PERCEPTIONS OF PRODUCTION HOME BUILDERS ON PRIMARY CAUSES OF

DELAY IN HOMEBUILDING IN TEXAS

A Thesis

by

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ABSTRACT

On-schedule delivery of projects has been a concern and major criticism of the construction industry. The recurring failure in the on-time delivery of projects has emphasized the need for a systematic investigation of the causes influencing delay. This research has employed an extensive literature review and interviews to elicit the primary causes of delay. A questionnaire survey was used to find out the ranking of delay causes for nine production homebuilding companies in Texas, and the type of projects considered in this study were Single-family detached homes. Twenty-four causes of delay were inferred and ranked with respect to Frequency, Severity and Importance indices. The overall top two delay factors were: Shortage of labor and Delays in subcontractor's work/ inefficient planning and execution by subcontractors. Responses categorized in different cities and on the basis of years of experience of participants were also analyzed to determine any underlying relationship between their perspectives on factors causing delay. Spearman rank correlation test showed that there is an agreement in the viewpoints across cities and respondents with varying experience. The findings of this research might help the practitioners in anticipating the root causes of delay that might exist in their present or future projects, and thus, enhancing the on-time delivery of projects.

DEDICATION

To me friends, for supporting me through my journey at Texas A&M University.

To my professors and teachers, who have helped me reach where I am today.

My mother Madhurima Gupta

My father Neeraj Gupta

My brother Anmol Gupta

To my family, for their undying support & love,

“Family is where Life begins & Love never ends

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NOMENCLATURE

F.I.	Frequency Index
S.I.	Severity Index
IMP.I.	Importance Index
IRB	Institutional Review Board

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CHAPTER I

INTRODUCTION

The construction industry as a whole in the United States of America is a significant indicator of the strength of the American economy and has contributed phenomenally in the socio-economic growth of the entire country. This industry holds more than 650,000 employers with over 6 million employees and generates nearly $1 trillion worth of structures each year (Simonson, n.d.). According to the National Association of Home Builders (NAHB), the housing sector alone contributes, on an average, 15-18% to the GDP. It does so in two ways: residential investment, which includes construction of new single-family and multifamily housing units, residential remodeling and production of manufactured homes contribute 3-5% to GDP, and consumption spending on housing services, including gross rents, utility payments by renters, as well as rents and utility imputed by owners, contributes 12-13% to GDP. Notwithstanding its economic importance and employment potential, the construction industry is marred by issues, such as a lack of qualified professionals, low productivity, limited mechanization and cost and time overruns (Doloi, Sawhney, & Iyer, 2012).

Delays and overruns are critical problems in the construction industry. Delays generate claims from both general contractors, subcontractors and developers, which many times entail lengthy court battles with huge financial repercussions (Ahmed, Azhar, Castillo, & Kappagantula, 2002). It is one of the leading reasons for construction project failure and losses to companies because the key objectives pursued in a construction project are time, cost, quality, and safety. Delays can adversely affect the multiple dimensions of project performance. It can exceed the project cost, lengthen schedules and jeopardize safety and quality. Delays are one of the most common issues that affect the interests of all stakeholders, including designers, owners, general contractors, sub-contractors, users and others (Faridi & ElSayegh, 2006). These delays often result from unorganized events and can pose risk for the projects, which if identified, managed and analyzed in a systematic manner could be minimized, mitigated or accepted to produce some favorable results and can minimize the possibility of further delay.

According to Chang (2002), in order to identify problems in construction projects and to formulate corrective measures, the first step is to determine the causes of delay. It is not only important to evaluate delay impacts on project performance but also to identify the primary causes of delay to effectively mitigate the effects (Doloi et al., 2012). Causes of construction project delays in the industry have been investigated by researchers from all over the world. Several studies with a different scope, type of construction, and involving different contractual parties, have been conducted investigating the primary reasons responsible for delays. One of the most interesting and noteworthy derivations from these studies is that the primary causes of delay varied with each of these variables. For example, a study conducted by Megha and Rajiv (2013), to rank the delay factors in residential construction projects in India, identified the labor shortage as the most critical cause of delay. Whereas, in the United Arab Emirates, change orders and lack of capability of client's representative were the primary delay factors (Motaleb & Kishk, 2010), and slowness in decision making by management personnel and design related changes were reported as the most the critical delay cause in Indonesia's construction projects (Alwi & Hampson, 2003). These results indicate that the factors responsible for delay in construction projects cannot be considered common across countries. Even within a country, different states and specific regions can differ in their nature of projects and construction. In Florida, for example (Ahmed et al., 2002), researchers reported that Code-Related delay was the most critical category in delay, especially on projects built in coastal areas. The most likely causes for the delay to happen related to this category were building permit approvals, changes in laws and regulations, Florida Building Code, Coastal Construction Control Line Permit, building regulations in coastal region and Florida Administrative Code. Clearly, most of these causes will not be as significant in non-coastal areas in the United States. Therefore, supporting the findings by Arditi, Akan & Gurdamar (1985), it is suggested to investigate the root causes of delay associated with the specific locations and underlying regional issues in order to manage the timely completion of projects effectively. Not only geographical location but, the type of construction project is also important in determining the critical causes of delay. Each of the above discussed projects has different scopes and types of construction projects in consideration, which derived different conclusions. These conclusions do not directly apply or hold direct relevance with the present study, which only deals with the single-family detached homes.

While construction delay causes have been widely studied, an investigation into the critical factors affecting the timely delivery of projects for the industry in Texas has not been conducted. Texas, being among the top six states for construction as a percentage of state GDP and reporting the maximum increment in housing units in 2016 (Markstein, 2015), is certainly an important market for understanding the primary causes of delay in order to address chronic issues causing them. Given this background, this study aims to address two questions. First, what are the most critical causes of delay in production homebuilding in major markets in Texas? Second, how does the significance of delay cause differs with respect to variables like geographic location of a project and the perspective of the homebuilders with varying experiences? The significance of this study relies on anticipating the critical causes of delay likely to occur in current and future residential projects in Texas. Thereby, helping the industry professionals to be proactive in managing the timely delivery of projects.

Research Objectives, Limitations, and Assumptions

The primary objective of this study is to first identify the causes of delay relevant to production homebuilding in Texas, through intensive literature review and expertise from the industry. Further, to identify the primary causes by ranking them in terms of their frequency of occurrence, severity, and importance. This paper also aims to uncover any underlying interrelationship existing among the primary causes of delay in different cities of Texas. It also targets the analysis among respondents holding varying years of experience in the industry. Finally, to test the strength of association between the identified rankings and determine their degree of agreement or disagreement using statistical analysis.

This study is limited to the four major markets in the state of Texas: Houston, Austin, San Antonio and Dallas-Fort Worth, and results are drawn from the perspectives of production homebuilders only. The research is conducted based on the assumption that the data provided by the respondents is based on their direct involvement in the completion of the project and they encountered the delay as they reported regarding the frequency and severity of the delay causes.

CHAPTER II

LITERATURE REVIEW

On-schedule delivery of construction projects has been a topic of research for several decades, with equal significance among the practitioners (Doloi et al., 2012). The extensive research literature on this subject from all around the world is collected and consolidated for the better understanding and documenting the current state of art.

Literature pertaining to Residential Construction

Even though a number of studies have been conducted to analyze the critical causes of delay in the construction industry as a whole, the investigation into primary factors of delay relevant to residential industry has been very limited. Among several studies that have been conducted to study delay causes, the below discussed studies are of prime relevance as they deal with the housing industry. But they may or may not directly apply to the present study because it is unclear if they specifically considered single-family detached homes or any other type of housing projects in conducting the research.

A study by Megha and Rajiv (2013), identified and ranked the causes of delay in residential construction projects in central Gujrat region of India. This study considered the three different perspectives: developers, contractors, and architects. It was interesting to note that according to developers and contractors, labor-related causes were ranked top, but design related causes were more responsible for delay when considered from the architect's point of view. All the three parties agreed that Labor-related delays, like shortage of labor and their low productivity, were most important and external factors were least important. Thus, for an effective delivery of a project, it is important to understand that causes of delay not only vary with its market and effects but also changes for the different players in the industry.

Investigating the critical causes of delay in residential projects in Jordan, a similar methodology of data collection, through survey and interviews, was adopted (Sweis, Sweis, Hammad, & Shboul, 2008). Common delay causes were evaluated through surveying consultant engineers, contractors, and owners, and interviews with senior professionals in the field were also conducted. Financial difficulties faced by the contractor was identified as the most critical and frequent cause of delay from the perspective of contractors, however, this factor was ranked second according to both the owners and the consultant. Poor planning and scheduling of a project was ranked as the major cause of delay by owners and consultants. Both of the above discussed studies clarify the perspective and the parties involved, but did not mention what kind of residential projects were dealt with in conducting these studies.

Similarly, another study in Jordan was conducted to investigate the causes of delays on 130 public projects (Al Momani, 2000), which included residential projects along with the office and administration buildings, school buildings, medical centers and communication facilities. Results indicated that poor design and negligence of the owner, change orders, weather condition, site condition, late delivery, and economic conditions were the main causes of delay. This study not only deals with residential projects but also takes the other types of construction into consideration.

A study was conducted to identify the causes and effects of construction delays on completion of housing projects in Nigeria (Odeyinka & Yusif, 1997). It was not discussed by the researchers what particular type of housing projects were considered in the study. But the perspective was clearly specified, it was done on the basis of a questionnaire survey of general contractors, consultants, and house owners. The paper showed that the causes of housing project's construction delays can be nested in four layers namely: Client-caused delay, Contractor-caused delay, Extra contractual delay, and Consultant-caused delay. Consultants and contractors placed the highest rank on owner related delay which was manifested mainly in terms of failure to meet financial obligations to the contractor. Whereas, house owners ranked contractor-caused delay highest while both the consultants and contractors themselves ranked it second.

Through a similar study in 2014, time-delays associated with the construction of private residential projects in the State of Kuwait were determined. A total of 450 private housing projects were randomly selected from among projects located in 27 metropolitan districts of Kuwait and their owners were surveyed for the collection of data. The three main causes of time-delay reported through the study were, in order, the number of change orders, financial constraints, and owner's lack of experience in construction (Koushki, AlRashid,

& Kartam, 2005). Like other discussed studies, this study too did not present the clear view of the kind of housing projects that were studied in the research.

Another study based on a research, that analyzed and ranked the causes of delays in building and housing type projects undertaken by governmental agencies in Kuwait, was conducted by Hashem M. (2002). A questionnaire survey conducted to gain perception of client representatives, contractors, and designers, included 53 delay causes which were categorized into eight major groups. The results of this study suggested that slow decision-making process in the client's organization was the most important factor of delay and was ranked first by contractors and second by design firms, however, contractor related factors were ranked high by the clients. Once again, the type the projects considered in the study remained questionable.

Other related literature

The literature search shows that there are several studies, which have been conducted to identify the critical causes of delay in sectors other than the residential construction industry. Generally, all these research studies were also conducted by questionnaire surveys and analysis of data obtained from the responses. Each study had a unique scope and unique results were derived from the questionnaire response data. Even though the context of these studies does not align directly with the scope of the present research, they hold value as we design the survey instruments.

Marzouk and El-Rasas (2014) analyzed the causes of delay in the construction industry of Egypt. This study was conducted through interviews and surveying construction experts through a detailed questionnaire, comprising 43 delay causes which were grouped into seven categories: owner, contractor, consultant, material, equipment, project, labor and external related. Ranking of delay factors was conducted using Frequency Index, Severity Index and Importance Index. Findings suggested that the owner related delay ranked top in both the Frequency and Importance Index, whereas, material related causes were ranked high according to Severity Index.

A study in India, developed a structural equation model for investigating the factors affecting delay in Indian construction projects. Results of this structural equation model suggested that one of the most significant factors affecting the time of delivery of a project is the client's influence, which is due to delay in approval process, design and scope changes, lack of rigorous organizational protocol and even change of project's subcontractors (Doloi et al., 2012). Similar findings were reported in the study by Iyer and Jha (2005) and Odeh and Battaineh (2002). The second significant cause found in this study was improper planning, and this finding is consistent with the results drawn in the past studies (Sambasivan and Soon, 2007). Another study targeting the Indian construction industry by Iyer and Jha (2005), identified the project failure and success attributes. Relative Importance Index (RII) was used to rank these attributes and Factor analysis was further carried out on a group of 30 success and 23 failure attributes separately to understand the relationship among them. As a result of this analysis, it was established that success factors were generally related to the personnel's competence and proper management practices; whereas, failure attributes were predominantly linked to the time and cost performance of projects. Also, this study used the regression analysis and reported "coordination among project participants" as the top factor to influence cost performance of a project positively (Iyer & Jha, 2005).

Investigating the UAE construction projects, Motaleb and Kishk (2010) reported the primary causes of delay and their effects. Change order was ranked as the most critical factor, followed by the lack of capability of client representative and slow decision making by client. These results were surprising as they were in partial agreement with the same study conducted in UAE by Faridi and El-Sayed (2006). All the top 15 factors recognized from the 2010 study were also reported in the study 0f 2006. Other than the lack of capability of client representative, which stood as the 2nd most critical cause in both the studies, the ranking of all other common factors has changed. The change order which is reported as the primary delay factor in the study by Motaleb and Kishk was found to be on rank 27th by Faridi and El-Sayed in their study conducted in 2006, highlighting the evolving nature of the construction industry and its projects.

Using the Importance index and Spearman rank correlation coefficient approach, research was conducted by Abd El-Razek, Bassioni & Mobarak (2008) to study the delay causes in Egypt. This study assessed the causes of delay by different party's perspectives, namely, contractors, consultants and owners. They were independently surveyed and ranking was assigned as overall and for each category separately as well, further facilitating the analysis of the degree of agreement between the different parties. The overall results were: financing by contractor during construction, delays in contractor's payment by owners and design changes by owner or his agent during construction, as three major causes. But these findings differ with the individual group ranks, where parties were in conflict in their opinions regarding causes of delay. When contractor and owner were found to have contrasting views, consultant reinforced the intermediate position in results. Furthermore, the causes of delay were discussed based on the size and type of project. Type of projects was categorized into Housing, Tourism, Industrial, Commercial and Education/Research. It was interesting, how factors of delay varied when studied through different categorizations. Results show similarity in the causes of project delays in the housing, tourism, and educational sectors which can be attributed to the similar methods of construction used in these three sectors in Egypt. The industrial and commercial sectors reported more differences in their rankings.

A similar study analyzing the causes of delay was conducted for Hong Kong building projects (Chan & Kumaraswamy, 2002). It assessed the ranking within each of three different building sub-sectors: public housing, public non-residential buildings, and private sector buildings. Labor supply and management were observed as the most important delay factors in public housing sub-sector. Whereas, factors such as minimizing midstream design changes and client's experience appeared crucial in public non-residential and private building projects.

Baldwin, Manthei, Rothbart & Harris (1971) studied the causes of construction industry delays in the US. Based on the responses from a nationwide survey of engineers, contractors, and architects, seventeen delay causes were examined and for those found to be significant, the study suggested the ways to minimize these costly delays. Another study in the US, limited to the Florida construction industry was conducted through a survey, to analyze the perception of different parties involved in a project regarding the causes of delay (Ahmed et al., 2002). It also discussed the type of delay and allocation of responsibilities of parties for each delay factor. The study identified the category of Code-related delay as most critical followed by Design-related and Construction-related.

From the above-discussed literature review, it is apparent that the causes of delay varied in each study. Findings also suggest that different factors were responsible for delay when assessed in different locations, size, and type of project and with a different perspective. Research in this chronic issue has been conducted widely across the world, but yet to be conducted for the residential construction industry of Texas. As such, it is the first attempt at investigating the primary causes of delay in production homebuilding in Texas metropolitan areas and the analysis in this study is representative of the perception of production homebuilders.

CHAPTER III

RESEARCH METHODOLOGY

This research adopted both the qualitative and the quantitative methods to identify the primary causes of delay in production homebuilding in Texas. A questionnaire survey was employed in order to collect the quantitative data required for the ranking of delay causes, and for the qualitative analysis, interviews focusing on understanding the building process in practice were conducted.

Questionnaire Design

A pilot questionnaire was designed on the basis of extensive literature review and significant studies available, pertaining to the issue of delays in the construction industry as a whole and their causes. As an outcome of the literature review, 47 causes of delays were identified and categorized under seven main groups: Owner related, Design related, Contractor related, Equipment related, Labor related, Management related and External factors, depending on their nature and mode of occurrence.

The questionnaire was carefully designed and organized into two sections. The first section was intended to gather information about the respondents' professional profile including their title, experience in the industry, average number of homes they are responsible for managing simultaneously, and the area division of their company. The second section relates to questions on the delay causes, and was designed to obtain the responses on the delay factors experienced by the respondents in the last year. For each factor, the respondents were requested to answer both frequency of occurrence and severity typically caused by it. Frequency was asked in terms of number of projects (homes) experiencing a particular delay in the past year, and their severity using a five-point Likert scale (1=Very Low, 2=Low, 3=Neutral, 4=High, and 5=Very high) to direct the participants in providing their responses with varying degree of severity.

The reason for setting the duration of one year in the questionnaire was to ensure that the data collected on frequency and severity of delays are associated with the projects of same timeframe, for all the participants. This will eliminate the need of considering any major changes and fluctuations in the labor market and cost variables of various construction items. Also, it aids the fact that by including a specific duration in the questionnaire, the respondents will be able to report a more accurate picture of the time delays – adding to the reliability of the database

Questionnaire Content Validity

The second phase was to validate the questionnaire developed from the literature review and customize it for the production homebuilding practice in Texas. To carry out this, 9 major production homebuilding companies in Texas were contacted for an interview aimed at understanding the process of homebuilding in their company. To assure the protection of research participants and to ensure Texas A&M University's compliance with the laws and regulations of human subject research, the study was reviewed and approved (IRB ID: IRB2017- 498) by the Institutional Review Board (IRB), prior to being initiated.

Eight out of nine companies participated in the study and interviews were conducted with the corporate managers of the company, focused on collecting information to record:

- overall process involved in a homebuilding project from its conception to completion,
- problems perceived in this process,
- schedule delays faced and their perceived primary causes,
- workflow structure of the company, and
- data regarding bonus and incentives if offered to avoid delays, and its impact on the process.

Information gathered in these interviews formed the roadmap for subsequent filtering and preparing a questionnaire distinctive to production homebuilding in Texas. The final questionnaire included 24 delay causes which were categorized in 6 groups: Owner/ Client related delays, Design related delays, Production related delays, Labor related delays, Material related delays, and External delays.

Questionnaire Administration

Usually, the vast majority of project delays occur during the 'construction' phase, which involves several unforeseen factors (Chan & Kumaraswamy, 1997). Thus, the participants for this study were Superintendents, Field Managers, or professionals with similar job responsibilities, who are representatives of construction practices and directly responsible for handling the process of construction in production home building projects. To maintain anonymity and to protect the personal information, the questionnaire survey was not sent directly to the participants but, was sent to the interviewees of the 8 companies, which was further distributed by them to the targeted participants.

A total of 108 responses were received in 4 months of survey duration. Before analyzing, a listwise deletion was carried out to eliminate any incomplete data and to ensure that they are adequate and appropriate for statistical testing. It resulted in seventy-six full and complete responses. The response rate from Austin, Houston, Dallas – Fort Worth, and San Antonio is 42.1%, 40.8%, 13.2%, and 3.9% respectively. Regarding the participants' experience in construction, 28.95% of respondents have less than or equal to 5 years, 32.89% of those have between 5 and 15 years, and 38.16% of those hold more than 15 years of experience. A fair distribution of responses can be observed on the basis of respondents' experience as compared to the area-wise distribution where participation from DFW and San Antonio was comparatively less.

Method of Analysis

The collected data was analyzed using three type of indices:

A) *Frequency Index*: This index is used to rank delay causes based on the frequency of occurrence as identified by the participants. It is computed as per following formula:

$$F.I. = \frac{\sum_{i=0}^{5}(a_i x_i)}{5N}$$

………… (1)

Where, a_i is a constant expressing the weight assigned to the i^{th} response (ranges from 1 for 0-20% homes experiencing delay up to 5 for 80-100%), x_i is the frequency of the i^{th} response, and N is total number of responses.

B) *Severity Index:* This index is used to rank delay causes based on the severity of factor that caused delay. It is computed as per following formula:

$$S.I. = \frac{\sum_{i=0}^{5}(a_i x_i)}{5N}$$

………… (2)

Where, a_i is a constant expressing the weight assigned to the i^{th} response (ranges from 1 for very low up to 5 for very high severity level, x_i is the frequency of the i^{th} response, and N is total number of responses.

C) *Importance Index:* This index provides an overview of factor based on both their frequencies and severity. It is calculated as a function of both indices

$$IMP.I. = F.I. \; * \; S.I.$$

……….. (3)

These three indices were used to determine the overall ranking of the identified delay causes, rankings across cities and among the respondents holding varying number of years' experience in the industry. Further, the Spearman coefficient of rank correlation was used to demonstrate the agreement or disagreement among the rankings of each pair of categories in the analysis. To examine the strength of relationships between different groups, the Spearman Rank Correlation Test was conducted. The degree of agreement is expressed as a "correlation coefficient", which is calculated as follows:

$$rs = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

………… (4)

Where "d" is the difference between the ranks indicated by different pair of groups for all causes of delay, and "n" is numbers of delay causes (n = 24).

CHAPTER IV

RESULTS

Overall Ranking of Delay Causes in Terms of Frequency of Occurrence, Severity, and Importance.

Table 1 shows the summary of indices and ranks of 24 delay causes that were investigated in this study. The overall ranking was assigned on the basis of all responses collected from participants, and was calculated using Frequency, Severity, and Importance Indices.

Based on the frequency of occurrence, the top 5 causes of delay were: 1) Delay in subcontractor's work/ inefficient planning and execution by subcontractors; 2) Shortage of labor; 3) Rework due to errors and deficiencies in construction; 4) Unforeseen weather conditions; 5) Unqualified workforce/ Incompetent subcontractors.

Causes	Overall F.I.	Rank 1	Overall S.I.	Rank 2	Overall IMP.I.	Rank 3	Groups
Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors	0.758	1	0.753	2	0.571	2	Production
Shortage of labor	0.753	2	0.787	1	0.593	1	Labor
Rework due to errors and deficiencies in construction	0.624	3	0.637	4	0.397	4	Production
Unforseen weather conditions	0.621	4	0.661	3	0.410	3	External
Unqualified workforce/ Incompetent subcontractors	0.558	5	0.603	5	0.336	5	Labor
Inadequate and unclear details and drawings	0.366	6	0.460	6	0.168	6	Design
Client initiated variation orders/ Design revisions	0.345	7	0.458	7	0.158	7	Owner/Client
Slow decision making by owners during design selection	0.339	8	0.460	6	0.156	8	Owner/Client
Delay in material delivery to the site	0.326	9	0.416	8	0.136	9	Material
Delay in producing design documents/ Slow revisions in documents	0.300	10	0.405	9	0.122	10	Design
Building permits approval process	0.287	11	0.374	10	0.107	11	External
Ineffective planning and scheduling of project by builder/ production contractor	0.279	12	0.326	12	0.091	12	Production
Slow information flow/ Lack of cordination between contractor and other project parties during construction	0.274	13	0.329	11	0.090	13	Production
Delay in final inspection (from a city)	0.189	14	0.234	15	0.044	15	External
Shortage of material in the market	0.180	15	0.274	13	0.049	14	Material
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.179	16	0.229	16	0.041	16	External
Poor communication and coordination by owner with other project parties	0.168	17	0.263	14	0.044	15	Owner/Client
Delay in third party inspection/ certification	0.153	18	0.205	17	0.031	17	External
Changes in government laws and regulations	0.110	19	0.145	20	0.016	18	External
Absenteeism and Strikes	0.108	20	0.147	19	0.016	18	Labor
Late procurement of materials	0.103	21	0.153	18	0.016	19	Material
Complexity of project design	0.089	22	0.134	21	0.012	20	Design
Effect of cultural and social factors (neighborhood)	0.032	23	0.055	23	0.002	21	External
Accidents during construction	0.021	24	0.071	22	0.001	22	External

Table 1. Overall ranking of causes of delay

Top 5 causes that appeared on the list of severity of delays were: 1) Shortage of labor; 2) Delay's in subcontractor's work/ inefficient planning and execution by subcontractors; 3) Unforeseen weather conditions; 4) Rework due to errors and deficiencies in construction; 5) Unqualified workforce/ Incompetent subcontractors.

The top 5 ranks on the basis of importance were: 1) Shortage of labor; 2) Delay's in subcontractor's work/ inefficient planning and execution by subcontractors; 3) Unforeseen weather conditions; 4) Rework due to errors and deficiencies in construction; 5) Unqualified workforce/ Incompetent subcontractors.

Delay's in subcontractor's work/ inefficient planning and execution by subcontractors was ranked top as per frequency, which was ranked 2nd in terms of severity and importance. Whereas, the Shortage of labor which was ranked 1st in severity and importance list was second in the frequency rankings. It was noted that the top 10 causes were common in all three lists and can be seen from the table that there is nearly no difference in the rankings for occurrence, severity, and importance. It suggests that the more a cause occurs frequently the more severely it impacts the overall duration of a project and thus, holds higher overall importance.

	Overall		Overall		Overall	
Delay Groups	**F.I.**	**Rank1**	**S.I.**	**Rank2**	**IMP.I.**	**Rank3**
Production Related Delays	0.484	1	0.511	2	0.287	2
Labor Related Delays	0.473	2	0.512	1	0.315	1
Owner/Client Related Delays	0.284	3	0.394	3	0.119	3
Design Related Delays	0.252	4	0.333	5	0.101	4
Material Related Delays	0.203	5	0.281	6	0.067	6
External Delays	0.199	6	0.389	4	0.0854	5

Table 2. Ranking of delay groups

The causes of delay were categorized into 6 groups, which were also ranked to find out if there is any consensus among the ranking of these categories, on the basis of three indices. Table 2 shows that the top 3 delay factors are same on the frequency, severity, and importance basis. Category of Production related delays was ranked 1st as per frequency of occurrence, which appeared 2nd on the list of severity and importance. On the other hand, 2nd on the frequency list – Labor related delays was 1st on the basis of severity and importance index. It can be observed that the deviation in rankings was very less, indicating a relationship between the occurrence, severity, and importance of a delay group.

Area-wise ranking of the delay causes

Data used in the present study were collected from four metropolitan areas of Texas: Austin, Houston, Dallas - Fort Worth, and San Antonio. Grouped responses were analyzed to determine their relative rankings and to uncover any relationship, if present between their perspectives on primary factors causing delay in their respective cities.

Due to uneven participation from different areas, the responses from San Antonio were not included in the area-wise analysis, considering that the relatively low response will not provide an adequate representation of the city. Responses from DFW area were also comparatively lower than Austin and Houston, thus, the reliability of its comparison with other two cities and derived conclusions are considered limited.

Table 3, 4 and 5 shows the comparison between the rankings of each city and with the overall ranking. Causes were assigned a rank for their frequency of occurrence, severity, and importance, listed in three different tables. The top factors ranked by Austin are Shortage of labor, Delay's in subcontractor's work/ inefficient planning and execution by subcontractors, Rework due to errors and deficiencies in construction, Unqualified workforce/ Incompetent subcontractors, and Unforeseen weather conditions. These factors can be seen common in all the three lists of Austin and were also top-ranked by Houston in all the three categories.

All these top 5 factors did not appear in the lists of DFW, however, the top 2 causes: Shortage of labor and Delay's in subcontractor's work/ inefficient planning and execution by subcontractors were still among the top 2 of DFW's all three lists.

While a close consensus was observed between the list of top factors of different cities and with the overall results, the ranks of some causes differed considerably. For example, Unforeseen weather conditions is the most frequently occurring cause of delay in Houston, which is ranked $4^{th}$by Austin and is at number 6 in DFW frequency list. This result is expected as the Houston metropolitan area experienced one of the most catastrophic tropical cyclone on record, Hurricane Harvey in 2017. It was reported, in addition, by most of the respondents that the entire construction process was slowed down primarily due to severe rainfall, which triggered the unprecedented flooding in Houston area. It can be seen in table 3, the difference in rankings of external delay causes like Building permit approval process and Delay in final inspection (from a city) for different areas. Building permit approval process was ranked 8^{th} most frequent cause by Austin, whereas, it appeared at 17^{th} and at 4^{th} in the frequency list of Houston and DFW respectively. Similarly, Delay in final inspection was 12^{th} most frequent delay cause for Austin, which was on the other hand, ranked 18^{th} by Houston. A similar pattern can be seen in the rankings on the basis of severity.

	Overall		Austin		Houston		DFW		
Causes	**F.I.**	**Rank 1**	**F.I.2**	**Rank 2**	**F.I.3**	**Rank 3**	**F.I.4**	**Rank 4**	**Groups**
Delay's in subcontractor's work/ Inefficient planning and execution by	0.758	1	0.831	2	0.703	3	0.7	1	Production
Shortage of labor	0.753	2	0.856	1	0.716	2	0.7	1	Labor
Rework due to errors and deficiencies in construction	0.624	3	0.725	3	0.516	4	0.64	2	Production
Unforseen weather conditions	0.621	4	0.569	4	0.800	1	0.3	6	External
Unqualified workforce/ Incompetent subcontractors	0.558	5	0.725	3	0.387	5	0.58	3	Labor
Inadequate and unclear details and drawings	0.366	6	0.538	5	0.258	10	0.24	8	Design
Client initiated variation orders/ Design revisions	0.345	7	0.500	6	0.335	6	0.22	9	Owner/Client
Slow decision making by owners during design selection	0.339	8	0.431	7	0.290	7	0.26	7	Owner/Client
Delay in material delivery to the site	0.326	9	0.413	9	0.277	8	0.26	7	Material
Delay in producing design documents/ Slow revisions in	0.300	10	0.375	11	0.265	9	0.18	11	Design
Building permits approval process	0.287	11	0.425	8	0.097	17	0.38	4	External
Ineffective planning and scheduling of project by builder/ production	0.279	12	0.381	10	0.181	12	0.32	5	Production
Slow information flow/ Lack of cordination between contractor	0.274	13	0.288	13	0.252	11	0.32	5	Production
Delay in final inspection (from a city)	0.189	14	0.338	12	0.077	18	0.12	14	External
Shortage of material in the market	0.180	15	0.225	17	0.135	14	0.2	10	Material
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.179	16	0.244	15	0.161	13	0.06	16	External
Poor communication and coordination by owner with other	0.168	17	0.275	14	0.123	15	0.16	12	Owner/Client
Delay in third party inspection/ certification	0.153	18	0.231	16	0.103	16	0.14	13	External
Changes in government laws and regulations	0.110	19	0.156	19	0.026	20	0.24	8	External
Absenteeism and Strikes	0.108	20	0.175	18	0.065	19	0.04	17	Labor
Late procurement of materials	0.103	21	0.125	21	0.065	19	0.16	12	Material
Complexity of project design	0.089	22	0.144	20	0.065	19	0.02	18	Design
Effect of cultural and social factors (neighborhood)	0.032	23	0.044	22	0.006	22	0.08	15	External
Accidents during construction	0.021	24	0.019	23	0.019	21	0.04	17	External

Table 3. Area-wise rankings of delay causes based on their frequency of occurrence

	Overall		Austin		Houston		DFW		
Causes	S.I.	Rank 1	S.I.2	Rank 2	S.I.3	Rank 3	S.I.4	Rank 4	Groups
Shortage of labor	0.787	1	0.738	2	0.865	1	0.86	1	Labor
Delay's in subcontractor's work/ Inefficient planning and execution by	0.753	2	0.756	1	0.735	3	0.82	2	Production
Unforseen weather conditions	0.661	3	0.600	4	0.826	2	0.4	11	External
Rework due to errors and deficiencies in construction	0.637	4	0.688	3	0.574	4	0.66	5	Production
Unqualified workforce/ Incompetent subcontractors	0.603	5	0.688	3	0.465	5	0.76	3	Labor
Slow decision making by owners during design selection	0.460	6	0.506	7	0.387	8	0.56	6	Owner/Client
Inadequate and unclear details and drawings	0.460	6	0.513	6	0.406	7	0.54	7	Design
Client initiated variation orders/ Design revisions	0.458	7	0.556	5	0.361	10	0.5	8	Owner/Client
Delay in material delivery to the site	0.416	8	0.475	9	0.368	9	0.46	9	Material
Delay in producing design documents/ Slow revisions in	0.405	9	0.406	11	0.419	6	0.4	11	Design
Building permits approval process	0.374	10	0.481	8	0.142	16	0.7	4	External
Slow information flow/ Lack of cordination between contractor	0.329	11	0.344	13	0.277	11	0.44	10	Production
Ineffective planning and scheduling of project by builder/ production	0.326	12	0.413	10	0.174	15	0.54	7	Production
Shortage of material in the market	0.274	13	0.288	15	0.239	12	0.38	12	Material
Poor communication and coordination by owner with other	0.263	14	0.313	14	0.181	14	0.38	12	Owner/Client
Delay in final inspection (from a city)	0.234	15	0.350	12	0.103	19	0.34	13	External
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.229	16	0.269	16	0.200	13	0.2	17	External
Delay in third party inspection/ certification	0.205	17	0.250	17	0.135	17	0.3	15	External
Late procurement of materials	0.153	18	0.156	21	0.116	18	0.26	16	Material
Absenteeism and Strikes	0.147	19	0.219	18	0.116	18	0.04	20	Labor
Changes in government laws and regulations	0.145	20	0.206	19	0.026	21	0.32	14	External
Complexity of project design	0.134	21	0.181	20	0.116	18	0.08	19	Design
Accidents during construction	0.071	22	0.019	23	0.071	20	0.14	18	External
Effect of cultural and social factors (neighborhood)	0.055	23	0.106	22	0.013	22	0.04	20	External

Table 4. Area-wise rankings of delay causes based on their severity

Causes	Overall		Austin		Houston		DFW		Groups
	IMP.I.1	Rank 1	IMP.I.2	Rank 2	IMP.I.3	Rank 3	IMP.I.4	Rank 4	
Shortage of labor	0.593	1	0.631	1	0.619	2	0.602	1	Labor
Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors	0.571	2	0.629	2	0.517	3	0.574	2	Production
Unforseen weather conditions	0.410	3	0.341	4	0.661	1	0.120	10	External
Rework due to errors and deficiencies in construction	0.397	4	0.498	3	0.296	4	0.422	4	Production
Unqualified workforce/ Incompetent subcontractors	0.336	5	0.498	3	0.180	5	0.441	3	Labor
Inadequate and unclear details and drawings	0.168	6	0.275	6	0.105	9	0.130	9	Design
Client initiated variation orders/ Design revisions	0.158	7	0.278	5	0.121	6	0.110	11	Owner/Client
Slow decision making by owners during design selection	0.156	8	0.218	7	0.112	7	0.146	7	Owner/Client
Delay in material delivery to the site	0.136	9	0.196	9	0.102	10	0.120	10	Material
Delay in producing design documents/ Slow revisions in documents	0.122	10	0.152	11	0.111	8	0.072	14	Design
Building permits approval process	0.107	11	0.205	8	0.014	15	0.266	5	External
Ineffective planning and scheduling of project by builder/ production contractor	0.091	12	0.157	10	0.031	13	0.173	6	Production
Slow information flow/ Lack of cordination between contractor and other project parties	0.090	13	0.099	13	0.070	11	0.141	8	Production
Shortage of material in the market	0.049	14	0.065	16	0.032	12	0.076	13	Material
Poor communication and coordination by owner with other project parties	0.044	15	0.086	14	0.022	14	0.061	15	Owner/Client
Delay in final inspection (from a city)	0.044	15	0.118	12	0.008	16	0.041	17	External
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.041	16	0.066	15	0.032	12	0.012	18	External
Delay in third party inspection/ certification	0.031	17	0.058	17	0.014	15	0.042	16	External
Absenteeism and Strikes	0.016	18	0.038	18	0.007	17	0.002	21	Labor
Changes in government laws and regulations	0.016	18	0.032	19	0.001	18	0.077	12	External
Late procurement of materials	0.016	19	0.020	21	0.007	17	0.042	16	Material
Complexity of project design	0.012	20	0.026	20	0.007	17	0.002	21	Design
Effect of cultural and social factors (neighborhood)	0.002	21	0.005	22	0.000	19	0.003	20	External
Accidents during construction	0.001	22	0.000	23	0.001	18	0.006	19	External

Table 5. Area-wise rankings of delay causes based on their importance

Next, the Spearman rank correlation was calculated to determine the exact strength of relationship between the responses from different cities. For this study, the test was conducted using a statistical software called JMP pro. In Table 6, Spearman rank correlation values are listed for each pair of cities on three different basis, and were calculated at the level of confidence of 99% ($\alpha = 0.01$). The coefficient value ranges from +1 to -1 indicating perfect positive and negative relationship between the tested pair respectively.

	Frequency Index		Severity Index		Importance Index	
Pairs	Spearman rank correlation	p value	Spearman rank correlation	p value2	Spearman rank correlation	p value3
Austin - Houston	0.918	0.0001*	0.8831	0.0001*	0.9168	0.0001*
Houston - DFW	0.749	0.0001*	0.7766	0.0001*	0.7492	0.0001*
Austin - DFW	0.8278	0.0001*	0.9175	0.0001*	0.8581	0.0001*

Note: *Correlation is significant at 0.01 level

Table 6. Spearman rank correlation for pair of cities

The top value of correlation coefficient can be seen for Austin –Houston pair when tested on the basis of their frequency of occurrence ranks, having the highest value of 0.918. The P- value for this coefficient is 0.0001 which is less than the level of significance, $\alpha = 0.01$, indicative of a strong relationship between Austin and Houston. The three lowest coefficient values were seen for Houston – DWF pair, each in category of frequency, severity, and importance. The values of 0.749, 0.7766, and 0.7492 are relatively low in the table but, still are high enough to indicate a positive relationship. As can be seen from the table, all the P-values are less than the level of significance ($\alpha = 0.01$), thus, suggesting that there exists a very good agreement between the rankings provided by different cities.

Ranking based on the experience of the respondents

Tables 7, 8 and 9 show the frequency, severity and the importance indices for 21 causes and their rankings across 3 different respondent groups. The respondent groups are divided based on their years of experience working in the construction industry, namely 0-5 years, 6-15 years and 16 & above. In terms of frequency of occurrence, the most frequently occurring delays seen are, delay in subcontractor work, shortage of labor, rework due to errors in construction, unforeseen weather conditions, incompetent workforce, inadequate & unclear drawings, design changes, shortage of labor, delay in owner decision making and delay in producing design documents. Out of the top 10 frequently occurring delays, we can see that some of the causes of delay are commonly ranked across all 3 respondent groups. The respondent group 0-5 years has similar top 10 delays as the overall ranking, whereas respondents 5-15 and 16 & above have building permits approval process and ineffective planning & scheduling as some of the additional frequently occurring delays in their top 10. Further, as a variance, delay in final inspection was not seen as a frequently occurring delay in response group 16 & above and was ranked 20, whereas it was seen ranked as 14 in the overall ranking.

	Overall		0 to 5 years		6 to 15 years		above 15 years		
Causes	F.I.	Rank 1	F.I.2	Rank 2	F.I.3	Rank 3	F.I.4	Rank 4	Groups
Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors	0.758	1	0.845	1	0.712	1	0.731	2	Production
Shortage of labor	0.753	2	0.818	2	0.656	2	0.786	1	Labor
Rework due to errors and deficiencies in construction	0.624	3	0.736	3	0.576	4	0.579	4	Production
Unforseen weather conditions	0.621	4	0.700	4	0.624	3	0.559	5	External
Unqualified workforce/ Incompetent subcontractors	0.558	5	0.555	5	0.472	5	0.635	3	Labor
Inadequate and unclear details and drawings	0.366	6	0.436	6	0.376	6	0.303	9	Design
Client initiated variation orders/ Design revisions	0.345	7	0.427	7	0.352	7	0.400	6	Owner/Client
Slow decision making by owners during design selection	0.339	8	0.382	9	0.320	9	0.324	8	Owner/Client
Delay in material delivery to the site	0.326	9	0.409	8	0.328	8	0.262	11	Material
Delay in producing design documents/ Slow revisions in documents	0.300	10	0.373	10	0.280	11	0.241	12	Design
Building permits approval process	0.287	11	0.236	15	0.280	11	0.331	7	External
Ineffective planning and scheduling of project by builder/ production contractor	0.279	12	0.245	14	0.312	10	0.276	10	Production
Slow information flow/ Lack of cordination between contractor and other project parties	0.274	13	0.291	12	0.200	14	0.324	8	Production
Delay in final inspection (from a city)	0.189	14	0.300	11	0.216	13	0.083	20	External
Shortage of material in the market	0.180	15	0.109	18	0.224	12	0.193	14	Material
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.179	16	0.300	11	0.144	16	0.117	17	External
Poor communication and coordination by owner with other project parties	0.168	17	0.209	16	0.168	15	0.200	13	Owner/Client
Delay in third party inspection/ certification	0.153	18	0.255	13	0.096	19	0.145	15	External
Changes in government laws and regulations	0.110	19	0.073	20	0.112	17	0.138	16	External
Absenteeism and Strikes	0.108	20	0.118	17	0.096	19	0.110	18	Labor
Late procurement of materials	0.103	21	0.100	19	0.064	20	0.138	16	Material
Complexity of project design	0.089	22	0.073	20	0.104	18	0.090	19	Design
Effect of cultural and social factors (neighborhood)	0.032	23	0.064	21	0.016	21	0.021	22	External
Accidents during construction	0.021	24	0.027	22	0.008	22	0.028	21	External

Table 7. Experience-wise rankings of delay causes based on their frequency of occurrence

	Overall		0 to 5 years		6 to 15 years		above 15 years		
Causes	**S.I.**	**Rank 1**	**S.I.2**	**Rank 2**	**S.I.3**	**Rank 3**	**S.I.4**	**Rank 4**	**Groups**
Shortage of labor	0.787	1	0.791	1	0.74	1	0.821	1	Labor
Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors	0.753	2	0.764	2	0.72	2	0.772	2	Production
Unforseen weather conditions	0.661	3	0.755	3	0.62	4	0.621	5	External
Rework due to errors and deficiencies in construction	0.637	4	0.636	4	0.63	3	0.641	4	Production
Unqualified workforce/ Incompetent subcontractors	0.603	5	0.582	5	0.51	6	0.697	3	Labor
Slow decision making by owners during design selection	0.460	6	0.436	9	0.42	7	0.510	6	Owner/Client
Inadequate and unclear details and drawings	0.460	6	0.482	8	0.52	5	0.393	10	Design
Client initiated variation orders/ Design revisions	0.458	7	0.409	10	0.51	6	0.462	7	Owner/Client
Delay in material delivery to the site	0.416	8	0.527	6	0.34	9	0.393	11	Material
Delay in producing design documents/ Slow revisions in documents	0.405	9	0.518	7	0.34	9	0.372	12	Design
Building permits approval process	0.374	10	0.355	11	0.34	9	0.414	8	External
Slow information flow/ Lack of cordination between contractor and other project parties	0.329	11	0.318	13	0.25	11	0.407	9	Production
Ineffective planning and scheduling of project by builder/ production contractor	0.326	12	0.245	16	0.36	8	0.359	13	Production
Shortage of material in the market	0.274	13	0.200	17	0.3	10	0.303	14	Material
Poor communication and coordination by owner with other project parties	0.263	14	0.273	15	0.23	12	0.283	15	Owner/Client
Delay in final inspection (from a city)	0.234	15	0.355	12	0.21	14	0.166	19	External
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.229	16	0.318	13	0.22	13	0.172	18	External
Delay in third party inspection/ certification	0.205	17	0.309	14	0.1	17	0.214	16	External
Late procurement of materials	0.153	18	0.136	19	0.1	18	0.214	16	Material
Absenteeism and Strikes	0.147	19	0.145	18	0.17	15	0.131	21	Labor
Changes in government laws and regulations	0.145	20	0.109	21	0.14	16	0.179	17	External
Complexity of project design	0.134	21	0.118	20	0.14	16	0.145	20	Design
Accidents during construction	0.071	22	0.109	21	0.03	20	0.076	22	External
Effect of cultural and social factors (neighborhood)	0.055	23	0.100	22	0.04	19	0.035	23	External

Table 8. Experience-wise rankings of delay causes based on their severity

Causes	Overall		0 to 5 years		6 to 15 years		above 15 years		Groups
	IMP.I.1	Rank 1	IMP.I.2	Rank 2	IMP.I.3	Rank 3	IMP.I.4	Rank 4	
Shortage of labor	0.593	1	0.647	1	0.488	2	0.645	1	Labor
Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors	0.571	2	0.646	2	0.513	1	0.565	2	Production
Unforseen weather conditions	0.410	3	0.528	3	0.389	3	0.347	5	External
Rework due to errors and deficiencies in construction	0.397	4	0.469	4	0.364	4	0.372	4	Production
Unqualified workforce/ Incompetent subcontractors	0.336	5	0.323	5	0.242	5	0.442	3	Labor
Inadequate and unclear details and drawings	0.168	6	0.210	7	0.196	6	0.119	10	Design
Client initiated variation orders/ Design revisions	0.158	7	0.175	9	0.180	7	0.185	6	Owner/Client
Slow decision making by owners during design selection	0.156	8	0.167	10	0.136	8	0.165	7	Owner/Client
Delay in material delivery to the site	0.136	9	0.216	6	0.113	9	0.103	11	Material
Delay in producing design documents/ Slow revisions in documents	0.122	10	0.193	8	0.096	11	0.090	13	Design
Building permits approval process	0.107	11	0.084	14	0.096	11	0.137	8	External
Ineffective planning and scheduling of project by builder/ production contractor	0.091	12	0.060	16	0.112	10	0.099	12	Production
Slow information flow/ Lack of cordination between contractor and other project parties	0.090	13	0.093	13	0.050	13	0.132	9	Production
Shortage of material in the market	0.049	14	0.022	18	0.068	12	0.059	14	Material
Poor communication and coordination by owner with other project parties	0.044	15	0.057	17	0.039	15	0.057	15	Owner/Client
Delay in final inspection (from a city)	0.044	15	0.106	11	0.045	14	0.014	21	External
Differing site/ ground conditions (e.g. soil, high water table, etc.)	0.041	16	0.095	12	0.031	16	0.020	19	External
Delay in third party inspection/ certification	0.031	17	0.079	15	0.010	20	0.031	16	External
Absenteeism and Strikes	0.016	18	0.017	19	0.016	17	0.014	20	Labor
Changes in government laws and regulations	0.016	18	0.008	22	0.015	18	0.025	18	External
Late procurement of materials	0.016	19	0.014	20	0.006	21	0.029	17	Material
Complexity of project design	0.012	20	0.009	21	0.014	19	0.013	22	Design
Effect of cultural and social factors (neighborhood)	0.002	21	0.006	23	0.001	22	0.001	24	External
Accidents during construction	0.001	22	0.003	24	0.000	23	0.002	23	External

Table 9. Experience-wise rankings of delay causes based on their importance

In terms of severity, the top 10 severe delays seen are: delay in subcontractor work, shortage of labor, rework due to errors in construction, unforeseen weather, unqualified workforce, inadequate and unclear drawings, design revisions, slow decision making, delay in material delivery to the site, slow revision in documents and building permits approval process. The ranking for all 3 response groups is very similar to the overall top 10 delays. For response group 16 & above, lack of coordination between contractor and other project parties was also seen in the top list of high severity. Comparing the most frequent and severe delays, we can see that both the tables have common delays in their top 10. This tells us that there is a strong correlation between frequency and severity, suggesting that the more frequently a delay occurs the more severe it is.

Further, the Spearman rank correlation was calculated to determine the degree of agreement or disagreement between all the pairs of respondents. Table 10, shows the Spearman rank correlation for each pair of response groups on the basis of frequency, severity, and importance. The test was conducted at 99% level of confidence ($\alpha = 0.01$) between the three pair, and as the coefficient value approaches +1 it indicates strong positive relationship and vice versa for -1.

On the basis of the frequency of occurrence, the highest correlation is seen between 0 to 5 years and 6 to 15 years with a value of 0.9138. The p-value for this correlation is seen as 0.0001 which is less than the level of significance $\alpha = 0.01$, which indicates that there is a strong relationship between 0 to 5 years and 6 to 15 years. The other two values of 0.899

and 0.8296 are also close to +1 indicative of again an agreement between the other two pairs of respondents.

With respect to the severity of delays, the highest correlation is seen between 6 to 15 years and above 15 years, with a correlation coefficient of 0.9188. Also, on the importance index, the highest correlation is also observed between 6 to 15 years and above 15 years with a value of 0.9224. The p-value for these correlations is also 0.0001 which is again less than the level of significance α = 0.01, suggesting that there exist comparatively strong consensus between this pair among the rest listed in Table 10.

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	Frequency Index		Severity Index		Importance Index	
Pairs	Spearman rank correlation	p value	Spearman rank correlation	p value2	Spearman rank correlation	p value3
(0 to 5 years) - (6 to 15 years)	0.9138	0.0001*	0.8935	0.0001*	0.9159	0.0001*
(6 to 15 years) - (above 15 years)	0.899	0.0001*	0.9188	0.0001*	0.9224	0.0001*
(0 to 5 years) - (above 15 years)	0.8296	0.0001*	0.878	0.0001*	0.847	0.0001*

Note: *Correlation is significant at 0.01 level

Table 10. Spearman rank correlation for pair of respondents with different experience

It can be seen in the results that people with high experience, ranging from 6 to 15years and above 15years have a similar perspective on delay causes in terms of their severity and importance. The lowest values of 0.8296, 0.878 and 0.847 are seen for the correlation between the lowest experience group of 0 to 5 years and the highest experience group of above 15 years but, the values are still high to reject the null hypothesis of no agreement between this pair.

CHAPTER V

DISCUSSION

This study set out to investigate the primary causes of delay in production homebuilding resulted in both types of findings, in line with the previous studies and novel. The results of overall analysis identified Shortage of labor, Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors, Rework due to errors and deficiencies in construction, Unforeseen weather conditions, and Unqualified workforce/ Incompetent subcontractors as the most critical causes of delay, and it can be noted clearly from the results that there is a close agreement in the ranking of these top factors with respect to their frequency of occurrence, severity, and importance. Thus, it can be drawn that the more a cause occurs frequently the more severely it impacts the overall duration of a project and thus, holds higher overall importance. Also, it is important to highlight that 4 out of top five factors are from the Production related and Labor related categories and even within the two categories these factors hold a similarity. They are related in a sense that they occur from a common source - subcontractors/labors. These results are in sync with the previous studies where labor and subcontractor related factors were ranked high by many investigators (Odeyinka and Yusif, 1997; Megha and Rajiv, 2013; Sambasivan, 2007; Sweis, 2007; Faridi, 2006; Assaf et al. 1995).

The good news is that several emerging technologies are already changing this equation and can eliminate delay concerning labor and subcontractors, for the companies that embrace them. Today’s project management tools are designed to increase productivity and keep everything on schedule, proving an invaluable resource to construction companies to monitor progress and keep all members of the project fully informed, in real time (Wright, 2016). Task management tools can streamline the entire process from start to finish and thus, are capable of reducing delay due to ineffective planning and execution by subcontractors. Building Information Management, or BIM, contains most of the solutions to reduce schedule delays and more to provide the ability to generate a 3D building plan and combine it with a construction schedule. Software products like BIM 360 Glue enables the subcontractors to get a 360 degree view of the plan while they are standing in the field. Using all the data in hand from BIM 360 Glue, critical tasks like constructability reviews can be conducted which in turn can prevent inaccuracies and the pitfall of rework (Bliss, 2017). Another example of a new technology is Robotic Total Station, which is simply a Total Station allowing for remote operation on site, and the benefits include more accurate measurements, fewer mistakes, and less rework. Thus, it can be recommended that such devices and software products can make it easier for the subcontractors and trades to match their work with the plan, thus, reducing the delay due to rework and inefficient execution.

These all-encompassing technologies are thoroughly integrated and can pave the way for prefabrication. Prefabrication building components have become a common element of construction projects, which reduce construction times by allowing much of the work to be done in a factory setting rather than on-site (Bliss, 2017). The biggest advantage of offsite construction is that the project can be parallelized (Hertzman, 2018). Instead of waiting for the completion of a particular stage, structures for another trade can be prepared. This reduces time and delay due to improper planning by subcontractors, and by prefabricating the structures it can also eliminate the scope of errors and deficient construction. Another automated way to construct structural elements is via 3D printing which allows for producing components that meet specifications precisely. Both the technologies have not hit the mainstream quite yet, but hold potential to make serious waves in the industry (Hertzman, 2018). Adoption of these methods can cater the issue of labor shortage and reduce human errors as well. With part of construction taking place in a manufacturing environment, fewer workers are needed at the jobsite and efficiency is also enhanced with less work needed to be handled manually, thereby improving the on-time delivery of projects.

On one hand where subcontractor and labor related delays are in line with previous studies, delay due to unforeseen weather condition is not observed at a high rank in the literature (Odeyinka & Yusif, 1997; Koushki, AlRashid, & Kartam, 2005; Abd El-Razek, Bassioni & Mobarak, 2008; Motaleb and Kishk, 2010; Megha and Rajiv, 2013). However, for this study involving the city of Houston, this factor appearing in top rank is not unexpected. Houston suffered a natural calamity, Hurricane Harvey and had catastrophic rainfalls in 2017, which as reported by the participants disrupted the entire process of construction. Extreme weather conditions like hurricane are normally out of a builder's control, however, conditions like mild rainfall are often "foreseeable". Effects of such conditions cannot be eliminated but mitigating its adversity is a duty of involved construction parties. Examples could be draining the work area promptly after precipitation or covering the areas can limit the effect of adverse conditions (Levine, 2017). If unfavorable weather is imminent, it is recommended to safeguard the work site in advance. Rather than trying to control it, the project managers need to have strategies to work around the weather. One such solution would be again, adoption of 3D printing and Prefabrication methods of construction. Indoor construction and off-site production of majority of components will protect the workers and materials from adverse weather conditions, and as the conditions allow the fabricated structure can be shipped and assembled on-site, thus, de-risking the project delay in that way.

The results of this study and literature review findings show that the rankings of delay factors differ with respect to location. None of the studies is comparable to any other and each study has different order of rankings for the delay factors and groups. Sambasivan and Soon (2007) stated that “the effects of delays in construction projects can be country-specific” whereas other studies has proven that project characteristics may even be region-specific (Ramanathan et al. 2012). The findings of this study have demonstrated a general agreement between the rankings of delay factors, however, ranks assigned to some factors are inconsistent among the cities. It can be seen that the location specific factors like ranking of Building permit process and Delay in final inspection varied across cities, indicating towards unique rules and regulations of each area. It can be suggested that with careful planning of the factors involving government and taking in account the city in which the project is in progress, the effect of such delays can be minimized. It is also notable that the causes of delay are not only location specific, but are also perceived differently by the professionals holding varying amount of experience. The strongest consensus is observed between the respondents of two high experience categories, and relatively weakest agreement is observed between the pair with lowest and highest experience. This observation is indicative towards the generation gap in the industry and the different viewpoints that they hold. It can also be inferred that due to different approach and style of work, people who have been in the industry for long and the ones who have relatively low experience have demonstrated a gap in their opinions on primary causes of delay.

CHAPTER VI

CONCLUSION

By conducting interviews and administering a questionnaire survey, this research has identified the causes of delay pertaining to production homebuilding in Texas and then ranked them with respect to three different indices. In overall context, Shortage of labor, Delay's in subcontractor's work/ Inefficient planning and execution by subcontractors, Rework due to errors and deficiencies in construction, Unforeseen weather conditions, and Unqualified workforce/ Incompetent subcontractors were found to be the five most frequent, severe and important factors of delay. Unusual, but not unexpected, high ranking of unforeseen weather condition factor is appropriate in this study for Texas. It was due to the occurrence of Hurricane Harvey in Houston in 2017 and is conclusive of the fact that natural disasters are expected to influence the construction process drastically. Following a natural catastrophic event, processes like removal of damaged property, general clean-up, return of evacuated project team and labor, mobilization time for equipment, re-planning logistics, will typically lag the rebuilding work by a period of time and the adjustment to the sudden increase in work volume will hinder the overall project schedule. This cause is also relatable to the existing shortage of labor, which has appeared as a top factor for delay across Texas, and the labor shortage is even likely to exacerbate by such natural calamities. The findings of this paper also highlight that the workforce shortage does not only concern quantity, but quality as well. Training of human resource for homebuilding industry is needed to be emphasized in order to meet the increasing demand of the competent workforce throughout the region.

On the basis of the analysis with respect to different cities, this paper presented consistency in the general ranking of factors but the rankings of location specific causes like Building permit process and Delay in final inspection varied in the area-wise analysis. Thus, like many other studies in past this investigation again validated the fact that the criticality of delay factors cannot be considered same in any two project settings. The root causes of delay are associated with multiple parameters including specific locations, perspective in consideration, types of project, underlying regional issues, and also the experience of participants, as proved by this study.

There have been many efforts focused on this domain but in fact, this is a first attempt to investigate the primary causes applicable to the homebuilding in Texas. It is well known that decisions made early in the life of a project have the most profound effect on the project's objectives of delivering a project within the time. The findings and conclusions drawn could help the industry professionals to gain a better understanding of the factors influencing the recurring failures in the on-schedule delivery of projects and thus, aid in developing their project managing strategies. With clarity on the root causes in their present and future projects, the practitioners can reduce and control the extent of delay, if not eradicate them completely.

For future investigation, it is recommended to conduct study involving more cities in Texas. Focused group discussion and Delphi technique can be incorporated to produce a more precise and specific list of delay factors relevant to production homebuilding in Texas.

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