthetics. Stephen (2004) designated the architectural-structural parallelism to be achieved through the precast technology and that's due to flexibility in embellishing any required form and finishing mechanisms. Harmonizing the previous idea Kaner (2007) and GUO et al (2015) have notified to the BIM "building information technology" which helps create a better culture of coordination and collaboration between architectural supplies and structural implementations. Due to the fact that precast concrete construction inflowing the market in high rates, however the existing challenges are may shrink its expansion. Thus, certain necessities and trappings should catch an imperative attention of the different interfering components in the construction cycle which will be discussed in the following section.

The necessity of scientific and theoretical bases to implement the industrialized building system for construction is argued by Thanoon et al (2003). This seems to be significant, since civil engineering programs lack the applied courses of precast construction accompanied by the necessary details of design and erection criteria. Polat (2010) signposted that the prominence of investing in trainings workshops and including a precast construction course in the academic programs in universities will help qualify the skills of workmanship and technicians. Perhaps, this has led to the lack of available contractors specialized in the corresponding job works due to poor university-industry collaborations and inexpert staff. Thus, the better the contribution of the theoretical basics to applicable practices the better outcome and the more decrease implementation errors, would result.

Thanoon et al (2003) claimed about the sufficient market tactics but less response from contractors is considered another issue that precast concrete suffer from, besides Yu et al (2008) showed that the high prices are due to lack of competitions incorporating in the market, as the case of Lebanon in which we have only three manufacturers weakening the competitive price offering. This will lead to decline in demand and a fickle market perilous for supplementary investment (Thanoon et al, 2003). Likewise high range prices come from the absence of attentiveness of contractors towards the benefits of precast structure and that's due to a truncated level of advertising and marketing activities showing the tangible welfares of prefabs (Polat, 2010). Also, the labor price requirement helps in increasing the precast general cost in developed countries in intensive usual methods, so Polat (2010) contributes that the labor price would augment in implementing tech-methods, and that is due to low wages, insufficient funds, lack of experience and tech-innovations, accompanied by trainings and workshops. Rogers (2007) added that precast is costly due to molds and jigs restrictions, taking into consideration the standard adopted molds that have limited dimensions and shapes in the manufacturing plants, so extraordinary demands would require additional charges. However, uniformity and homogeneity of architectural recommendations involve consuming the same molds, but that would drop the engineering creativity.

Recently, there has been much interest in applying precast concrete in the civil engineering projects. Yet, certain structural disputes are controversial. Structural issues comprise the complex and the critical precast connections, "the prefab construction is initially defined by assembling manufactured elements with each other (beams, slabs, columns, walls…), and hence connections would result between these elements." Thanoon et al (2003) argued that connections and joints of prefab elements is still a predicament which is very precarious and subtle to faults. Theodosiou (2013) considered that the permanence of working schedule of precast construction entails a very intensive level of precision implemented by the contractor. Another, major drawback is signified by fragile seismic and earthquake response of precast concrete due to the deficiency found in the connections between the elements. For instance, many precast building were damaged due to seismic loads as in 1994 Northridge earthquake, the 1998 Adana-Ceyhan, Turkey Earthquake, the 2012 Emilia earthquake, and the 1999 Marmara Earthquake, (Liu et al, 2017). Following asymptotic indications, Arditi et al (2000) and Polat (2010) specified that deformations and failures were due to the connection failures and distresses. However, it was surprising to have a high precast-building rigidity and stability against seismic loads as the case in 1995 Kobe earthquake in Japan, in which short and tall buildings found meager damage and were ready for immediate continued occupancy as revealed by Gosh (1995) in his report about structure performance in Kobe Earthquake.

Arditi et al (2000) and Polat (2010) revealed that precast transportation is a problem especially in highly congested areas; also precast elements are heavyweight and of highly condensed bulks which will be an obstacle for the transportation services. While Arditi et al and Polat argued about the fragile level of communication among the supply-chain management parties leading to project delays, especially between designers, manufacturers, and contractors, Abedi et al (2015) contributed about the necessity of integrating the supply-chain phases. Each sector should be involved to the modern data and apprises. To mitigate the connection issues, he modeled a prototype "Cloud Computing Information Systems (CCIS)" that helps to incorporate process, network, activities, and information between designers, customers, consultants, freelancers, creators, architects/engineers, subcontractors and workers.

Abedi et al (2015) exhibited that in order to catch the benefits in the most resourceful mode of precast construction method, there must be kind of coordination between the precast supply-chain management phases which are: Planning, design, manufacturing, transportation, installation, and construction. Each party should be involved to the latest evidence and updates, contributing to heightened cooperation, sustainability and incorporating all its facets. Cho et al (2017) furthered the requirements for obtaining the best proficiency of precast construction by assigning high labor workmanship skills, and allocating automations for systematic management processes.

CHAPTER III

METHODOLOGY

In this section we will demonstrate the process that we implemented in our conducted study to collect the data which corresponds to the advantageous potentials offered by the precast technique, at the same time ascertain the main reasons behind the deficiency in adopting precast systems in Lebanon. The strategy of the research is presented in the figure 1 summarizing the espoused study framework.

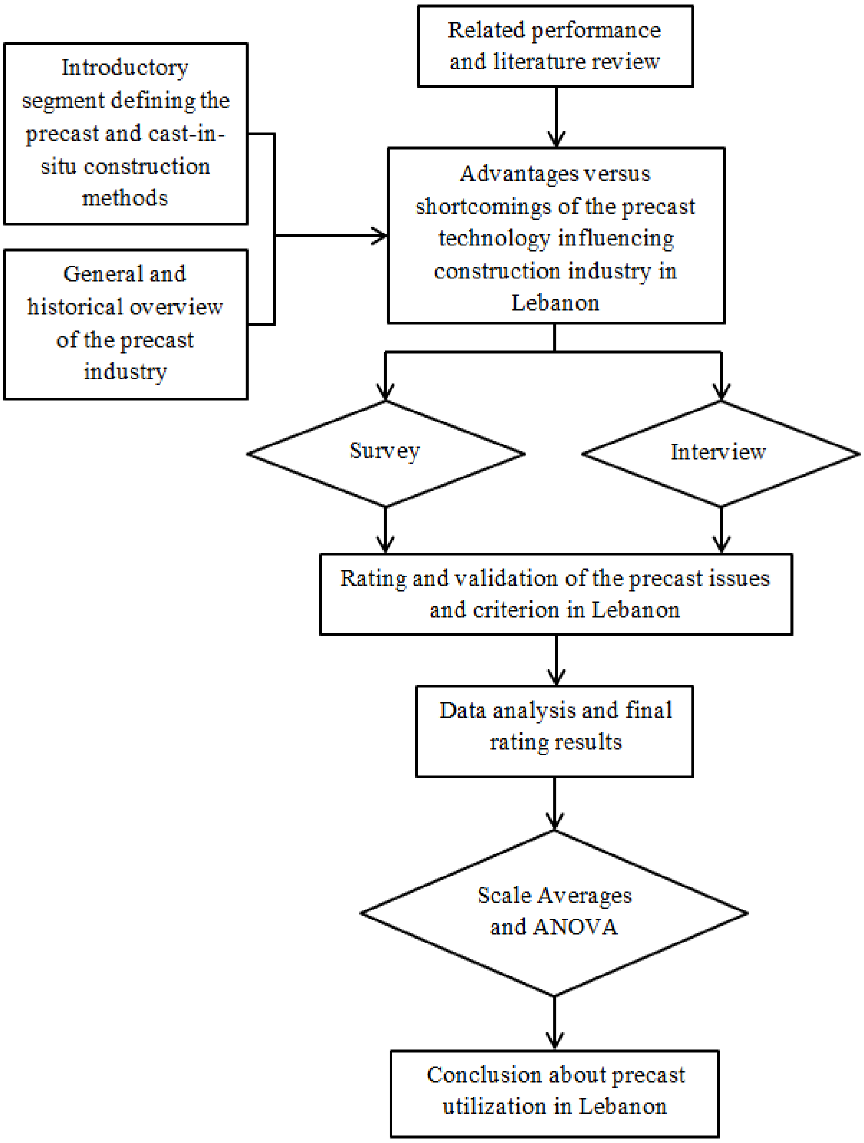


Figure 1: Research Framework

Our research framework will embrace a multidimensional approach, combining quantitative and qualitative methods. The obtained results will help us cover all precast aspects in terms of advantages and shortcomings and adapting them to the Lebanese environment. The results would also exceed other publications by determining a common knowledge about precast situation in the Lebanese construction market.

A. Quantitative Approach

Quantitative research relies on numerical collected data to thoroughly approve or dissent a proposed situation (Watson, 2015). Our quantitative investigation would include collecting the statistical data, rating and measuring the data, and data analysis followed by drawing conclusions. The statistical data may be collected from two types of examinations; experiments and surveys. In particular we've chosen the survey approach for our study, since our aim is to collect vital numbers form construction advocates and experts.

Throughout a wide scope of the literature and the previous works, we were able to assemble a list of advantages versus shortcomings of the precast approach in the construction field. Actually, there was no inclusive list of the main criteria that should be assumed and analyzed while the stakeholder decision making process is in progress, which is to embrace either the precast systems, or the traditional ways of construction, or maybe both "Hybrid System" as termed by Theodosiou (2013). So, we aimed to collect sufficient principles that our study would be based on, through several researches in interrelated areas, in which the proposed criteria were recognized through the material in the previous literatures.

The general configuration of our survey is consisted of two major sections; the shortcomings of precast utilization contrasted by a list of the advantages and potentials that it does offer to the construction market. The advantages title is also divided into subtitles that may be summarized by the cost/productivity, time reduction, environmental impact, and structural factors. Polat (2010) and Arditi et al (2000) were considered as major motivations to our study, since they engrossed their works with the reasons behind the limitations of precast technologies in their regions Turkey and US respectively. Hence, we enlarged the study of the precast method all through paralleling the shortcomings with the compensations in Lebanon through rating each of the deficiency criteria to identify reasons behind the shortage of the precast technology in Lebanon. The congregated criteria are listed as the following tables.

Table 1: Precast Shortcomings

1	Size & load transportation restrictions
2	Far delivery distances between manufacturers-site locations and manufacturers-raw material zones
3	Seismic fragile resistance
4	Lack of skilled designers, contractors, and labors
5	Lack of academic programs adopting precast design and implementation
6	Lack of communication and collaboration among supply-chain involved parties
7	Architectural complex requirements VS uniform and monotone precast manufactured elements
8	Labor associations & unions
9	Lack of precast industry management
10	Contractors aren’t recognizing cost saving benefits
11	Decline in demand VS shortage in supply
12	Lack of public sector investments

13	Users aren’t satisfied by precast built structures

Table 2: Precast Advantages "Productivity & Cost"

1	Cost saving in smooth surfaces (no need for plastering)
2	Cost saving in scaffolding
3	Cost saving in formwork
4	Less maintenance
5	Elements coming to the site fully equipped with plumbing, electrical and painting materials
6	Erection Flexibility
7	Reduction in labor conditions in production plants
8	Higher site safety
9	Manufacturing plant workers are given definite tasks increasing their proficiency

Table 3: Precast Advantages “Environmental Impact”

1	Decrease site disturbances and noises
2	Reduction of CO2 emissions
3	Diminish wastages on the site
4	Recycling the waste generated in the manufacturing plant

Table 4: Precast Advantages “Time Reduction"

1	Time reduction by synchronization manufacturing elements while casting others
2	Time reduction by applying the masonry works just after the hollow-core are laid
3	No required scaffolding
4	No required formwork

5	No required finishing
6	Casting process isn't affected by weather conditions (convenient temperatures inside the manufacturing plant, so no delays in the fabrication)

Table 5: Precast Advantages "Structural Factors"

1	Better deflection and cracking values
2	High precisions in the openings and voids
3	Improve durability
4	Enhance quality
5	Lighter self-weight and thus smaller designed concrete sections

Our survey was directed towards determining the level of importance of each criterion within its corresponding title. The rating will be assigned to given numbers represented by a scale ranging from 0 to 3 in which their respective indications vary from "Not important at all", "Of little importance", "Of average importance", and "Very important" (Brown, 2010). This type of rating would result in reliable responses. The procedure was based on an online survey via Google Documents, which has been sent to a sample of 100 Lebanese construction companies including consultants, contractors, and manufactures. It was planned to be filled within 10 minutes.

B. Qualitative Approach

The qualitative approach was targeted to perceive the points of views of the experts in the construction field who have experienced the precast technology. Hence, they would be able to provide us with the appropriate data and knowledge. While gathering facts about the precast industry in different regions and construction markets, questions and analogous evidences were generated for the case of Lebanon trying to acquire specific and detailed records about the precast industry situation in the Lebanese construction field.

We have identified 20 companies and have decided to filter them based on the following criteria: company size in terms of yearly turnover, company reputation, company history, availability of decision makers and willingness to cooperate, and precast technology experience. The targeted companies helped us identify other eligible companies “snowball effect” and to arrange further meetings.

Semi-structured interviews provided an open-ended standard of conferences were embraced in our study. The open-ended meetings were performed in a way that the sequence of questions was grouped according to their concepts. This would help reduce the variation of the answers on the modeled questions (Patton, 2002). Besides, the semi-structured interviews facilitated our communication with the interviewees which helped them understand the questionnaire and respond given their equivalent qualifications.

The procedure followed in each interview started with a general and brief knowledge about our study. Then, we assure that the contribution was voluntary and according to their preference of place and time. Afterwards we handle the interviewee the consent form to be signed. Subsequently, we start asking the questions while taking notes simultaneously. The interviews have taken an average of 40 minutes, excluding some interviews that elongated to 60 minutes in which the interviewees were inspired to provide us with additional information from their experience. Most of the interviewees were project managers, or civil engineers having an experienced based knowledge. Each time we want to ask an unmentioned question, we would kindly request if we can recognize an explicit example regarding a definite point10 out of 20 interviews were conducted due to a 50% unwillingness to contribute and sophistications in organizing meetings.

C. Sampling and Participant Knowledge

Selecting the appropriate sample is a critical step that should be considered as credible criteria for obtaining accurate and trustworthy results. Our survey participants should be construction companies in Lebanon such as consultants and contractors that have a general experience about construction projects so that they may have their own knowledge and points of view of the precast technology. Whereas the participants of the conducted interviews should have experienced the precast systems in their projects such as precast manufacturers, consultants, and contractors leaders in Lebanese construction market, moreover they are filtered and condensed to 20 participants according to the following criteria: company size in terms of yearly turnover, company reputation, company history, and the availability of decision makers and willingness to cooperate. This would help insure the provision of proper data and precise numbers and percentages regarding the precast situation in Lebanon. Furthermore, snowball sampling was adopted in the qualitative method so that participants would recommend us to have connections with other reliable companies; this would enhance the quality of our results associated with more integrity. Other minor characteristics that are espoused for the participants in our methodology are presented in the consent forms for the survey and interviews.

Refer to the consent forms of the survey and interviews.

D. Data Analysis

The analysis of data that is related to the quantitative study will be executed though excel sheets and SPSS software, whereas the data collected form the qualitative method will be considered throughout our overall study each time introducing realistic and consistent evidences. Excel sheets would provide us with descriptive analysis, rating percentages and average rating-scales. Whereas the SPSS software checks the Reliability Test, KMO and Bartlett's Test. Additionally, and considered as further discussions, we will conduct an ANOVA test using SPSS software to compare the results obtained from the samples of the population of construction companies which are contractors, manufacturers, and consultant.

E. Research Ethics

Each conducted research should be compatible with an ethical protocol to guarantee that the participants aren't harmed from investigation activities. A major step that our research achieved was getting the Institutional Review Board approval confirming all included ethical codes and requirements.

The research method ensures that both the interview and survey participants are anonymous, can't be identified and their provided information is trusted. The collected data were saved on a laptop secured by a password in which only the principal and co-investigators have an access to the data. The risks that the participants may face are nothing but the daily life risks; liability release forms were completed and signed by the principal investigator and then submitted to the corresponding departments.

Survey and interview consent forms were also achieved to reveal the purpose of our study, and to ensure that the participants are protected in which they're free to quit from contributing. Email invitations for interviews and surveys are prepared and accepted form the IRB office.

CHAPTER IV

RESULTS AND FINDINGS

The multi-dimensional approach of our method with a combined quantitate-qualitative study has resulted in major findings contributing to our research purpose. First the interviews allowed us to gather our desirable facts about the precast concrete technology situation in Lebanon. Second, the survey endorsed in reliable numeric dataset to signpost the main reasons behind the deficiency of the precast utilization, and on the other hand to clarify the major promises that precast method offers to the construction stakeholders.

A. Rate of Response

From the targeted sample of the 100 construction companies including consultant, contractors, and precast manufacturers, a total of 35 participants were involved in our study. So, the survey results was of n=35. The rate of response is presented in the following table.

Table 6: Rate of Survey Response

Type of recipient	Number of targeted companies		Rate of Response (%)
	Targeted	Responded	
Manufacturers	3	3	100
Consultants	35	8	23
Contractors	62	24	39
Total	100	35	35

The rate of response R of manufacturers was 100% since the three existing manufacturers participated on our survey, whereas the rate of response decreased to

23% and 39% with consultants and contractors respectively since some consultants and contractors claimed that they have never experienced precast buildings in their projects. The overall rate of response R=35% which is higher than the respective values 31% and 34% achieved by Polat (2010) and Arditi et al (2000).

B. Reliability Test

Additionally a reliability test was performed on the variables of the assigned criteria using SPSS software. A score of α = 0.962 (> 0.7), this indicates that the adopted tool to measure variables is of an excellent reliability fitting our purpose of the study. The results are shown in table 7.

Table 7: Reliability Score

Cronbach's Alpha	N of Items
.962	37

C. Factor Analysis

KMO and Bartlett's test of sphericity was conducted to check the suitability of the data for the factor analysis. SPSS software has determined the KMO measures of sampling adequacy of each type of variables, and scores of 0.848, 0.755, 0.786, 0.602, and 0.770 are obtained. All the previous variables are greater that the threshold of 0.6. This indicates that the data is adequate for factor analysis.

As for the Bartlett's Test a score of 0.000 in all types of variables indicates that all factors are significantly different from each other. The results are depicted in table 8.

Table 8: KMO and Bartlett's Test

Shortcomings		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.848
Bartlett's Test of Sphericity	Approx. Chi-Square	475.202
	df	78
	Sig.	.000
Advantages “Productivity & Cost”		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.755
Bartlett's Test of Sphericity	Approx. Chi-Square	251.210
	df	36
	Sig.	.000
Advantages “Environmental Impact”		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.786
Bartlett's Test of Sphericity	Approx. Chi-Square	69.636
	df	6
	Sig.	.000
Advantages “Time Reduction”		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.602
Bartlett's Test of Sphericity	Approx. Chi-Square	138.134
	df	15
	Sig.	.000
Advantages “Structural Factors”		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.770
Bartlett's Test of Sphericity	Approx. Chi-Square	116.274
	df	10

	Sig.	.000

D. KMO and Bartlett's test

KMO and Bartlett's test of sphericity was conducted to check the suitability of the data for the factor analysis. SPSS software has determined the KMO measures of sampling adequacy of each type of variables, and scores of 0.848, 0.755, 0.786, 0.602, and 0.770 are obtained. All the previous variables are greater that the threshold of 0.6. This indicates that the data is adequate for factor analysis.

As for the Bartlett's Test a score of 0.000 in all types of variables indicates that all factors are significantly different from each other. The results are depicted in table 8.

Table 9: KMO and Bartlett's Test

Shortcomings		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.848
Bartlett's Test of Sphericity	Approx. Chi-Square	475.202
	df	78
	Sig.	.000
Advantages "Productivity & Cost"		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.755
Bartlett's Test of Sphericity	Approx. Chi-Square	251.210
	df	36
	Sig.	.000
Advantages "Environmental Impact"		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.786

Bartlett's Test of Sphericity	Approx. Chi-Square	69.636
	df	6
	Sig.	.000
Advantages “Time Reduction”		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.602
Bartlett's Test of Sphericity	Approx. Chi-Square	138.134
	df	15
	Sig.	.000
Advantages “Structural Factors”		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.770
Bartlett's Test of Sphericity	Approx. Chi-Square	116.274
	df	10
	Sig.	.000

E. Rating Average

1. Shortcomings

We calculated the average scale of each precast shortcomings which ranges in the [0; 3] interval resulting from the assigned survey scales according to Brown (2010). The sample averages of the criteria would indicate the degree of severity of each shortcoming that restrains the precast utilization in Lebanon.

Designate by S = {A, B … M} the set of the shortcomings that we will reveal the rating scale averages of each according to the results obtained by the online participants, manufacturers, contractors, and consultants. The following table and bar-diagrams depict the averages rating-scale of importance of the precast shortcoming criteria.

Table 10: Shortcomings Average Rating-Scales

Shortcomings S		Average importance score of the participants				Average score
		Online participants	Manufacturers	Contractors	Consultants	
A	Size & load transportation restrictions	1.88	1	1.25	2.25	1.8
B	Far delivery distances between manufacturers-site locations and manufacturers-raw material zones	1.64	0	0.5	1.75	1.43
C	Seismic fragile resistance	2	0.5	2.25	1.75	1.91
D	Lack of skilled designers, contractors, and labors	1.96	0.5	1	1	1.66
E	Lack of academic programs adopting precast design and implementation	1.72	2.5	2	1.25	1.74
F	Lack of communication and	1.32	0	0.75	1	1.14

	collaboration among supply-chain involved parties					
G	Architectural complex requirements VS uniform and monotone precast manufactured elements	2	1.5	2	2.25	2
H	Labor associations & unions	1.28	0.5	0.25	0.25	1
I	Lack of precast industry management	1.56	0.5	1.25	1	1.4
J	Contractors aren't recognizing cost saving benefits	1.88	2	1.5	1.75	1.83
K	Decline in demand VS shortage in supply	1.68	1.5	0.75	1.25	1.51
L	Lack of public sector investments	2.08	1	1.75	2	1.97
M	Users aren't satisfied by precast built structures	1.36	0	1	1.25	1.23

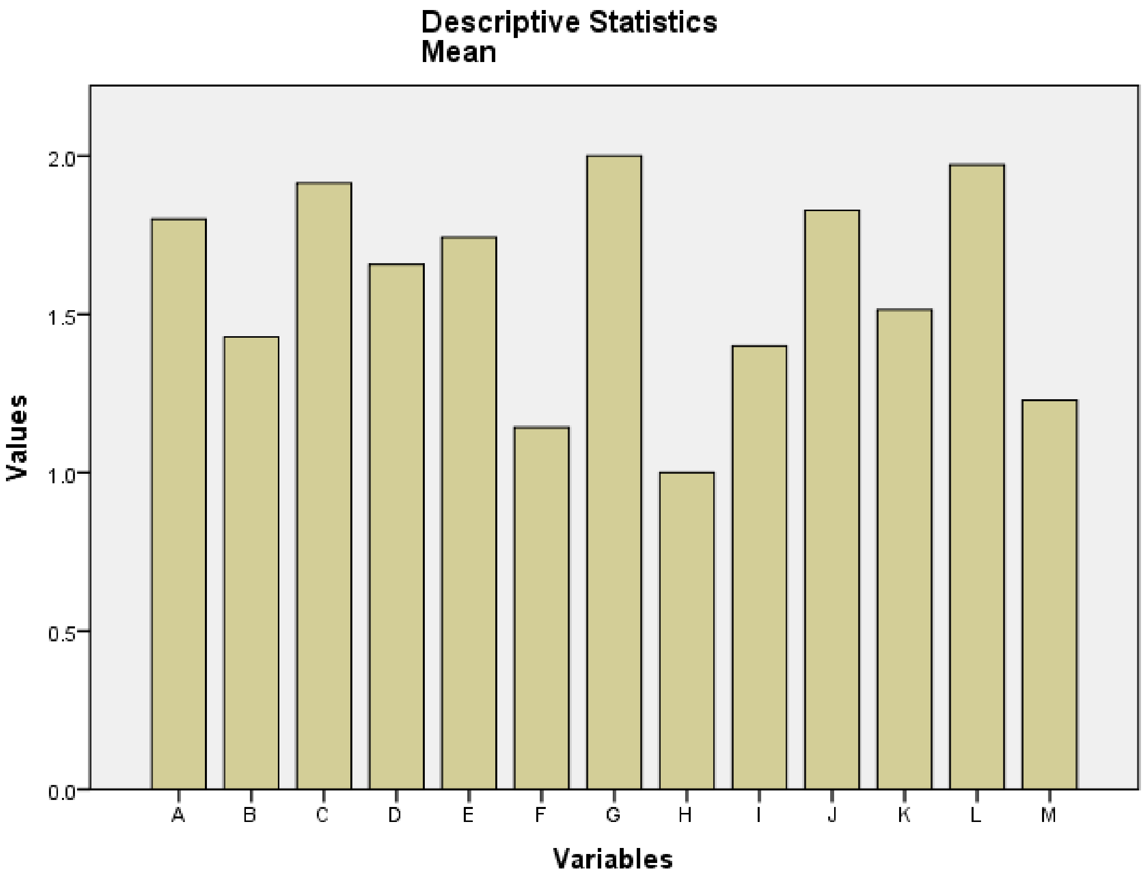


Figure 2: Average Scores of Shortcomings

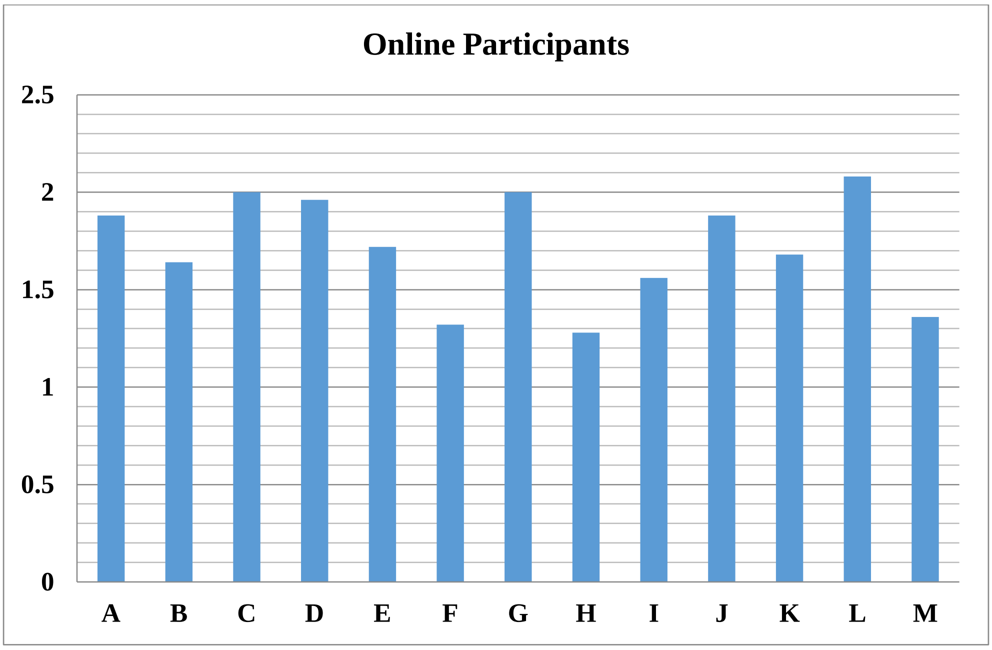


Figure 3: Scale Average of Online Participants

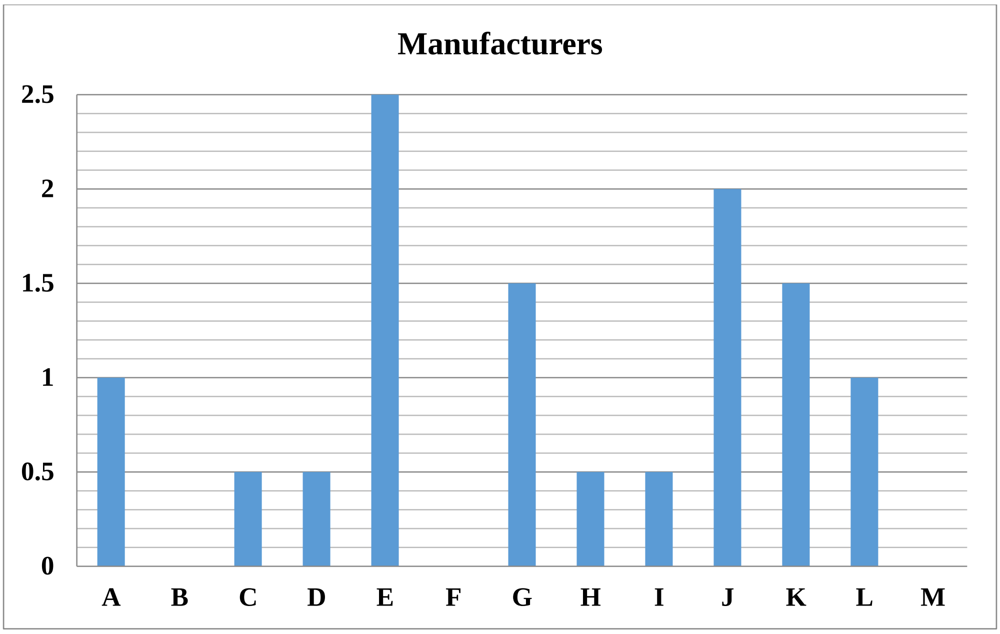


Figure 4: Scale Average of Manufacturers

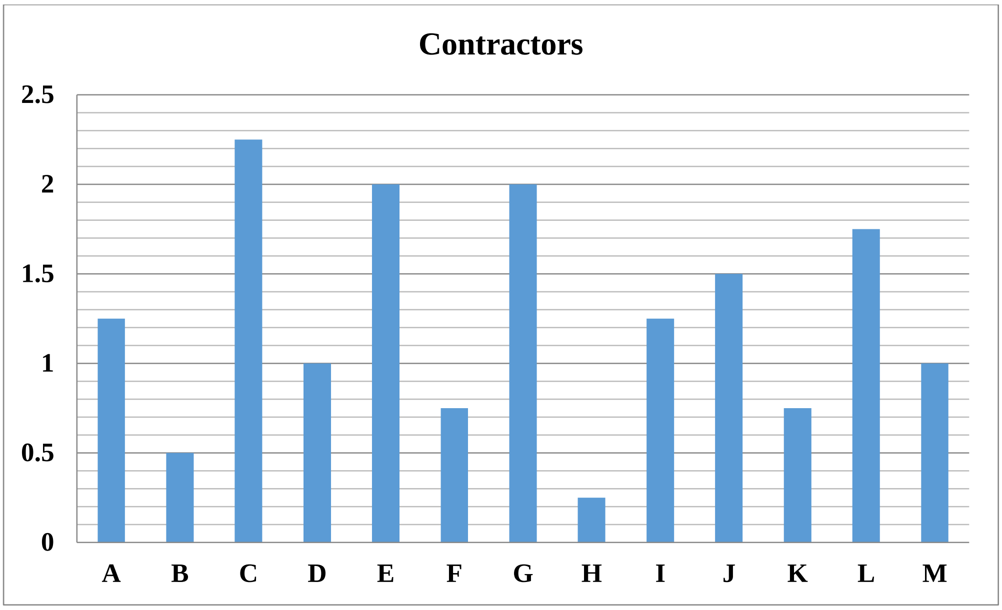


Figure 5: Scale Average of Contractors

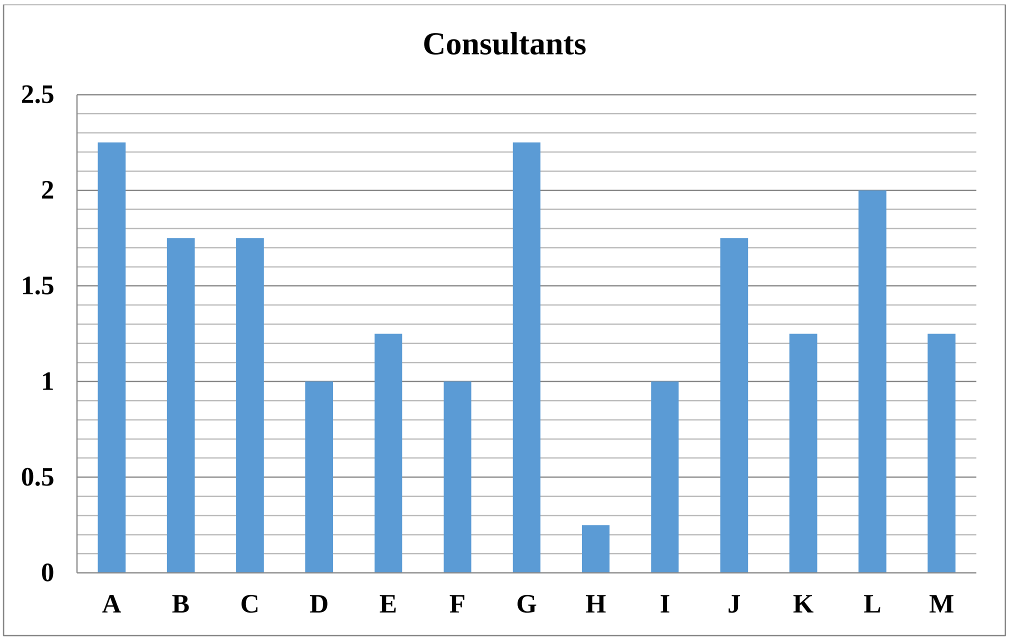


Figure 6: Scale Average of Consultants

2. Advantages

We also determined the average scale of the precast advantages which ranges in the [0; 3] interval resulting from the assigned survey scales according to Brown (2010). The sample averages of the criteria would reveal that the factors are vital for the construction projects.

Designate by $S_1 = \{A_1, B_1, C_1, D_1, E_1, F_1, G_1, H_1, I_1\}$ be the set of the first section of variables of the advantages defined be "Productivity and Cost". $S_2 = \{A_2, B_2, C_2, D_2\}$ be the set of the second section of variables of the advantages defined be "Environmental Impact". $S_3 = \{A_3, B_3, C_3, D_3, E_3, F_3\}$ be the set of the third section of variables of the advantages defined be "Time Reduction". $S_4 = \{A_4, B_4, C_4, D_4, E_4\}$ be the set of the forth section of variables of the advantages defined be "Structural Factors". The results of the averages rating-scale of importance of the advantages of all the sections, obtained from mixed online participants, manufacturers, contractors, and consultants will be depicted by the tables through 10 till 13 and bar-diagrams.

Table 11: Advantages "Productivity and Cost" Average Rating-Scales

Advantages S_1		Average importance score of the participants				Average score
		Online participants	Manufacturers	Contractors	Consultants	
A_1	Cost saving in smooth surfaces (no need for plastering)	2.28	3	2.5	2.5	2.37
B_1	Cost saving in scaffolding	2.04	2.5	2.75	1.75	2.11
C_1	Cost saving in formwork	2.56	3	3	2	2.57
D_1	Less maintenance	2.16	3	1.75	2	2.14
E_1	Elements coming to the site fully equipped with plumbing, electrical and painting materials	2.08	2	1.25	1.5	1.91
F_1	Erection Flexibility	2.08	2.5	1.5	2.25	2.06
G_1	Reduction in labor conditions in production plants	2	3	2	1.75	2.03
H_1	Higher site safety	1.8	2.5	1.5	2	1.83
I_1	Manufactu	1.72	2.5	2.75	2.5	1.97

	ring plant workers are given definite tasks increasing their proficienc y					

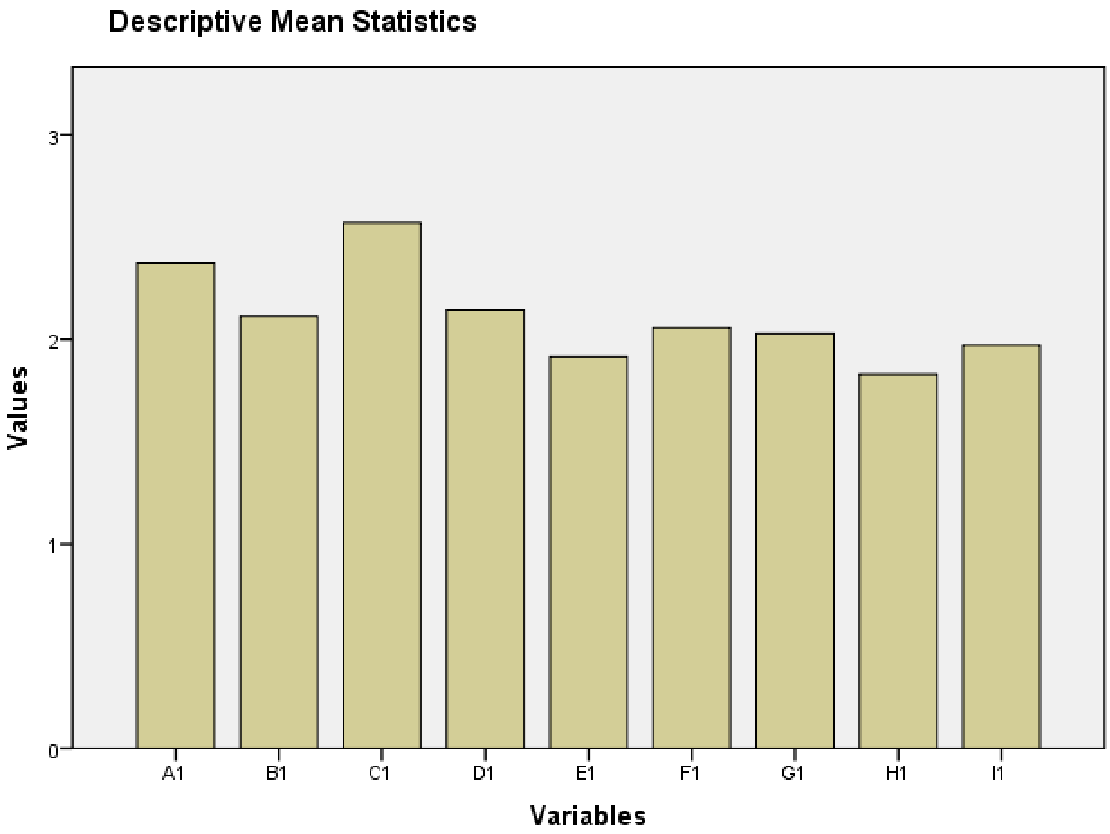


Figure 7: Average Scores of Advantages "Productivity & Cost"

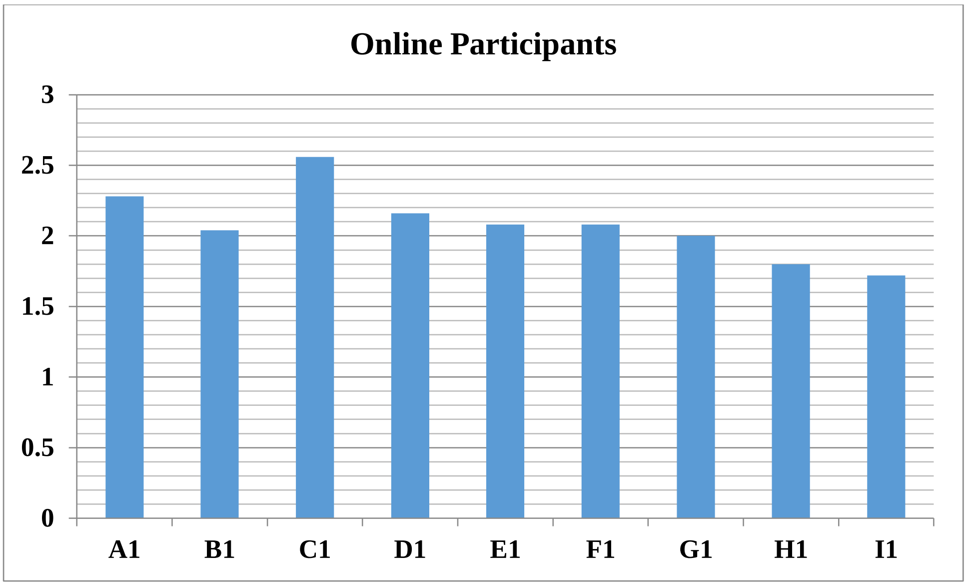


Figure 8: Scale Average of Online Participants

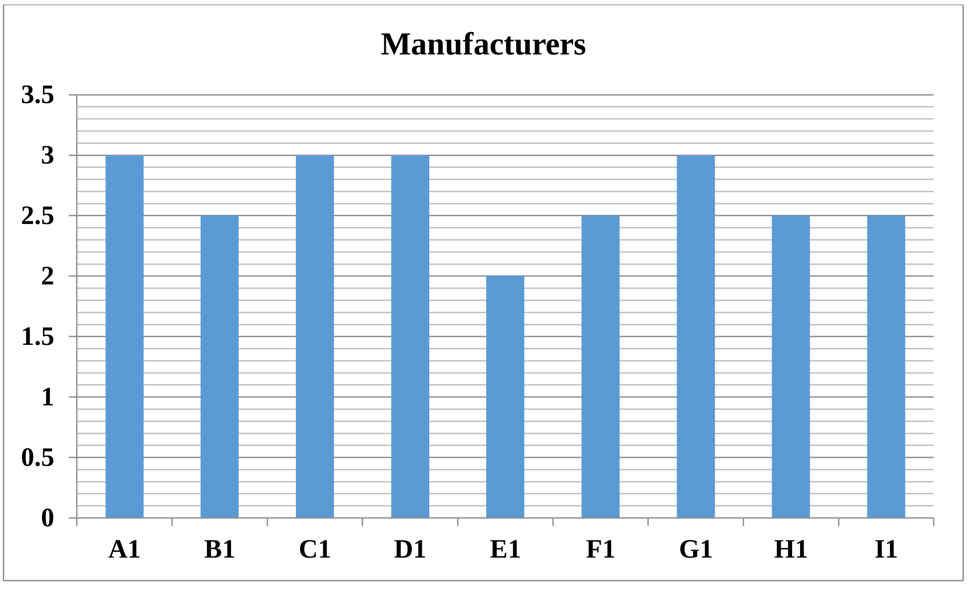


Figure 9: Scale Average of Online Participants

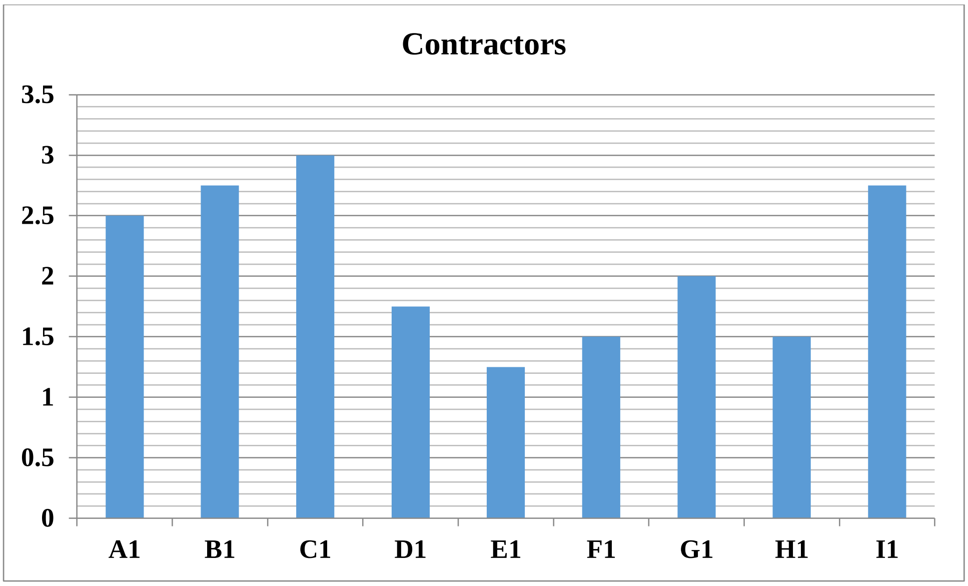


Figure 10: Scale Average of Contractors

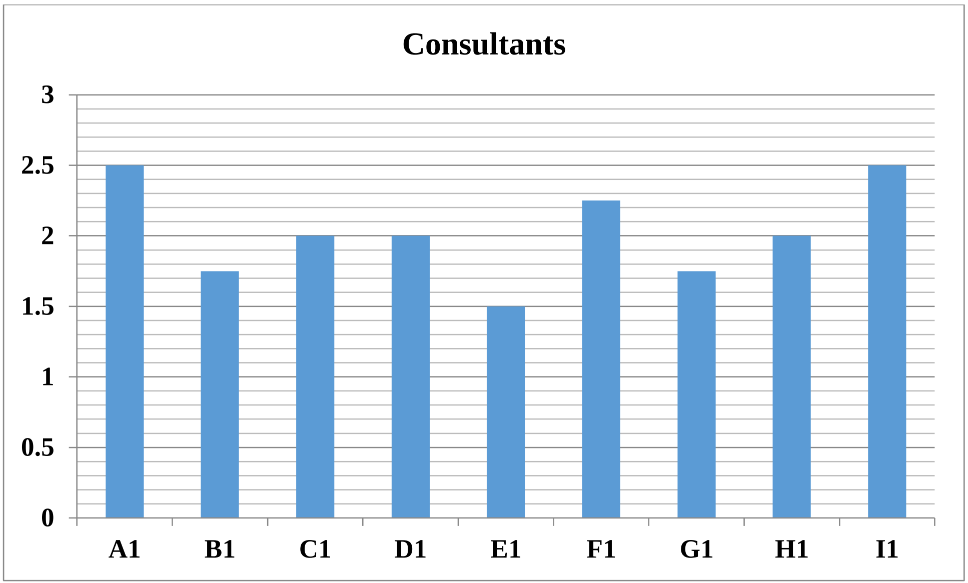


Figure 11: Scale Average of Consultants

Table 12: Advantages "Environmental Impact" Average Rating-Scales

Advantages S_2		Average importance score of the participants				Average score
		Online participants	Manufacturers	Contractors	Consultants	
A_2	Decrease site disturbances and noises	2.08	1.5	2	2	2.03
B_2	Reduction of CO2	2.12	1.5	1	1.75	1.91

	emissions					
C_2	Diminish wastages on the site	2.32	2	2.25	2.5	2.31
D_2	Recycling the waste generated in the manufacturing plant	1.92	2	1.25	1.5	1.8

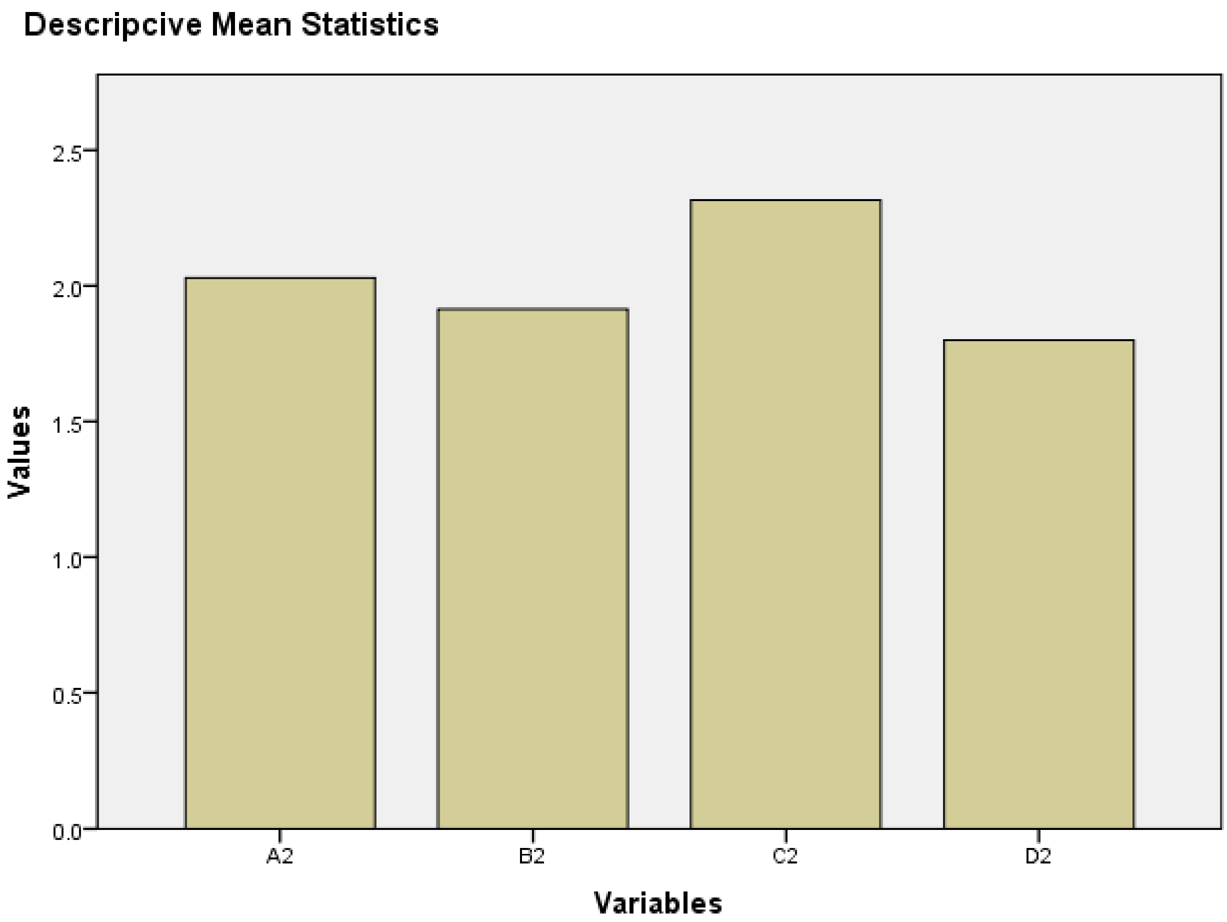
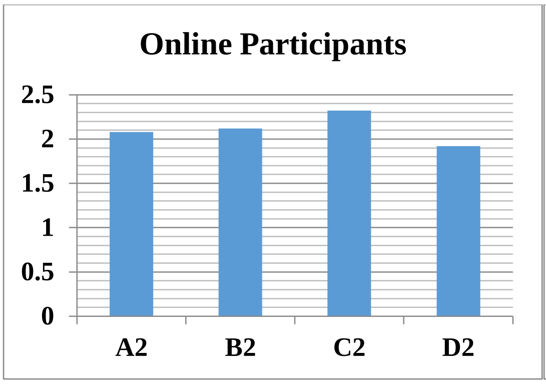


Figure 12: Average Scores of Advantages "Environmental Impact"



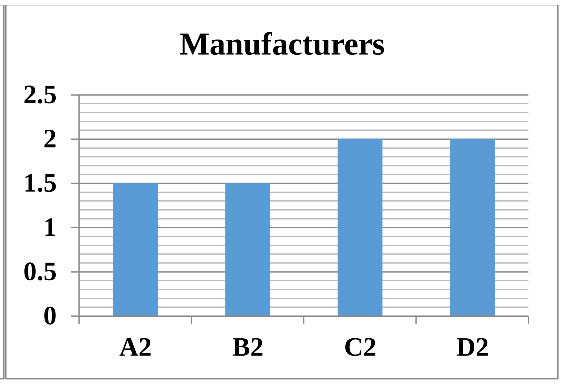
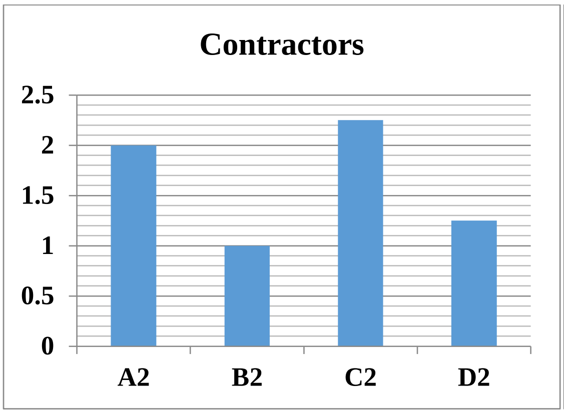


Figure 13: Scale Average of Online Participants Figure 14: Scale Average of Manufacturers



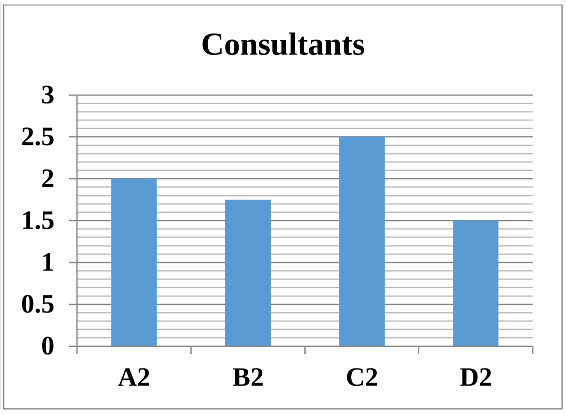


Figure 15: Scale Average of Contractors

Figure 16: Scale Average of Consultants

Table 13: Advantages "Time Reduction" Average Rating-Scales

Advantages S_3		Average importance score of the participants				Average score
		Online participants	Manufacturers	Contractors	Consultants	
A_3	Time reduction by synchronization manufacturing elements while casting others	2.4	3	3	2.5	2.51
B_3	Time reduction by applying the	2.24	1.5	2.25	2	2.17

	masonry works just after the hollow-core are laid					
C_3	No required scaffolding	2	2	1.5	1.75	1.91
D_3	No required formwork	2.36	3	2.25	1.75	2.31
E_3	No required finishing	2.36	3	2	2	2.31
F_3	Casting process isn't affected by weather conditions (convenient temperatures inside the manufacturing plant, so no delays in the fabrication)	2.72	3	2.25	2.75	2.69

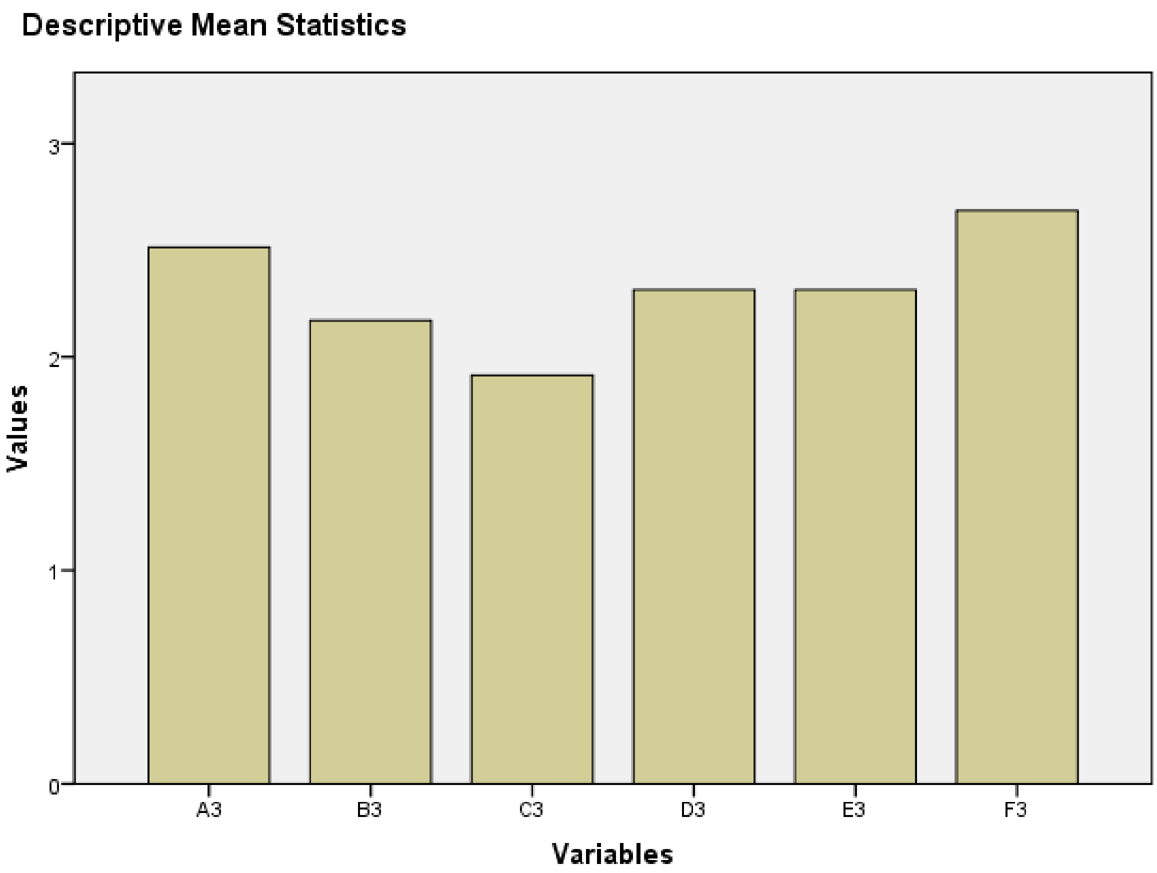


Figure 17: Average Scores of Advantages "Time Reduction"

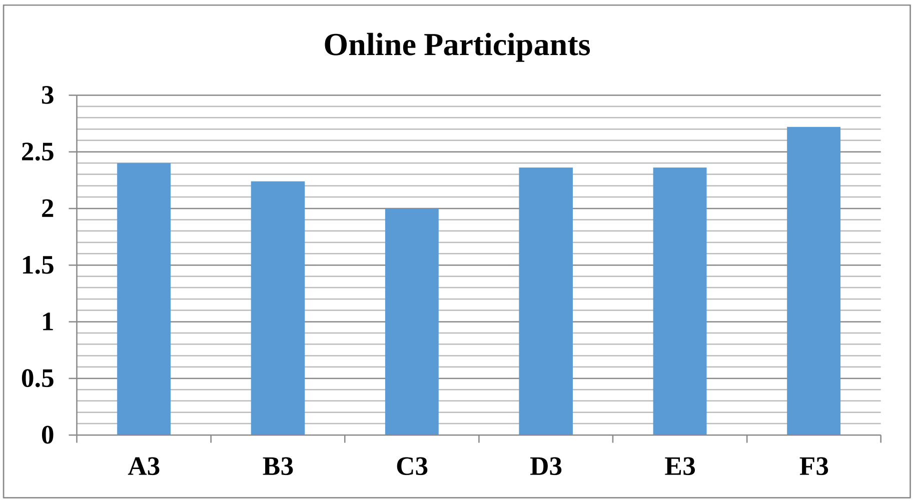


Figure 18: Scale Average of Online Participants

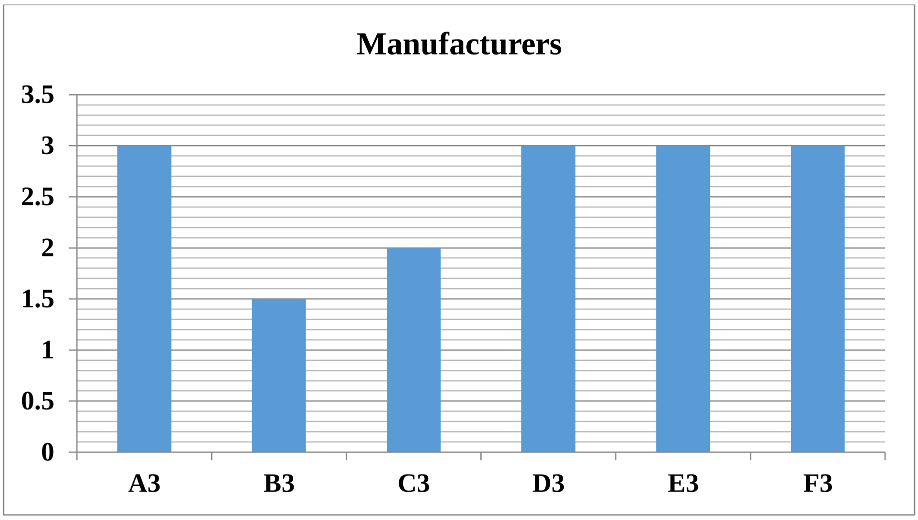


Figure 19: Scale Average of Manufacturers

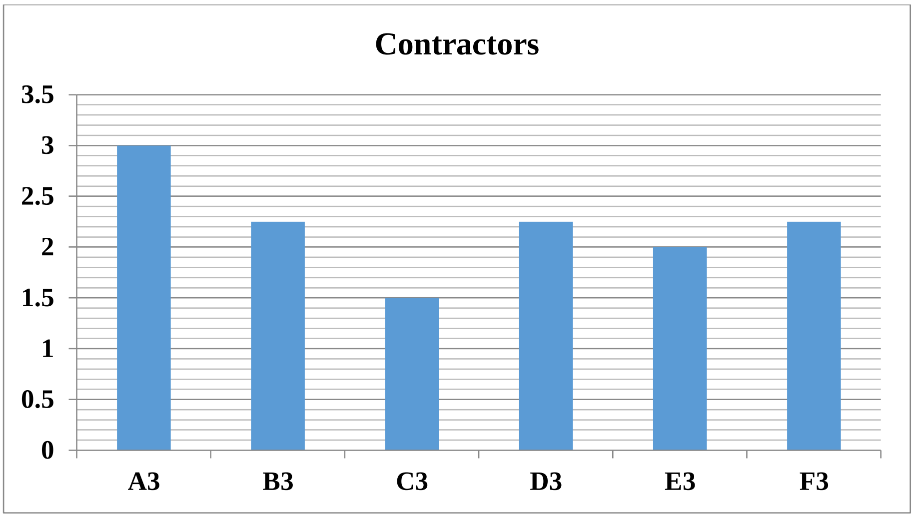


Figure 20: Scale Average of Contractors

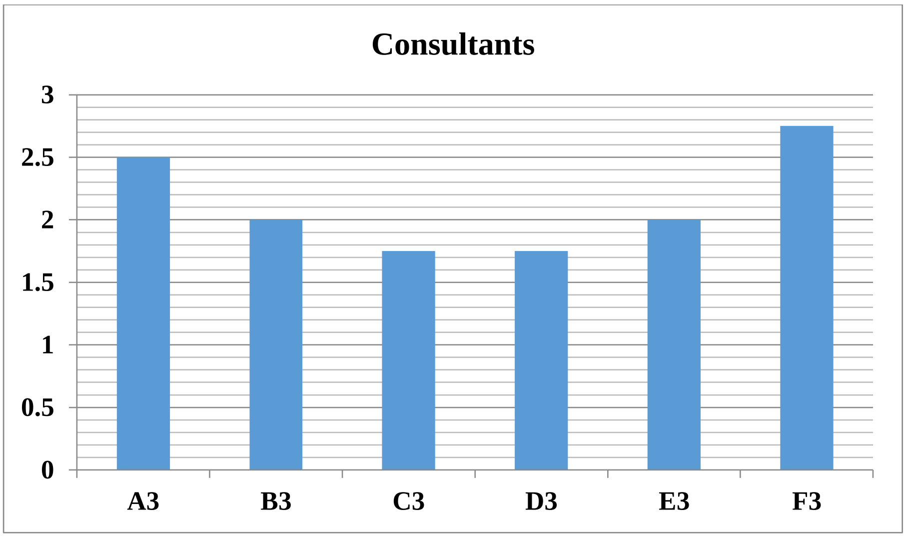


Figure 21: Scale Average of Consultants

Table 14: Advantages "Structural Factors" Average Rating-Scales

Advantages S_4		Average importance score of the participants				Average score
		Online participants	Manufacturers	Contractors	Consultants	
A_4	Better deflection and cracking values	2.44	2.5	1.5	2.75	2.37
B_4	High precisions in the openings and voids	2.16	2	2.5	2.5	2.23
C_4	Improve durability	2.08	2.5	2.25	2	2.11
D_4	Enhance quality	2.08	3	2.5	2.5	2.23
E_4	Lighter self-weight and thus smaller designed concrete sections	2.28	2	2	2.5	2.26

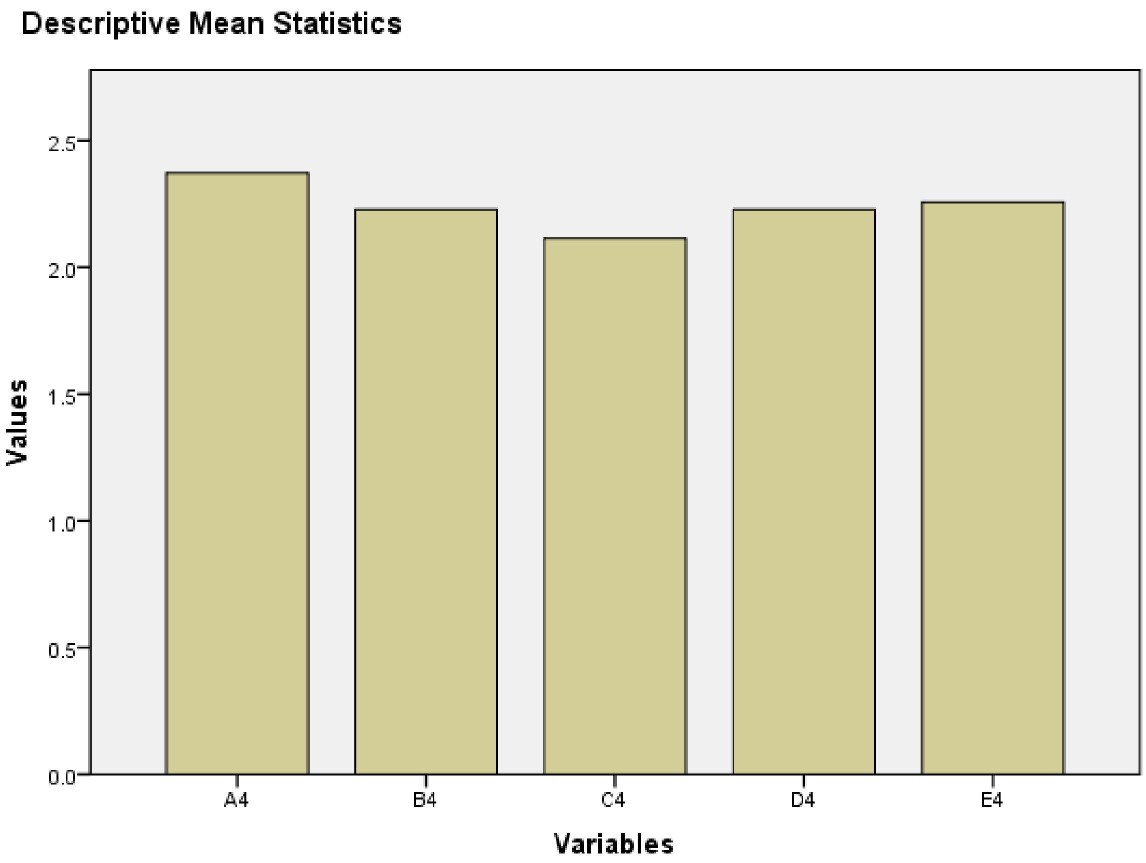


Figure 22: Average Scores of Advantages "Structural Factors"

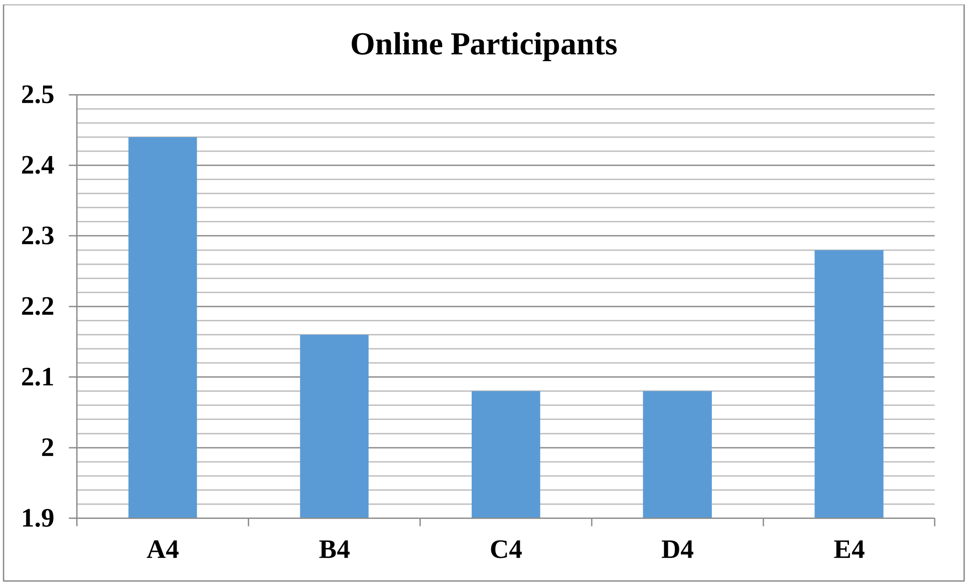


Figure 23: Scale Average of Online Participants

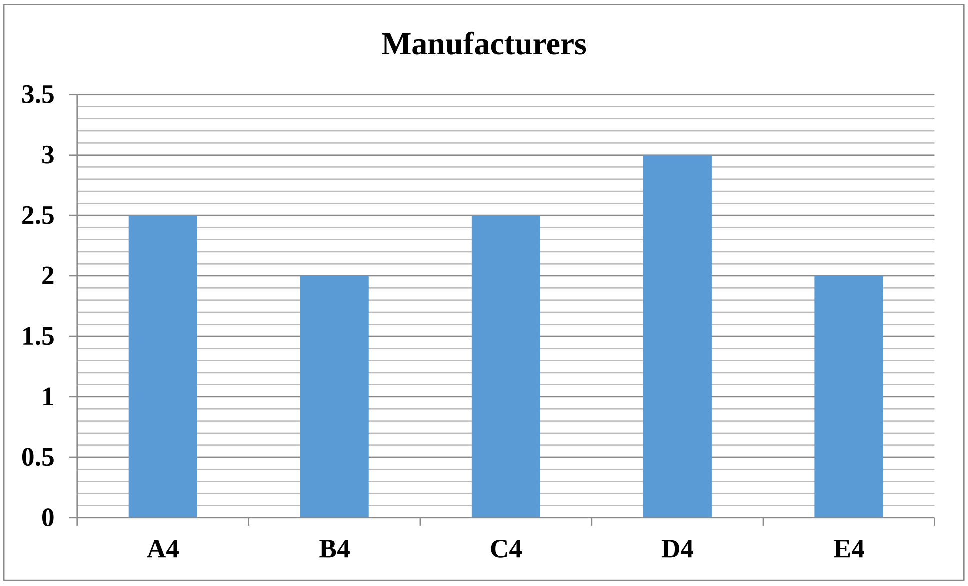


Figure 24: Scale Average of Manufacturers

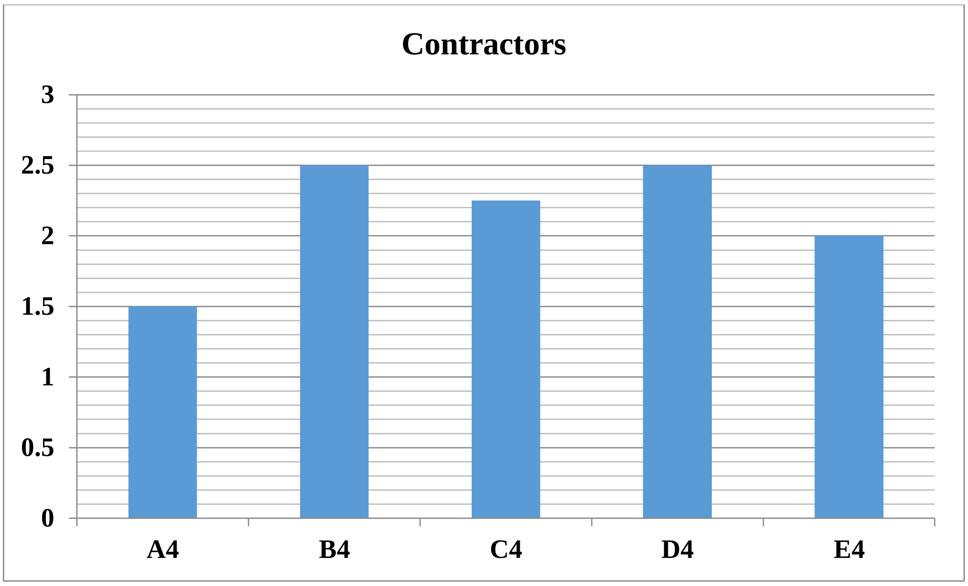


Figure 25: Scale Average of Contractors

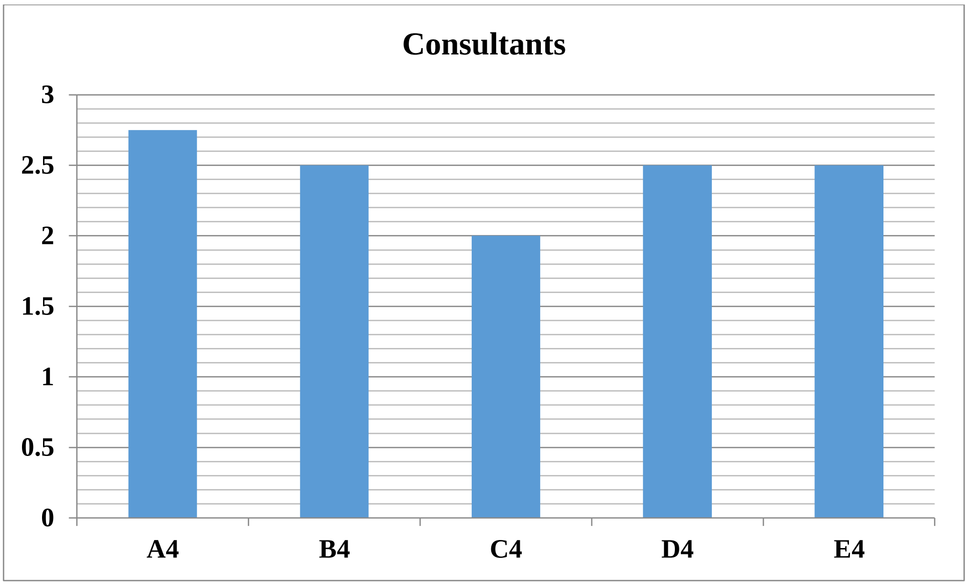


Figure 26: Scale Average of Consultants

F. Analysis of Variance "Mean Comparison"

It's significant to statistically explore the difference in the opinions between the Lebanese construction companies of either adopting precast or not. Thus, ANOVA would be a helpful technique to compare the three sample company's means of precast adoption choice. So, if the rating sample mean is below 2, the precast method would be a non-feasible method in the specific tested criteria, otherwise, it will be a practical technology to be adopted.

Our three detected samples are the types of participants which are the manufacturers, consultants, and contractors and the data will be tested on our four advantages criteria. In order to use the ANOVA, the sample data should follow a normal distribution or the sample size should be of $n > 30$. Consider the manufacturers, consultants, and contractors as the respective samples S_1, S_2, and S_3.

1. Data Normality check

We calculated the average means of the criteria of each advantage title under each type of participant, S_1-S_2-S_3, and with the help of SPSS we checked if the samples follow a normal distribution via the following three tests.

- Kurtosis and Skew-ness Test

This checking method is based on the following condition: -1.96 < Statistic/Std. Error < 1.96. And as we noticed that the results obtained in table 14 indicate that the variables are kurtotic and skewed for all samples, but it doesn’t differ significantly. Thus, the sample’s data follow a normal distribution.

Table 15: Kurtosis and Skew-ness Test

		Statistic	Std. Error	**Check**
Advantages "Productivity & Cost"	Mean	2.188	0.195	
	Std. Deviation	0.617		
	Skew-ness	-0.911	0.687	**Ok**
	Kurtosis	0.881	1.334	**Ok**
Advantages	Mean	1.775	0.202	

"Environmental Impact"	Std. Deviation	0.639		
	Skew-ness	0.708	0.687	**Ok**
	Kurtosis	-0.256	1.334	**Ok**
Advantages "Time Reduction"	Mean	2.25	0.165	
	Std. Deviation	0.522		
	Skew-ness	-0.608	0.687	**Ok**
	Kurtosis	-0.223	1.334	**Ok**
Advantages "Structural Factors"	Mean	2.32	0.112	
	Std. Deviation	0.355		
	Skew-ness	0.464	0.687	**Ok**
	Kurtosis	0.054	1.334	**Ok**

- Shapiro-Wilk Test

The Shapiro-Wilk test is used to confirm the normality distribution of our data which is considered as a requirement for the ANOVA test. The normality condition is considered when the p-value > than 0.05, meaning failing to rejecting the null hypothesis that is the data follows a normal distribution. The p-values of all criteria obtained in table 15 are significantly greater than 0.05, implying that the data follows a normal distribution.

Table 16: Shapiro-Wilk Test

Tests of Normality			
	Shapiro-Wilk		Check
	Statistic	Sig. (p-value)	
Advantages "Productivity & Cost"	0.928	0.428	**Ok**
Advantages "Environmental Impact"	0.911	0.29	**Ok**

Advantages "Time Reduction"	0.945	0.605	**Ok**
Advantages "Structural Factors"	0.965	0.841	**Ok**

- Q-Q Box Plot

The Q-Q and Box plots test is also used to ensure that the data follows a normal distribution, the plot is drawn through, as the following: Designate by j=0, 1…N and a value 100*(j-0.5)/N, and plot the former values versus scale-rating data. If the diagram obtained is a straight line, then we can assume that the data follows a normal distribution.

The following figures illustrate the normality conditions of our data, due to the straight line obtained and due to the closeness of the data points to the line. The box plots of “productivity and cost-environmental impact-time reduction-structural factors” indicate that the data is a bit negatively-positively-negatively-normally skewed respectively.

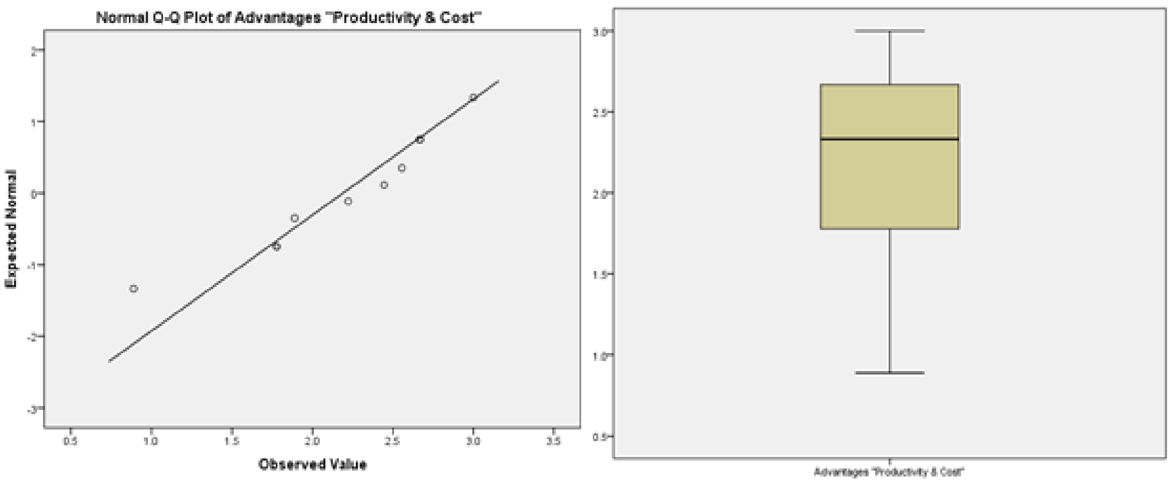


Figure 27: Q-Q and Box Plots "Productivity and Cost"

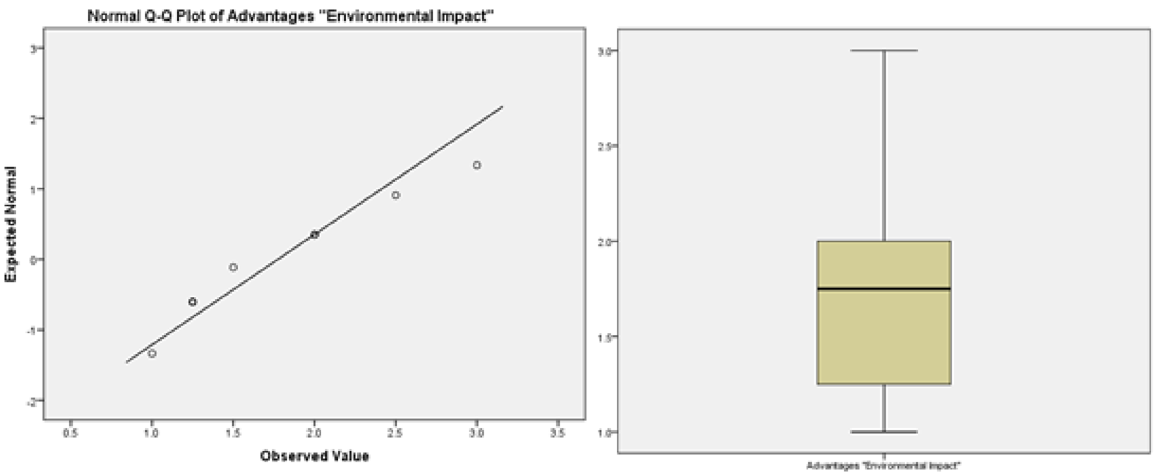


Figure 28: Q-Q and Box Plots "Environmental Impact"

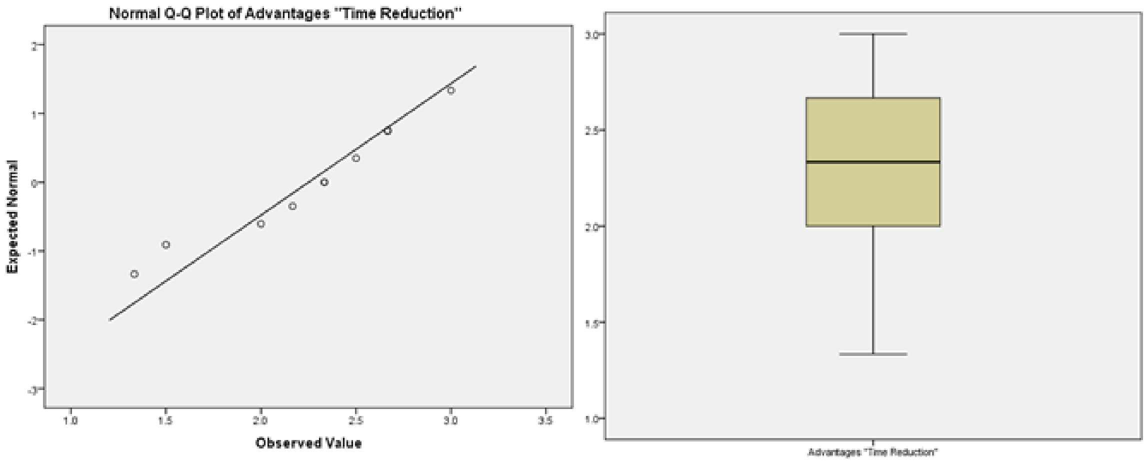


Figure 29: Q-Q and Box Plots “Time Reduction"

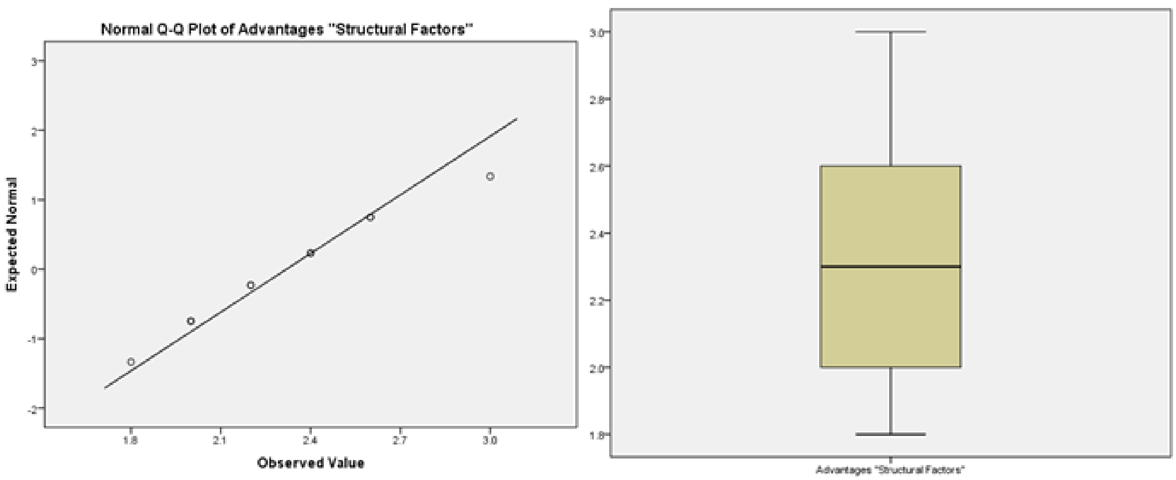


Figure 30: Q-Q and Box Plots “Structural Factors"

2. ANOVA

- Conditions and Assumptions

After the normality check, ANOVA method will be executed by using SPSS software to compare the averages obtained from the types of participants considered as the samples for the criteria. The ANOVA to be efficient our model should follow the subsequent conditions:

- ✓ Independence of observations: our observations are the rating scales, and they are considered independent in all the advantages criteria.
- ✓ Normality conditions that are proved in section F.1, for all advantages criteria.
- ✓ The homogeneity of variances is also proved by SPSS by the Levene's Test of Equality of Variances.

Table 17: Levene's Test of Equality of Error Variance Advantages "Productivity & Cost"

F	df1	df2	Sig.
4.154	2	7	.065

Table 18: Levene's Test of Equality of Error Variance Advantages "Environmental Impact"

F	df1	df2	Sig.
12.810	2	7	.005

Table 19: Levene's Test of Equality of Error Variance Advantages "Time Reduction"

F	df1	df2	Sig.
.814	2	7	.481

Table 20: Levene's Test of Equality of Error Variance Advantages "Structural Factors"

F	df1	df2	Sig.

2.870	2	7	.123

All the obtained p-values >0.05, hence we fail to reject the null hypothesis that the error variance of the dependent variables are equal across the groups. This will indicate that our data is suitable for the interpretation of fisher's LSD test. Table 20 will present a summary of the descriptive statistics representing the mean and standard deviation of the 3 samples of all the criteria.

Table 21: Descriptive Statistics of the Three Samples

Participant Type	**Mean**	**Std. Deviation**
Interviewed Manufacturer	2.666	.0000
Interviewed Contractor	2.111	.3513
Interviewed Consultant	2.027	.9089
Participant Type	**Mean**	**Std. Deviation**
Interviewed Manufacturer	1.750	.3535
Interviewed Contractor	1.625	.4330
Interviewed Consultant	1.937	.9655
Participant Type	**Mean**	**Std. Deviation**
Interviewed Manufacturer	2.583	.1178
Interviewed Contractor	2.208	.4976
Interviewed Consultant	2.125	.6854
Participant Type	**Mean**	**Std. Deviation**
Interviewed Manufacturer	2.400	.0000
Interviewed Contractor	2.150	.3415
Interviewed Consultant	2.450	.4434

- Fisher's Least Significant Test

Fisher's Least Significant Difference test will be adopted as the Post-Hoc test for the ANOVA, in which a pairwise comparison would be adopted for each sample type. The results are shown in the tables from 21 to through 24. The null and the alternative hypothesis are presented in the following (α=0.05).

H_0: $\mu_1 = \mu_2 = \mu_3$; where μ_i is the hypothesized sample mean of the criteria according to the type of participants.

H_1: at least one mean is different.

Table 22: Fisher's LSD Test "Productivity and Cost"

Multiple Comparisons						
Advantages "Productivity & Cost"						
LSD						
(I) Participant Type	(J) Participant Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Interviewed Manufacturer	Interviewed Contractor	.555	.5524	.348	-.750	1.861
	Interviewed Consultant	.638	.5524	.285	-.667	1.945
Interviewed Contractor	Interviewed Manufacturer	-.555	.5524	.348	-1.861	.750
	Interviewed Consultant	.083	.4510	.859	-.983	1.149
Interviewed Consultant	Interviewed Manufacturer	-.638	.5524	.285	-1.945	.667
	Interviewed Contractor	-.083	.4510	.859	-1.149	.983

Table 23: Fisher's LSD Test "Environmental Impact"

Multiple Comparisons
Advantages "Environmental Impact"

LSD						
(I) Participant Type	(J) Participant Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Interviewed Manufacturer	Interviewed Contractor	.125	.6110	.844	-1.319	1.569
	Interviewed Consultant	-.187	.6110	.768	-1.632	1.257
Interviewed Contractor	Interviewed Manufacturer	-.125	.6110	.844	-1.569	1.319
	Interviewed Consultant	-.312	.4988	.551	-1.492	.867
Interviewed Consultant	Interviewed Manufacturer	.187	.6110	.768	-1.257	1.632
	Interviewed Contractor	.312	.4988	.551	-.867	1.492

Table 24: Fisher's LSD Test "Time Reduction"

Multiple Comparisons						
Advantages "Time Reduction"						
LSD						
(I) Participant Type	(J) Participant Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Interviewed Manufacturer	Interviewed Contractor	.375	.4818	.462	-.764	1.514
	Interviewed Consultant	.458	.4818	.373	-.680	1.597
Interviewed Contractor	Interviewed Manufacturer	-.375	.4818	.462	-1.514	.764
	Interviewed Consultant	.083	.3933	.838	-.846	1.013
Interviewed Consultant	Interviewed Manufacturer	-.458	.4818	.373	-1.597	.680
	Interviewed Contractor	-.083	.3933	.838	-1.013	.846

Table 25: Fisher's LSD Test "Structural Factors"

Multiple Comparisons						
Advantages "Structural Factors"						
LSD						
(I) Participant Type	(J) Participant Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Interviewed Manufacturer	Interviewed Contractor	.250	.3173	.457	-.500	1.00
	Interviewed Consultant	-.050	.3173	.879	-.800	.700
Interviewed Contractor	Interviewed Manufacturer	-.250	.3173	.457	-1.00	.500
	Interviewed Consultant	-.300	.2591	.285	-.912	.312
Interviewed Consultant	Interviewed Manufacturer	.050	.3173	.879	-.700	.800
	Interviewed Contractor	.300	.2591	.285	-.312	.912

CHAPTER V

ANALYSIS AND DISCUSSIONS

In this part, we'll discuss the results obtained and derive some inclusive analysis. This section will be divided into two parts; the first will provide a thorough discussion on the rating averages of the precast advantages and disadvantages obtained from the online survey and analyze the reported qualitative data from obtained from the interviewed companies. The second section will examine the comparison of the results obtained from the types of participants and evaluate the difference of the points of view construction companies towards precast technology. The first and second part will help us answer our research questions which are:

- What are the main causes behind the deficiency in precast utilization in Lebanon?
- Why the precast technology is highly recommended for construction projects?

Furthermore, the third part of this section will be considered as a furthered discussion for our research adding an attention towards the markets attitudes on precast method.

A. What are the main causes behind the deficiency in precast utilization in Lebanon?

The results obtained from the shortcomings part of the survey had contributed to major inferences. As mentioned in the results section in table 9 and as presented in figure 2, the results of the average rating-scale range from 1 to 2. This indicates that all of the included shortcomings are considerable in the Lebanese market diminishing the precast usage in the construction projects. Moreover, the shortcoming **G**, “architectural complex requirements VS uniform and monotone precast manufactured elements”, had scored the maximum rating average value, displaying a severe impact in the overall precast usage. Note that the architectural complex requirements generate a conflict with the manufacturing plants due to the uniformity of the precast molds which confines the creativity and aestheticism. However, the criteria showing the least rating average is as expected the shortcoming **H**, “labor associations & unions”, in which the Lebanese construction market has never experienced such active associations and labor unions arguing about the precast consequence which reduce the labor amount at the site.

In what follows, each precast shortcoming criteria will be discussed and related to a broader literature.

✓ Size & load transportation restrictions

One of the significant shortcomings is transporting the precast elements to the site; large, heavy and condensed weight cells may hinder the truck capability of transferring the cells to the site. Moreover, Polat (2010) states that in highly congested areas the transportation is also a major problem. Particularly in Lebanon, and as well-known that road congestion is one of the foremost daily unsolved issue, this may upsurge the transportation constraint as indicated by the majority of the interviewed companies. In terms of size limitations Arditi et al (2000) added that the elements’ heights are also limited by the clear distances under the tunnels, and the outsized masses may be inadequate for the designed allowable highways and bridges, which in turn applicable to the Lebanese case where the tunnels heights’ are restricted. This criterion had scored an average of 1.8 which is closest to the average importance of contributing to the precast deficiency in Lebanon.

✓ Far delivery distances between manufacturers-site locations and manufacturers-raw material zones

The geographic limits, distance supply ability, economic transportation and availability of raw-materials are factors that control conveying manufactured products or services to the aligned ventures and large scale projects as indicated by Sacks et al (2004). In Lebanon, the only three precast manufacturing factories are located in Zouk Mosbeh (Kesrouane) "PPB Structure. Derviche Haddad Sal", Thoum El Tahta (Batroun) "Mega prefab Sal", and in Halat "Soprel Liban" this indicates that the factories are assembled in the northern regions. So this would aggravate the issue of far delivery distances, mainly if a project located in Bekaa valley or in Southern regions. However, the interviews with these manufacturing companies and referring to the results obtained in the comparison of the types of companies, this criterion is considered of a meager importance and this will be discussed in the second part of the discussions part. One of the suggested solutions was argued by Azman et al (2014) considering the optimal distances that should be implemented before any factory construction, taking into consideration the attractive project zones that entice precast technology. This criterion had scored an average of 1.43 which is close to the little importance, indicating that this factor is of considerably minor influence on the precast usage in Lebanon.

✓ Seismic Fragile Resistance

UBC 97 (Uniform Building Code 1997) while portioning the world map into seismic zones, allocated Lebanon in a substantial area exposed to considerable a seismic acceleration = 0.25g. Thus all structures worth to be designed to resist earthquake effects especially for high buildings. For that, the Lebanese Order of Engineers and Architects in 2017 mandate all buildings to be designed and approved against seismic confrontations. The precast buildings are articulated together by joint connections which are deliberated to be fragile in a structural point of view upon applying seismic loads. Deformations and failures occur due to high distress values resulting in structural catastrophes. For instance, in 1994 Northridge earthquake displayed severe distortions and failures (Polat, 2010), in 1998 Adana-Ceyhan, Turkey, Emilia 2012 and Marmara 1999 earthquakes as indicated by Liu et al (2017). Moreover, the Platinum Tower and the Beirut Mall projects in Lebanon were built via cast-in-situ methods since the consulting company were reticent towards precast technique due to the seismic fragility, as argued by some of the interviewed companies. The precast building has low energy consumption and damping ratios due which declines the energy dissipation leading to significant harming effects.

However, Kosowatz (1990) argued about the similarity of earthquake effects on precast and conventional constructed buildings after the experience of Armenia 1998 earthquake. Furthermore, it is unexpected that Liu et al (2017) concluded in his investigation, that both the conventional and precast structures have same energy dissipation, bearing and deformation capacity. Therefore, experts assert on the structural design organizations such as, PCI and NSF, to direct the research towards more proficient designs against high seismic acceleration forces. The average scale result in this debatable criterion is 1.91 which close to the average importance and that was due to the divergent opinions between manufacturers, consultants and contractors. It’s notable to indicate that interviewed manufacturers and some of the consultants ensured that inclusive researches have initiated methods and techniques for design and implementation for more resisting precast buildings.

Lack of skilled designers, contractors, and labors

Construction industry suffers from lacking skilled personnel; precast technology entails introducing the high-tech processes of designing and implementing. The deficiency in structural and architectural designers accompanied by absence of specialized workmanship and low labor wages, generally in developing countries (Polat, 2010) is mainly due to the shortage of initiatives in investing in human resources and aptitudes. Hence, assigning periodic trainings and workshops provide incessant updating to innovative technological methods and adopting BIM technologies in design phases to reduce shop drawing errors as indicated by Kaner (2007). The majority of the interviewed contractors indicated that for the labor productivity boost, implementing safety requirements convoyed by acquiring the effective erection experience of the precast methods help in qualifying workmanship and technicians as well as stimulating the labor society to incorporate in the advanced precast construction field and to progress the overall productivity. The average scaling rate of this criterion is 1.66 which is close to the average importance as a reason for limiting the utilization of precast technology. This implies that the Lebanese construction market considerably lack the skilled resources for the precast method. Nevertheless, the discrete results obtained from the contractors and manufacturers are relatively low and that may be explained by the affiliation to their businesses showing high skillful resource available for the projects.

✓ Lack of academic programs adopting precast design and implementation

Professionalism and expertise shall be attained by incorporating the precast technology in the academic curriculums (Arditi et al, 2000). Educational university programs lack the adequate proper discipline of introducing the appropriate methods of design and erection of the precast structures. For example in Lebanon, rarely do universities postulate the prefab design and implementation codes as subjects to be educated as indicated by the bulk of interviewed companies, the same as in many countries such as in the US (Arditi et al, 2000). Note that for elucidating the argument stating that precast design and implementation are adopted by the academic curriculums, the interviewed manufacturers and consultants agreed on the providing the pre-stressed design by civil engineering programs in the Lebanese universities and not precast design and implementation. Although the precast depend on pre-stressed conventions and methods, precast technology should be separated for its associated phases. Many approved books and articles embrace the precast systems that may be adopted by academic syllabuses. It can be stated that the other main reason behind the precast specialized civil and architectural engineers resulting in poor designs and erections. This criterion scored an average of 1.74 signifying the importance of restraining the precast deployment in Lebanon urging the civil engineering programs to allocate precast courses, workshops and trainings to familiarize the precast knowledge among the civil engineering society augmenting the rank of connoisseurs in the precast construction field.

✓ Lack of communication and collaboration among supply-chain involved parties

Precast systems are interconnected with lots of actions, practices, and procedures. The precast supply-chain phases are listed in the successive manner as the following: Planning, design, manufacturing, transportation, installation, and construction (Abedi et al, 2015). Clients, consultants, structural-architectural engineers, manufacturers, and contractors should be involved and updated to the latest information. Communication may be achieved through periodic consulting meetings and visits initiated by all the participants. Scheduling and task implementations should be also discussed will accelerate the construction process. In addition, BIM technologies help in creating backgrounds sharing the available database among the involved participants. Moreover, BIM embrace proficient collaborations between team members and enable the information flow, as well as incorporating the stakeholders with the appropriate construction phases throughout the project life-cycle (Ismail, 2017). However, one of the main issues is that the majority of Lebanese contractors aren't recognizing the cost reduction by using precast technologies and that's due to the delay in time deliverables and erection plans. Yet in fact, these deferrals may be a result form the poor connection between the precast involved parties. For instance, the manufacturers are limited to their molds standard dimensions, so the designers (architectural and structural) should communicate with the manufacturer to identify the restricted sizes, measurements, architectural details such as voids and openings, and structural designs in case of special loadings that may be vital for each project. The average score of the lack of communication between the parties in Lebanon is 1.14 which is almost of little importance which contradicts the fact of the lack of communication and collaboration and supports the enrichment of collaboration and the constructive interference of the parties.

- ✓ Architectural complex requirements VS uniform and monotone precast manufactured elements

Architectural designs are highly recommended for the aesthetic features of buildings, so complex requirements collide with the narrow available manufacturing capabilities. Lebanese manufacturing industrial units espouse their standard molds and erecting patterns for producing the precast elements such as PCI, BPEL, and CPT standards. However, providing the adequate casts to supply the vital proposals of architects would be expensive (Arditi et al, 2000), as in the case of domes, shells and curved designs. This would result in obstinacy in compromising the supply-demand issue of precast panels, leading to monotony and repetitive profiles (Thanoon et al, 2003). On the other hand, it's essential to indicate that the responses of the interviewed manufacturers confirm on the ability of supplying any requested architectural shape but, with requiring additional costs. The reason of the conflict between the architectural requirements and the uniformity of manufacturing molds scored an average rate of 2 which is considered as a substantial factor behind restricting the adoption of the precast method.

- ✓ Labor Association & Unions

After introducing the technological aspects designated by the prefab buildings products in the construction industry, labor unions and associations anticipated to preserve the traditional construction methods and to keep on the unit mechanisms. They confronted the prefab technology through arguments, disputes and sometimes boycotting (Smith, JR, 1972). Nevertheless Kazaz et al (2008) stated that laborers produce under hard and risky conditions, accompanied by low-wage environments. Furthermore, precast technology tends to reduce the workforce and the labors at the site due to the flexibility in erection; consequently labor unions arise and claim about their rights, affecting the precast procedures in the construction engineering. However, the average rating scale obtained by the results for this criterion is 1 which is the lowest value among all factors, ultimately shows that the labor associations are scarcely presented in Lebanon which comes on parallel along with the opinions in the interviewed companies that insisted on the absence of such organizations and associations in Lebanon.

- ✓ Lack of precast industry management

Most researches and studies have taken the precast concrete systems from the structural and design point of view, whereas very few considered the managerial tasks of precast technology (Chu et al, 2017). The supply-chain processes of precast method requires severe and perfect management and engineering procedures (Sacks et al, 2002), starting from the design phases, passing by the architectural simulation and reaching the site erection. The manufacturing management responsibilities adopt the lean production systems which are summed up by Wu et al (2010): 1- site lay-out management (affecting the overall production) 2- delivery management of raw materials (the method of managing orders and deliveries with JIT system) 3- production management (setting up molds, rebar work, concreting, de-molding, and quality control), and stock-management (yards are essential for stocking). However, as formerly stated the contractors aren't recognizing the high potentials of precast industry in saving costs, since the some managerial phases such as, motivation of workforce, deliveries, storage on site, space constrains, storage duration, buffer stocks, transportation, reimbursement and sharing of savings, coordination with pre-casters etc… aren't well executed; hence deeper considerations should be applied along with precast management systems (Pheng et al, 2001). The attained results of rating the lack precast industry management is 1.4 which seems noticeably low inferring that management techniques are well embraced in the precast industry in Lebanon.

✓ Contractors aren't recognizing cost saving benefits

One of the main disadvantages of the precast tradition is translated by the contracting companies not recognizing the cost saving capabilities that precast industry promises (Sacks et al, 2004). The lack of competition due to the shortage of the number of manufacturers contributing in the Lebanese construction market will increase the precast overall budgets and restrict the availability of economical prices. In addition, poor promotional and advertising activities oriented to the precast technology benefits (Polat, 2010) affect the stakeholders' decision making processes to approve on the prefab methods for their projects. Besides, lack of skilled precast, technicians and designers as well as poor functional managers lead to delays in time deliverables and thus cost augmentations.

In Lebanon the labor work force costs is considerably cheap in contrast to the developed countries. However, reducing labor works is measured as the main cost cutting capability offered by precast technology. Hence, interviewed contractors indicated that they are inspired to adopt the traditional ways of casting rather than precast methods.

Precast techniques are usually implemented and adopted in decent economic environments and high percentages of housing projects and higher labor costs (Yu et al, 2008) knowing that according to World Bank (2017) Lebanon ranks 135 in the construction permits field among 190 economies; this would necessitate the significance of the investments in the construction markets, which will consequently enhance the productivity and efficiency of the precast method. The fact that the Lebanese contractors aren't recognizing costs benefits attained by precast method scored an average scale of 1.83 which is as close as the average importance of limiting it's utilization in Lebanon.

- ✓ Decline in demand VS shortage in supply

Market demand and supply capabilities play a vital role in identifying precast sharing proportions in the construction market. The stakeholders' basic desires are to condense expensive construction methods, thus demand on low-cost technologies should grow. However, the developing countries suffer from declines in calling the precast concrete systems. Market demand drops accompanied by contractors considering the precast industry as a volatile method inspire investors to capitalize their funds in safer markets like cast-in-situ methods. Therefore, the acceptance of such technologies requires open-minded construction organizations to allow the precast industry to emerge the global market (Thanoon et al, 2003). In fact, in Lebanon some outsized precast projects necessitated considerable energies to be provided by the desired demand as indicated by the majority of the interviewed consultants. On the other hand, the interviewed manufacturers agree on the main precast delivered components to the Lebanese construction markets are beams, ledgers, girders, columns, and hollow-core slabs, in addition to different types of concrete walls including basement walls, shear walls, sandwich panels, and façade panels. However, these components are supplied exclusively by the only three Lebanese manufacturers "*Mega Prefab, Derviche Haddad Sal and Soprel Liban"*, which may lead to dearth in supplying precast elements in case of high demand. This conflict between the supply-demand tradeoff has scored an average scale of 1.51 which is closer to the average importance to be a reason behind the precast restriction in Lebanon.

✓ Lack of public sector investments

Public sectors and governmental units control the economic development and contribute in the continuous growth. However, the interviewed companies have indicated that the majority of the Lebanese public investments and funding are concentrated in the infrastructure portion of the construction field. Their main purposes are to integrate the corporate social responsibility and develop the cultures. On the other hand the private sector's participation is usually concentrated in the super-structural projects. Meanwhile, the private sector stakeholders and investors would be satisfied due to the high economic feasibility of low-risk projects. It's significant to identify that some infrastructure projects such as highways, bridges, sewer and water supply systems require prefabricated elements: beam girders and box culverts for highways and bridges, manholes and VCP (vitrified clay pipes) for sewer and water supply projects etc…which are delivered by the Lebanese manufacturers. So, from infrastructure point of view, this should encourage the precast technologies to supply such prefab elements demand, yet the Lebanese governmental infrastructure investments are moderately low. Moreover, and based on World Bank Policy Research, Kenny (2007) stated that Lebanon admits high levels of construction corruption in terms of licenses, permits, and labor inspections reflecting a general shortage in the superstructure projects; consequently affecting the precast buildings professions. The lack of the public investments scored an average of 1.97 which is the average importance of being a substantial reason behind diminishing the adoption of precast technologies.

- ✓ Users aren't satisfied by precast built structures

Precast industry proposes high potentials of production improvement, time cycle reduction and cost savings by incorporating factory-built constructing systems and applying decent levels of management skills (Yu et al, 2008). Therefore, precast method is capable of aggregating the level of conviction of users occupying precast concrete structures. However, the level of occupant's satisfaction may fluctuate due to the architectural monotony and normalization, accompanied by initial defects in prefabrication due to lack of expertise and quality control thoroughness which lead to cracks, imperfections, moisture penetration (poor connections and irregular waterproofing systems), as well as poor thermal insulation that may be included with the precast panels such as walls and hollow-core slabs (Thanoon et al, 2003; Polat, 2010; Arditi et al, 2000). Moreover, dissatisfaction may augment due to the seismic fragility, resulting in high values of story drifts in structural buildings. The average score of this criterion is 1.23 which is relatively low and close to the little importance for limiting the precast method adoption in Lebanon.

B. Why the precast technology is highly recommended for construction Lebanese projects?

Precast industry offer significant potentials to the construction corporations with productivity boost accompanied by overall high opportunities for cost reduction, time reduction, lower environmental impacts and better structural engineering values; precast technology provides better sustainable performance of the buildings in terms of social, environmental and economic criteria (Chen et al, 2010; Bonev et al, 2015).

In what follows, each precast advantage criteria will be discussed and related to a broader literature.

✓ Productivity and Cost

The precast manufacturing plants and particularly the Lebanese ones ensure the utilization of standard molds having even and smooth surfaces. So, after the concrete is batched and poured into the mold, provided with well concreting and curing processes according to the followed standards, the dense concrete would fill the molds consistently and uniformly. Moreover, the manufacturing quality control processes guarantee the surface aesthetics avoiding irregular appearances such as “bug holes and honey combs” (Manrique et al, 2007). Hence, smooth and flat planes would result eliminating the need for plastering phases that is costly and time consuming. This criterion scored an average rating scale of 2.37 which is relatively of high importance, meaning that precast technology is highly recommended due to the cost savings in the smooth surfaces.

- Cost saving in scaffolding

Generally, scaffolding is usually required to ensure the reinforced concrete stability before it reaches its hardening phase and the necessary compressive strength. However, the interviewed manufacturers guarantee that the prefabricated elements are subjected to precise concreting and curing systems scaffolding is usually required to ensure the reinforced concrete stability before it reaches its hardening phase and the necessary compressive strength. Nevertheless, the precast elements require minor scaffolding systems as indicated by some contractors in the case of long spans. This would allow the precast industry to cut the scaffolding costs by eliminating the need for consistent scaffolds. According to the Irish Precast Concrete Association precast concrete method saves costs by 75-90% in the scaffolding phase required for shoring the concrete formwork in cast-in-situ method (Liu et al, 2017). The savings in scaffolding criterion scored an average scale of 2.11(close to high importance) which indicates the significant role of the precast method attracting construction projects.

- Cost saving in formwork

The concrete elements, casted away in the manufacturing plant, are characterized by their even shapes and textures conferring to the architectural and structural requirements. So, adopting precast technology condenses the need of shuttering and de-shuttering works that are principally vital for casting the concrete on sites. Additionally, the frequently used type in Lebanon is the timber or plywood formwork having a specific lifetime or number of reuses. Whereas, the molds adopted in the manufacturing plants are more efficient and can be used multiple of times and simultaneously realizing better qualities. Levitt (1982) stated that according to the type of the mold used, the number of utilizations is estimated. Steel molds for example, may be used for around 1000 times; wooden molds would last for a period serving a 20 to 100 times; plastic molds serves for 200 to 1000; aluminum molds may be used for thousands of times and all provided with proper repair application. Eventually, this would allow the precast technology to reduce costs in the shuttering and de-shuttering phase as well. For instance, Irish Precast Concrete Association precast states that precast concrete method saves costs by 75% in the formworks including its installation and removal stages compared to the cast-in situ method (Liu et al, 2017). The savings in formwork criterion scored an average scale of 2.57, which is the highest resulted value in terms of productivity and cost factors, this implies that the precast technology is ultimately efficient in its high potentials in formwork cost savings.

- Less maintenance

Construction projects usually admit defective items in structural and architectural components; quality management plans recommends high precision in the quality monitoring validating the associated acceptance criteria for the project. The interviewed manufacturers and consultants pointed out that cast-in-situ construction methods disclose higher uncertainties in resulting with imperfect implementations, consequently necessitating higher maintenance costs. Conversely, they added that prefabricated elements are produced by a reputable, skilled and qualified labor force operating in factories with manufacturing purposes. Moreover, the production factories are equipped by high-technological instruments provided with precise molds as the case in the Lebanese production plants. Each phase of fabrication is subjected to inspection and examination to assure the accuracy and eminence of the dimensional features, material used, concrete covers, and controlled mix deigns in accordance with the embraced quality system (stephen, 2004) and as ensured by the Lebanese manufactures. Thus, longer life spans are expected for precast buildings accompanied by less maintenance requirements. The less maintenance criterion scored an average scale of 2.14 which is close to the average importance inferring that precast method is vastly recommended for construction projects reducing the long-short term maintenance costs.

- Elements coming to the site fully equipped with plumbing, electrical and painting materials

One of the most vital pluses of the precast elements is their ability to attain the jobsites fully equipped with the finishing utilities which may reduce the cost of working labors and lessen the number of contracting companies performing such works, since most of the contractors develop plans to perform finishing works due to its high profitability. These finishing phases require additional works applied on the masonry walls and some structural elements. In Lebanon, the most common prefab product is the hollow-core slab which occupies high selling magnitudes in the market as indicated by the interviewed companies. However, the finishing supplies are partially furnished at the Lebanese manufacturing plants and finalized at the project sites. So, the exact locations and paths of the plumbing and electrical materials are determined and provided with unfilled cavities in the hollow-core slabs, which assist the assigned site workers to wrap up the necessary applications.

According to the painting phase, it’s also feasible to pre-paint the elements reducing particular costs and realizing better qualities (Rogers, 2007), but the interviewed contractors indicated that, in Lebanese projects painting phases are similarly applied on the sites.

Working labor costs may be also reduced through the other finishing phase such as thermal isolation, in which the hollow-core slabs and the structural-architectural façade panels may comprise isolation and synthetic materials to be thermally efficient having R-values that validate the thermal standard in Lebanon. The case is likewise applied for the waterproofing and acoustic insulation, yet the Lebanese projects comprise the isolation task to be performed on the site discounting for the labor cost saving. The average scale resulted in this criterion is 1.91 which is close to the average importance indicating that while global precast method embrace equipping site elements, it's less common in the Lebanese construction market.

- Erection Flexibility

Construction flexibility has a vigorous role in augmenting the overall productivity of the precast technology providing faster implementation and thus, reduction of project delays risks. The precast system offers the facility of positioning the prefab elements using a tower-crane. However, the tower-cranes are limited to certain lift capacities. In Lebanon the cranes capacity range between 0.9 tons and 25 tons for small and huge tower cranes accordingly, and also it ranges according if the masses are lifted at the tip or not as indicated by the interviewed contractors; this in a way may restrict designers to reduce the concrete sections, which at the same time help decrease the self-weight loading in the structures and accordingly the costly foundation systems. The Lebanese consulting companies have shown an advanced method of reducing the lifted concrete elements by dividing long span and massive elements into parts and setting them just beside each other especially for the huge beams as in the "ABC Verdun" project. In fact, the reduction of each 1 m3 in the concrete works could diminish costs by an average of 200$ as revealed by some interviewed companies.

On the other hand, some contractors showed that erecting high rise buildings and lifting massive elements up to highly elevated levels may be an adverse issue, requiring more caution. For instance, if the weather conditions were severe as in a high wind exposure, the cranes may delay the erection processes for the safety necessities. However, unexpected responses that some interviewed consultants has considered that precast systems are more desirable for high buildings since it would eliminate the necessity of oversized pumps that may lead to concrete casting errors such as segregations in addition to their high costs. So, using precast systems high cranes are required for erecting these elements.

Moreover, better installation flexibility would be attained with lighter elements. Furthermore, enterprises or supply-chain phases within one project contribute in parallel manner for site erection and off-site manufacturing which contributes in enhancing efficiency (Bonev et al, 2015). Erection of an average of 13 of 10m2 façade panels, 10 of 10m columns, 200m2 of hollow-core slabs may be achieved per day, provided the necessary sequence of casting structural components as indicated by the interviewed manufacturers. For instance, the ABC project, Verdun-Beirut in Lebanon, an area of 126,000 m2 design, production, installation and casting had engrossed about 18 months to be finished and the manufacturer and designer of precast structures was “MegaPrefab Sal”. Also, the company responsible for precast structures “Derviche-Haddade” in Mobilitop project declared that it managed to erect a 750m2 per day. Another comparable example of precast erecting comes from the US, in which 1,803 panel pieces of an area of 18,643 m2 were casted in 5 months with 6-man crew in “GSU Piedmont Central Student” in the US (Gardiner, 2018). The flexibility in the erection process achieved a score of 2.06 which is relatively high revealing considerable cost and productivity potentials.

- Reduction in labor conditions in production plants

The production of the precast structures is centralized at the manufacturing plants which are usually reliant on automation and robotic instruments. This would help reduce the labor conditions and the exhausting mechanisms that cast-in-situ technique requires (Thanoon, 2003). In our interviews, we asked about the level of technology attained in the major manufacturing factories in Lebanon; the responses were rigorous ensuring the well-organized production systems with high-tech machinery based schemes and efficient allocation of labor activities controlled by decent management environment. This complies with the score achieved by the survey which is 2.03 demonstrating the importance of reducing the labor conditions at the manufacturing plants.

- Higher site safety

One of the essential assessment criteria in the decision making process is the safe building procedures; hence the construction technique should encounter the ease and safety while the clients and stakeholders desires are met. Precast method reduces the number of processes to be achieved on site in terms of labor works providing higher security. So, the designers should play a role in the contribution of a safe site conditions mainly if they take notice to providing suitable functioning margins. This would end-up reducing injuries and accidents delaying the assigned works (Lam et al, 2007). However, the precast technology arouse the risk of falling objects especially in the case of high buildings and the interviewed practitioners suggested more contingent and cautious execution processes. The precast additional safety scored an average of 1.83 which is close to the average importance. Yet, this criterion is realized as the lowest cost and productivity factor, and that may be explained by the stated fact of falling objects.

- Manufacturing plant workers are given definite tasks increasing their proficiency

At the manufacturing plants the production management is usually implemented and controlled in which systematized processes are executed. So, technical and quality control managers are authorized to assign definite and certain tasks for the resources empowering the fabrication proficiency to increase. In Lebanon, the three manufacturing plants adopt different production management procedures; nonetheless their staffs are satisfied by their jobs and productivity, as per the data obtained from the majority of the interviewed manufacturers. This criterion scored an average of 1.97 that's relatively high coming in parallel with the responses of the manufacturers and some consultants matching the manufacturing process with an industry.

✓ Environmental Impact

- Decrease site disturbances and noises

The adoption of precast technology in the construction sites helps reduce disturbances and noise produced (VanGeem, 2006; Polat, 2010). The interviewed consultants indicated that fewer trucks will be attaining the site, and the need for erecting equipment using precast would be lower than that using cast-in-situ method. For instance cast-in-situ involves the presence of pumping trucks and concrete mixer trucks attaining the site, whereas the only needed trucks in the precast technique are those transporting the elements which may be turned off after reaching. Moreover, the concrete structures are prefabricated in an off-site manufacturing plant provided with the possibility of equipping the elements with finishing utilities, which help reduce the induced noises especially in urban areas as the case of the majority of Lebanese regions. The potentiality of reducing site noises scored an average of 2.03 which is relatively high, so in terms of environmental impact the precast method would reduce the noises and disturbances that may result on the site.

- Reduction of CO_2 emissions

Buildings worldwide are considered a major cause of CO_2 emanations with a percentage ranging between 5-7% of the overall contribution. The precast method of construction reduces the CO_2 emissions by 10% for each 1 m^3 concrete (Dong et al, 2015). In Lebanon and considering the embraced Green Building Code, the CO_2 building emissions have certain limitations, so the precast technique may help in enhancing the green features of Lebanese buildings allowing in achieving green rewards such as the LEED building certification. Moreover, CO_2 discharges may be diminished from the initiation of precast elements in the manufacturing plants by reducing the non-valuable actions (Wu et al, 2010). This is also, confirmed by the obtained survey results in which it scored an average of 1.91 that's considered close to the average importance of attracting construction projects.

- Diminish wastages on site

One of the significant environmental issues is the construction generated waste from the projects. Thus, construction management systems are recently dealing with methods of waste minimization; a study generated by Lachimpadi et al (2012) has indicated that the waste generated by the precast method is about 0.016 ton/m^2, whereas that resulted by the cast-in-situ is 0.048 ton /m^2.The majority of the interviewed companies have signposted that Lebanon is suffering from an incessant issue that is how to better manage the solid wastes. In particular, Beirut city has encountered nearly 1 million tons of building wastage during the recent years (Tamraz et al, 2011). Therefore, directing the buildings to be built via precast systems would have a noticeable contribution to reducing the produced wastages on the construction sites. Diminishing the site wastages criterion scored an average scale of 2.31 which is the highest score in the environmental impacts which denotes that precast processes reduce considerable volumes of solid wastages.

- Recycling the waste generated in the manufacturing plant

The waste that is generated from the whole precast manufacturing process shall be managed through reusing-recycling construction materials such as plastic materials, packaged products, timber and plywood, tiles, bricks, concrete aggregates, and sand. A study conducted by Lachimapadi et al (2012) resulted that cast-in-situ method can recycle a 3- 5.3% of the construction project, whereas the precast method varies between 3.5- 10%. Developing the precast technique in Lebanon in the construction projects can enhance the efficiency of the manufacturers-contractors and at the same time reduce the waste generated which is a convenient way rather than landfilling and unsystematic waste placing. Recycling the waste generated in the manufacturing plants scored an average of 1.8 indicating the proximity of the average importance of the precast contributing to the capacity of recycling the generated production waste.

✓ Time Reduction

- Time Reduction by synchronization of manufacturing elements while casting others on site

Precast technology proposes a distinctive scheduling feature to fast-track tasks (setting them in a parallel sequence), which may decrease the overall projects duration. This is considered by the synchronization of the manufacturing processes and supplying the required precast elements to the site. So, building components can attain the site to be erected while casting other elements reducing the creation of task lags due to the delayed time for the element supply. Moreover, resource management techniques can be applied to the supply and demand of precast elements such as just-in-time manufacturing (JIT) which is originated from manufacturers to supply the exact precast components to the worksites (Pheng et al, 2001). The interviewed manufacturers furthered the discussions by signifying that buffer stocks and storage on the site may help in supplying reserved elements, provided with the storage constraints and available spaces. The average rating score that this factor achieved from the survey is 2.51 which is very high. Hence, precast methods cuts a substantial time by considering simultaneous manufacturing and casting elements on the site.

- Time Reduction by applying the masonry works just after the hollow-core are laid

Prefabricated building components, consistently casted and cured governed with a high quality, attain the site with an advanced maturity level in terms of concrete compressive strength and pre-stressed cables resistive forces. Whereas when the concrete is casted in place the contractor should wait the concrete to gain a considerable percentage of the compressive strength (about 7 days) before any loading effect. Therefore, precast elements would be ready to carry building loads, masonry works can start introducing the ability of other finishing works to be in the floors. However, the interviewed contractors and consultants pointed out to the time delay that contractors should take into account represented by the time associated with applying a thin slab-layer of reinforced concrete above the hollow-core slabs which is still inferior to the delays as in the case of cast-in-situ methods. This time reduction factor scored an average of 2.17 inferring that precast method cuts additional time by the direct masonry works.

- No required scaffolding

As aforementioned precast concrete do not require scaffolding systems to maintain the concrete stability before gaining the necessary compressive strength, due to attaining the site structurally ready to carry the designed loads. Despite the latter fact, some interviewed Lebanese companies, particularly contractors, indicated that minimal scaffolding would be essential for long spans to insure safety requirements. As a time reduction factor the elimination of scaffolding processes scored an average of 1.91 which is close to the average importance, and the difference between this value and the others can be explained by the former indication provided by the contractors with a minimal scaffolding requirements.

- No required formwork

As mentioned before adopting precast method for building construction allow time schedules to reduce tasks that are considered to be time consuming. Specifically, the precast concrete don't require framework tasks as in the case of cast-in-situ method in which the wet concrete should have and exterior form to realize the required structural and architectural designs. However, the designed concrete sections are submitted to the manufacturer to ascribe the appropriate molds, so the concrete will take the shape of the molds. Yet, if the designed attributes are restrained with complex shapes and forms the manufacturer will charge higher prices due to the limitations in the available molds as shown by the interviewed manufacturers. The majority of the interviewed companies approved that precast concrete is thoroughly dispensable of carpenter shuttering tasks, for the prefabricated elements knowing that formworks are used in most of the projects due to the hybrid (precast and cast-in-situ) implemented systems. This comes in parallel with the results obtained from the survey realizing a score of 2.31.

- No required finishing

Generally finishing phases, which may include several distinct tasks, are considered to be time consuming associated with risks of project or phase delays. However, precast utilization enables better flexibility for finishing phases; prefabricated elements may attain the site fully or partially equipped with MEP materials, in which most of the interviewed companies indicated that precast elements in Lebanon are pre-reserved in the manufacturing plants facilitating the MEP site works and expediting tasks completion. Yet, this requires more collaborative environment between designers, manufacturers, and contractors to specify the exact positions of element reservations in order avoid reworks. Moreover, precast elements such as façades slabs, columns, and beams… are casted in uniform faced molds which end up resulting in smooth concrete surfaces, so plastering phase may be of minimal requirements. Clients are satisfied by the precast smooth surfaces most probably in cases of false ceiling and interior decoration applications, as shown by interviewed companies. Facilitating the finishing works scored an average of 2.31. Hence, precast method can reduce project overall durations through lessening the requirements of finishing phases.

- Casting process isn't affected by weather conditions (convenient temperatures inside the manufacturing plant, so no delays in the fabrication)

Casting processes occurring in the manufacturing plants take place under a controlled system integrating many factors that affect the concrete casting, such as curing methods and sustaining adequate temperature necessary for concrete maturing. Interviewed manufacturing companies ensured that no matter how the weather conditions are outside or at the site, fabrication procedures aren't affected and thus no delivery delays would result. However, in the case of windy weathers the erection at the site may be impeded due to the safety conditions. The average score of this factor is 2.69 which is the highest among the time reduction criteria implying that all of the participating companies agree on the insusceptibility of external weather conditions on the prefabrication processes enabling to supply the elements at the right time.

✓ Structural Factors

- Better deflection and cracking values

Precast systems are based on pre-stressed concrete fundamentals (pre-tension and post-tension); the prefabricated elements like beams and slabs are the structural components behave as un-cracked sections. Pre-stressing is known by enhancing and controlling the deflection values and allowing the architectural design to have better design flexibility by having longer column spans. Basically, precast elements rely on substituting cables instead of steel reinforcement which has much greater tensile strength and by using high compressive concrete strength. The average score of enhancing the cracking and deflection values is 2.37 which is relatively high indicating the main contribution of precast pre-stressed systems in reducing cracks and deflection in structural elements.

- High precisions in the openings and voids

The prefabrication process occurs under a high level of precision with the help of automation and technological instruments in which the concrete is casted in predefined molds having exact dimensions as pointed out by the interviewed manufactures. Architectural-structural voids and openings may be clearly built-in the mold form, so the precast slabs and facades would have the required openings in their precise positions. However, questioned consultants and contractors necessitated a collaborative information environment between designers and manufacturers to specify the correct location of the voids and circumvent the possibilities of rework. The potentials of precast systems in determining higher void precisions scored an average scale of 2.23 certifying precise manufacturing standards.

- Improve durability

Precast based structures have better values in terms of durability with longer life-spans that may reach 65 years, as indicated by the majority of the interviewed companies, which is higher than 50 years, the average life-span for cast-in-situ based structures. Durability is achieved through the higher concrete compressive strength used and better quality control and management at the manufacturing plants. Moreover, higher precision regarding technical concrete and element features such as concrete cover, steel reinforcement detailing, concrete sections, mix designs…etc. The score of improving durability in the survey is 2.11 endorsing the higher durability achieved by precast structures that that of cast-in-situ buildings.

- Enhance quality

Precast concrete manufacturing systems are mainly based on automation and high technological tools which enhance the quality features of the elements produced (Cho et al, 2017). The interviewed manufacturers directed the works towards the application of quality control management systems helping in obtaining final products meeting the stakeholders' requirements; this is achieved through quality assurance, quality measurement, continuous improvement, and benchmarking actual products and quality metrics to the other competing factories to help generate new improvement ideas. They also showed that the Lebanese precast manufacturing plants adopt tech-based systems and apply production management with quality assurance processes.

Precast quality control should cover the whole manufacturing process where periodic inspections are practiced to each phase. The resulted average score of enhancing the quality is 2.23; this means that the production will ensure better technical and aesthetic features of the concrete which best serves the structural necessities and simultaneously achieve the architectural desires.

- Lighter self-weight and thus smaller designed concrete sections

Precast building elements are basically designed based on pre-stressed concrete sections; pre-stressing systems, substituting steel reinforcement by cable reinforcement with a high compressive strength and conforming pre-stressing standards, offer enhanced design methods to reduce concrete sections with less long and short-term deflection and higher ability to resist vertical loads. This help in having lighter self-weights and thus diminish the concrete section costs and these facts are well guaranteed by the majority of interviewed companies, coming in parallel along with the resulted average which is 2.26. Hence, project design phases established on precast systems not only enhance the structural features, but also decrease element costs.

C. Further Discussions

In this part we will further our discussions by directing our attentions towards comparing the results obtained from the three different types of companies. The ANOVA technique that was adopted in the results section F has resulted in many contributions.

The precast technique is considered as a debatable construction method, in which different type of business companies vary by their approach towards precast. The consulting companies that are not executing the actual work on the site would prefer adopting precast technique for their projects due to the offered potentials. However intuitively, it can be considered that contractors relying on construction details and implementation works for achieving higher profits by charging additional expenses for detail execution, would rather refute the embracing the precast method for their projects. For example, some interviewed contracting companies, revealed an apathetic behavior when they recognized that the main topic of the research is about precast technology, moreover they considered that the only potential that precast technique contributes, is the time reduction effect considering that supplementary expenses would be included if precast technology is comprised resulting in higher project costs. On the other hand, it may be obvious to assume that manufacturers are the best supporters to precast construction practice, essentially because it's their own jobs to advertise for their products, in which if the precast market boosts their companies' profits would ultimately increase.

After inspecting the normality distributions in section F1 with the three methods offered by SPSS, ANOVA Post-Hoc Fisher's Least Significant Difference test was used to determine the significant difference in the means of the rating scales of each sample according to each factor, by testing the null hypothesis stated in 5.5.2.2 with a two sided test.

First referring to the section F.2.b we discern that LSD test shows that all the pairwise comparisons resulted in p-values that are higher than 0.05 indicating that there isn't a significant difference between each two mean rating scales. This implies that the opinions towards the productivity and cost reduction that the precast technique offers vary slightly between each type of the companies. And this reflects the business perspectives of each company.

Yet, when we shed lights on the pairwise comparisons in the productivity and cost and time reduction, we observe that the least p-value are attained, 0.285 and 0.373 respectively, between the manufacturers and consultants signifying that both types of companies disagree to a certain extent on the precast technique offering better potentials in terms of productivity and cost and time reduction. This may be explained by the originated difference between both types of businesses in which the manufacturers aim is to market their products to increase profitability, whereas the consultant companies aim to achieve additional profits from consultancy activities and project designs that may be executed by cast-in-situ methods.

In terms of environmental impact and structural factors the significant difference amplifies between the contractors and consultants with lowest resulted p-values, 0.551 and 0.285 meaning that resembling the non-business but technical former factors, the consultants vary by their design phase of precast buildings in terms of the impacts on the environment and structural incorporating features of a building from the execution phase of a contractor.

D. Research Limitations

It's significant to specify the incurred limitations in our whole research to open wider opportunities for future researches. First, in the data collection process we encountered some problems with assigning meetings with managers that would customize specific times for the meetings. Second, the geographical locations of construction companies with different territories were considered as an additional constraint for the interviews. Moreover, the limitation of the number of manufacturers to three bounds our data collected. Furthermore, the results of the p-values in the

ANOVA test would have been of lower indicating for more significant differences in case of a larger sample of construction companies and widening the rating scale interval. So, it’s obvious that the p-values are greater than 0.05 due to the narrow scaling interval. We believe that of response rate would increase if the former notions are attained.

CHAPTER VI

CONCLUSION

Based on our conducted study, we attained several inferences about precast industry in Lebanon. We concluded that the listed limitations have contributed in restricting the usage of precast techniques in construction projects. Some factors were non-significant in the Lebanese market case, while others had extreme consequences. On the other hand, the precast potentials on the whole levels and the results attained, confirmed the fundamental promises for restored construction field systems. Thus stakeholders, who're accountable for enhancing the construction industry, can rely on the potentials and the corresponding results to improve productivity, cost, time, environmental impacts and structural values. Amplifying the utilization of precast methods would increase its ratio to the whole construction projects. Lastly, the conflict between the precast shortcomings and the advantages in Lebanon will sustain, since each company has an attitude towards precast and cast-in-situ methods permitting the appearance of the booming hybrid systems combining both methods in one single project, each for particular assemblies.

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