IDENTIFYING AND PRIORITIZING BARRIERS AND OVERCOMING STRATEGIES IN IMPLEMENTING LEAN CONSTRUCTION PRINCIPLES AND METHODS WITHIN TRANSPORTATION PROJECTS

By

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ABSTRACT

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The purpose of this thesis was to prioritize the barriers and the overcoming strategies in implementing Lean Construction within transportation projects in Michigan, United States. Lean Construction was a paradigm shift in thinking, organizational behavior, and working culture that focuses on eliminating waste and maximizing project value. The construction industry, as a significant U.S. gross domestic product contributor, does not experience growth in labor productivity when compared to industries such as manufacturing. In the publicly financed construction of highways, streets and bridges, it was crucially important to ensure that projects are delivered as efficiently as possible.

Recent research showed a lack of studies on Lean Construction implementation barriers in the transportation industry within the U.S. An in-depth literature review was performed to identify Lean Construction implementation barriers. The findings of the literature review make the basis for the design of a survey questionnaire used to gather the perceptions of transportation project stakeholders (e.g. owners, constructors, and designers) on implementation barriers and the overcoming strategies to Lean Construction.

This study found that a lack of training and mentoring for Lean methods was the greatest barrier within transportation projects in Michigan. Many of the project team members who perform the physical work were unaware of Lean methods and were not often adequately rewarded. To overcome these barriers, this study found that the employees and workers need to be trained in Lean Construction, in order to create a continuous improvement mindset.

This thesis was dedicated to
My mother, Rahima Kawish, who had the hard task of raising five children by herself.
To my father, Dr. Sayed Noorulhaq Kawish, who inspired me to learn.
To my wife, Sediqa Yousof, who has supported me in all my endeavors.
To my two brothers Sayed Sulaiman Kawish and Sayed Younes Kawish, and two sisters, Muzhda Kawish and Khojesta Kawish, for always believing in me.

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CHAPTER 1 – INTRODUCTION

1.1 Background of the Problem

The construction industry was crucial to the U.S. economy and contributed 4% to the U.S. Gross Domestic Product (GDP) in 2015. In Michigan construction contributed 3.7% to the state's GDP (AGC of America, 2016). However, the construction industry was not experienced the same efficiency and productivity gains when compared to other industries (Rowe, Sveikauskas, Mildenberger, Price, and Young, 2016; Shrestha, Burns, & Shields, 2013; Loosemore, 2014; and Abdel-Wahab and Vogl, 2011). According to a draft titled "Proposed Innovative Contracting Project List" published by Michigan Department of Transportation (MDOT), most the construction projects -- especially construction of highways, streets, and bridges -- were implemented using traditional project delivery methods such as design-bid-build (MDOT, 2016; Bellgowan, 2017; and Stein, 2017). Studies have shown that the construction industry was still considered broken, and cost overruns and delays continue to threaten project success (Seed, 2016). Labor productivity shows no sign of increase, and in some cases, it decreases (Seed, 2016). When it comes to the spending taxpayers' money, project responsiveness and the project's performance efficiency becomes even more crucial. Taxpayers and project beneficiaries want their money to be spent in the most efficient way possible. Implementing Lean principles and methods in the construction industry are among the new paradigms in construction improvements that aim to increase labor productivity by maximizing value and minimizing waste during the construction processes. However, this paradigm was still in its early implementation; it has not been widely utilized in the construction industry and specifically in highway, street and bridge construction, which primarily was delivered using the traditional design-bid-build project delivery method. This research identified existing barriers to Lean implementation and then examined those findings within the Michigan transportation industry. It further prioritizes the barriers and the overcoming strategies to implementation of Lean Construction principles and methods within transportation projects.

1.2 Construction Industry Productivity and Performance

Construction inefficiency findings reveal that 25-50% of project costs go to waste (Tulacz, 2007). While all other non-farming labor efficiency has at least doubled since the 1960s, overall construction labor efficiency has decreased, and projects are over budget and delivered late (Seed, 2016). Another study by Construction Industry Resources (2016) reveals that 49% of owners, contractors and unions are experiencing a decrease (10% or higher) in overall productivity and an additional 22% saw no improvement in identified poor productivity factors (Construction Industry Resources, 2016). Figure 1.1 shows a historical graph on construction productivity from 1950 – 2012.

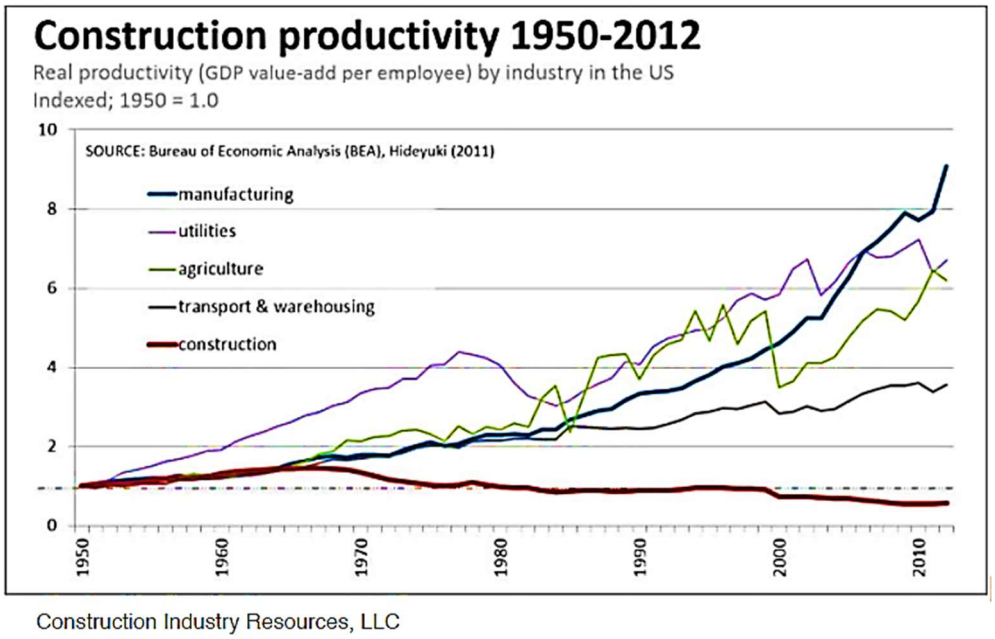

Figure 1.1 Construction Productivity

When compared to the manufacturing industry, the construction industry differs on three levels: site production, temporary organization and one-of-a-kind product (Korb, 2016). The very nature of construction projects – their characteristics, topography, land variations among projects, and limitation of available data -- make it exceptionally challenging to measure the effectiveness of production in a construction context (Rowe et al., 2016). However, existing estimates of labor productivity and growth in construction suggest that it has been declining for many years (Rowe et al., 2016).

The construction industry was a major contributor in the U.S. economy, making up to 4% of U.S. Gross Domestic Product (GDP) in 2015, and creating nearly $1 trillion worth of structures annually. According to a report published by Associated General Contractors (AGC) of America, the total construction spending from July 2015 to July 2016 was $1.21 trillion, and the total construction employment was 7 million. Given this significant contribution to the U.S. economy, the construction industry was still considered broken (Lean Construction Institute, 2016). Cost overruns and delays continue to threaten project success. A research by Loosemore (2014), found that productivity in the construction industry directly relates to the quality of the relationships between the prime contractor and lower tier contractors, and their early involvement in the design process.

Labor productivity in the construction of highways, streets and bridges has experienced ups and downs from 2002-2014 (Rowe et al, 2016). Rowe et al., 2016 found that with a substantial burst in residential construction, labor productivity declined in highway construction and vice versa, and after 2009 labor productivity in highway construction stagnated. (Rowe et al., 2016); thus, it can be inferred that labor productivity was a challenge, and tools such as Lean principles and methods can favorably impact part of the challenge. Figure 1.2 shows the output, labor input, and labor productivity from 2002-2014. NAICS 23731 stands for North American Industry Classification System and code 23731 relates to the Construction of Highways, Streets, and Bridges.

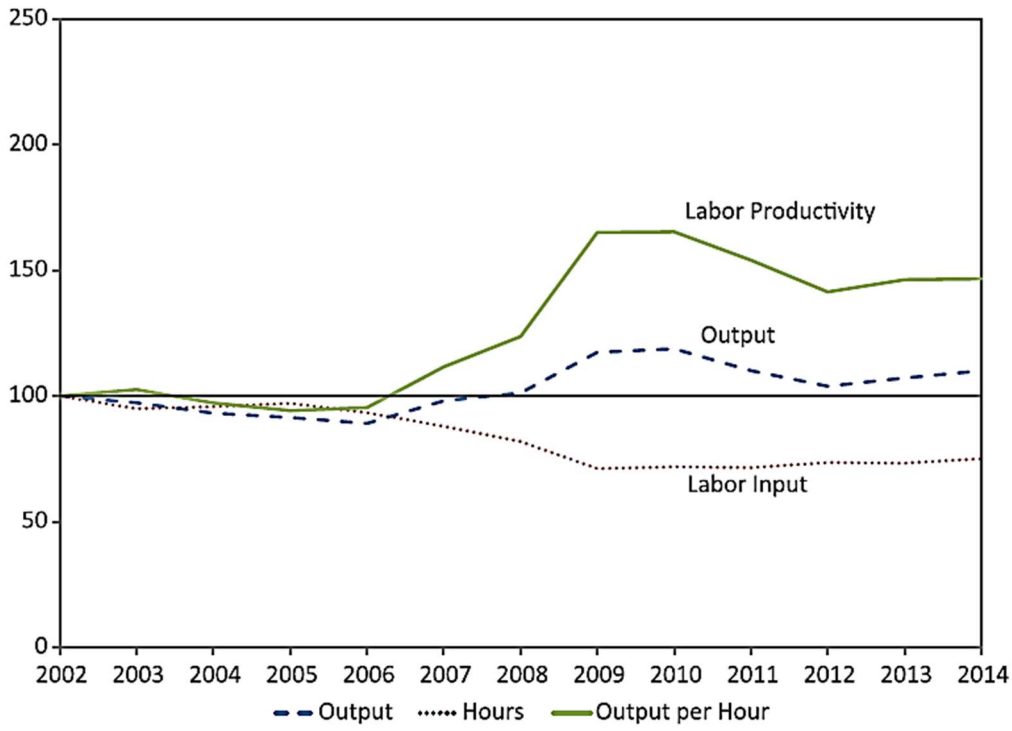

Figure 1.2 Output, Labor Input, and Labor Productivity in the Construction of Highways, Streets, and Bridges, 2002-2014. Image by Rowe et al., (2016)

Although the study by Rowe et al. (2016) examined several influences on construction productivity growth, researchers believed they were insufficient to explain why productivity growth was much lower in the construction industry than in other industries. The data analyzed by Rowe et al., (2016) came from the U.S. Census Bureau (2012), which the authors believed was the only source of consistent information on output and input. Rowe et al., (2016) distinguished their study on "productivity growth in construction" from other similar studies by claiming that high-quality output deflators such as Turner Construction Cost Index were scarce, and therefore the reports on total construction productivity could be inaccurate. Their estimates found substantial productivity growth in four industries, including construction of highways, streets and bridges. However, they believe it was too soon to state that productivity growth has been positive in overall construction (Rowe et al., 2016).

From a non-U.S. perspective, Abdel-Wahab and Vogl (2011) found that there was a downturn in construction labor productivity across Organization for Economic Co-Operation and Development (OECD) member countries, apart from the U.K. In their study, Abdel-Wahab et al. (2011) utilized

European Union Capital (K), Labor, Energy, Materials, and Service (EU KLEMS) data and found that the capital, labor quality and total factor productivity (TFP) were among factors contributing to productivity growth between 1971-2005. The authors also believed that a reasonable way to understand the drivers of productivity growth was to compare cross-country productivity for the construction sector; they found that EU KLEMS data offers a new opportunity for that purpose (Abdel-Wahab et al., 2011).

Furthermore, other studies demonstrated that labor productivity growth reports showed uncertainty (Abdel-Wahab and Vogl, 2015, and Rojas and Aramvareekul, 2003). In their study, they thought that "any investigation of international productivity differences in construction at the industry level was highly problematic because these productivity estimates did not compare like for like." (Abdel-Wahab et al., 2015, p.1). Data definition and coverage can vary significantly across countries, and deflators and exchange rates used to convert output into a common currency are untrustworthy (Abdel-Wahab et al., 2015). Thus, they believed that construction productivity comparisons at the project level between countries can enable more detailed analysis of the construction process (Abdel-Wahab et al., 2015). Moreover, the findings of the Rojas et al. (2003) study revealed controversial results on labor productivity growth based on the findings of macroeconomics and microeconomics data in the United States from 1979-1998. Rojas et al. (2003) asserted that the ambiguity created in the process of computing labor productivity growth made it less possible to conclude whether labor productivity has increased, decreased, or remained unchanged in the construction industry between 1979-1988 (Rojas et al., 2003).

1.3 Statement of Problem

As stated previously, construction labor productivity has not shown improvement when compared to other industries such as manufacturing. Given the fact that highway, street and bridge construction costs billions of taxpayers' dollars annually, the issue of labor productivity needs to be addressed. Lean Construction principles and methods are known to address some of the labor productivity challenges, but the findings in existing literature do not show a proven record of Lean Construction outcomes. Since the

adoption of Lean methods, more focus was on developing tools and less on identifying and prioritizing barriers (Shang and Pheng, 2014); therefore, this study intended to identify the barriers to implementation of Lean Construction within transportation sector.

1.4 Why Lean Construction

A study of construction productivity brings up one of the reasons behind the flat or decreased construction productivity as compared to other industries such as manufacturing: The construction industry has not benefited from the Lean Construction approach greatly when compared to the manufacturing industry (Construction Industry Resources, 2016).

Tommelein (2015) defines Lean Construction from three perspectives. The first was attaining simultaneously a project's time, budget and quality goals. Successful construction projects are delivered on time, on budget, and of the highest quality. Often, one of these three factors are sacrificed for another. A project delivered at a lower cost and a faster pace may suffer quality issues, and vice versa (Tommelein, 2015). The concept of Lean in the construction industry was to achieve the three above-mentioned components of success at the same time, by attaining a set of principles, tools and methods (Tommelein, 2015). The second definition was from a production perspective initiated by Lauri Koskela (Tommelein, 2015). It views an efficient system as a breaking down of the whole into independently operating pieces (transformation) by acquiring needed resources to give the transformation pieces the required flow. Also, this was known as transformation-flow-value (TFV) (Tommelein, 2015). The third definition comes from a variation perspective, where Lean persistently drives out the bad variation from the system (Tommelein, 2015). A paradigm shift in thinking, organizational behavior and a working culture that emphasizes on waste elimination and development of human resources are factors that contribute to the successful implementation of Lean practices (Shang et al., 2014).

Jorgensen and Emmitt (2008) say that while there are success stories of Lean tools and approaches in construction, the documentation and critical literature was weak (Jorgensen et al., 2008). Lean started out

in the manufacturing industry, which has its own peculiarities as compared to construction projects (Jorgensen et al., 2008). The manufacturing environments are highly standardized and repetitive, and production improvement processes emphasize the means and methods to shorten lead-time. The focus in the construction environment was on the non-repetitive project (except for building construction); also, the construction industry does not utilize mass production techniques (Jorgensen et al., 2008). According to Womack and Jones (Ogunbiyi, Goulding, and Oladapo, 2014) five principles eliminate waste in any organization:

1) Specifying value from the perspective of customer;

2) Identifying the value stream;

3) Creating flow;

4) Allowing customer demands to pace and pull production; and

5) Managing continuous improvement.

The various aspects of Lean Construction can be grouped into six core elements: reduction in waste, focus on the process of production planning and control, focus on end customer, continuous improvement, cooperative relationships, and system perspective (Ogunbiyi et al., 2014). Implementation of Lean principles can vary from organization to organization, and there was a lack of a universal and standard implementation method (Bhasin, 2012; and Achanga, Shehab, Roy, and Nelder, 2006). In addition, there was a need for a consistent vision -- in other words, knowing where and how to achieve a conductive culture (Bhasin, 2012). Moreover, management involvement and commitment (Achanga et al., 2006) are the primary prerequisites to Lean implementation within organizations.

1.5 The Lean Progression ® a Roadmap for Lean Journey

Spata (2016) believes that the roadmap to becoming a Lean practitioner was defined in five levels. The first level was theory. As shown in Figure 1.3, waste, value and flow are the foundational principles of Lean. The key was to identify waste, discover how to improve flow, and understand client value. However, a vision was needed to apply the theory. The vision was a project delivery method as a coordinated enterprise system. Regardless of Lean intensity, every project requires a coordinated effort, aligned expectations and a productive, continuously improving system (Spata, 2016).

Process was at the heart of Lean Progression. The big four processes include the Last Planner System (LPS)® for scheduling; Target Value Design (TVD) for budgeting; Set Based Design (SBD) for problem solving; and Choosing By Advantages (CBA) for decision-making. The big four are based on the expectation established in the fifth process: the Conditions of Satisfaction (COS). To help Lean processes to happen, Lean tools are required. There are many Lean tools. Many more will be invented. Lean tools enable and support Lean processes. Some common tools include the Big Room, A3 Thinking, Visual Management (Spata, 2016).

Finally, there are five universal Lean habits. PlusDelta and Takeaway enhance feedback mechanisms. The Kaizen cycle drives continuous improvement and Breakdown declaration prevents error. What the five habits have in common was a need for a psychological safe zone established by leadership. In return, they drive the culture and system of Lean creating a virtuous circle (Spata, 2016). Figure 1.3 shows the five levels of Lean Progression proposed by Spata (2016).

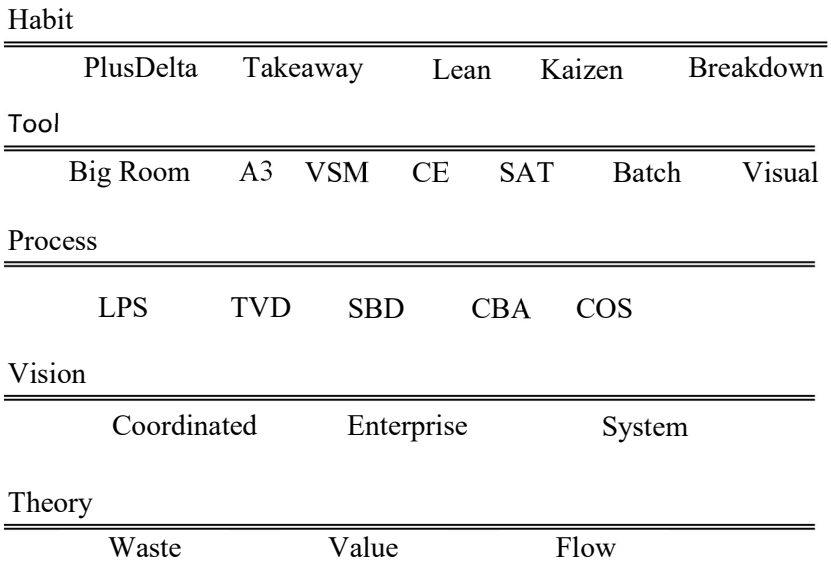

Figure 1.3 Lean Progression® by Sam Spata (2016)

Although implementation of Lean in construction was not without challenges and barriers, practitioners already have benefited from it. A study by McGraw Hill Construction on Lean Construction in partnership with Dassault Systèmes, as illustrated in Figure 1.4, shows that Lean practitioners have experienced a higher level of worker safety and quality, greater customer satisfaction, improved labor productivity, and saved costs when compared to not using Lean methods. (Construction, 2013).

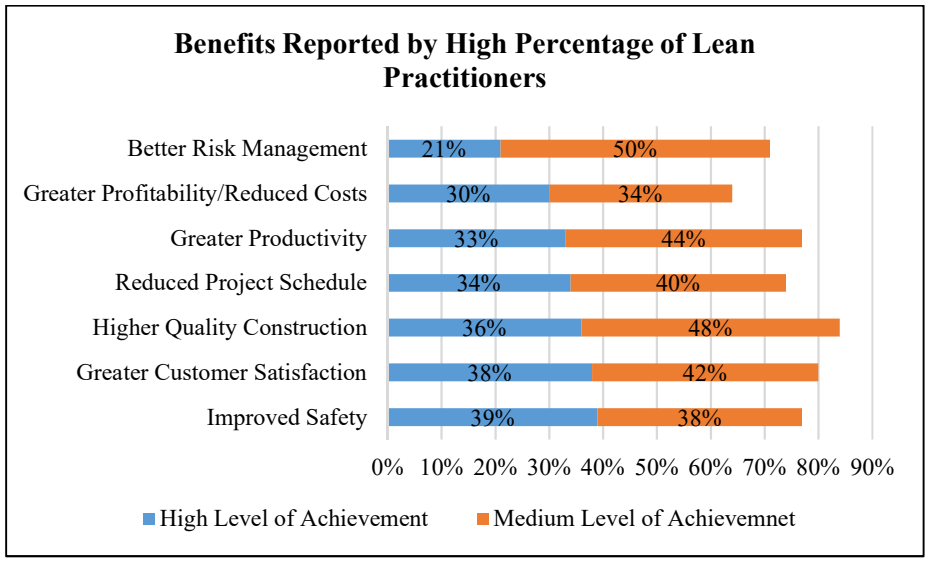

Figure 1.4 Benefits of Lean (Source: McGraw Hill Construction, 2013)

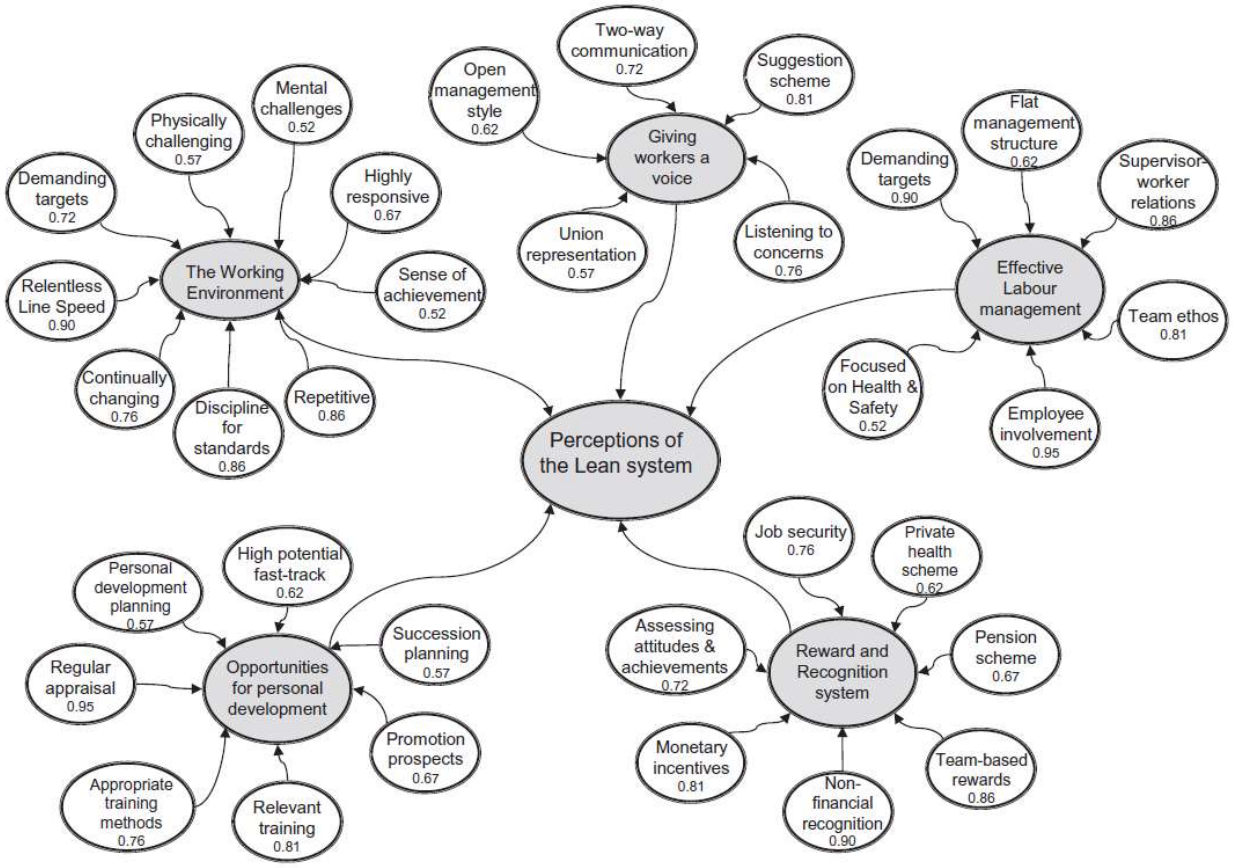

Figure 1.5 Work environment in a Lean system. Source: Taylor, Taylor, & McSweeney, (2013)

A research study in the U.K. production industry found that organizations adopt Lean because they believe its methods lead to improved performance, competitive pressures and customer pressure, and Lean creates a team spirit (Bhasin, 2012).

The perceptions of a Lean system as illustrated in Figure 1.5 above, was comprised of four sub perceptions: work environment; opportunities for personal development; reward and recognition system; effective labor management; and an environment in which workers have a voice. For example, a Lean work environment challenges the team physically and mentally and ensures that the work was highly responsive, and consistently applied (Taylor et al., 2013). The other factors that make up each sub-perception of a Lean system also are shown in Figure 1.5.

1.6 Research Significance

The gaps in the current literature reveal a lack of research identifying and prioritizing barriers and overcoming strategies in implementing Lean Construction principles and methods in the United States. A thorough review of the literature found these research gaps:

1. The researcher found that more literature exists which prioritizes barriers to implementing Lean principles in other industries such as manufacturing, small-and-medium enterprises (SME), than in the construction industry.
2. To the best of the researcher's knowledge, there was a lack specific research on prioritizing barriers and the overcoming strategies in implementing Lean Construction principles and methods focusing on construction of infrastructure highways, streets and bridges.
3. Given the fact that the nature of barriers was multi-dimensional -- including lack of knowledge and skills, attitudinal, cultural, and legislative barriers – the researcher did not find research that contextualizes the barriers and the overcoming strategies within the United States and particularly in the State of Michigan's transportation projects.

As indicated earlier in the chapter, the purpose of this research was to identify and prioritize implementation barriers and the overcoming strategies to Lean methods within Michigan transportation projects. Lean methods and principles provide opportunities for boosting labor productivity by minimizing risks and maximizing value. Performance efficiency, labor productivity and project responsiveness are of crucial importance in the construction of publicly financed highways, streets and bridges.

The findings of this study will add value to the existing body of knowledge surrounding construction labor productivity issues within the transportation sector. Knowing where the problem exist was the first step toward resolving the problem. Identifying and prioritizing Lean Construction barriers and the overcoming strategies was the first step toward addressing its implementation.

1.7 Study Objectives

To answer the research question -- What are the barriers and the overcoming strategies in implementing Lean Construction within transportation projects -- the study breaks down the query into the following objectives:

a. Determine Lean Construction implementation barriers by conducting an in-depth and diverse literature review. The literature includes construction, manufacturing, public sector, and small-and-medium enterprises (SME) industries.
b. Seek transportation project stakeholders' perceptions of the barriers identified in the literature review through a survey questionnaire.
c. Recommend strategies to overcome the barriers identified in (b) by collecting input from survey respondents within transportation project stakeholders.

1.8 Overview of Methods

This research intends to explain the causality of Lean Construction implementation barriers, and could be considered as explanatory research. An in-depth literature review provided current barriers to implementation of Lean principles in general. Due to the inadequate literature focusing on Lean Construction barriers in the transportation sector, this literature review includes the barriers to implementation of Lean in construction, manufacturing, public sector and small-and-medium enterprises (SME) industries. Based on the literature, a survey questionnaire was designed and distributed among key transportation project stakeholders operating in the State of Michigan. The questionnaire was facilitated via Qualtrics, which was Michigan State University's official subscription for online survey software. After responses were collected, they were analyzed by prioritizing barriers based on the intensity of agreement and disagreement of responses collected via the survey. Furthermore, suggestions for overcoming strategies to the existing barriers were received from survey respondents on the open-ended

question and reported. An author's discussion and results on the research findings concluded this research.

1.9 Thesis Layout

This thesis was designed in five chapters. In Chapter One – Introduction, the reader was introduced to the construction industry and infrastructure highway and bridge construction trends and delivery methods, challenges, shortcomings, and opportunities for improving methods and study design.

Chapter Two provides an in-depth literature review on the construction industry starting with the role of the construction industry contribution to the U.S. economy in whole and public work construction projects in the state of Michigan. Next, the barriers to implementing Lean methods are sought. Prior research that has been done on the topic are investigated and the need for this study was identified.

Chapter Three details the methods used to conduct this study. It describes the design of the survey questionnaire, the research population, data collection method and the data analysis framework.

Chapter Four presents the findings of the survey questionnaire. This chapter initially describes the empirical data by charts and tables, then discusses the findings followed by a comparison of empirical results and the findings in the literature review.

Chapter Five provides the conclusion of this study and recommendations for future research.

1.10 Summary

The construction industry was a significant contributor to the U.S. economy. The findings of AGC of America shows that this industry makes up to 4.0% of the U.S. gross domestic product. However, the construction industry has not experienced the significant labor productivity growth of other industries. The infrastructure industry, specifically construction of highways, streets and bridges, spent billions of taxpayers' dollars yearly. Yet it was still predominantly implemented using traditional project delivery

methods such as design-bid-build (DBB). Lean Construction methods and principles seek to increase productivity by minimizing waste and maximizing value in the processes of design and construction of capital projects. This was still a new paradigm in the delivery of projects, and the findings of the studies show that there are potential barriers to implementing Lean methods.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This chapter reviews existing literature on barriers hindering implementation of Lean methods. To conduct an in-depth review of the literature, this study utilized the Snowballing method to review the most relevant and diverse journal papers. The research keywords are defined and the first set of papers were selected. Care was taken to use scholarly and peer-reviewed journal papers issued by a variety of publishers. The findings in this section show that 203 barriers to implementation of Lean methods were cited within the existing literature review. This study further merged and grouped the barriers into 10 barrier types. Among the 10 barrier types, knowledge and skills related barriers; technical barriers; cultural and attitudinal; structural and organizational; and commitment and support related barriers were cited and ranked more frequently than other types, such as governmental or logistical barriers.

2.2 Methodology followed in sourcing literature

In this research, a systematic review of the literature on the barriers to implementation of Lean Construction methods was conducted using the Snowballing method. The journal papers were found via Michigan State University's electronic library and Google Scholar search engines. Figure 2.1 illustrates the process of the literature review conducted in this research.

First, to prepare the start set of academic papers for this literature review, a careful selection of keywords was made. Examples include "barriers," "hindrance," "challenges," "obstacles," "implementation," "lean," "construction," and "transportation."

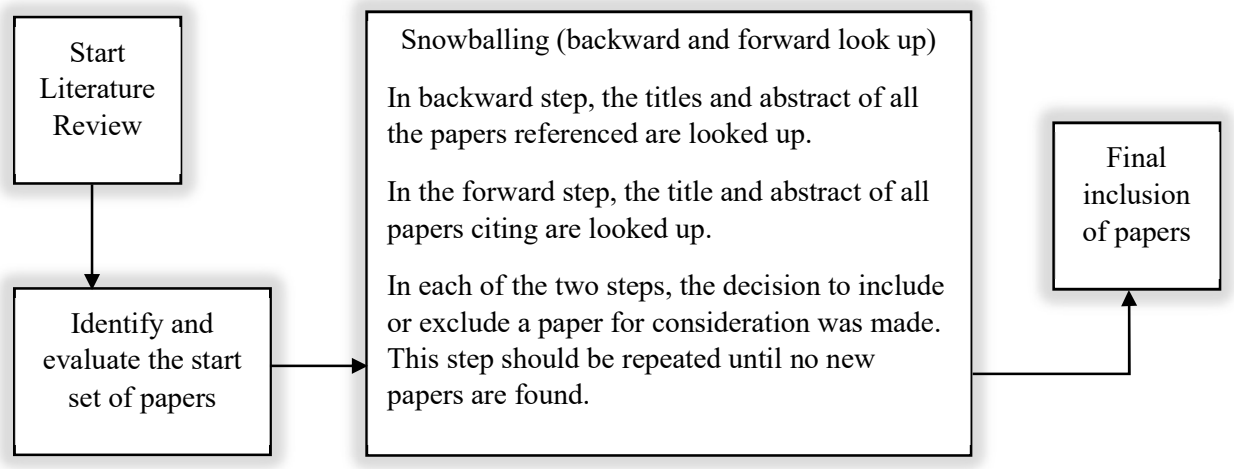

Figure 2.1 Snowballing Procedure. Concept. (Source: Wohlin, 2014)

Then, the resulting search was confined to recent scholarly and peer-reviewed journal papers, published within the last ten years (2006-2016).

The selection criteria for the starting set of papers was based on the following characteristics adopted from Guidelines for Snowballing in Systematic Literature Studies by Wohlin (2014):

- Relevant papers should come from different communities to address the risk of papers being independent clusters. For this research, papers were chosen from Lean Construction, Lean Manufacturing, Lean SME, and Lean Six Sigma
- The number of papers in the starting set should not be too small relative to the breadth of the study. Therefore, a total of six papers were selected for iteration process.
- Highly cited papers were preferred if many papers were found within a topic. In this research, due to the narrowed search strings, the number of relevant papers were not many. However, the starting set of papers are all cited.
- The starting set should represent an array of publishers, years and authors. For this research, selected papers were diverse. *Journal of Technology Management in China* published by Emerald Insight, *Acta Technica Corviniensis – Bulletin of Engineering*, *International Journal of Lean Six*

Sigma, International Journal of Productivity and Performance Management, and Asian Business and Management published by Macmillan Publishers Ltd., are among the journal and publishers included in the selected papers for start set

- The starting set ought to be formulated from keywords in the research question, while preferably taking synonyms into account. For this research, terms such as "challenges," "hindrance," and "obstacle" were used as synonyms for the keyword "barrier." And terms such as "practice," "application," "apply," and "successful application" were used as synonyms for the keyword "implementation."

2.3 Overview of barriers to implementing Lean Construction

A review of the current literature showed emphasis on several factors including but not limited to lack of long term philosophy; workers' resistance to change; and attitudinal, organizational, and cultural barriers to implementation of Lean in construction context (Shang et al., 2014). The methodology adopted to identify and prioritize the barriers by Shang et al., (2014) included 91 Chinese building professionals. A 5-Point Likert scale was used to measure the participants' degree of agreement.

Due to the lack of adequate studies on this topic, the literature review expanded to include implementation barriers to Lean within other contexts such as Lean in the manufacturing industry and Lean in small and medium enterprises. Furthermore, Womack and Jones (1997) believed that Lean practices not only would spread in all areas of manufacturing but cross into other industries as well. This study found that the literature on other industries, such as manufacturing, share more similar business and supply chain decision-making processes with the construction industry than other industries, such as healthcare. Therefore, the start set of the literature review was chosen from scholarly papers focused within the construction industry.

A study by Alves, Milberg, and Walsh (2012) found that failure to engage people in meaningful learning experiences was the primary barrier to implementation of Lean methods. Practicing Lean methods will be in vogue if the experiences are equipped with sustained efforts to engage people in meaningful learning experiences (Alves et al., 2012). The study by Alves et al., (2012) further notes that lack of consent in interpreting Lean and lack of academics to closely work with industry practitioners on adapting Lean concepts are the other challenges facing this new concept in construction industry (Alves et al., 2012). Alves et al., (2012) findings were based on insights obtained from a meeting with industry practitioners in California and Brazil, literature review and published case studies.

Wodlaski, Thompson, Whited, and Hanna (2011) summarized the barriers and impediments to Lean construction in public settings (transportation and infrastructure works) into seven barriers. They were: legislative issues, fear of change, incompatibilities with traditional state transportation authorities (STAs) and processes, lack of resources, risk management, insurance, and lack of a guaranteed cost (Wodalski et al., 2011). Most state transportation authorities (STAs) are required to choose the lowest bidder, which was inherent in the traditional method of Design-Bid-Build project delivery and was an obstacle to utilizing Lean project delivery (LPD), where the lowest bidder was not always the winner. Wodalski et al., (2011) utilized case-studies that documented the successful use of Lean techniques within the infrastructure industry such as Albanian Motorway Project, Jubail Industrial City and Bechtel's case-studies. Since this report's results were based on case studies and interviews with Bechtel's international projects, it did not represent the U.S. infrastructure and transportation projects.

Shang and Pheng (2014) surveyed 22 barriers to implementing Lean in construction in China and categorized them into six factors: people and partner, managerial and organizational, lack of support and commitment, cultural and philosophical, government related and procurement-related. The top five barriers found by Shang et al., (2014) were lack of long-term philosophy, absence of a Lean culture in the organization, multi-layer subcontracting, insufficient management skills and lack of support from top

management. While the study provided a general overview of the major barriers to implementing Lean in the construction industry, it focused on the Chinese market, and not on U.S. transportation projects.

Jadhav, Mantha, and Rane (2013) reviewed Lean implementation and found twenty four Lean barriers. Lack of resources to invest, or necessity of high investments or financial constraints; lack of senior management involvement and commitment; worker's or employees' attitude, cultural difference; and lack of strong leadership were among the top five barriers found in the literature reviewed by Jadhav et al., (2013). The methodology adopted by Jadhav et al., (2013) was a literature survey of peer-reviewed journal articles, survey reports, theses and dissertations. However, the study's focus was on the manufacturing industry and did not address the specific working atmosphere and environment of transportation projects.

Abolhassani, Layfield, and Gopalakrishnan (2015) defined the major obstacles to implementing Lean practices as lack of management commitment, unfit culture, unsustainability, high cost of investment and Lean past failures. The research methodology adopted by Abolhassani et al., (2015) was a survey questionnaire which was distributed to 327 manufacturing facilities and 51 usable responses were collected. However, these obstacles were studied in the U.S. manufacturing context and not within the transportation context.

Continuous improvement or Kaizen as one of the five pillars of Lean, faces the three barriers of technical, technological and cultural barriers (Protzman, Whiton, Kerpchar, Lewandowski, Stenberg, and Grounds, 2016). Without getting the company's chief executive officer (CEO) and chief financial officer (CFO) on board for Lean implementation, middle managers failed to execute Lean principles at the project level (Protzman et al., 2016).

In their case-study report on the presence of Lean construction principles in Norway transportation and infrastructure projects, Rodewohl, (2014), classified the barriers to Lean implementation as cultural and structural. Rodewhol, (2014) believed that a lack of understanding of the fundamental concepts and ideas

of Lean was the primary barrier followed by lack of the management support and difficulty in paradigm shift toward Lean thinking.

Oladiran, (2008) believed it was likely that the barriers to implementing Lean in the Nigerian construction industry may be placed into one or more of the seven groups. Perhaps construction practitioners did not possess sufficient skills or knowledge, or can live with wrong motives such as selfishness, resistance to change, or even arrogation of unnecessary power to architects (Oladiran, 2008). These barriers were followed by lack of support from top management, government bureaucracy and corruption and logistical and financial barriers (Oladiran, 2008). The methodology adopted by Oladiran (2008), was a survey of ten companies selected by quota sampling technique and personal interviews.

Inadequate knowledge and skills were identified as the top challenge to the prioritization of Lean in the Libyan construction industry, while the least problem was the lack of group work culture, shared vision and consensus (Omran & Abdulrahim, 2015 and Alinaitwe, 2009). A survey questionnaire was distributed by Omran et al., (2015) to forty-six construction firms in Libya. Alinaitwe, (2009) carried out structured interviews with technical managers of building firms to collect their perceptions of the barriers to Lean Construction. Inability to measure the team performance negatively affects the effective management of resources in large construction firms (Omran et al., 2015). Omran et al., (2015) found that lack of management and leadership followed by poor communication were the most important barriers to implementation of total quality management (TQM).

A thorough review of the existing literature over the last 10 years of scholarly and peer-reviewed journal papers found 203 barriers that challenge implementation of Lean methods. The breakdown of these barriers was presented in the next section. Out of the 203 barriers, several of the same obstacles were cited by different papers; therefore, this study has further merged the barriers and summarized them to 87. See Appendix A for a complete list of these barriers.

While several articles prioritized the barriers such as Omran and Abdulrahim (2015); Shang and Pheng (2014); Alinaitwe (2009); Sarhan and Fox (2013); Bashir, Suresh, Oloke, Proverbs and Gameson (2015); Jadhav, Mantha, and B. Rane (2014); and Albliwi, Anthony, Abdul Halim Lim and van der Wiele (2014), other authors did not express the same level of priority such as Da, Milberg, and Walsh (2012), Rahbek Gjerdrum Pedersen and Huniche (2011), Mehri (2006), Abolhassani, Layfield, and Gopalakrishnan (2016), Halling and Wijk (2013).

Omran et al., (2015) prioritized the barriers to Lean construction in the Libyan construction industry into seven barriers. Inadequate knowledge and skills, lack of organizational culture and supporting team work, and inability to measure performance of the team and gauging their progress were the top three, while lack of capability of the team to maintain alignment with other teams and lack of group culture were ranked the sixth and seventh respectively (Omran et al., 2015). However, it was found that the nature of the barriers differed with respect to their prioritization. Shang et al., (2014) found 20 barriers to implementation of Lean construction in China, led by the lack of a long-term philosophy, absence of Lean culture in the organization and multi-layer subcontracting.

Alinaitwe (2009) found that inability to supply inputs on time, lack of infrastructure in transportation and communication and incapability of teams to maintain alignment with other teams were the top three of 31 barriers; lack of leadership in management was way down on the prioritized list of barriers. Interestingly, Lean Construction in the U.K. construction industry were different. It was found that cultural and attitudinal barriers top the list followed by cost of implementation and lack of Lean knowledge (Bashir et al., 2015, Sarhan et al., 2013). Alves et al., (2012) also found that there was a knowledge gap between academia and industry and more collaboration was needed to fulfill the lack of consensus on the meaning and interpretation of Lean and foster sustained efforts to engage participants in meaningful learning experiences.

2.4 Breakdown of barriers found in the literature

A thorough and diverse review of the existing literature cited 203 barriers to implementation of Lean. The barriers include construction, manufacturing, public sector, and small- and medium-sized enterprises in the U.S., Europe, Africa and Asia.

After a thorough review of the barriers found in the literature review, the research noticed that most of the them can be categorized into one of the ten barrier types showed in Figure 2.2. For example, lack of training, lack of awareness, and employees' and workers' knowledge of Lean were categorized in Knowledge and Skills related barriers. Attitudinal barriers, and resistance to change related barriers were categorized in cultural and attitudinal barriers.

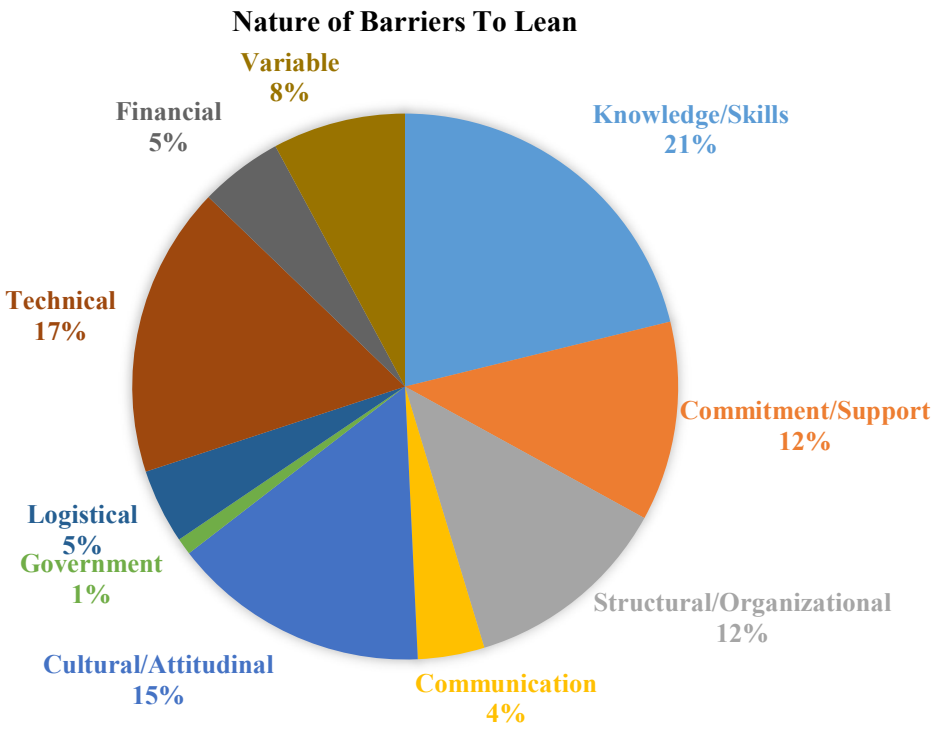

Figure 2.2 Contribution percentage of the barriers found in the literature review.

Figure 2.2 shows that majority of the barriers (21%) are categorized in lack of knowledge and skills in Lean principles and methods. The second major barrier types were technical and cultural/attitudinal barriers that made 17% and 15% of the total cited barriers, respectively. Structural and organizational

obstacles, and commitment and support barriers each contributed 12%. Financial, logistical, communication, and governmental barriers each contribute less than 5% to the existing barriers cited by the literature; 8% vary in nature, including but not limited to lack of long-term philosophy, unsustainability of Lean and its slow response to market.

2.4.1 Lack of Knowledge and Skills

Inadequate knowledge and skills was a major factor affecting worker's productivity (Omran et al., 2015). Alinaitwe (2009) believed that lack of knowledge and skills was a barrier to team work and concurrent engineering, both of which both were considered key concepts of Lean construction. Lack of knowledge of implementation could also pose technical issues to the construction supply chain by creating uncertainty of workflow reliability, which will subsequently affect the application of the Just-In-Time (JIT) approach -- another key concept of Lean construction (Alinaitwe, 2009). Lack of knowledge also affected the application of Lean Six Sigma®, which was another key concept of Lean construction (Albliwi et al., 2014).

In addition to the workers' lack of knowledge and skills, the organization's managers and leaders lacked certain skills. Inaccurate pre-planning, limited experience in change management, poor selection of candidates for training and Lean certification programs, lack of estimation of implementation cost, and lack of project team skills were among the managerial and leadership gaps hindering implementation of Lean in the organizations (Shang et al., 2014; Alinaitwe, 2009; Pedersen, 2011; Albliwi, 2014; and Halling et al., 2013).

Insufficient training for workers and inadequate knowledge of Lean were other major barriers under the subcategory of knowledge and skills. A complete list of the barriers filtered for Knowledge/Skills was shown in Table 2.1.

Table 2.1 Barriers to implementation of Lean found in the literature review. Barrier nature: Lack of Knowledge and Skills

No.	Barrier Name	Details	Source	Industry
B1	Inadequate knowledge and skills	- Lack of knowledge and skills of workers, - Lack of experience in Lean/Six Sigma project implementation	Omran & Abdulrahim, 2015; Alinaitwe, 2009; Albliwi et al., 2014	Libyan Construction Industry, Ugandan Construction Industry, U.S., U.K., & Indian SME
B11	Insufficient leadership and management skills	- Inaccurate pre-planning, - Lack of leadership in management, - Limited experiences in change management, - Poor selection of candidates for belts training, - Lack of estimation of implementation cost, - Lack of project team skills	Shang et al., 2014; Alinaitwe, 2009; Rahbek Gjerdrum Pedersen & Huniche, 2011; Albliwi et al., 2014; Halling & Wijk, 2013	Chinese Construction Industry, Ugandan Construction Industry, Danish Public Sector, U.S., U.K., & Indian SME, Swedish Manufacturing Industry
B14	Insufficient training	- Inadequate training and education, - Lack of formal training for workers, - Lack of formal training for managers, - Lack of training and education, - Lack of leadership skills and visionary and supportive leadership, - Inadequate education and training of entrepreneurs	Shang et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Sarhan & Fox, 2013; Jadhav et al., 2014; Albliwi et al., 2014; Rymaszewska, 2014	Chinese Construction Industry, Danish Public Sector, U.K. Construction Industry, U.S. Manufacturing Industry, Finland SME

Table 2.1 (Cont'd)

B16	Insufficient knowledge of Lean	- Lack of adequate Lean awareness and understanding, - Misconceptions about Lean, - Lean has human costs, - Insufficient understanding of the potential benefits, - Lean was a gimmick, - Lack of awareness of the benefits of Lean/Six Sigma (LSS), - Wrong selection of LSS tools, - Narrow view of LSS as a set of tools, techniques and practices, - Lack of awareness of the need for LSS, - Consultants with limited Lean knowledge, - Operators lack Lean knowledge, - Insufficient workforce, supervisory, and managerial skills to implement Lean, - Lack of consensus on the meaning of Lean	Shang et al., 2014; Sarhan & Fox, 2013; Bashir et al., 2015; Mehri, 2006; Abolhassani et al., 2016; Albliwi et al., 2014; Halling and Wijk, 2013; Bhasin, 2012; Alves et al., 2012	Chinese Construction Industry, U.K. Construction Industry, Japanese Manufacturing Industry, U.S., U.K., & Indian SME, Swedish Manufacturing Industry, U.K. Manufacturing Industry, U.S. & Brazil Construction Industries, Swedish Manufacturing Industry
B44	Not understanding of needs of customers, i.e., internal and external	- Lack of understanding of the different types of customers	Alinaitwe, 2009; Albliwi et al., 2014	Ugandan Construction Industry, U.S., U.K., & Indian SME
B51	No real or perceived crisis		Rahbek Gjerdrum Pedersen & Huniche, 2011	Danish Public Sector
B54	Little/no knowledge transfer		Rahbek Gjerdrum Pedersen & Huniche, 2011	Danish Public Sector
B69	Lack of consultants in the field		Jadhav et al., 2014	U.S. Manufacturing Industry

2.4.2 Lack of Commitment and Support

Lack of commitment and support was prioritized differently in the current literature. Some studies, for example, found that lack of management's commitment and support was the major barrier to implementation of Lean principles in organizations. Shang et al. (2014) found that lack of long-term philosophy ranked number one in prioritizing Lean in China's construction industry. Omran et al., (2015) prioritized that lack of support and organizational culture and lack of top management commitment as second among seven barriers found in Libya's construction industry. In addition, lack of top management commitment was ranked second of the 10 barriers found to implementing Lean Construction in the U.K construction industry (Sarhan et al., 2013). However, this research found that other studies ranked the lack of leadership in the management of the organization at the bottom of its barrier prioritization list, as in Ugandan construction industry (Alinaitwe, 2009), or have not prioritized the barriers. Furthermore, Bashir et al., (2015) found that lack of long-term forecast and investment, which the researcher interprets as lack of management's commitment and support, was ranked eighth of 11. A complete list of barriers filtered for Lack of Commitment and Support was shown in Table 2.3.

Table 2.2 Barriers to implementation of Lean found in the literature review. Barrier nature: Lack of Commitment and Support

No.	Barrier Name	Details	Source	Industry
B12	Lack of support from top management	- Lack of top/senior management, involvement, commitment, and support, - Lack of strong/good leadership, - Inadequate time and cash flow management, - Lack of adequate empowerment to shop floors, - Lack of support functions of from HR, - Lack of management awareness and support	Shang et al., 2014; Jadhav et al., 2014; Abolhassani et al., 2016; Albliwi et al., 2014; Halling and Wijk, 2013; Bhasin, 2012; Rymaszewska, 2014; Albliwi et al., 2014; Sim and Rogers (2008;2009); Halling and Wijk, 2013; Rahbek Gjerdrum Pedersen & Huniche, 2011; Sarhan & Fox, 2013	Chinese Construction Industry, U.S. Manufacturing Industry, U.S., U.K., & Indian SME, Swedish Manufacturing Industry, U.K. Manufacturing Industry, Finland SME, U.S. Manufacturing Industry, Swedish Manufacturing Industry, Danish Public Sector, U.K. Construction Industry
B30	Lack of collaborative work between academia and construction industry		Alves et al., 2012	U.S. & Brazil Construction Industries
B45	Lack of client involvement		Alinaitwe, 2009	Ugandan Construction Industry
B47	Lack of continuous improvement		Alinaitwe, 2009	Ugandan Construction Industry
B59	Lack of long term forecast and investment (management related)		Bashir et al., 2015	U.K. Construction Industry
B60	Low effort to learn		Bashir et al., 2015	U.K. Construction Industry

Table 2.2 (Cont'd)

B62	Backsliding or lack of perseverance		Jadhav et al., 2014	U.S. Manufacturing Industry
B65	Lack of supplier collaboration or lack of mutually beneficial strategic partnership with suppliers and customers	- Lack of supplier involvement	Jadhav et al., 2014; Alinaitwe, 2009	U.S. Manufacturing Industry, Ugandan Construction Industry
B68	Lack of logistic support		Jadha et al., 2014	U.S. Manufacturing Industry
B76	Lack of employee engagement and participation/lack of team autonomy		Albliwi et al., 2014	U.S., U.K., & Indian SME
B84	Misalignment between the project aim, the main goals of the company and the customer demand		Albliwi et al., 2014	U.S., U.K., & Indian SME

2.4.3 Cultural and Attitudinal Barriers

The literature also revealed a general resistance to change (Shang et al., 2014; Abolhassani et al., 2016; and Rahbek Gjerdrum Pedersen & Huniche, 2011). Therefore, this study clustered the resistance to change as a cultural and attitudinal barrier. Current literature showed that employees' resistance to change was cited more often than management's resistance to change, as shown in Table 2.3. Personal preferences and lack of cooperation and mutual trust between management and employees were among the cultural and attitudinal barriers to implementing Lean principles in construction, manufacturing, and small-and-medium enterprises (SME) industries. A complete list of the barriers filtered for Cultural and Attitudinal barrier was shown in Table 2.3.

2.4.4 Technical Barriers

Bashir et al. (2015) and Albliwi et al. (2014) found that lack of understanding on how to get started was among the barriers hindering Lean implementation in the U.K construction industry, and in the U.S., U.K., and Indian SME industries (Table 2.4). Among the other barriers that the researcher clustered as "technical" was the slow pace of change which Pedersen et al., (2011) and Bashir et al., (2015) found among implementation barriers to Lean in Denmark's public sector and the U.K. construction industry.

Other barriers such as communication barriers, financial barriers, governmental, logistical, and structural and organizational barriers are presented in the Appendix A.

Table 2.3 Barriers to implementation of Lean found in the literature review. Barrier nature: Cultural and Attitudinal

No.	Barrier Name	Details	Source	Industry
B2	Lack of organizational culture supporting team work	- Organizational culture supporting teamwork	Omran & Abdulrahim, 2015; Alinaitwe, 2009	Libyan Construction Industry, Ugandan Construction Industry
B4	Individual needs and personal differences of team members		Omran & Abdulrahim, 2015	Libyan Construction Industry
B7	Lack of group culture, shared vision and shared consensus	- Group culture, shared vision and shared consensus	Omran & Abdulrahim, 2015; Alinaitwe, 2009	Libyan Construction Industry, Ugandan Construction Industry
B9	Absence of a lean culture in the organization	- Lack of sustained efforts to engage people in the meaningful learning experiences, - Need for culture change	Shang et al., 2014, Alves et al., 2012; Rahbek Gjerdrum Pedersen & Huniche, 2011	Chinese Construction Industry, U.S. & Brazil Construction Industries, Danish Public Sector
B13	Management resistance to change	- Top management's resistant to change	Shang et al., 2014; Abolhassani,et al., 2016; Albliwi et al., 2014; Jadhav et al., 2014	Chinese Construction Industry, U.S. Manufacturing Industry
B18	Using guanxi or relationships to conceal mistakes		Shang et al., 2014	Chinese Construction Industry
B19	Avoid making decisions and taking responsibility		Shang et al., 2014	Chinese Construction Industry
B21	Absence of a lean culture in the partners		Shang et al., 2014	Chinese Construction Industry
B23	Employee tolerance of untidy workplaces (undisciplined work habits)		Shang et al., 2014	Chinese Construction Industry

Table 2.3 (Cont'd)

B26	Employee resistance to change	- Employee resistant to change, - Workers' attitude or resistance (unionized workers or unwillingness of workers),	Shang et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Bhasin, 2012; Abolhassani et al., 2016; Jadhav et al., 2014; Bashir et al., Gameson, 2015	Chinese Construction Industry, Danish Public Sector, U.K. Manufacturing Industry, U.S., U.K., & Indian SME, U.S. Manufacturing Industry, U.K. Construction Industry
B38	Defect prevention		Alinaitwe, 2009	Ugandan Construction Industry
B55	Culture and human attitudinal issues	- Lean does not fit culture, - Reactive culture, - Cultural difference, - Japanese Lean was culturally un-American, - Silo thinking (Lack of whole-system optimization mindset)	Sarhan & Fox, 2013; Abolhassani et al., 2016; Bhasin, 2012; Jadhav et al., 2014; Mehri, 2006; Rahbek Gjerdrum Pedersen & Huniche, 2011	U.K. Construction Industry, U.S. Manufacturing Industry, U.K. Manufacturing Industry, Japanese Manufacturing Industry, Danish Public Sector
B67	Cross-functional conflicts		Jadhav et al., 2014	U.S. Manufacturing Industry
B70	Lack of cooperation and mutual trust between management and employees	- Lack of cooperation from employees	Jadhav et al., 2014; Bashir et al., 2015	U.S. Manufacturing Industry, U.K. Construction Industry
B87	Reliance upon outdated, labor intensive technologies and traditional management practices		Rymaszewska, 2014	Finland SME

Table 2.4 Barriers to implementation of Lean found in the literature review. Barrier nature: Technical

No.	Barrier Name	Details	Source	Industry
B3	Inability to measure performance of the team and to gauge the team progress	- Lack of the use of process based Performance Measurement Systems (PMSs)	Omran & Abdulrahim, 2015; Alinaitwe, 2009; Sarhan & Fox, 2013; Albliwi et al., 2014	Libyan Construction Industry, Ugandan Construction Industry, U.K. Construction Industry, U.S., U.K., & Indian SME
B17	Inadequate delivery performance	- Poor execution, - Poor project selection and prioritization, - Poor selection of change agents and improvement teams, - Lack of technical knowledge, - Problems with machine and modernization of equipment	Shang et al., 2014; Albliwi et al., 2014; Abolhassani et al., 2016; Albliwi et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Jadhav et al., 2014	Chinese Construction Industry, U.S., U.K., & Indian SME, U.S. Manufacturing Industry, U.S., U.K., & Indian SME, Danish Public Sector, U.S. Manufacturing Industry
B27	Limited use of off-site construction techniques	- Lack of prefabrication	Shang et al., 2014; Alinaitwe, 2009	Chinese Construction Industry, Ugandan Construction Industry
B28	Construction firm's limited involvement in the design		Shang et al., 2014	Chinese Construction Industry
B29	Limited use of design-and-build procurement mode	- Procurement and contracts issues	Shang et al., 2014; Sarhan & Fox, 2013	Chinese Construction Industry, U.K. Construction Industry
B33	Certainty in the supply chain		Alinaitwe, 2009	Ugandan Construction Industry
B35	Lack of buildable designs	- Design/construction dichotomy - Incomplete/inaccurate designs, - Rework, - Lack of buildable designs, - Disruption to construction due to design changes	Alinaitwe, 2009; Sarhan & Fox, 2013	Ugandan Construction Industry, U.K. Construction Industry
B36	Lack of participative management style for workforce		Alinaitwe, 2009	Ugandan Construction Industry

Table 2.4 (Cont'd)

B40	Certainty in the production process, i.e., workflow reliability		Alinaitwe, 2009	Ugandan Construction Industry
B41	Lack of benchmarks		Alinaitwe, 2009	Ugandan Construction Industry
B42	Not using standard components	- Lack of work standards and clear and cut procedures - Lack of an effective model or roadmap to guide implementation	Alinaitwe, 2009; Halling and Wijk, 2013; Albliwi et al., 2014	Ugandan Construction Industry, Swedish Manufacturing Industry, U.S., U.K., & Indian SME
B48	Lack of documenting agreements and procedures	- Failure to document benefits from lean	Alinaitwe, 2009; Rahbek Gjerdrum Pedersen & Huniche, 2011	Ugandan Construction Industry, Danish Public Sector
B52	Slow pace of change	- Long implementation time	Rahbek Gjerdrum Pedersen & Huniche, 2011; Bashir et al., 2015	Danish Public Sector, U.K. Construction Industry
B58	Complexity (technical issue)	- Lack of understanding of how to get started	Bashir et al., 2015; Albliwi et al., 2014	U.K. Construction Industry, U.S., U.K., & Indian SME
B64	Lack of influence over suppliers or lack of involvement of suppliers in the actual implementation		Jadhav et al., 2014	U.S. Manufacturing Industry
B77	Lack of process thinking and process ownership		Albliwi et al., 2014	U.S., U.K., & Indian SME
B82	Replicating another organization's Lean strategy		Albliwi et al., 2014	U.S., U.K., & Indian SME
B83	Lack of application of statistical theory		Albliwi et al., 2014	U.S., U.K., & Indian SME

2.5 Summary

This research utilized snowballing as a method to conduct a thorough literature review. Due to inadequate scholarly and peer-reviewed journal papers spanning 2006-2016, the researcher expanded the search for existing literature beyond the construction industry, such as manufacturing and SME industries.

The researcher found that the barriers to Lean implementation were diverse, and clustered the barriers in to 10 sub-groups, including lack of commitment and support, cultural and attitudinal barriers, lack of adequate knowledge and skills, technical difficulties, structural and organizational barriers, communication barriers, government and legislative obstacles, financial barriers, and those miscellaneous barriers which the researcher found that do not fit in any of the abovementioned subcategories are classified as variable barriers. A complete list of these barriers can be found in Appendix A.

This literature provided the base input to the researcher to proceed with the next step of the research, which was collecting transportation project stakeholders' perceptions and opinions in the state of Michigan.

CHAPTER 3 - RESEARCH METHODS

3.1 Introduction

This chapter, addresses the research strategy adopted to address the gaps identified in the literature, together with the approach to collecting empirical data for analysis, including research population sample and the analysis method. As shown in Table 3.1 the basic research approach adopted in this study includes a thorough literature review and collection of empirical data by survey questionnaire. Table 3.1 shows the inputs and outputs of each of the phases from this study.

Table 3.1 Inputs and outputs per phase of the study

Phase	Inputs	Outputs
Phase 1 – Literature Review	Existing body of knowledge on the challenges and barriers to implementation of Lean principles	Barriers to implementing lean principles and methods in construction, manufacturing, and SME industries
Phase 2 - Survey	Questionnaire & Phase 1 Outputs	Perceptions of transportation project stakeholders on prioritizing barriers to implementing Lean Construction
Phase 3 – Findings	Literature Review & Survey Outputs	Barriers and the overcoming strategies to implementing Lean Construction in Michigan transportation projects

3.2 Overall Research Strategy

The nature of this research falls into the broader topic of construction productivity due to the qualities and aims of Lean Construction. Research around construction productivity was dominated by the qualitative, quantitative and multi-methods (Panas & Pantouvakis, 2010). Topics surrounding construction productivity, not only include pure investigation of project technical aspects (such as project time and cost), but also intense survey of project soft skills as well as attitudinal, managerial and cultural alterations of the project stakeholders-- therefore the multi-method (quantitative and qualitative) research strategies gain more momentum (Panas et al., 2010).

The goal of this research was to “identify” and “prioritize” Lean Construction barriers and the overcoming strategies within Michigan’s transportation projects. Therefore, a survey of the project stakeholders’ perception (qualitative study) was acquired through the distribution of questionnaires. However, the methods and research instrumentation was more of a typical quantitative means. On the other hand, the questions also included behavioral, organizational, and opinionated characteristics.

3.2.1 Idea Development

Despite significant innovations and technological advancements, a review of the literature found that the construction industry has not experienced an increase in productivity growth in the past 50 years, as have other industries such as manufacturing. Moreover, there was a continuous need for a better and sustained infrastructure, specifically highways, streets and bridges in the state of Michigan. Each year, billions of taxpayers’ dollars are spent to fix the roads in the United States. Spending public money requires projects to be responsibly delivered, on-time, on-budget, and of the highest possible quality.

Traditional project delivery methods such as design-bid-build (DBB) are still predominantly practiced within state of Michigan (MDOT, 2016, Bellgowan, 2017, Stein, 2017). Studies have shown that trending productivity improvement techniques such as implementing Lean principles and methods can significantly improve productivity by minimizing waste, maximizing value and streamlining the work flow. However, this study found that Lean Construction was still considered to be in its infancy and its practice was not widespread. The researcher believes that this has led to the potential existence of barriers to implementing Lean Construction principles and method, specifically within the transportation sector. An overall research strategy framework that the researcher has chosen to adopt in this study was illustrated in Figure 3.1

3.2.2 Literature Review

The development of the idea – that barriers might exist to implementing Lean Construction within transportation projects – has led the researcher to conduct a thorough study on existing literature. As shown in Figure 3.1, the findings of the literature showed that the barriers to Lean implementation are widespread. Several studies show that the nature of barriers was multi-dimensional, such as lack of awareness and skills, lack of commitment and support and cultural and attitudinal obstacles. These barriers were found within various contexts such as construction, infrastructure, manufacturing, and public sector in the U.S., Brazil, Norway and China.

3.2.3 Survey Questionnaire

Prior to distributing the survey questionnaire, the researcher sought approval for collecting research data outside Michigan State University from the Institutional Review Board (IRB) and received approval on January 5, 2017 from the Office of Regulatory Affairs Human Research Protection Programs. A copy of the IRB approval was available in Appendix B.

A survey was a representative selection from the population of a specific type (Biggam, 2008). The empirical research in this study was aimed at collecting project stakeholders' views of the barriers and the overcoming strategies to Lean Construction implementation within transportation projects in Michigan; how would the contractors' senior executives rate the barriers related to commitment and support? Was there an adequate awareness of Lean Construction principles and methods within transportation projects? Are there cultural barriers to implementation of this type of project delivery within the U.S. construction industry? It was possible, via a questionnaire survey, to collect the views of a larger population to the above researchable questions rather than focusing on an in-depth analysis of a single project.

The gaps identified in the literature led the researcher to collect Michigan practitioners' perceptions of challenges to adopting Lean Construction within transportation projects. As shown in Figure 3.2, a survey questionnaire was designed to ask transportation project stakeholders' views how they interpret the barriers that were identified in the literature.

3.2.4 Questionnaire Distribution

The gathering basis of empirical data for this research was based on a survey questionnaire to allow an analysis of the general perceptions of the experts and potential Lean Construction practitioners within transportation projects.

The researcher approached different associations that would potentially have a directory of Michigan transportation project stakeholders. Among the organizations and associations that aided distribution of the survey questionnaire to research participants:

- Michigan Department of Transportation (MDOT)
- County Road Association of Michigan (CRA)
- Michigan Infrastructure & Transportation Association (MITA)
- American Council of Engineering Companies of Michigan (ACEC)

MDOT and CRA were the agencies that represented the project owners target population. Because most road and bridge contractors are registered members of the Michigan Infrastructure & Transportation Association, most respondents from the project constructors target population were contacted via the MITA. The American Council of Engineering Companies of Michigan assisted in distributing this research survey questionnaire among road and bridge design and engineering firms operating in Michigan.

The survey questionnaire was made available online to participants from January 16, 2017 to March 10, 2017.

3.2.5 Justifying Research Strategy

The research strategy used to collect the empirical data for this research was a survey questionnaire. Its purpose was to produce statistics, that was, quantitative or numerical descriptions about some aspects of the study population (Fowler, 2013). Asking people (a sample or a fraction of the population) questions was the main way of gathering information and their answers create data to be analyzed (Fowler, 2013).

To support the study objectives, a survey was used to collect project stakeholders' opinions. A research survey approach facilitated this study to identify and prioritize from a large community of transportation construction practitioners' responses to hindrances in implementation of Lean Construction principles and methods in transportation projects. The survey questionnaire was designed in such a way that it would collect project stakeholders' opinions on barriers and the overcoming strategies by including an open-ended question to gather suggestions.

Other research methods are unfit for the purposes of this study. For example, a case study approach probes deeply and analyzes intensely as opposed to surveys that can investigate phenomena and context together, yet lack the in-depth investigation of a case study approach (Biggam, 2015). This research did not intend to perform an in-depth study of barriers to implementation of Lean; instead it aimed to provide the perception of a larger community of construction practitioners in transportation projects. The findings of the literature review indicated that lack of adequate commitment and support from senior management, lack of awareness, knowledge and work skills, and cultural and attitudinal issues were among the barriers hindering implementation of Lean not only within construction projects, but in manufacturing and small- and medium-sized enterprises as well. However, the researcher believes that these barriers may not be

aligned with the U.S. transportation projects contexts. Therefore, this research was focused on comparing what was discovered in the literature review with the results of the survey questionnaire.

3.2.6 Data Analysis

After collecting the survey responses, this study depicted the results by analyzing the findings via descriptive methods, including charts and tables. By analyzing the degree of agreement, disagreement, and neutrality of the survey respondents, this study prioritized the barriers to and strategies to overcome them in them implementing Lean Construction principles and method within transportation projects in Michigan.

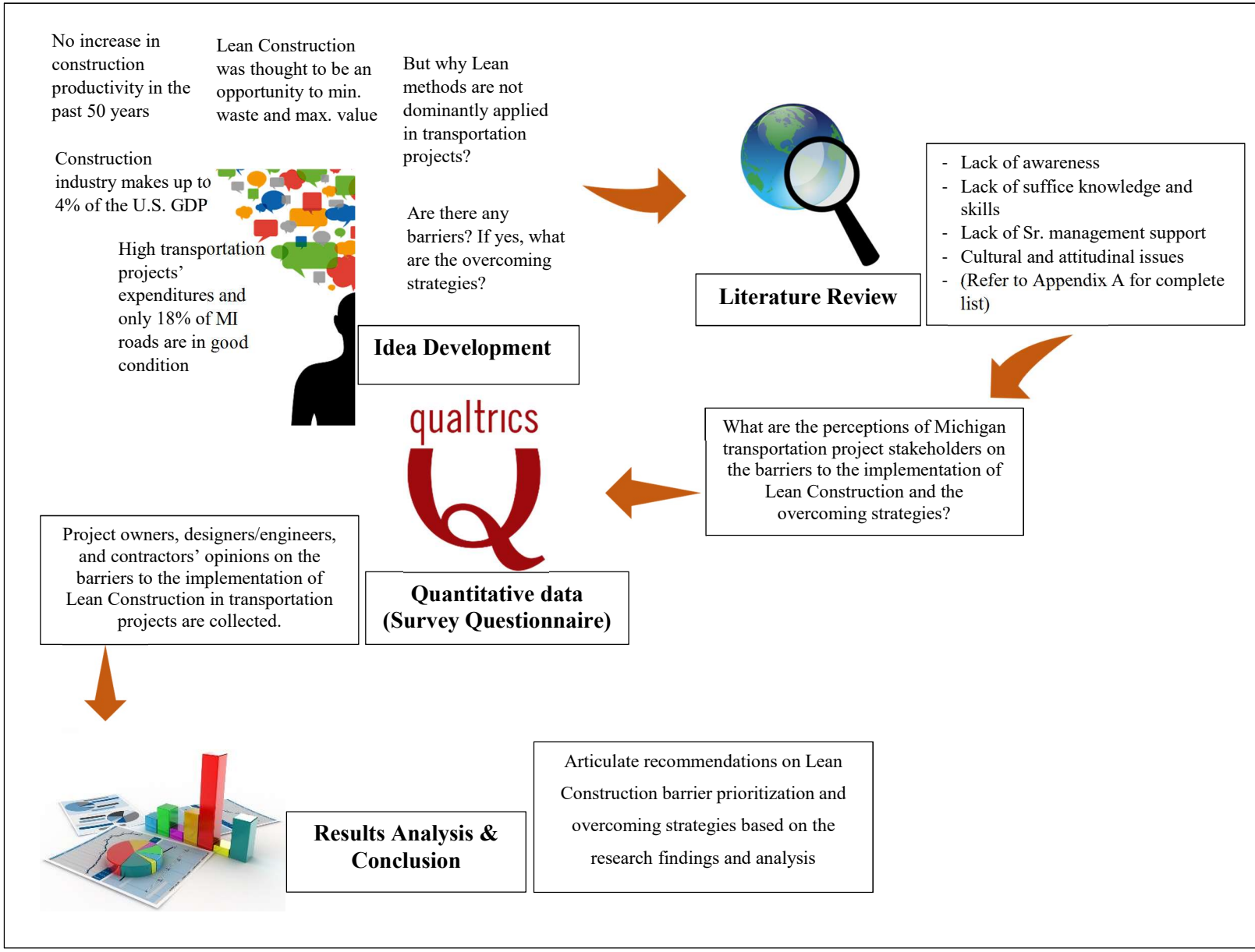

Figure 3.1 The overall research strategy diagram

3.3 Research Questions

To address the problem statement – a decrease or no improvement in construction labor productivity and minimal research of the barriers hindering Lean implementation – the research questions for this study include the following:

a. What are the barriers to implementation of Lean Construction in transportation projects?
b. What are the Michigan transportation project stakeholders' opinions on barriers and strategies to overcome them to implementing Lean Construction?

The answer to the part (a) of the primary research question was accomplished by means of in-depth and diverse review of the existing literature in Chapter 2. Due to the lack of adequate scholarly and peer-reviewed journal papers on the specifics of this topic, the literature review's focus was on barriers to adopting Lean methods in the construction industry, along with gathering Lean barriers in other relevant industries including manufacturing, public sector, and small and medium enterprise (SME) industries. The researcher found that a gap exists within the current literature. This research did not find scholarly and peer-reviewed academic papers that have prioritized Lean Construction barriers and the overcoming strategies in Michigan transportation projects. Furthermore, the researcher did not find empirical data on how project stakeholders view Lean methods and principles in the construction of highways, streets and bridges in the state of Michigan, nor how they recommend improving the current state of this innovative project delivery method.

The answer to the part (b) of the primary research question takes this research one step further by filling the gap identified in the literature through the collection and analysis of empirical data obtained from Michigan transportation project stakeholders; e.g., project owners, road and bridge builders and designers. The empirical data included the project stakeholders' perceptions of barriers identified in the literature, and includes their strategies on how to overcome the obstacles.

3.4 Research Variables

The dependent variables are the test items that can vary among the survey participants. The dependent and independent variables for this research were identified by the researcher as follows:

- Dependent Variables
    - Implementation Barriers
        - Commitment and support barriers
        - Knowledge and awareness barriers
        - Cultural and attitudinal barriers
        - Legislative barriers
        - Technical/financial/other barriers
    - The overcoming strategies
- Independent Variables
    - Owners' perceptions on the state of Lean implementation
    - Constructors' perceptions on the state of Lean implementation
    - Designers' perceptions on the state of Lean implementation

The literature review showed that despite the vast utilization of Lean concepts and methods in the manufacturing sector and its application in construction industry -- and despite its proven results-- Lean Construction was not in widespread use in construction, and particularly within the infrastructure development and construction of highways, streets and bridges (Shang et al., 2014). To reach a variety of project stakeholders; i.e., project owners, contractors, subcontractors and suppliers that play important roles in the construction supply chain, this research brings an opportunity to reinforce Lean implementation in transportation projects by uncovering some of the existing perceived barriers to Lean Construction implementation within the transportation projects.

3.5 Research Population

As this research intends to identify and prioritize the driving forces and barriers to implementation of Lean Construction principles and methods in the construction of highways, streets and bridges in the state of Michigan, the target population for this study includes project owners, designer/engineers, and contractors involved the delivery of a typical transportation construction supply chain network. More specifically, within each of the three groups in the study population, this study intended to target specific roles within the organizations. In the Owners category, the opinions of managing directors, engineers, technicians and supervisors were collected. Within the Constructors category, the perceptions of chief executives, senior executives, estimators, project managers, superintendents and project engineers were gathered. Finally, the opinions of road and bridge designers and consultants were collected within the Designers category.

Since transportation projects are dominantly funded by federal and state agencies, the project owners for this research are Michigan Department of Transportation (MDOT), and county road commissions. Figure 3.5 shows the regional offices of MDOT to which this research questionnaire was distributed.

Designers and engineers contribute significantly to the delivery of the transportation projects. They are usually owners' representatives and decide the technical aspects of the projects, including their early involvement in deciding the project delivery type. Thus, it was found important to collect designers' and engineers' perceptions on implementation of Lean Construction within transportation projects.

Constructors deliver physical results of the project. For this research, the constructors were selected based on pre-qualified contractors listed in MDOT's website. Figure 3.4 illustrates the research participants reach out process.

Other project stakeholders include the public --taxpayers -- who also benefit from projects, but are not included in this study population due to their minimal role in project delivery type and project implementation.

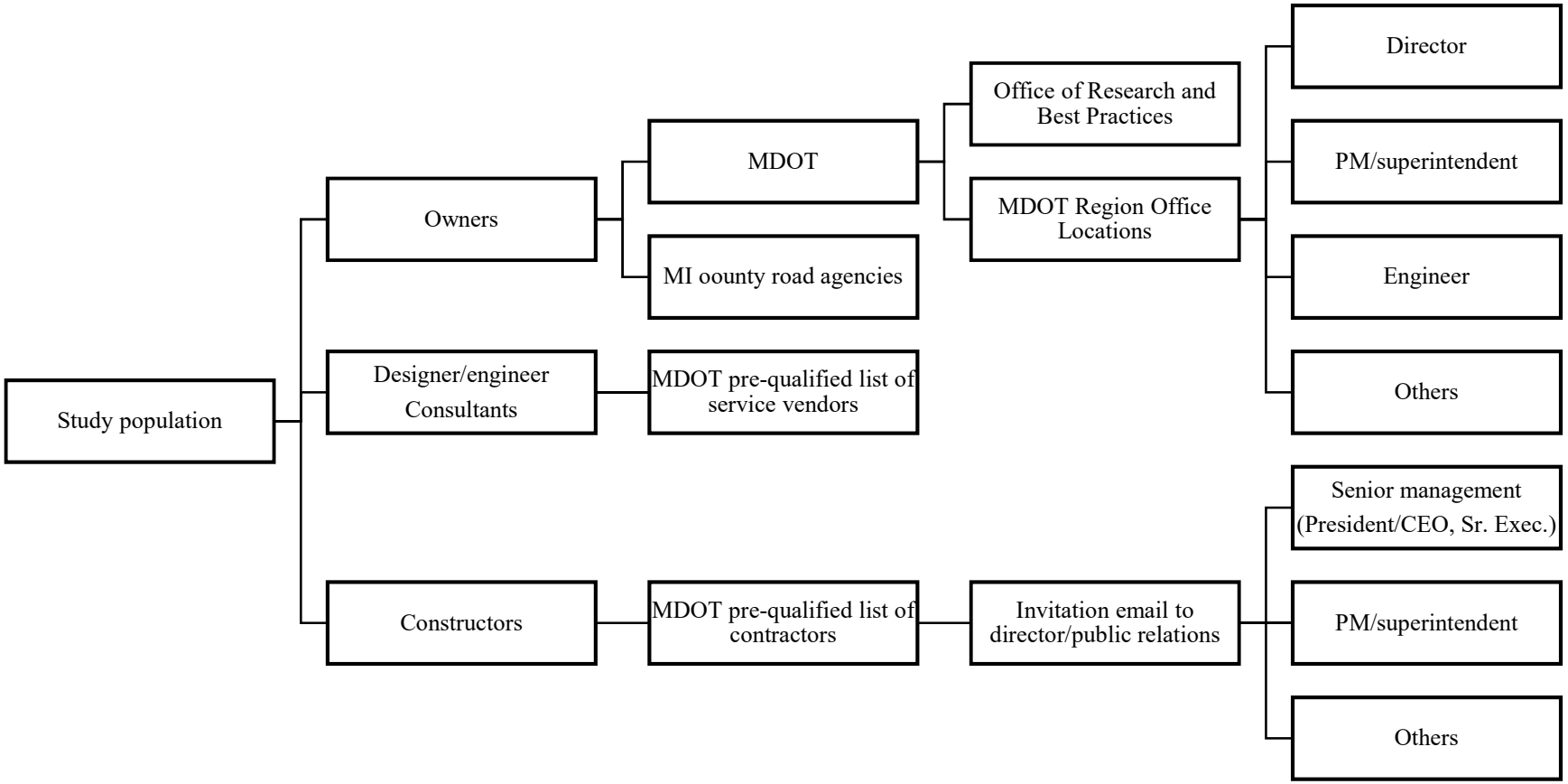

Figure 3.2 Research population reach out process

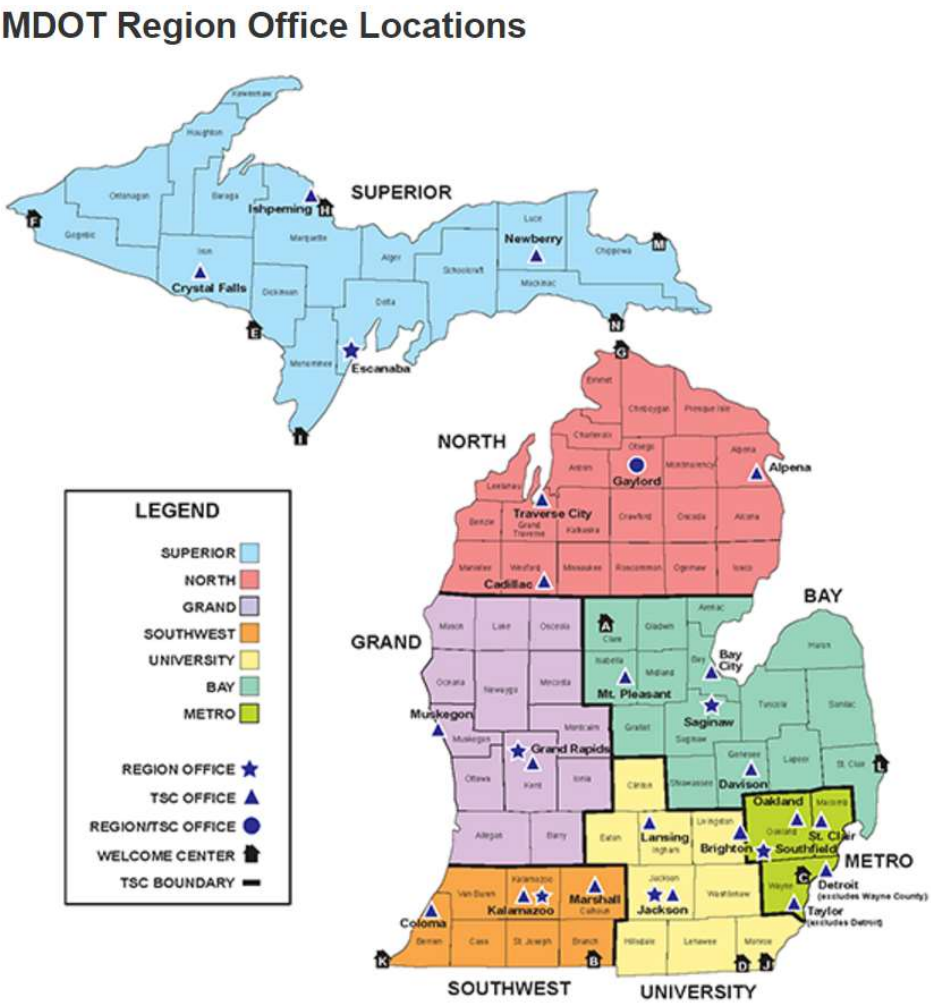

Figure 3.3 Research population: project owners. MDOT Region Office Locations. (Source: Michigan Department of Transportation)

3.6 Data Collection Techniques

It was as important to choose an appropriate technique or techniques to collect data as it was to choose an appropriate research strategy (Biggam, 2015). This research captures the data in two phases. The barriers to implementing Lean methods was first identified in the literature review, and then the perceptions of Michigan's transportation project stakeholders were collected by survey questionnaire.

The research participants' perceptions on obstacles to implementing Lean Construction found in the literature review were tested, re-identified and prioritized by means of a research survey questionnaire to U.S. construction of highways, streets and bridges context and within the state of Michigan. The questionnaire was communicated electronically with survey participants via Qualtrics, the research software that was available to Michigan State University for teaching and research.

3.7 Survey Design

The responses to the questionnaire make up the qualitative data for this research, which was the input for the descriptive data analysis. A copy of the blank survey questionnaire, which was shared with project stakeholders, was available in Appendix C. The survey asked research participants to volunteer suggestions. The research consent form was included in the introductory part of the survey questionnaire, which was available in Appendix C. A sample of the emailed invitation to participate in the survey was included in Appendix D. Collecting transportation project stakeholders' general perceptions on obstacles to Lean Construction implementation, and their recommendations for the overcoming strategies was the sole purpose of this research. The researcher did not seek in-depth and detailed input from project stakeholders on their suggestions to overcome Lean Construction implementation barriers.

3.8 Data Analysis Framework

After the responses were received, they were reviewed to determine how many responses were usable. Based on completed responses, barriers were prioritized per designated weighting system, which was a 7-Point Likert Scale (7 indicating strong agreement, and 1 indicating strong disagreement). Due to the qualitative nature of this study (perception survey), the researcher used a 7-Point Likert scale that enables gathering a broader level of agreement or disagreement when compared to a 5-Point Likert scale. The barriers that rank higher were those with higher intensity of agreement.

After a general prioritization of the barriers, the relationship between the participants' responses and other clusters were compared and reported. The connection between the respondents and their roles in the project, years of experience and knowledge and practice to implementing Lean Construction within their organizations were determined and presented accordingly.

3.9 Qualitative Data Analysis

The process of qualitative analysis of the data was composed of the two components of data analysis; data description and data interpretation (Biggam, 2015). Figure 3.7 illustrates the process for qualitative data analysis adopted from Bigamy (2015). As shown in Appendix B, the survey questions were structured in four themes: Demographic and Background, Knowledge of Lean Construction, Practice of Lean Construction, Lean Implementation Barriers and the Overcoming Strategies. Once the raw data – questionnaire responses – were collected, they were described within their themes. The data analysis links themes, adding cumulative meaning and comparing the raw data description and analysis with the findings of literature review.

Figure 3.4 Framework for description and analysis of qualitative data

3.10 Proposed Sample Size

The target population of this research was calculated based on information available on Michigan Department of Transportation (MDOT), and Michigan county road commissions. Based on the nature of the research type, the Normal Distribution formula was used to calculate the sample size as below:

$$\boldsymbol{Sample\ Size} = \frac{\frac{\boldsymbol{z^2 x\ p(1-p)}}{\boldsymbol{e^2}}}{\boldsymbol{1} + (\frac{\boldsymbol{z^2 x\ p(1-p)}}{\boldsymbol{e^2 N}})}$$

Where:

N = Population size. For this research, total population was determined based on the information provided on the Michigan Department of Transportation (MDOT)'s website and county road commissions across Michigan. Total population was counted 1,004. The breakdown includes 693 constructors, 127 design and engineering firms, and 184 owners.

e = Margin of error. For this research, 5% error margin was assumed.

p = Percentage picking a choice expressed in decimals. For this research, normal distribution percentage (50%) was used to calculate the optimum sample size.

z = z-score or the number of standard deviations a given proportion was from the mean. Based on the selected confidence level of 80% for this study, the z-score was 1.28.

After entering numbers in the above formula, the sample size was calculated and yielded 141.

3.11 Summary

This chapter, presented the details of the research strategy adopted to address the gaps identified in the literature review, together with empirical data collected for analysis, including research population sample, and the analysis method.

The overall research strategy adopted for this research included a two-phase study: literature review and empirical data collection. Literature review uses the snowball method in Chapter 2. The outputs of the literature review, became inputs for designing the research survey questionnaire to collect the perceptions of transportation project stakeholders on barriers to Lean Construction implementation, and the overcoming strategies within Michigan.

The overall research diagram was provided in Figure 3.1, and all the processes including research idea development, literature review, survey questionnaire and data analysis were briefly introduced. Each adopted method, such as collecting data by a questionnaire, and the qualitative analysis methods were justified accordingly.

Part (a) of the primary research question seeks to identify barriers to implementation of Lean Construction in transportation projects and part (b) contextualizes part (a) within the state of Michigan in the United States.

The target populations for this research were owners such as MDOT and county road commissions, road and bridge constructors, and designers. The procedure to collect data was presented and a copy of the questionnaire survey and consent form are presented in the appendices.

The framework to analyze the data after the responses were collected and presented. They included organizing usable responses from the survey, prioritizing barriers, presenting and discussing the results of the responses in their themes, and finally comparing participants' responses to the findings of literature review.

CHAPTER 4 – SURVEY FINDINGS, DESCRIPTIONS, ANALYSIS AND SYNTHESIS

4.1 Overview

This chapter reports the results of the surveys administered to participants as described in Chapter 3 – Research Methods. The research participants were owners, road builders (constructors), and designers. These three groups are primarily involved in construction of road and bridges and have the potential to implement Lean Construction principles and methods within transportation projects in Michigan. Project owners within the Michigan Department of Transportation (MDOT) and county road commissions manage taxpayers' money and provide the budget to construct the roads and bridges; designers and constructors provide professional design services and road construction operations in Michigan.

The survey questionnaire was highly structured. First, survey findings are described. Research participant groups are defined and the start date and end date of survey questionnaire was specified. Next, the number of complete responses received was described, followed by demographic information. The survey responses on knowledge and practice of Lean methods are presented. The participants' responses on barriers and the overcoming strategies to implement Lean Construction principles and methods in transportation projects are initially presented in their barrier group types: Knowledge and Skills-related; Commitment and Support; Structural and Organizational; Communication, Cultural and Attitudinal; Governmental and Legislative; Logistical; and Other barriers. Of the 87 barriers found in the literature, 37 were relevant to the scope of this study; i.e., transportation projects. Next, responses collected via 7-Point Likert scale on the 37 barriers clustered into seven groups are presented and ranked from B1 to B37, with B1 being the most important barrier and B37 the least. The analysis and comparison between the findings of the empirical data and those of the literature review concludes this chapter.

4.2 Response Rate

The total population set for this study was about 1,004. This number included 693 road builders (constructors), 127 design and engineering firms, 184 members from the Michigan Department of Transportation, and members from the state's 83 county road commissions. During the two-month – response period of the online survey questionnaire, 119 partial and complete responses were received using Qualtrics online research tool. Since 47 responses were completed, the researcher decided to analyze the responses based on completed responses only. In the researcher's point of view, there are various reasons behind the partial responses submitted by the participants to this survey. Lack of respondents' awareness and knowledge about Lean Construction principles and methods, plus lack of respondents' practical experience on implementing Lean Construction are among the major reasons for receiving incomplete responses. The limited research time, overall survey length, and the non-compensatory participation of the respondents were among the other possible reasons of the smaller sample size.

4.3 Participants Demographics

The research participants as shown in Table 4.1 are composed of several project stakeholders, including project Owners, Constructors, Designers, Consulting and the Other category.

The researcher thought that it was important to understand the potential entities and individuals who may have the opportunity and the tools to implement Lean Construction principles and methods in office and jobsites; therefore, the research survey questionnaire was designed in such a way that participants could identify their primary job role and position titles within their organizations. Thirteen of 47 people identified their primary job as "Other." This study found that they could be fit into one of the three categories of owner, designer, or constructor. After adjusting the participants' responses to the question of identifying their primary job role, the participants' demographics results showed that more than half of

the survey participants came from the Owner category (53%). Constructors made up 26% of the research participants, Design and Consulting firms combined made up 13%, and 7% were categorized as Other. The primary job roles of the participants are shown in Figure 4.1.

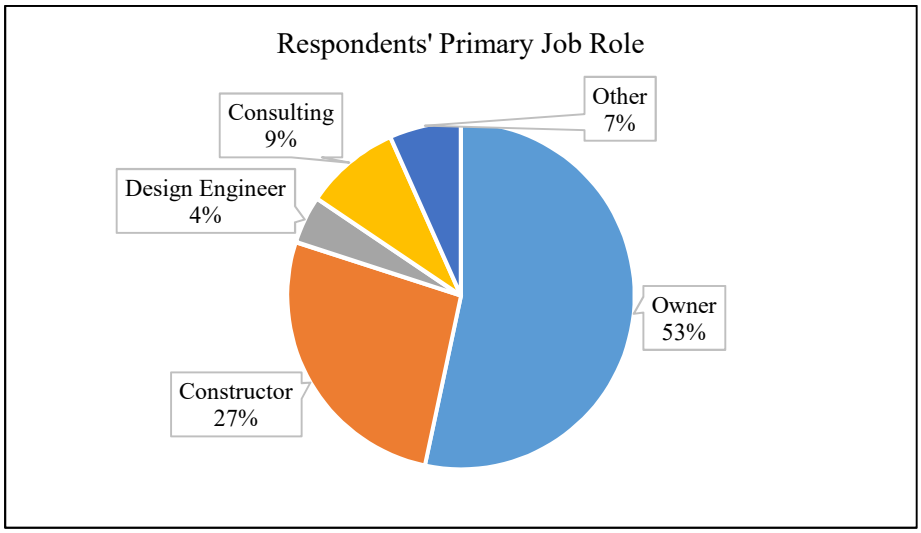

Figure 4.1 Participants' Primary Job Role

The respondents' job responsibilities varied across the research participants. In the Owners category, Managers, Engineers, and Supervisors have participated with Engineers more than Managers and Supervisors as shown in Figure 4.2. The job positions of Constructors are shown in Figure 4.3. One road designer and one bridge designer, plus one road and bridge designer, participated in this study.

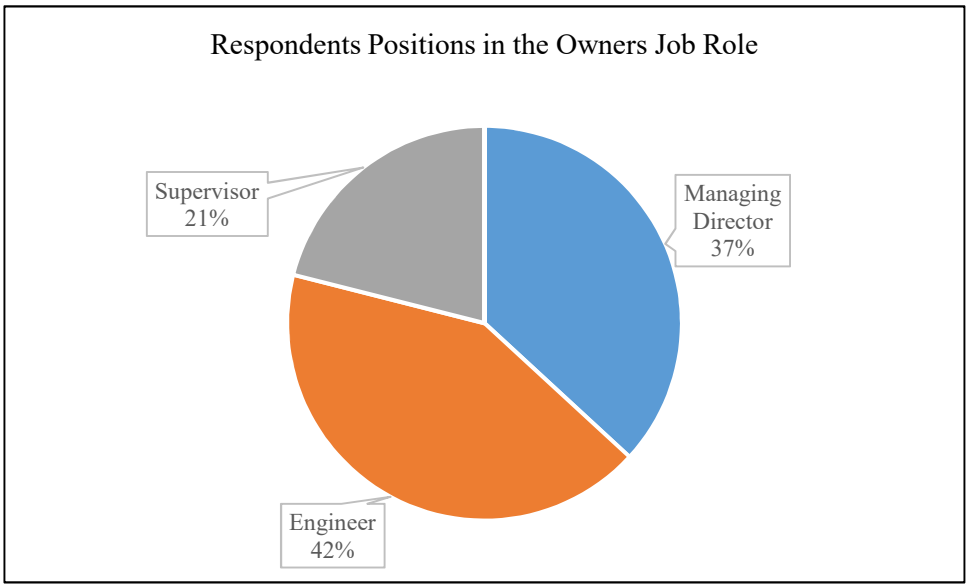

Figure 4.2 Respondents' Positions in the Owners Job Role

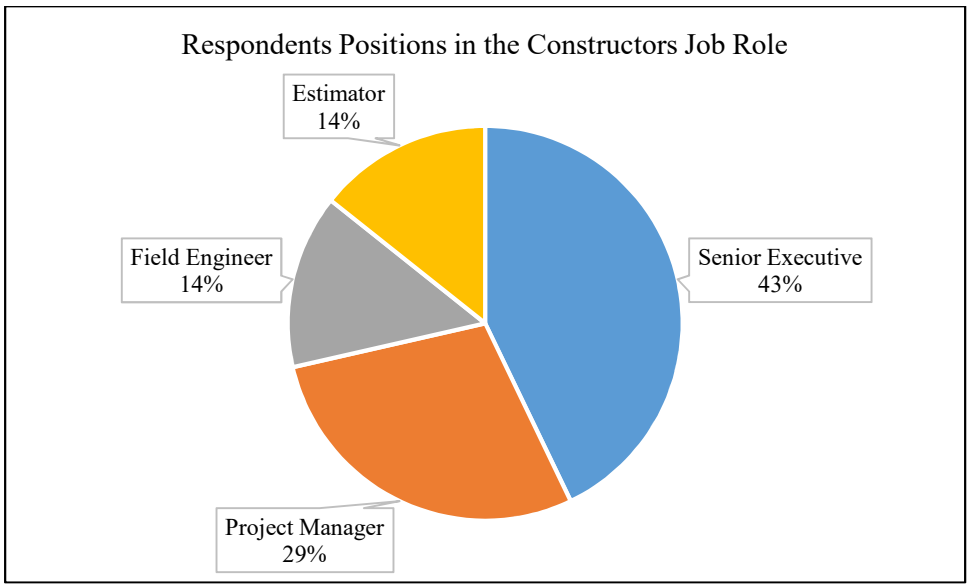

Figure 4.3 Respondents Positions in the Constructors Job Role

Nearly half of the participants (43%) were senior executives of their organizations, 29% were project managers and 14% field engineers and estimators each.

4.4 Participants' Knowledge and Practice of Lean Construction

Most the participants were highly experienced. More than half of the research respondents have more than 20 years of experience, as shown in Figure 4.4

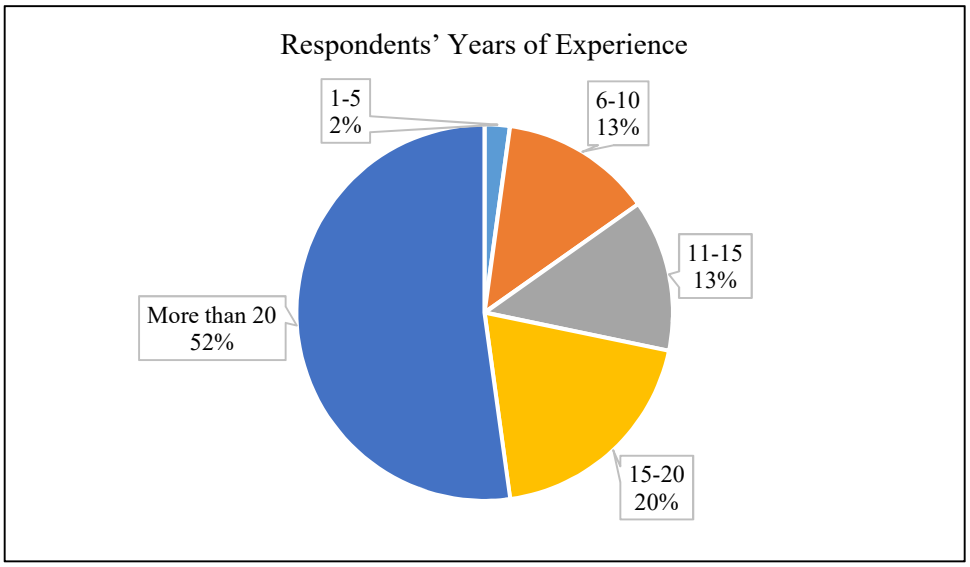

Figure 4.4 Respondents' Years of Experience

However, most of the respondents (84%) had no training in Lean Construction and 30% have not utilized Lean principles and methods in their organizations.

4.5 Prioritizing Barriers to implementing Lean Construction in Transportation Projects

This study identified 37 barriers in the literature review and further gathered the level of agreement and disagreement of Michigan's transportation project stakeholders on these barriers. Road and bridge constructors, owners, and designers responded and their opinions are presented here in the order of importance. The respondents were asked to rate their degree of agreement, disagreement, and neutrality in a 7-point Likert scale (Likert point 7 being "Strongly agree" and 1 being "Strongly disagree).

The top barrier was identified as "Lack of training and mentoring in Lean methods," This barrier, which was one of the Knowledge and Skills barrier types identified in the literature review, received the most agreement of all barriers on the list. As shown in Figure 4.5, 17% of the respondents strongly agreed, 47% agreed, and 17% somewhat agreed that lack of training and mentoring was the top barrier to implementing Lean Construction principles and methods within transportation projects.

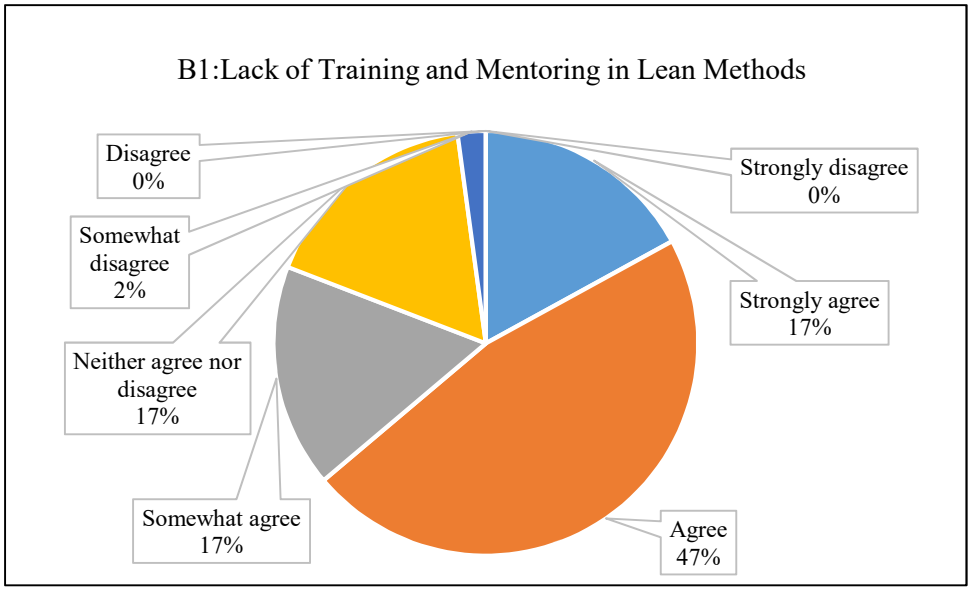

Figure 4.5 Participants' Opinion on B1: Lack of Training and Mentoring in Lean Methods

On the 7-Point Likert scale, this barrier acquired an average value of 5.596 and was listed on the top of the Prioritized List of Barriers in Table 4.1. Insufficient training was ranked seventh among Lean implementing barriers in the Chinese construction industry (Shang et al., 2014) and U.K. construction industry (Sarhan et al., 2013). In the U.S. manufacturing industry, lack of formal training for workers and for managers as ranked 15th and 20th respectively (Jadhav et al., 2014).

With a slightly lower average value on the Likert scale, "Lack of shared vision, consensus, and group culture in the organization" was identified as the second greatest barrier hindering implementation of Lean Construction within Michigan's transportation sector. As shown in Figure 4.6, 22% of the respondents strongly agreed, 35% agreed, and 26% somewhat agreed that there was a lack of shared vision, consensus and group culture in the organization.

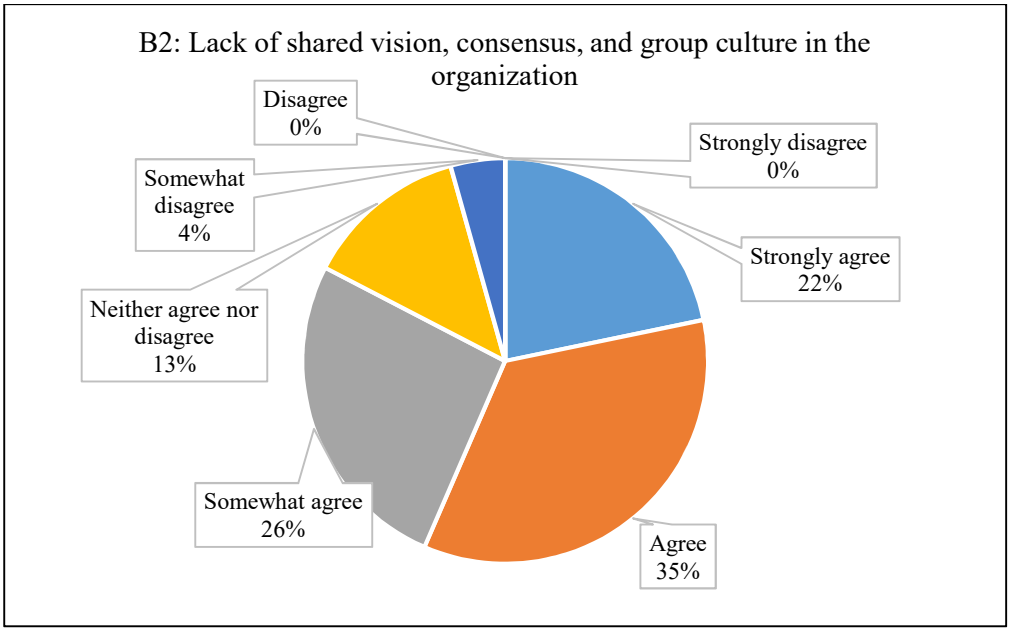

Figure 4.6 Participants' Opinion on B2: Lack of shared vision, consensus, and group culture in the organization

Many aspects of Lean methods are cultural and attitudinal. While this barrier was ranked 7th in Lean Construction implementation barriers in the Libyan construction industry (Omran et al. 2015), it was found that a lack of group culture was more obvious in the Michigan's transportation sector. This had a

slightly lower average value (5.565) on the 7-Point Likert scale than the previous barrier and was listed as the second greatest barrier in Table 4.1.

The third-ranked barrier was identified as "Employees/workers are not aware of Lean methods." As shown in Figure 4.7, 17% of the survey respondents strongly agreed, 38% agreed, and 30% somewhat agreed that lack of employees/workers' awareness of Lean methods hinders implementation of Lean Construction within Michigan's transportation projects.

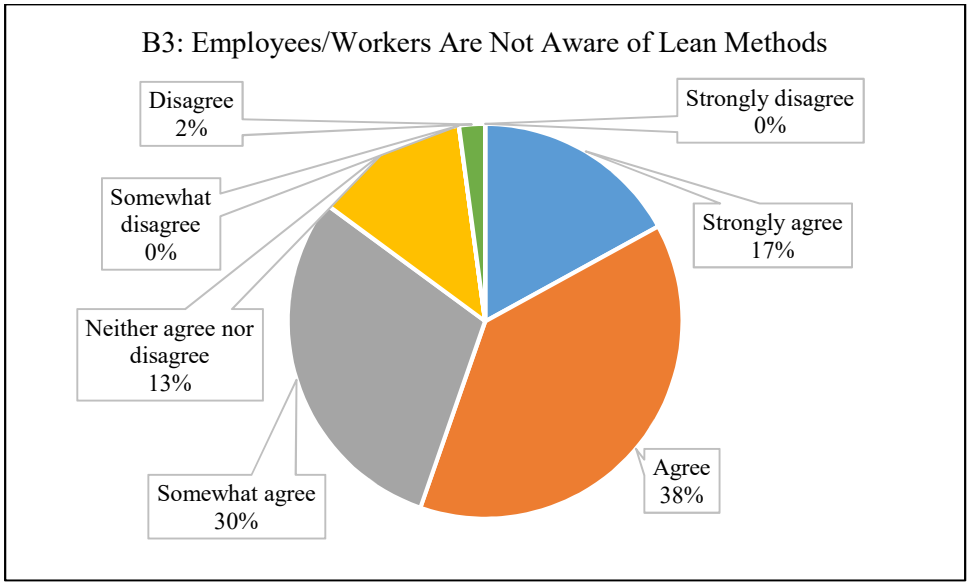

Figure 4.7 Participants' Opinion on B3: Employees/Workers are not aware of Lean methods

This barrier attained an average value of 5.532 at the Likert scale, which makes it the third most important barrier in the prioritization list in Table 4.1. This barrier was ranked ninth in the Chinese construction industry (Shang et al., 2014), and first and third greatest barrier to implementing Lean methods within the U.K construction industry (Sarhan et al., 2013 and Bashir et al., 2015). Moreover, the Abolhassani et al. (2016) study identified lack of understanding of the benefits of Lean as the number one barrier in the U.S. manufacturing industry. The pattern in the literature review and the findings of this study showed that lack of awareness of Lean methods and principles was a major barrier in its implementation.

The fourth greatest barrier was identified as "Failure to document Lean benefits." This barrier received an average value of 5.133 on the Likert scale. As shown in Figure 4.8, 9% of the respondents strongly agreed, 29% agreed and 33% somewhat agreed that failure to document Lean benefits challenges its implementation.

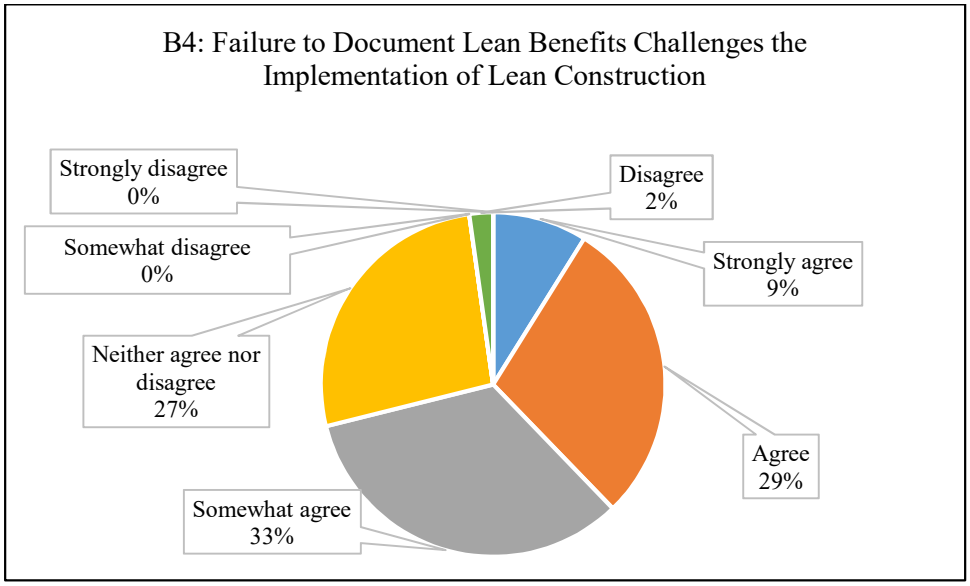

Figure 4.8 Participants' Opinion on B4: Failure to document Lean benefits

The "cultural difference between project stakeholders" was found as the fifth-ranked barrier to implementation of Lean Construction within transportation projects in Michigan. Unlike most of the other barriers about which the 47 respondents expressed their opinions, only 30 respondents expressed an opinion on this barrier. Among those respondents, as shown in Figure 4.9, 14% strongly agree, 27% agreed, and 40% somewhat agreed that cultural differences among project stakeholders challenges implementation of Lean Construction. This barrier received an average value of 5.100 on the Likert scale and ranked fifth in Table 4.1.

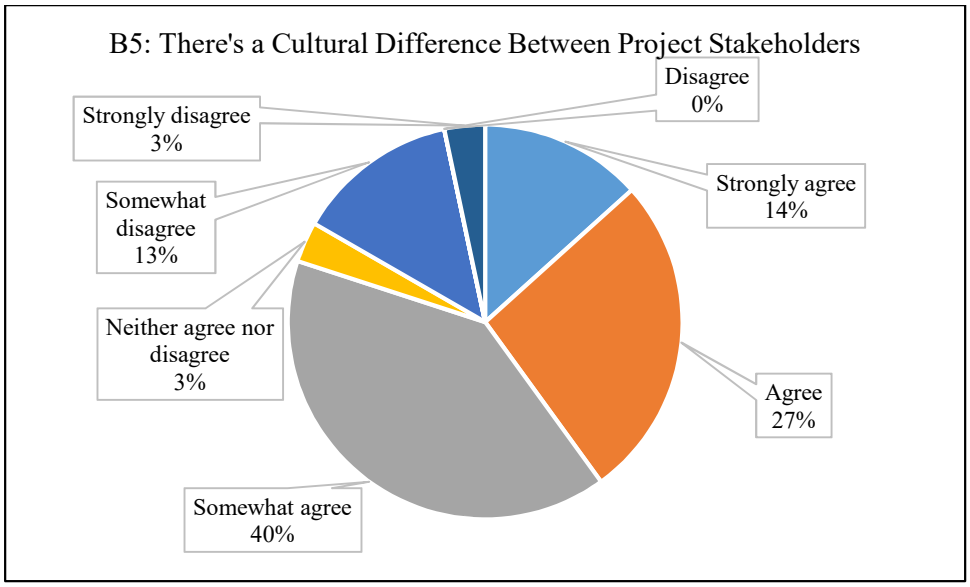

Figure 4.9 Participants' Opinion on B5: Cultural difference between project stakeholders

The sixth-ranked barrier related to the reward system for employees and workers as a motive to apply Lean Construction methods and principles within the organization. This study found that "employees and workers are not rewarded" enough. This barrier received an average value of 5.065 on the Likert scale and was listed as the sixth barrier in Table 4.1.

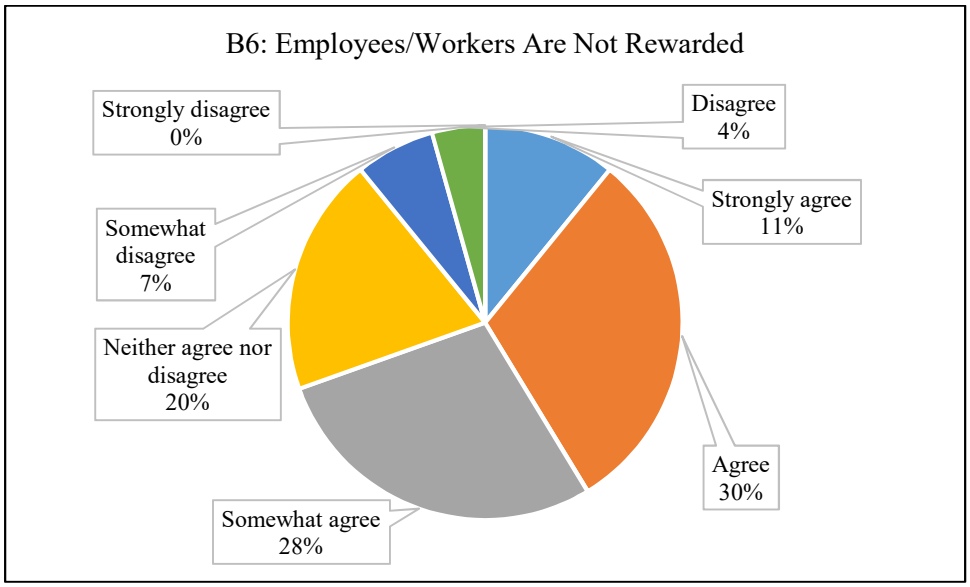

Figure 4.10 Participants' Opinion on B6: Employees/workers are not rewarded

As shown in Figure 4.10, 11% of the respondents strongly agreed, 30% agreed, and 28% somewhat agreed that employees or workers are not rewarded.

The remaining 31 barriers received an average value of less than 5.000 on the 7-Point Likert scale. Therefore, this study interpreted those opinions as "neutral." Twenty-four barriers that received an average value between 4.000-4.911. However, this study by no means aimed to suggest they are not legitimate barriers to implementation of Lean Construction within transportation sector. The analysis pie-charts for these barriers (B7 – B30) are available in Appendix E.

This study found that seven barriers identified in the literature review were not considered barriers in implementation of Lean Construction within transportation projects in Michigan. These seven barriers are as follows:

1. Limited use of off-site construction methods (prefabrication) deter implementation of Lean Construction;
2. Lean was not sustainable;
3. Lean failed previously;
4. Traditional practices are just fine;
5. Lean's journey to increase productivity are a burden to workers, create unsafe conditions, and was not a good cultural fit;
6. Increased labor productivity causes labor layoffs; and
7. Employees/workers are incapable of delivering a quality performance

The above-mentioned barriers received an average value between 3.800-2.778 and therefore this study excluded them as barriers to implementation of Lean Construction within transportation in Michigan. The analysis pie-charts for these barriers (B31 – B37) are available in Appendix E.

Table 4.1 Barriers Prioritization List

#	Barrier Description	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
B1	There was a lack of training and mentoring for Lean methods	8	22	8	8	1	0	0	47	5.596
B2	Lack of shared vision, consensus, and group culture in the organization hinders implementation of Lean Construction	5	8	6	3	1	0	0	23	5.565
B3	Employees/workers are not aware of Lean methods	8	18	14	6	0	1	0	47	5.532
B4	Failure to document Lean benefits challenges implementation of Lean Construction	4	13	15	12	0	1	0	45	5.133
B5	There's a cultural difference between project stakeholders	4	8	12	1	4	0	1	30	5.100
B6	Employees/workers are not rewarded	5	14	13	9	3	2	0	46	5.065

This study found that the nature of the top six barriers, as identified in the study, vary among four categories. Lack of training and mentoring for Lean methods (B1), and Lack of employees/workers' awareness of Lean methods (B3), were Knowledge and Skills-related barriers. Lack of shared vision, consensus and group culture in the organization (B2), and the cultural difference between project stakeholders (B5), were related to the Cultural and Attitudinal-type of barrier. Failing to document Lean benefits related to the technical complexity of Lean Construction methods, and lack of an adequate employees/workers' reward system, were related to the structural and organizational barrier type.

The list of barriers and their respective nature of barrier are summarized in Table 4.2.

Table 4.2 Nature of top six barriers

#	Barrier Description	Average Value	Barrier Nature
B1	There was a lack of training and mentoring for Lean methods	5.596	Knowledge and Skills
B2	Lack of shared vision, consensus, and group culture in the organization hinders implementation of Lean Construction	5.565	Cultural and Attitudinal
B3	Employees/workers are not aware of Lean methods	5.532	Knowledge and Skills
B4	Failure to document Lean benefits challenges implementation of Lean Construction	5.133	Technical
B5	There's a cultural difference between project stakeholders	5.100	Cultural and Attitudinal
B6	Employees/workers are not rewarded	5.065	Structural and Organizational

This study analyzed, separately, the nature of all 37 barriers; that analysis was available in Appendix F. Also, the master list of all 37 barriers sorted from B1 to B37 was available in Appendix G.

4.6 The Overcoming Strategies

The researcher included an open-ended question at the end of the survey asking participants to offer suggestions on how to overcome the barriers to implementing Lean Construction within transportation projects. Ten respondents of 47 provided their suggestions to overcome the barriers.

Table 4.3 Respondents' Opinions on Overcoming Strategies to the Barriers in Implementing Lean Construction

Overcoming Strategies to the Barriers in Implementing Lean Construction in Transportation Projects
Work with Federal and State agencies to overcome the barriers that are present with regard to government/publicly funded projects due to policies, regulations, laws, etc.
State/federal contracting policies (ex off-site prefab was very limited under Davis Bacon).
If funding allows, involve the designer, contractor, sub-contractors and significant material suppliers to all meet at the preliminary design phase.
Empower the employees in the field to make decisions.
Engineers tend to always go to a reference book as 'the only answer.' I think schools are now providing more guidance in school on developing a solution instead there only being one answer. It was harder to give exisiting older staff the authority to be flexible. Training would be helpful to get people to be comfortable.
Client (at state and federal level) need to support and develop guidelines that would allow for it.
Allow sole sourcing of products and no longer be required to go with the low bidder.
State and Federal concepts of MOBILITY and traffic restrictions are so strongly entrenched, my 35 years of experience on both sides of the fence make it clear the agencies will NEVER give up the command and control restrictions to implement your or anybody's attempts to improve process and delivery!
Implementing Lean in the traditional methods would be very difficult within Federaly funded projects due to lack of control with prefered subcontractors and/or suppliers.
Too many competing companies.

The participants' suggestions to overcome Lean Construction implementation barriers vary as shown in Table 4.3. One respondent suggests that traditional project delivery methods may to change to allow contractors to proceed with preferred subcontractors and/or suppliers. Some respondents believe that current policies and regulations regarding publicly funded projects inhibit implementation of innovative project delivery approaches such as Lean Construction. For example, one stated that off-site and prefabrication use was limited under Davis Bacon. Other respondents think that employee decision-making at the job site needs to be encouraged. State and federal agencies may need to prepare Lean Construction guidelines for contractors to allow them to implement it. It also was suggested that sole sourcing of products may be required, rather than simply accepting the lowest bid.

4.7 Integrative Analysis of Empirical Data against Literature Review Findings (Synthesis)

In this subsection, the researcher intends to compare the results of the empirical findings to those found in the literature review. Recalling Figure 2.2, contribution percentage of the barriers found in the literature review, the nature of the barriers varies between knowledge and skills, cultural and attitudinal, commitment and support, structural and organizational, technical, governmental, and other barriers. These percentages reveal how frequently the barriers related to each category are cited in the existing literature.

However, the findings of this study reveal that participants who agree to some degree that the barriers identified in the literature review, are barriers to implementing Lean Construction within transportation projects in Michigan as illustrated in Figure 4.11. The results reveal that respondents somewhat agree that knowledge and skills along with cultural and attitudinal contribute more than other barriers types to implementing Lean Construction within transportation projects in Michigan.

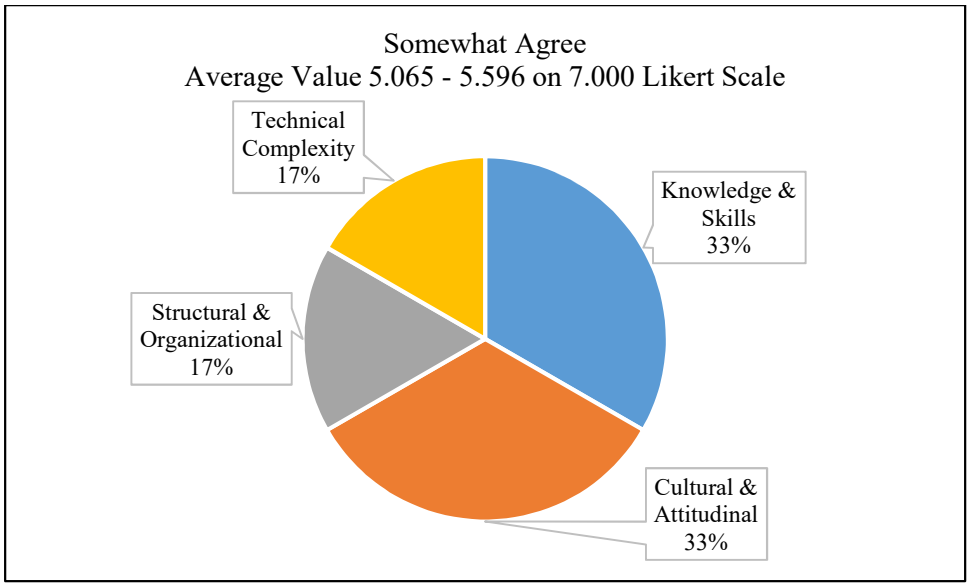

Figure 4.11 Respondent Degree of Agreement (Somewhat Agree: Average Value 5.065 – 5.596)

When research participants neither agree, nor disagree on whether the identified barriers in the literature review apply to Lean Construction in transportation projects, their opinions vary among seven barrier types as shown in Figure 4.12.

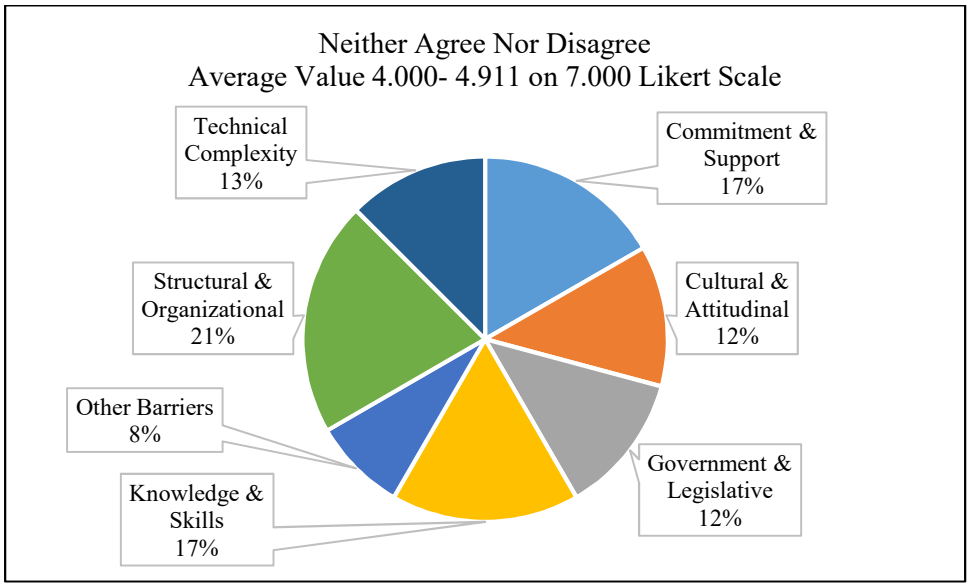

Figure 4.12 Respondent Degree of Agreement (Neither agree, nor disagree: Average Value 4.000 – 4.911)

Most the respondents neither agree nor disagree about most of the barriers identified in the literature review.

Moreover, as illustrated in Figure 4.13, the researcher found that the respondents' degree of disagreement of the barriers identified in the literature review varies between cultural and attitudinal, technical complexity, structural and organizational, or other barriers. Cultural and attitudinal and Other barriers comprise most the barriers in this response group. The Other barriers category, includes "Lean being not sustainable", and "previous failures of Lean".

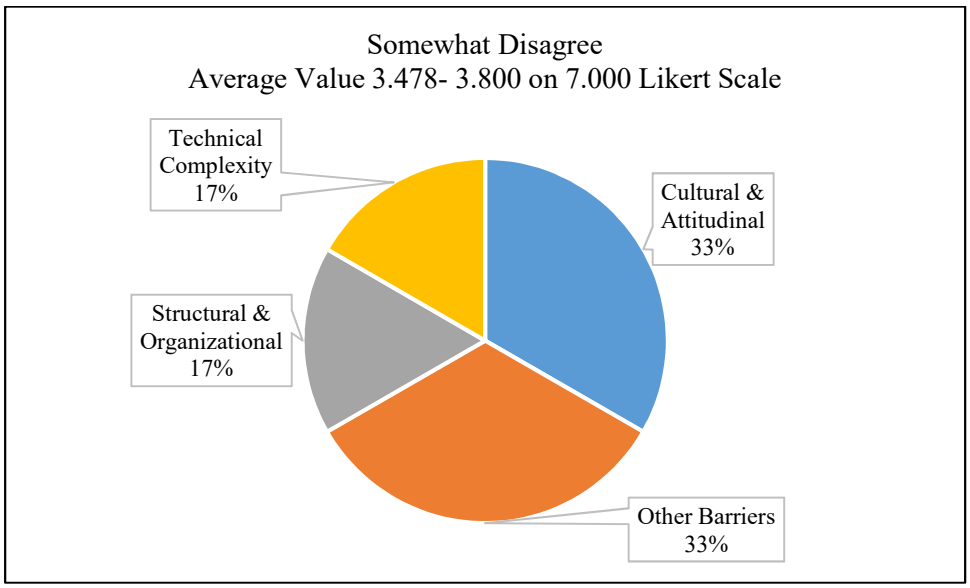

Figure 4.13 Respondent Degree of Disagreement (Somewhat disagree: Average Value 3.478 – 3.800)

Participants disagreed that technical complexity hinders implementation of Lean Construction within transportation projects in Michigan. This barrier category was the only barrier type which the respondents disagreed, and it scored an average value of 2.778 on a 7.000 Likert scale. The respondents do not agree that employees/workers are incapable of delivering quality performance.

It was found that the barriers prioritized in this study were different from the articles in the literature review. For example, "Lack of training and mentoring in Lean methods" was ranked first in this study, while it was ranked 7th and 15th in the Chinese construction and U.S. manufacturing industries respectively. This could be due to stronger training programs and Lean implementation in the U.S. manufacturing, when compared to the transportation projects. Lean methods were initially proposed in a manufacturing context (Toyota), and since then, more focus was placed on developing training and

mentoring in a manufacturing context. Therefore, it can be inferred that training and mentoring maybe lacking in transportation projects.

When the cultural aspects of Lean implementation are compared between the findings of this study and those of the literature, it can be inferred that there was a stronger group culture, shared vision and consensus in the Libyan construction industry.

4.8 Summary

This chapter presents the survey findings and provides descriptive analysis including prioritizing barriers and comparing empirical findings with those of the literature review.

To summarize, the questionnaire was distributed among three major project stakeholders in delivering transportation projects in Michigan: owners, constructors, and designers. In the owner's category, the Michigan Department of Transportation (MDOT), and county road commission engineers were included. Road and bridge builders were included in the constructor category, and in the designer's category, the road and bridge designers were included.

The demographics of the research participants were also presented, followed by their self-reported knowledge and practice of Lean Construction.

The respondents' perceptions of the barriers identified in the literature review was presented. First, the respondent results for each of the nine barrier types such as knowledge and skills, cultural and attitudinal, and structural and organizational barriers are presented in Tables 4.12 to 4.20. The respondents' opinions are prioritized according to the average value each barrier scores within the category. The average value was based on 7.0 Likert scale, with 7 indicating strongly agreement and 1 indicating strong disagreement.

Secondly, all the barriers -- regardless of their nature -- are provided in a master list and sorted in the order of their average value, from B1 to B37. B1, "lack of training and mentoring for Lean methods" was identified as the top barrier, scoring an average value of 5.596, while B37, "employees/workers are

incapable to deliver quality performance" was identified as the barrier that research participants disagree with.

Thirdly, all individual barriers were analyzed from a closer look. As seen in Appendix E, pie charts demonstrate respondents' degree of agreement, neutrality and disagreement. These are represented in percentages of the total number of people who expressed their opinion for that specific barrier.

Finally, the survey questionnaire results were compared to those of the literature review. Respondents somewhat agreed that knowledge and skills, and cultural and attitudinal barriers were among the obstacles with which respondents agree; most respondents neither agreed nor disagreed with many of the findings in the literature review.

CHAPTER 5 – CONCLUSION

5.1 Introduction

This chapter summarizes the results of previous chapter, Survey Findings, Descriptions, Analysis and Synthesis. Recommendations for future work was deliberated. By assuming this structure, it was intended that the research work will be concluded to reflect on whether the purposes stated at the start of this research have been met, including consideration of the value of this study.

The construction industry was a major contributor to the U.S. economy; every year billions of taxpayers' money was spent to fix highways, streets, and bridges. While other sectors such as manufacturing have experienced major growth in labor productivity, the construction industry has not. Lean Construction principles and method was an opportunity to address some of the challenges to increasing labor productivity in construction. Lean Construction practitioners have noticed improved productivity, a shortened project schedule, improved safety and greater customer satisfaction. Implementation of Lean principles and methods in the construction industry was not as significant as it was in the manufacturing industry, where this concept started. The purpose of this research was to identify and prioritize the barriers and offer strategies to implementing Lean Construction within Michigan's transportation sector.

To achieve this goal, a literature review was conducted to find the existing barriers to Lean methods within diverse industries, including construction. The literature review found that the barriers were diverse – and included lack of commitment and support to lack of adequate knowledge and skills, and cultural and attitudinal barriers to government and legislative obstacles. To contextualize the findings of the literature review within Michigan transportation sector, this study surveyed road builders, designers and owners, collecting their opinions of the barriers identified in the literature review and gathering their suggestions on some overcoming strategies. The descriptive analysis method was utilized to present the results of the survey findings.

5.2 Findings

This study prioritized the barriers to implementation of Lean Construction principles and methods within Michigan's transportation construction sector. The research studied and analyzed barriers to Lean, and collected opinions and experiences of owners, constructors and other project stakeholders.

There was a consensus belief among the practitioners of Lean Construction that several barriers are hindering its methods. This study found that the barriers to implementation of Lean Construction principles and methods within transportation projects are multi-dimensional. Knowledge and skills-related barriers, as well as cultural and attitudinal barriers, stood on the top of barriers. Also, barriers exist related to structural, organizational and technical complexity of the projects. Based on the research survey, the respondents indicated that the following are the top six barriers hindering implementation of Lean Construction within transportation projects:

1. Lack of training and mentoring in Lean methods
2. Lack of shared vision, consensus, and group culture in the organization
3. Employees/workers unaware of Lean methods
4. Failure to document Lean benefits
5. Cultural differences between project stakeholders
6. Employees/workers are not rewarded

Comparing the results of this study to the findings of the literature, it can be inferred that Lean Construction principles and methods are not broadly known by Michigan transportation project stakeholders. Moreover, the amount of training and mentoring of Lean methods in the construction industry seems to be less than those in manufacturing. There may be several possible reasons for this difference. As an example, the construction industry does not have as many repetitive processes as an assembly line in a manufacturing plant. While it would be difficult for a general contractor, in the pursuit

to become Lean, to design a wide-ranging Lean education program that includes subcontractors and suppliers, it would be possible for general contractors set a labor productivity growth target for a specific project, and require the same target to be achieved from the subcontractors and suppliers. This way, the overall project will be optimized rather than individual assignments within one project.

Moreover, survey respondents suggested that the following strategies may be able to overcome barriers identified in this research:

1. Training on Lean Construction needs to be provided to employees. The training should focus on continuous improvement, instead of single-answer solutions.
2. Employees should be rewarded and empowered to make field decisions.
3. An implementation guidebook should be developed that specifically reflects on Lean practices and methods.
4. State and federal agencies may need to revisit policies and regulations, to provide less stringent and more flexible contract procurement.
5. While maintaining the competitive bidding process, it would be helpful to give prime contractors more control over selecting lower-tier contractors.

This study further recommends that for project stakeholders in the transportation sector to address some of the challenges facing construction labor productivity, they may need to consider adopting Lean Construction principles and methods. The process starts with setting the target for achieving a higher return from labor productivity, followed by educating the team with Lean methods, and continuously supporting the team. There are several Lean Education programs available, such as education programs sponsored by Lean Construction Institute and Lean Construction Education program sponsored by Associated General Contractors of America that has proven success stories available within their organizations.

5.3 Limitations of the Study

This study was neither intended to conduct an exhaustive, in-depth root cause analysis of the barriers, nor provide broad generalization of the barriers impeding implementation of Lean Construction. Due to small sample size, the perceptions of the participants according to their primary job roles are not discussed in this study. It was beyond the scope of this research to conduct an in-depth qualitative study on the root cause analysis of the barriers and seeking overcoming strategies. Instead, this research was limited to gathering a general perception of Lean Construction practitioners in the transportation sector.

5.4 Recommendations for Future Work

Future work can conduct more in-depth analysis and compare owners, constructors, and designers' perceptions. To evaluate detailed barriers and overcoming strategies, future work may need to select a case-study approach, along with face-to-face interviews with experts-- specifically those who are familiar with the concept of Lean Construction and have practiced its methods.

While this study provides some general perceptions of Lean Construction practitioners in the transportation sector, an experiment of a case study would enable the researcher to see things in real and actual conditions, compare the results from the two other phases and delve into identification of the barriers to implementation of Lean principles and method in construction of highways, streets and bridges.

APPENDICES

APPENDIX A – List of Barriers Found in the Literature Review

Table 4.4 Total list of barriers to implementation of Lean found in the literature review

No	Barrier Name	Barrier Nature	Details	Source	Industry
B1	Inadequate knowledge and skills	Knowledge/Skills	- Lack of workers' knowledge and skills, - Lack of experience in Lean/Six Sigma project implementation	Omran & Abdulrahim, 2015; Alinaitwe, 2009; Albliwi et al., 2014	Libyan Construction Industry, Ugandan Construction Industry, U.S., U.K., & Indian SME
B2	Lack of organizational culture supporting team work	Cultural/Attitudinal	- Organizational culture supporting teamwork	Omran & Abdulrahim, 2015; Alinaitwe, 2009	Libyan Construction Industry, Ugandan Construction Industry
B3	Inability to measure performance of the team and to gauge the team progress	Technical	- Lack of the use of process based Performance Measurement Systems (PMSs)	Omran & Abdulrahim, 2015; Alinaitwe, 2009; Sarhan & Fox, 2013; Albliwi et al., 2014	Libyan Construction Industry, Ugandan Construction Industry, U.K. Construction Industry, U.S., U.K., & Indian SME
B4	Individual needs and personal differences of team members	Cultural/Attitudinal		Omran & Abdulrahim, 2015	Libyan Construction Industry
B5	Lack of defined focus in senior management	Variable	- Lack of well-defined focus of teams	Omran & Abdulrahim, 2015; Alinaitwe, 2009	Libyan Construction Industry, Ugandan Construction Industry
B6	Lack of capability of team to maintain alignment with another team	Communication	- Capability of teams to maintain alignment with other teams, - Lack of information sharing/communication with suppliers	Omran & Abdulrahim, 2015; Alinaitwe, 2009; Jadhav et al., 2014	Libyan Construction Industry, Ugandan Construction Industry, U.S. Manufacturing Industry

Table 4.4 (Cont'd)

B7	Lack of group culture, shared vision and shared consensus	Cultural/Attitudinal		Omran & Abdulrahim, 2015; Alinaitwe, 2009	Libyan Construction Industry, Ugandan Construction Industry
B8	Lack of a long-term philosophy	Variable	- Lack of clear vision and a future, - No vision	Shang et al., 2014; Albliwi et al., 2014; Halling and Wijk, 2013	Chinese Construction Industry, U.S., U.K., & Indian SME, Swedish Manufacturing Industry
B9	Absence of a lean culture in the organization	Cultural/Attitudinal	- Lack of sustained efforts to engage people in the meaningful learning experiences, - Need for culture change	Shang et al., 2014; Alves et al., 2012; Rahbek Gjerdrum Pedersen & Huniche, 2011	Chinese Construction Industry, U.S. & Brazil Construction Industries, Danish Public Sector
B10	Multi-layer subcontracting	Structural/Organizational	- Fragmentation and subcontracting	Shang et al., 2014; Sarhan & Fox, 2013	Chinese Construction Industry, U.K. Construction Industry
B11	Insufficient leadership and management skills	Knowledge/Skills	- Inaccurate pre-planning, - Lack of leadership in management, - Limited experiences in change management, - Poor selection of candidates for belts training, - Lack of estimation of implementation cost, - Lack of project team skills	Shang et al., 2014; Alinaitwe, 2009; Rahbek Gjerdrum Pedersen & Huniche, 2011; Albliwi et al., 2014; Halling and Wijk, 2013	Chinese Construction Industry, Ugandan Construction Industry, Danish Public Sector, U.S., U.K., & Indian SME, Swedish Manufacturing Industry

Table 4.4 (Cont'd)

B12	Lack of support from top management	Commitment/Support	- Lack of top/senior management involvement, commitment, and support, - Lack of strong/good leadership, - Inadequate time and cash flow management, - Lack of adequate management support and empowerment to shop floors, - Lack of support functions from HR, - Lack of management awareness and support,	Shang et al., 2014; Jadhav et al., 2014; Abolhassani et al., 2016; Albliwi et al., 2014; Halling and Wijk, 2013; Bhasin, 2012; Rymaszewska, 2014; Albliwi et al., 2014; Sim and Rogers 2008;2009; Halling and Wijk, 2013; Rahbek Gjerdrum Pedersen & Huniche, 2011; Sarhan & Fox, 2013	Chinese Construction Industry, U.S. Manufacturing Industry, U.S., U.K., & Indian SME, Swedish Manufacturing Industry, U.K. Manufacturing Industry, Finland SME, U.S. Manufacturing Industry, Swedish Manufacturing Industry, Danish Public Sector, U.K. Construction Industry
B13	Management resistance to change	Cultural/Attitudinal	- Top management resistance to change	Shang et al., 2014; Abolhassani et al., 2016; Albliwi et al., 2014; Jadhav et al., 2014	Chinese Construction Industry, U.S. Manufacturing Industry, U.S. Manufacturing Industry
B14	Insufficient training	Knowledge/Skills	- Inadequate training and education, - Lack of formal training for workers and managers, - Lack of leadership skills and visionary and supportive leadership	Shang et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Sarhan & Fox, 2013; Jadhav et al., 2014; Albliwi et al., 2014; Rymaszewska, 2014	Chinese Construction Industry, Danish Public Sector, U.K. Construction Industry, U.S. Manufacturing Industry, Finland SME

Table 4.4 (Cont'd)

B15	High turnover of workforce (employees leave during certain period)	Variable		Shang et al., 2014	Chinese Construction Industry
B16	Insufficient knowledge of lean	Knowledge/Skills	- Lack of adequate Lean awareness and understanding, - Lean has human costs, - Lean was a gimmick, - Wrong selection of Lean tools, - Consultants with limited Lean knowledge, - Operators lack Lean knowledge, - Insufficient workforce skills to implement Lean, - Insufficient supervisory skills to implement lean.	Shang et al., 2014; Sarhan & Fox, 2013; Bashir et al., 2015; Mehri, 2006; Abolhassani et al., 2016; Albliwi et al., 2014; Halling and Wijk, 2013; Bhasin, 2012; Alves et al., 2012	Chinese Construction Industry, U.K. Construction Industry, Japanese Manufacturing Industry, U.S., U.K., & Indian SME, Swedish Manufacturing Industry, U.K. Manufacturing Industry, U.S. & Brazil Construction Industries, Swedish Manufacturing Industry
B17	Inadequate delivery performance	Technical	- Poor execution, - Poor project selection and prioritization, - Poor selection of change agents and improvement teams, - Lack of technical knowledge, - Problems with machine and modernization of equipment	Shang et al., 2014; Albliwi et al., 2014; Abolhassani et al., 2016; Albliwi et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Jadhav et al., 2014	Chinese Construction Industry, U.S., U.K., & Indian SME, U.S. Manufacturing Industry, U.S., U.K., & Indian SME, Danish Public Sector, U.S. Manufacturing Industry

Table 4.4 (Cont'd)

B18	Using guanxi or relationships to conceal mistakes	Cultural/Attitudinal		Shang et al., 2014	Chinese Construction Industry
B19	Avoid making decisions and taking responsibility	Cultural/Attitudinal		Shang et al., 2014	Chinese Construction Industry
B20	Lack of support from government	Government		Shang et al., 2014	Chinese Construction Industry
B21	Absence of a lean culture in the partners	Cultural/Attitudinal		Shang et al., 2014	Chinese Construction Industry
B22	Stringent requirements and approvals from government	Government	- Legislative issues	Shang et al., 2014; Wodlaski et al., 2011	Chinese Construction Industry, US Construction Industry
B23	Employee tolerance of untidy workplaces (undisciplined work habits)	Cultural/Attitudinal		Shang et al., 2014	Chinese Construction Industry
B24	Less personal empowerment to employees from management	Structural/Organizational	- Lack of empowerment of employees, - Lack of motivation from management to the senior hourly skilled worker	Shang et al., 2014; Jadhav et al., 2014; Sim and Rogers 2008;2009	Chinese Construction Industry, U.S. Manufacturing Industry
B25	Hierarchies in organizational structures	Structural/Organizational	- Organizational silos	Shang et al., 2014; Halling and Wijk, 2013	Chinese Construction Industry, Swedish Manufacturing Industry

Table 4.4 (Cont'd)

B26	Employee resistance to change	Cultural/Attitudinal	- Employee resistance to change, - Workers' attitude or resistance (unionizes workers or unwillingness of workers)	Shang et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Bhasin, 2012; Abolhassani et al., 2016; Jadhav et al., 2014; Bashir et al., 2015	Chinese Construction Industry, Danish Public Sector, U.K. Manufacturing Industry, U.S., U.K., & Indian SME, U.S. Manufacturing Industry, U.K. Construction Industry
B27	Limited use of off-site construction techniques	Technical	- Lack of prefabrication	Shang et al., 2014; Alinaitwe, 2009	Chinese Construction Industry, Ugandan Construction Industry
B28	Construction firm's limited involvement in the design	Technical		Shang et al., 2014	Chinese Construction Industry
B29	Limited use of design-and-build procurement mode	Technical		Shang et al., 2014; Sarhan & Fox, 2013	Chinese Construction Industry, U.K. Construction Industry
B30	Lack of collaborative work between academia and construction industry	Commitment/Support		Alves et al., 2012	U.S. & Brazil Construction Industries
B31	Provision of inputs just when required, i.e., pull driven scheduling	Logistical	- Fluctuations in raw materials availability and prices	Alinaitwe, 2009; Rymaszewska, 2014	Ugandan Construction Industry, Finland SME
B32	Lack of infrastructure in transportation and communication	Logistical		Alinaitwe, 2009	Ugandan Construction Industry

Table 4.4 (Cont'd)

B33	Certainty in the supply chain	Technical		Alinaitwe, 2009	Ugandan Construction Industry
B34	Reward systems based on teams' goals	Structural/Organizational	- Lack of incentives, - Incompatibility of Lean/JIT with the company bonus, rewards or incentives systems	Alinaitwe, 2009; Rahbek Gjerdrum Pedersen & Huniche, 2011; Bashir et al., 2015; Jadhav et al., 2014	Ugandan Construction Industry, Danish Public Sector, U.K. Construction Industry, U.S. Manufacturing Industry
B35	Lack of Buildable designs	Technical	- Incomplete/inaccurate designs, rework, - Disruption to construction due to design changes	Alinaitwe, 2009; Sarhan & Fox, 2013	Ugandan Construction Industry, U.K. Construction Industry
B36	Lack of Participative management style for workforce	Technical		Alinaitwe, 2009	Ugandan Construction Industry
B37	Lack of Parallel execution of different development tasks in multidisciplinary teams	Structural/Organizational	- Multi-functional layout on jobsite	Alinaitwe, 2009	Ugandan Construction Industry
B38	Defect prevention	Cultural/Attitudinal		Alinaitwe, 2009	Ugandan Construction Industry
B39	Lack of communication within teams	Communication	- Lack of communication between management and workers,	Alinaitwe, 2009; Rahbek Gjerdrum Pedersen & Huniche, 2011; Jadhav et al., 2014; Albliwi et al., 2014; Halling and Wijk, 2013	Ugandan Construction Industry, Danish Public Sector, U.S. Manufacturing Industry, U.S., U.K., & Indian SME, Swedish Manufacturing Industry
B40	Workflow reliability	Technical		Alinaitwe, 2009	Ugandan Construction Industry

Table 4.4 (Cont'd)

B41	Lack of benchmarks	Technical		Alinaitwe, 2009	Ugandan Construction Industry
B42	Not using standard components	Technical	- Lack of work standards and clear and cut procedures, - Lack of an effective model or roadmap to guide implementation	Alinaitwe, 2009; Halling and Wijk, 2013; Albliwi et al., 2014	Ugandan Construction Industry, Swedish Manufacturing Industry, U.S., U.K., & Indian SME
B43	Lack of steady work engagement	Variable		Alinaitwe, 2009	Ugandan Construction Industry
B44	Not understanding of needs of customers, i.e., internal and external	Knowledge/Skills	- Lack of understanding of the different types of customers	Alinaitwe, 2009; Albliwi et al., 2014	Ugandan Construction Industry, U.S., U.K., & Indian SME
B45	Lack of client involvement	Commitment/Support		Alinaitwe, 2009	Ugandan Construction Industry
B46	Lack of quality materials	Logistical	- Quality problems with supplied material	Alinaitwe, 2009; Jadhav et al., 2014	Ugandan Construction Industry, U.S. Manufacturing Industry
B47	Lack of continuous improvement	Commitment/Support		Alinaitwe, 2009	Ugandan Construction Industry
B48	Lack of documenting agreements and procedures	Technical		Alinaitwe, 2009; Rahbek Gjerdrum Pedersen & Huniche, 2011	Ugandan Construction Industry, Danish Public Sector
B49	Cost-cutting, layoffs	Structural/Organizational	- Threat of redundancy	Rahbek Gjerdrum Pedersen & Huniche, 2011; Albliwi et al., 2014	Danish Public Sector, U.S., U.K., & Indian SME

Table 4.4 (Cont'd)

B50	Lack of aligned work	Variable		Rahbek Gjerdrum Pedersen & Huniche, 2011	Danish Public Sector
B51	No real or perceived crisis	Knowledge/Skills		Rahbek Gjerdrum Pedersen & Huniche, 2011	Danish Public Sector
B52	Slow pace of change	Technical	- Long implementation time	Rahbek Gjerdrum Pedersen & Huniche, 2011; Bashir et al., 2015	Danish Public Sector, U.K. Construction Industry
B53	No ownership to improvement initiatives	Structural/Organizational		Rahbek Gjerdrum Pedersen & Huniche, 2011	Danish Public Sector
B54	Little/no knowledge transfer	Knowledge/Skills		Rahbek Gjerdrum Pedersen & Huniche, 2011	Danish Public Sector
B55	Culture & human attitudinal issues	Cultural/Attitudinal	- Lean does not fit culture, - Reactive culture, - Japanese Lean was culturally un-American, - Silo thinking (Lack of whole-system thinking)	Sarhan & Fox, 2013; Abolhassani et al., 2016; Bhasin, 2012; Jadhav et al., 2014; Mehri, 2006, Rahbek Gjerdrum Pedersen & Huniche, 2011	U.K. Construction Industry, U.S. Manufacturing Industry, U.K. Manufacturing Industry, Japanese Manufacturing Industry, Danish Public Sector
B56	Time and commercial pressure	Financial		Sarhan & Fox, 2013	U.K. Construction Industry
B57	Financial issues	Financial	- Insufficient internal and external funding, - Lack of resources to invest or necessity of high investments/costs or Financial Constraints,	Sarhan & Fox, 2013; Bhasin, 2012; Rymaszewska, 2014; Jadhav et al., 2014; Rahbek Gjerdrum Pedersen & Huniche, 2011; Albliwi et al., 2014	U.K. Construction Industry, U.K. Manufacturing Industry, Finland SME, U.S. Manufacturing Industry, Danish Public Sector

Table 4.4 (Cont'd)

B58	Complexity (technical issue)	Technical	- Lack of understanding of how to get started	Bashir et al., 2015; Albliwi et al., 2014	U.K. Construction Industry, U.S., U.K., & Indian SME
B59	Lack of long term forecast and investment (management related)	Commitment/Support		Bashir et al., 2015	U.K. Construction Industry
B60	Low effort to learn	Commitment/Support		Bashir et al., 2015	U.K. Construction Industry
B61	Management's high expectations (management related)	Variable		Bashir et al., 2015	U.K. Construction Industry
B62	Backsliding or lack of perseverance	Commitment/Support		Jadhav et al., 2014	U.S. Manufacturing Industry
B63	Suppliers resistance or lack of cooperation (support) from vendors/suppliers	Logistical	- Weak linking to suppliers	Jadhav et al., 2014; Albliwi et al., 2014	U.S. Manufacturing Industry, U.S., U.K., & Indian SME
B64	Lack of influence over suppliers or lack of involvement of suppliers in the actual implementation	Technical		Jadhav et al., 2014	U.S. Manufacturing Industry

Table 4.4 (Cont'd)

B65	Lack of supplier collaboration or lack of mutually beneficial strategic partnership with suppliers and customers (supply chain members)	Commitment/Support	- Lack of suppliers' involvement	Jadhav et al., 2014; Alinaitwe, 2009	U.S. Manufacturing Industry, Ugandan Construction Industry
B66	Absence of a sound strategic action/logistical planning system	Logistical	- Lack of keeping needed items in the right places	Jadhav et al., 2014; Alinaitwe, 2009	U.S. Manufacturing Industry, Ugandan Construction Industry
B67	Cross-functional conflicts	Cultural/Attitudinal		Jadhav et al., 2014	U.S. Manufacturing Industry
B68	Lack of logistic support	Commitment/Support		Jadhav et al., 2014	U.S. Manufacturing Industry
B69	Lack of consultants in the field	Knowledge/Skills		Jadhav et al., 2014	U.S. Manufacturing Industry
B70	Lack of cooperation and mutual trust between management employees	Cultural/Attitudinal	- Lack of cooperation from employees	Jadhav et al., 2014; Bashir et al., 2015	U.S. Manufacturing Industry, U.K. Construction Industry
B71	Slow response to market	Variable		Jadhav et al., 2014	U.S. Manufacturing Industry
B72	Lean was unsustainable	Variable		Abolhassani et al., 2016	U.S. Manufacturing Industry
B73	Previous failures of Lean	Variable		Abolhassani et al., 2016	U.S. Manufacturing Industry

Table 4.4 (Cont'd)

B74	Weak link between the CI projects and the strategic objectives of the organization	Structural/Organizational		Albliwi et al., 2014	U.S., U.K., & Indian SME
B75	Lack of consideration of the human factors	Structural/Organizational		Albliwi et al., 2014	U.S., U.K., & Indian SME
B76	Lack of employee engagement and participation/lack of team autonomy	Commitment/Support		Albliwi et al., 2014	U.S., U.K., & Indian SME
B77	Lack of process thinking and process ownership	Technical		Albliwi et al., 2014	U.S., U.K., & Indian SME
B78	Poor organization capabilities	Structural/Organizational		Albliwi et al., 2014	U.S., U.K., & Indian SME
B79	High implementation cost	Financial		Albliwi et al., 2014; Bashir et al., 2015; Jadhav et al., 2014; Bhasin, 2012	U.S., U.K., & Indian SME, U.K. Construction Industry, U.S. Manufacturing Industry, U.K. Manufacturing Industry
B80	Ineffective project management	Structural/Organizational	- Reliability upon one-person management intuitive rather than analytical decision-making	Albliwi et al., 2014; Rymaszewska, 2014	U.S., U.K., & Indian SME, Finland SME
B81	Weak infrastructure	Variable		Albliwi et al., 2014	U.S., U.K., & Indian SME

Table 4.4 (Cont'd)

B82	Replicating another organization's Lean strategy	Technical		Albliwi et al., 2014	U.S., U.K., & Indian SME
B83	Lack of application of statistical theory	Technical		Albliwi et al., 2014	U.S., U.K., & Indian SME
B84	Misalignment between the project aim, the main goals of the company and the customer demand	Commitment/Support		Albliwi et al., 2014	U.S., U.K., & Indian SME
B85	A need to convince shareholders/owners	Structural/Organizational		Bhasin, 2012	U.K. Manufacturing Industry
B86	Shortage of skilled employees	Structural/Organizational		Rymaszewska, 2014	Finland SME
B87	Reliance upon outdated, labor intensive technologies and traditional methods	Cultural/Attitudinal		Rymaszewska, 2014	Finland SME

APPENDIX B – Institutional Review Board Approval

MICHIGAN STATE UNIVERSITY

Initial IRB Application Determination *Exempt*

January 5, 2017

To: Mohamed El-Gafy
114 Human Ecology

Re: **IRB# x16-1615e** Category: Exempt 2
Approval Date: January 5, 2017

Title: Barriers and overcoming strategies in implementing Lean Construction in transportation projects

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **your project has been deemed as exempt** in accordance with federal regulations.

The IRB has found that your research project meets the criteria for exempt status and the criteria for the protection of human subjects in exempt research. **Under our exempt policy the Principal Investigator assumes the responsibilities for the protection of human subjects** in this project as outlined in the assurance letter and exempt educational material. The IRB office has received your signed assurance for exempt research. A copy of this signed agreement is appended for your information and records.

Renewals: Exempt protocols do not need to be renewed. If the project is completed, please submit an ***Application for Permanent Closure***.

Revisions: Exempt protocols do not require revisions. However, if changes are made to a protocol that may no longer meet the exempt criteria, a new initial application will be required.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants regarding the risk and benefits of the project must be reported to the IRB.

Follow-up: If your exempt project is not completed and closed after three years, the IRB office will contact you regarding the status of the project and to verify that no changes have occurred that may affect exempt status.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

c: Sayed Elyas Kawish

Office of Regulatory Affairs
Human Research Protection Programs

Biomedical & Health Institutional Review Board (BIRB)

Community Research Institutional Review Board (CRIRB)

Social Science Behavioral/Education Institutional Review Board (SIRB)

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APPENDIX C – Survey Questionnaire (Blank)

Barriers and the Overcoming Strategies to implementing Lean Construction in Transportation Projects

Q1 Research Participant Information and Consent Form

Study Title: Barriers to implementing lean construction in transportation projects

Investigators: Mohamed El-Gafy, +1(517) 432-6512, elgafy@msu.edu, and S. Elyas Kawish, +1(517) 348-2888, kawishsa@msu.edu

Department and Institution: School of Planning, Design and Construction; Michigan State University, 552 W. Circle Drive Room 314, East Lansing, MI 48824

We would like to invite you to participate in a research study. We are asking you to be a participant in this study because your involvement in the construction of infrastructure highways and bridges. Participation in this study should take about 15 minutes. The aim of this research study was to identify the potential barriers and the overcoming strategies to implementation of lean principles and methods to transportation projects. The investigators are required to provide a consent form for you. Also, to inform you of the purpose of the study, to participate in this research survey, and to convey that your participation was completely voluntary. You do have the right to not participate in the research study. You may change your mind at any time and withdraw from the study and may also choose not to answer specific questions. The survey includes demographic information, participant's knowledge and practice of lean construction and set of matrix tables seeking participant's perception of the barriers. If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researchers.

By clicking Next, you voluntarily agree to participate in this research study.

Q2 Which of the following best describes your primary job role?

- ❍ Owner
- ❍ Constructor
- ❍ Design Engineer
- ❍ Consulting
- ❍ Other _____

Q3 What position best describes your responsibilities in your organization?

- ❍ Managing Director
- ❍ Engineer
- ❍ Supervisor
- ❍ Inspector
- ❍ Other _____

Q4 What position best describes your responsibilities in your organization?

- ❍ President/CEO
- ❍ Senior Executive
- ❍ Estimator
- ❍ Project Manager
- ❍ Project Superintendent
- ❍ Assistant Project Manager
- ❍ Assistant Superintendent
- ❍ Project Engineer
- ❍ Field Engineer
- ❍ Other _____

Q5 What position best describes your responsibilities in your organization?

- ❍ Road and Highway Designer
- ❍ Bridge Designer
- ❍ Other _____

Q6 How many years of experience do you have in construction industry?

- ❍ 1-5
- ❍ 6-10
- ❍ 11-15
- ❍ 15-20
- ❍ More than 20

Q7 This was a two-minutes introductory video to key concepts of Lean Construction. The video was a copyright of Lean Construction Institute and was publicly available on YouTube via URL https://www.youtube.com/watch?v=iETiCQ4eiiA

Q8 Have you had any training or workshop in Lean? If yes, please indicate what institution provided the training?

- ❍ Yes _____
- ❍ Maybe
- ❍ No

Q9 Have you ever applied Lean Principles in your transportation projects?

- ❍ Yes
- ❍ Maybe
- ❍ Maybe No
- ❍ No

Q10 How difficult it was to implement Lean Construction in your organization?

- ❍ Very difficult
- ❍ Difficult
- ❍ Moderate
- ❍ Easy
- ❍ Very Easy
- ❍ I do not know

Q11 Lack of awareness and adequate training on Lean was sometimes cited as one of the barriers to its implementation. What was your perception on the following knowledge and skills related barriers to implement Lean Construction?

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
Employees/workers are not aware of Lean methods	❍	❍	❍	❍	❍	❍	❍
Management/supervisory skills are insufficient to implement Lean	❍	❍	❍	❍	❍	❍	❍
There are misconceptions about lean methods; e.g., Lean was a gimmick	❍	❍	❍	❍	❍	❍	❍
There was a lack of training and mentoring for Lean methods	❍	❍	❍	❍	❍	❍	❍
Lack of sufficient workforce skills to implement Lean	❍	❍	❍	❍	❍	❍	❍
Wrong methods of Lean tools are selected	❍	❍	❍	❍	❍	❍	❍

Q12 The following barriers to Lean are related to the lack of adequate commitment and support from project stakeholders. How would you rate your overall insight?

	Strongly Agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
Senior management was not supportive and committed enough	❍	❍	❍	❍	❍	❍	❍
Employees/workers are resistant to change	❍	❍	❍	❍	❍	❍	❍
Subcontractors/suppliers are not participating and are not collaborative	❍	❍	❍	❍	❍	❍	❍
There was insufficient time and money to implement lean methods	❍	❍	❍	❍	❍	❍	❍

Q13 Hierarchies and organizational structure are often believed as hindrance to change management within organizations. How would you rate the following structural/organizational barriers to implementation of Lean within your organization?

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
Employees/workers are often not empowered enough	❍	❍	❍	❍	❍	❍	❍
Employees/workers are not rewarded	❍	❍	❍	❍	❍	❍	❍
Hierarchies in the organization discourages change initiatives	❍	❍	❍	❍	❍	❍	❍
Multi-functional layout of the job sites	❍	❍	❍	❍	❍	❍	❍
Multi-layer subcontracting	❍	❍	❍	❍	❍	❍	❍
Increase in labor productivity causes labor lay offs	❍	❍	❍	❍	❍	❍	❍
High workforce turnover (workers leave during certain period)	❍	❍	❍	❍	❍	❍	❍

Q14 The existing literature found that there was a communication gap hindering Lean implementation. Using drag and drop, rank the following communication barriers.

_____ Lack of communication between management and employees/workers
_____ Incapability of project teams to maintain alignment with each other
_____ Lack of communication between management and subcontractors/suppliers

Q15 There's a consensus that Lean was cultural and attitudinal. How would you rate your perceptions on the following cultural and attitudinal barriers to Lean?

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
Lack of sustained efforts to engage employees in the meaningful learning experiences hinders implementation of Lean Construction	❍	❍	❍	❍	❍	❍	❍
Employees/workers do not participate in continuous improvement processes	❍	❍	❍	❍	❍	❍	❍
Lack of Lean culture in subcontractors/suppliers leads to barrier in Lean Construction implementation	❍	❍	❍	❍	❍	❍	❍
Lack of shared vision, consensus, and group culture in the organization hinders implementation of Lean Construction	❍	❍	❍	❍	❍	❍	❍
There's a cultural difference between project stakeholders	❍	❍	❍	❍	❍	❍	❍
Lean journey to increase productivity cause overloading workers and create unsafe conditions and was not culturally fit	❍	❍	❍	❍	❍	❍	❍
Traditional practices are just fine	❍	❍	❍	❍	❍	❍	❍

Q16 Majority of the transportation projects are publicly funded and require competitive bidding and traditional project delivery methods. How would you rate the following governmental barriers?

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
There are liability consequences over implementing Lean project delivery	❍	❍	❍	❍	❍	❍	❍
Federal and or State agencies do not support lean projects	❍	❍	❍	❍	❍	❍	❍
Lean methods can be applied in parallel with traditional project delivery methods	❍	❍	❍	❍	❍	❍	❍

Q17 The following are assumed to be the logistical barriers to implementation of lean in transportation projects. Using drag and drop, please rank them in their order of importance.

_____ Material delivery just when required
_____ Lack of public infrastructure in transportation
_____ Material quality
_____ Suppliers are not aligned with the project due to absence of a sound strategic (long-term) relationship

Q18 Some projects are complex and technical capability can be a major barrier to implementation of Lean. How would you rate the following technical barriers?

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
There was no actual performance measurement system	❍	❍	❍	❍	❍	❍	❍
Employees/workers are incapable to deliver quality performance	❍	❍	❍	❍	❍	❍	❍
Limited use of off-site construction methods (prefabrication) deter implementation of Lean Construction	❍	❍	❍	❍	❍	❍	❍
Limited involvement of construction firm in the design obstruct implementation of Lean Construction	❍	❍	❍	❍	❍	❍	❍
Failure to document Lean benefits challenges implementation of Lean Construction	❍	❍	❍	❍	❍	❍	❍
Project complexity and lack of technical knowledge was a barrier to implementation of Lean Construction	❍	❍	❍	❍	❍	❍	❍

Q19 Other barriers

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
Lack of long-term continuous improvement strategy	❍	❍	❍	❍	❍	❍	❍
Lack of client support	❍	❍	❍	❍	❍	❍	❍
Lean was not sustainable	❍	❍	❍	❍	❍	❍	❍
Lean failed previously	❍	❍	❍	❍	❍	❍	❍

Q20 If you think barriers to implementation of Lean Construction methods and principles exist, what are your general suggestions to overcome these barriers?

Q21 Would you be interested to receive a copy of the research results? If yes, please type in the email address you wish to receive the results.

Q22 Did you find this survey easy to understand? Please write your feedback and comments in the following box.

APPENDIX D – Sample Invitation to Participate Email

Dear Participant,

I am Elyas Kawish, a master student of Construction Management program at Michigan State University. I am reaching out to transportation project stakeholders like you to voluntarily participate in my research.

As a major U.S. economy contributor, construction industry's productivity has not seen much improvement in the past 50 years. When it comes to the construction of highways, streets, and bridges, which are mainly funded through taxpayers' money, the issue of labor productivity becomes crucial. Waste, value, and flow are the fundamental principles of Lean. How to be able to see waste, how to improve flow, and how to understand client value. This research intends to identify and prioritize **barriers to implementing Lean Construction methods and principles within Michigan transportation projects**.

We are asking you to be a participant in this study because of your involvement in the construction of infrastructure highways and bridges. Your feedback was valuable to this research and it will take about 15 minutes of your time.

Your feedback was valuable to this research and it will take about 15 minutes of your time. Please feel free to share this email within your network of colleagues and friends whom this research will be relevant to.

Thank you in advance for your time and for taking part.

Best Regards,

S. Elyas Kawish
Graduate Student
Construction Management Program
Michigan State University
Kawishsa@msu.edu
(517)-348-2888

APPENDIX E – Individual Analysis of Barriers to implementation of Lean Construction within Transportation Projects

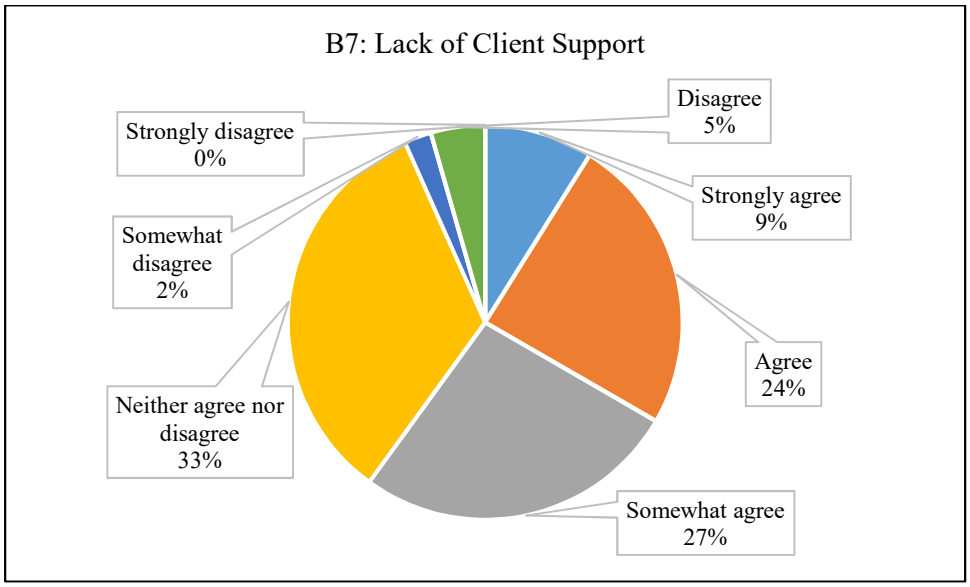

Figure 4.14 Participants' Opinion on B7: Lack of client support

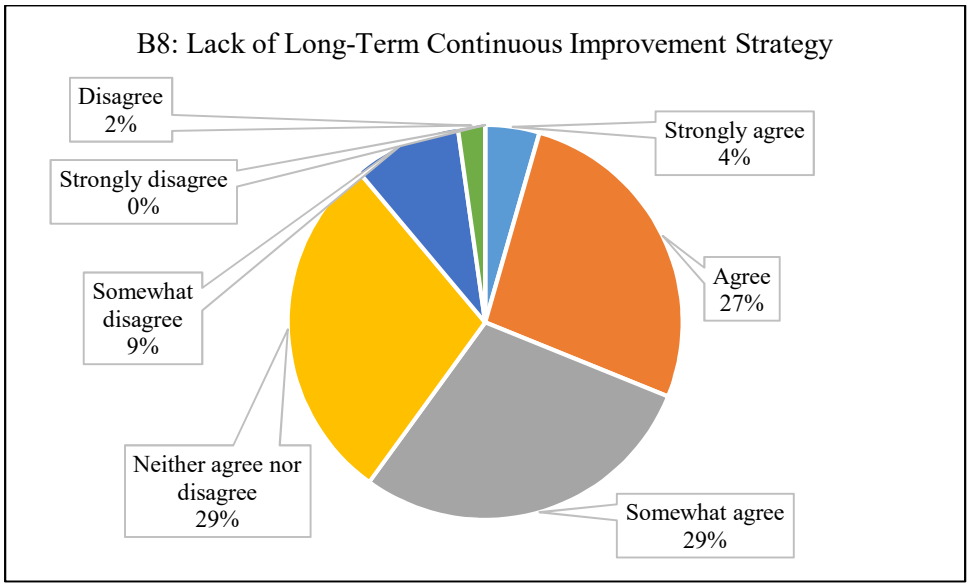

Figure 4.15 Participants' Opinion on B8: Lack of long-term continuous improvement strategy

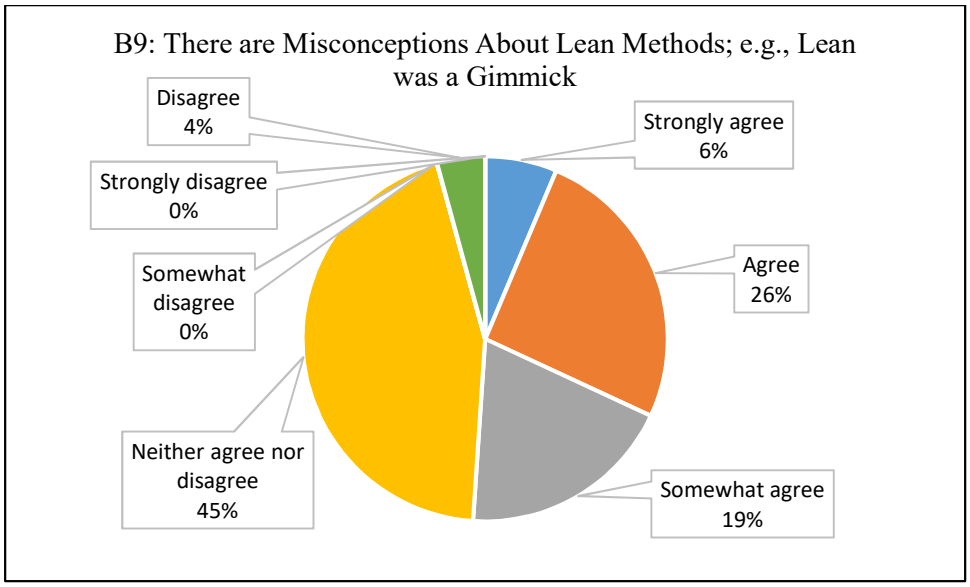

Figure 4.16 Participants' Opinion on B9: Misconceptions about Lean methods

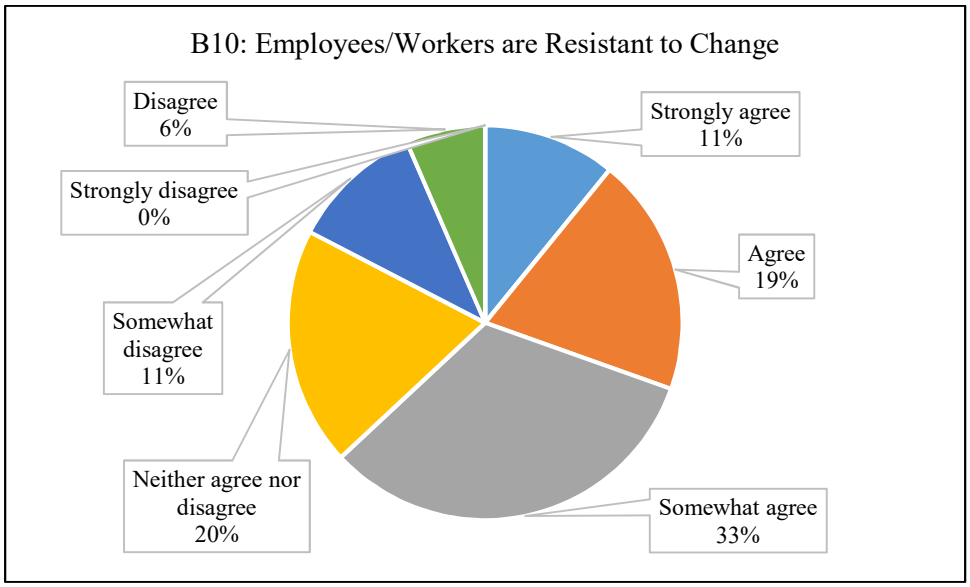

Figure 4.17 Participants' Opinion on B10: Employees/workers' resistance to change

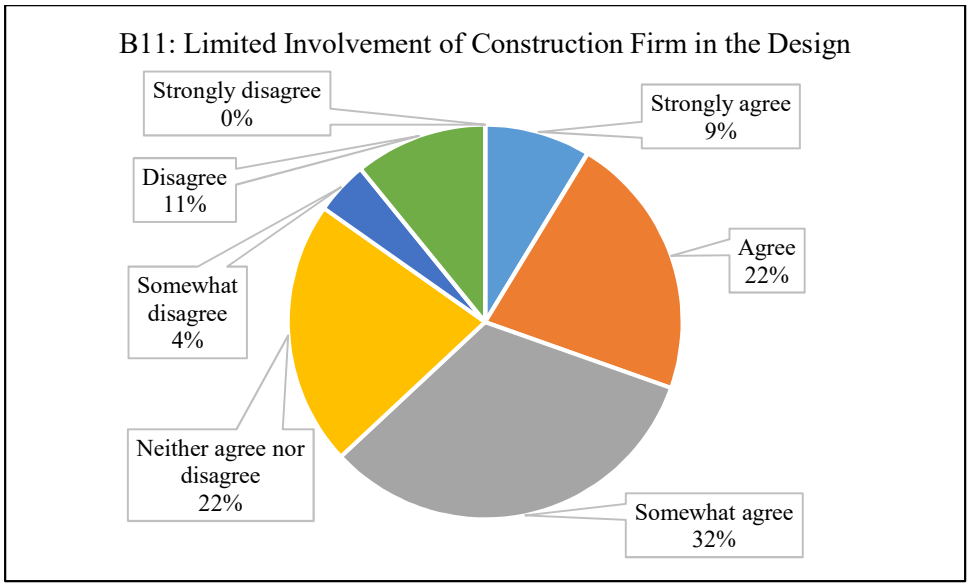

Figure 4.18 Participants' Opinion on B11: Limited involvement of construction firm in the design

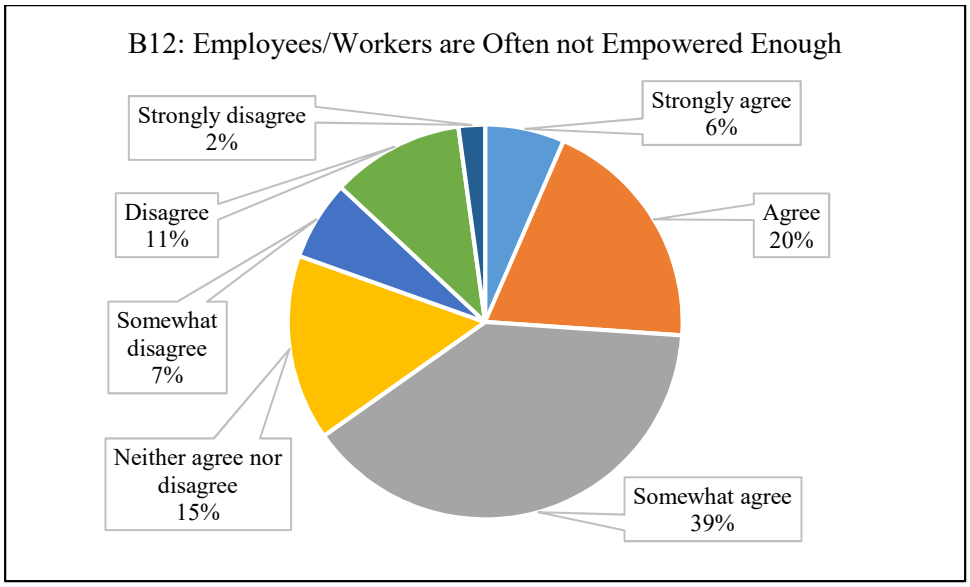

Figure 4.19 Participants' Opinion on B12: Employees/workers are often not empowered enough

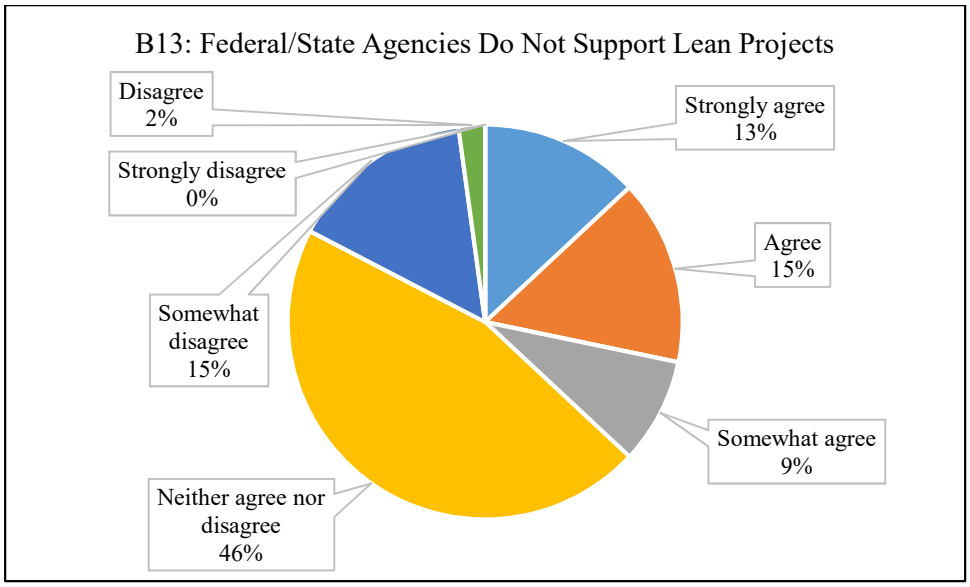

Figure 4.20 Participants' Opinion on B13: Lack of support from Federal/State agencies

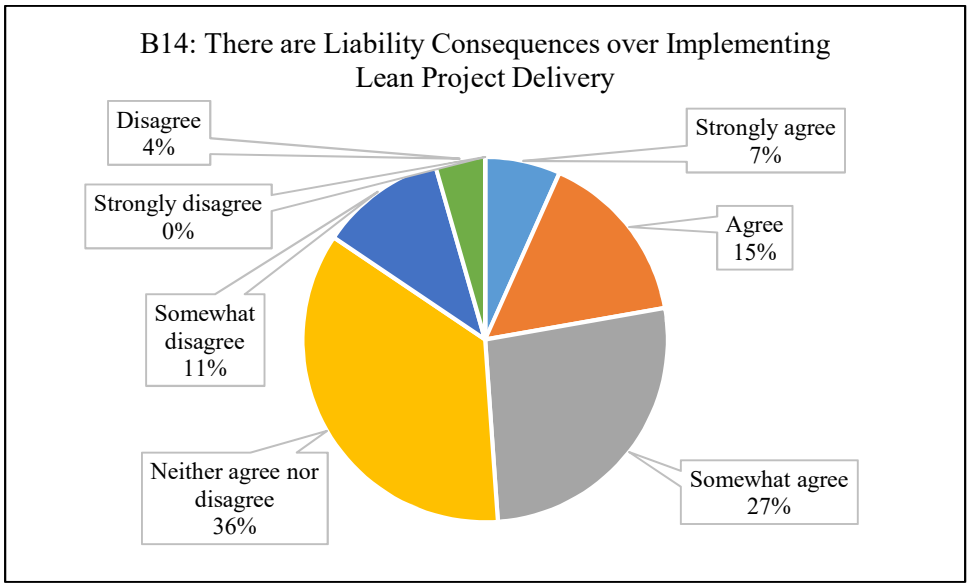

Figure 4.21 Participants' Opinion on B14: Liability consequences over implementing Lean project delivery

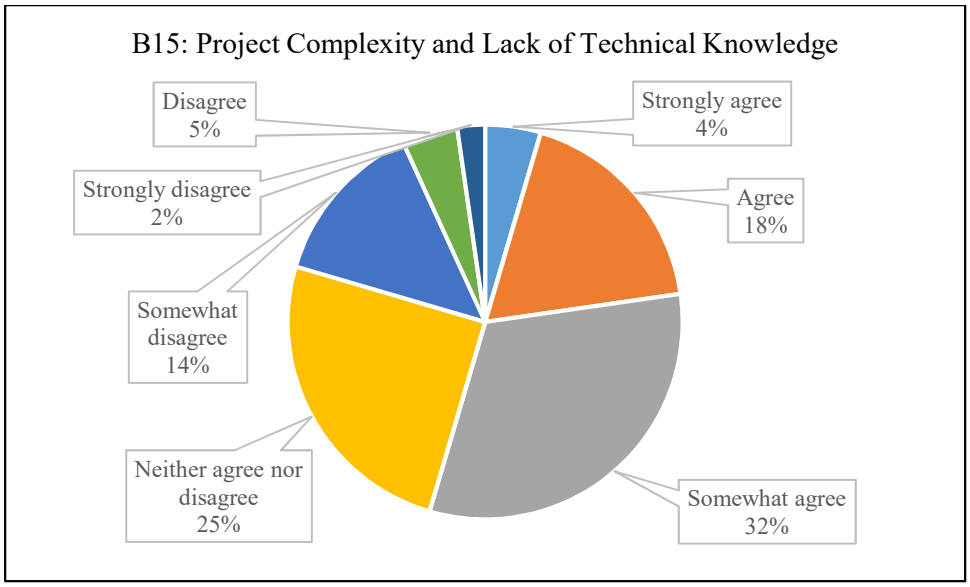

Figure 4.22 Participants' Opinion on B15: Project complexity and lack of technical knowledge

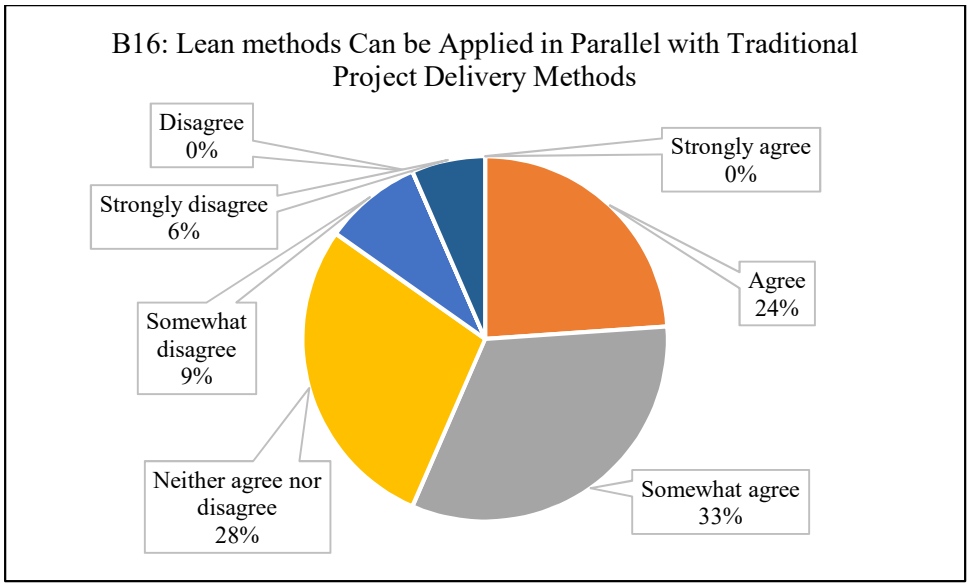

Figure 4.23 Participants' Opinion on B16: Parallel application of Lean methods and traditional project delivery methods

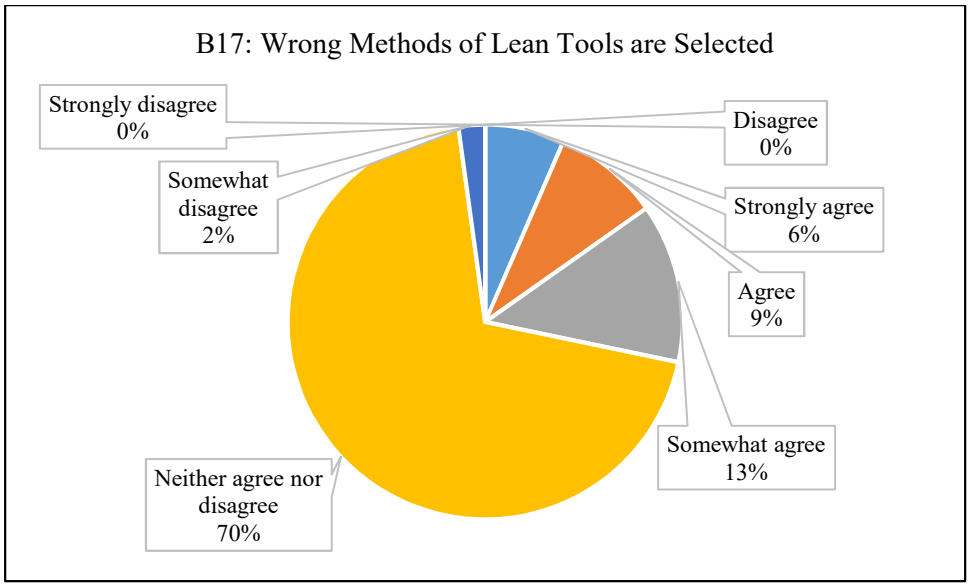

Figure 4.24 Participants' Opinion on B17: Utilizing wrong methods of Lean tools

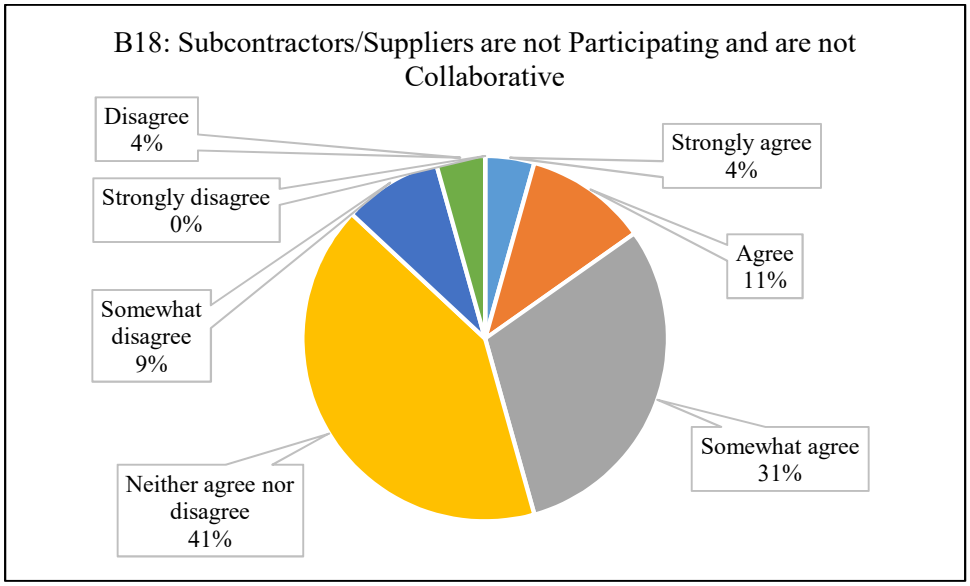

Figure 4.25 Participants' Opinion on B18: Non-participative and non-collaborative subcontractors/suppliers

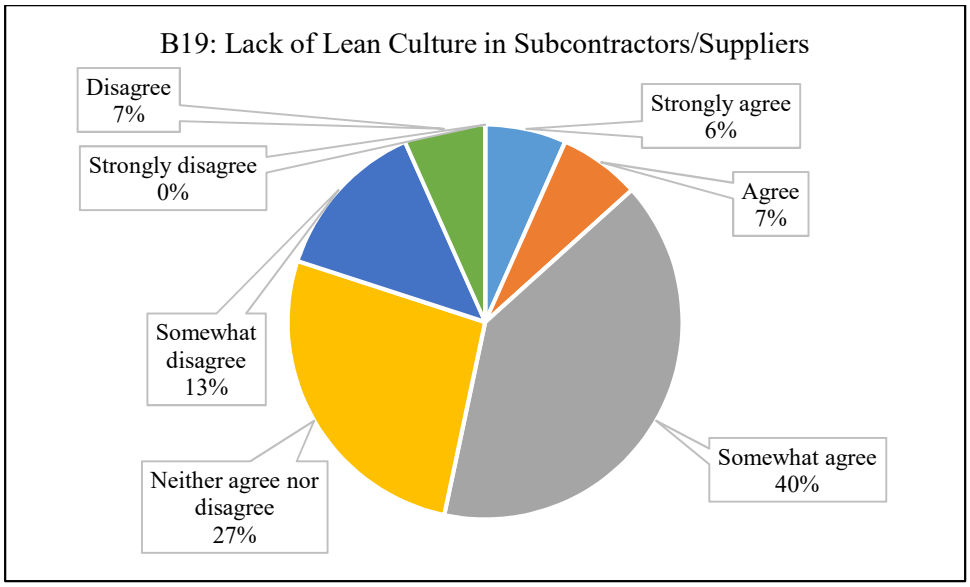

Figure 4.26 Participants' Opinion on B19: Lack of Lean culture in subcontractors/suppliers

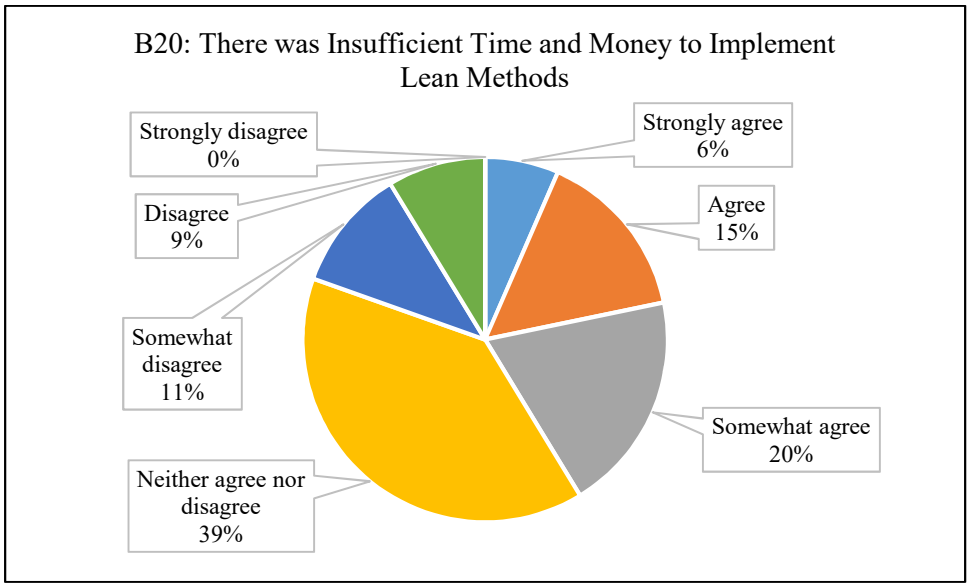

Figure 4.27 Participants' Opinion on B20: Insufficient time and money to implement Lean methods

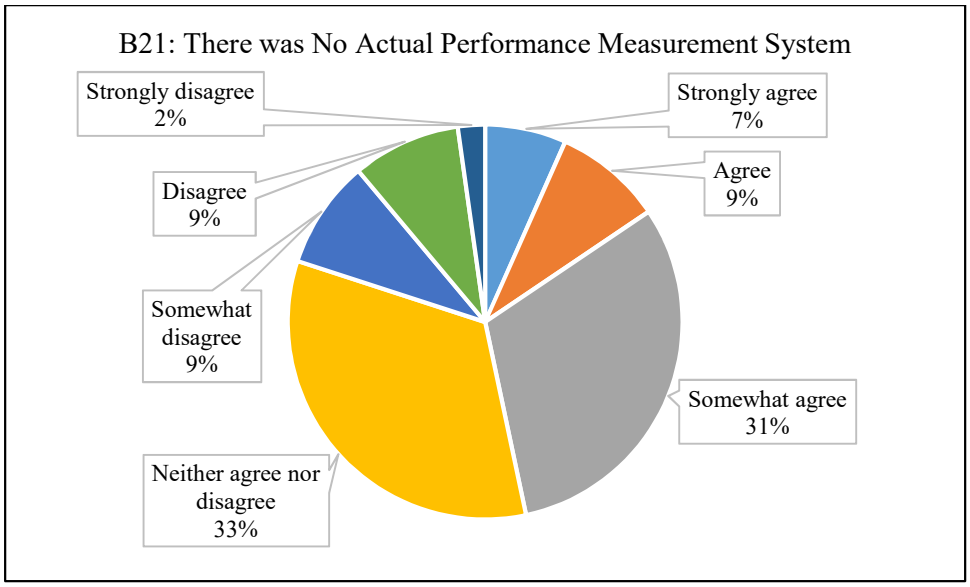

Figure 4.28 Participants' Opinion on B21: Lack of actual performance measurement system

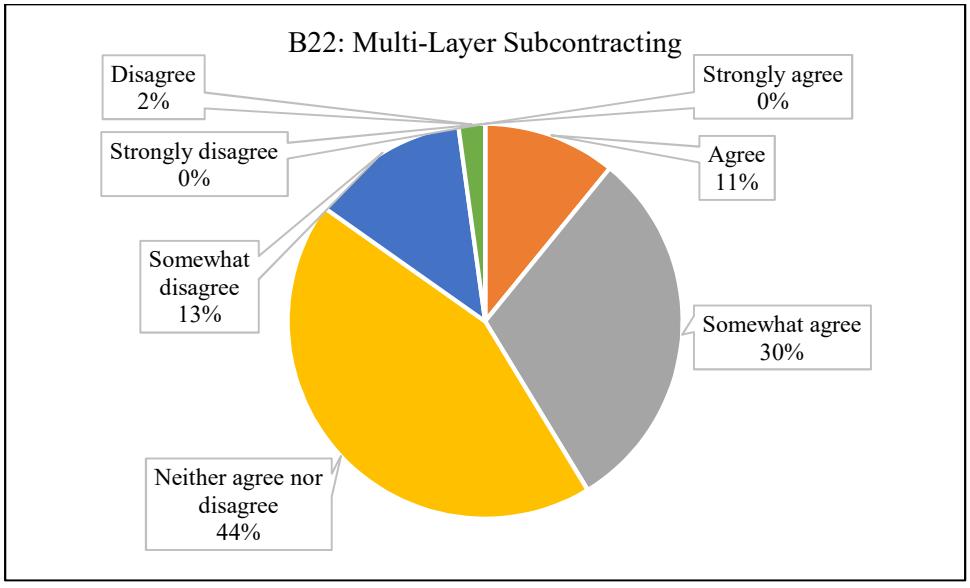

Figure 4.29 Participants' Opinion on B22: Multi-layer subcontracting

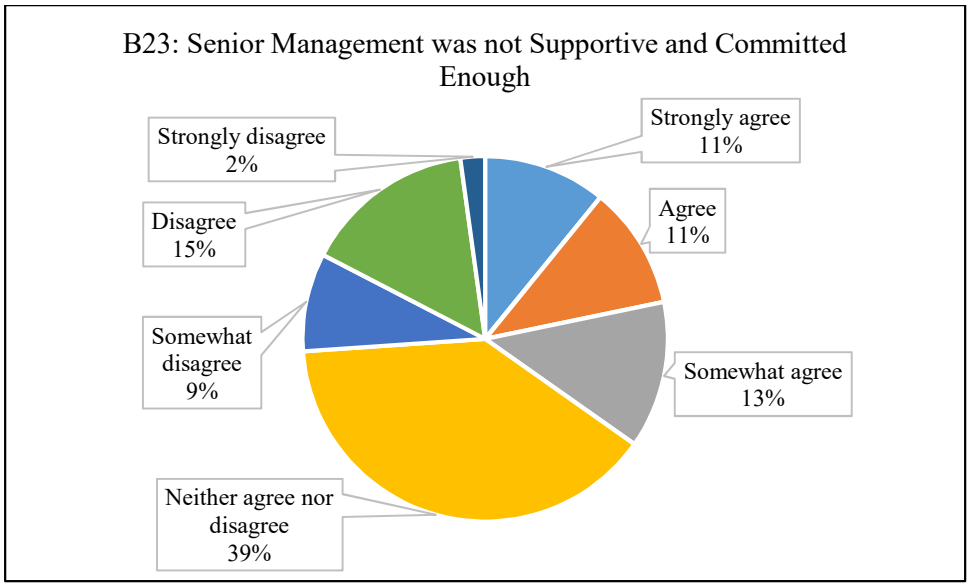

Figure 4.30 Participants' Opinion on B23: Lack of enough support and commitment from senior management

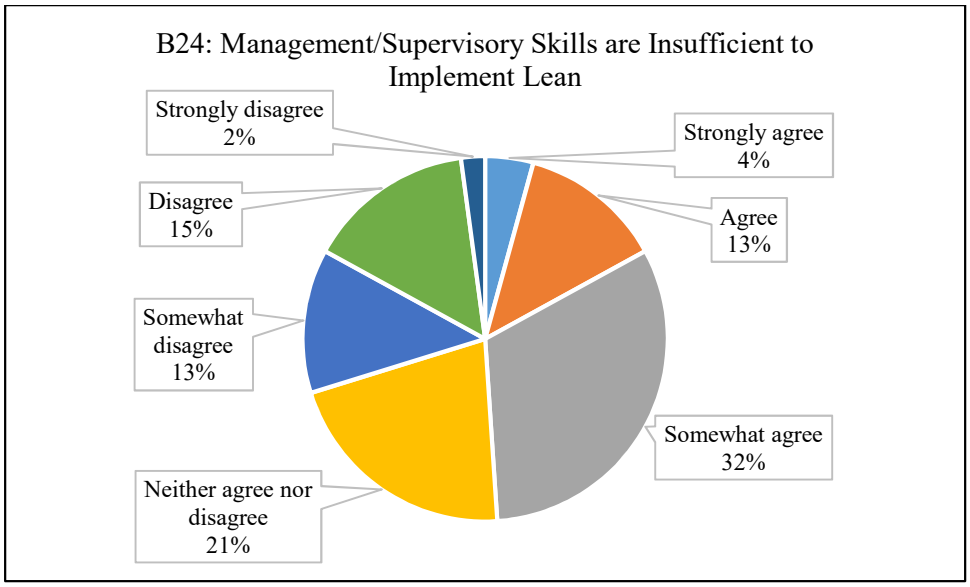

Figure 4.31 Participants' Opinion on B24: Insufficient managerial or supervisory skills

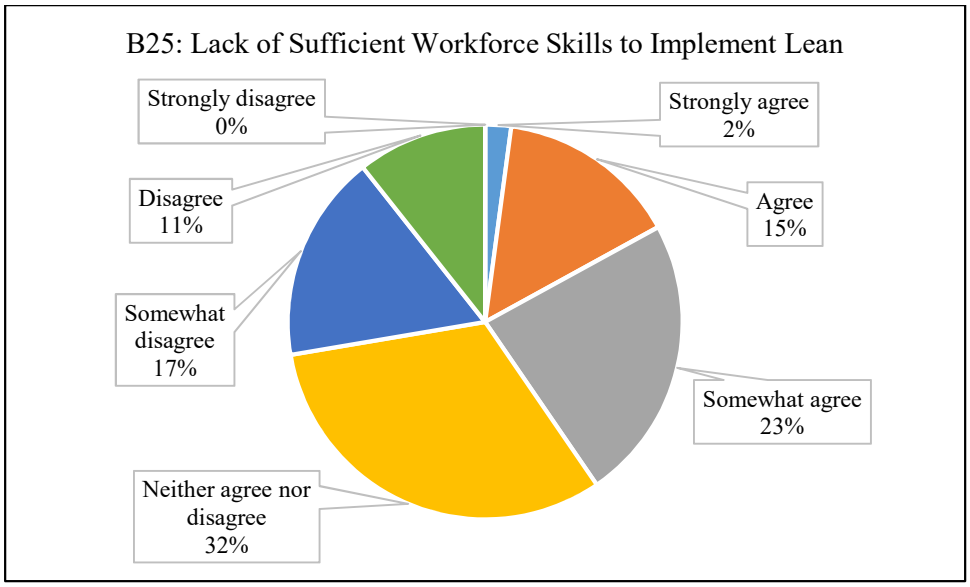

Figure 4.32 Participants' Opinion on B25: Lack of sufficient workforce skills

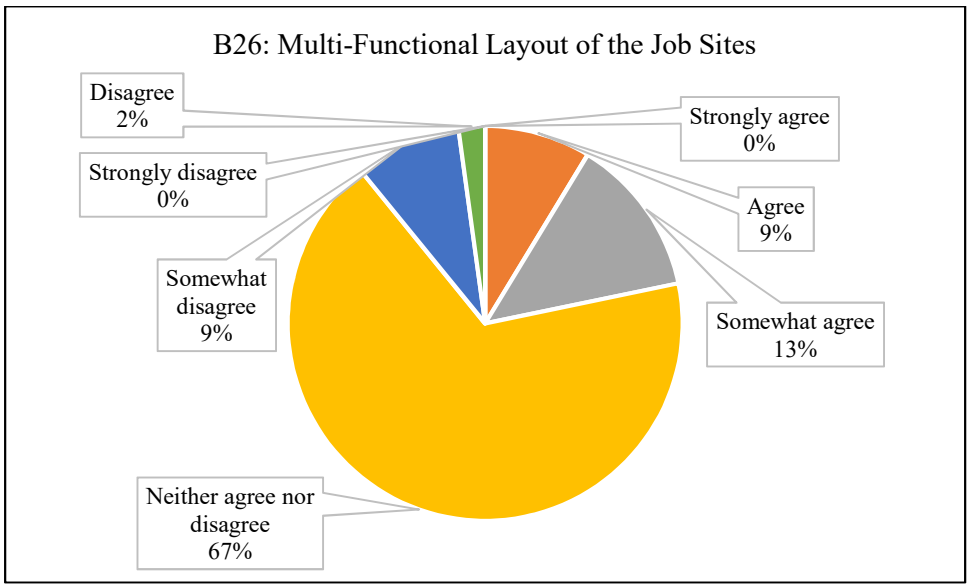

Figure 4.33 Participants' Opinion on B26: Multi-functional layout of the job sites

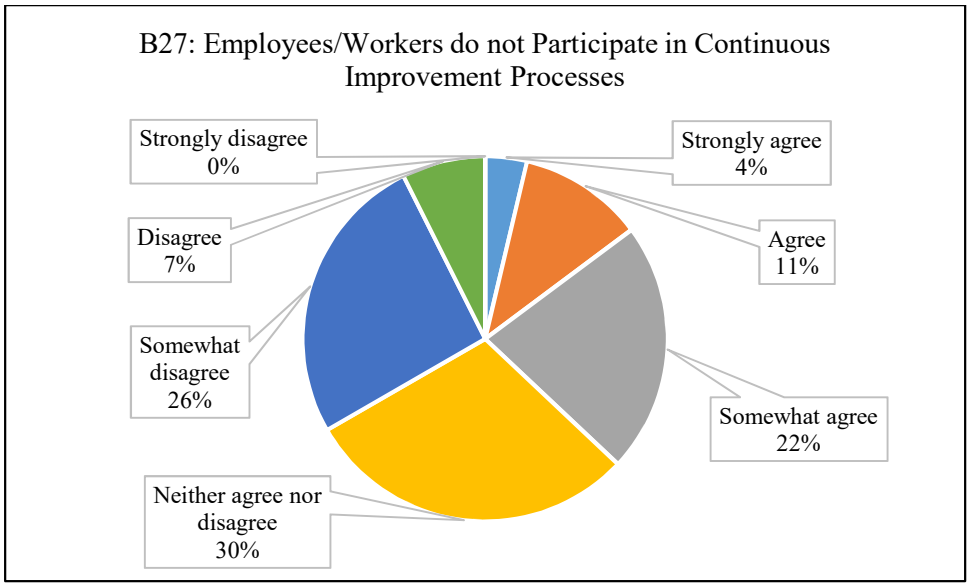

Figure 4.34 Participants' Opinion on B27: Employees/workers do not participate in continuous improvement process

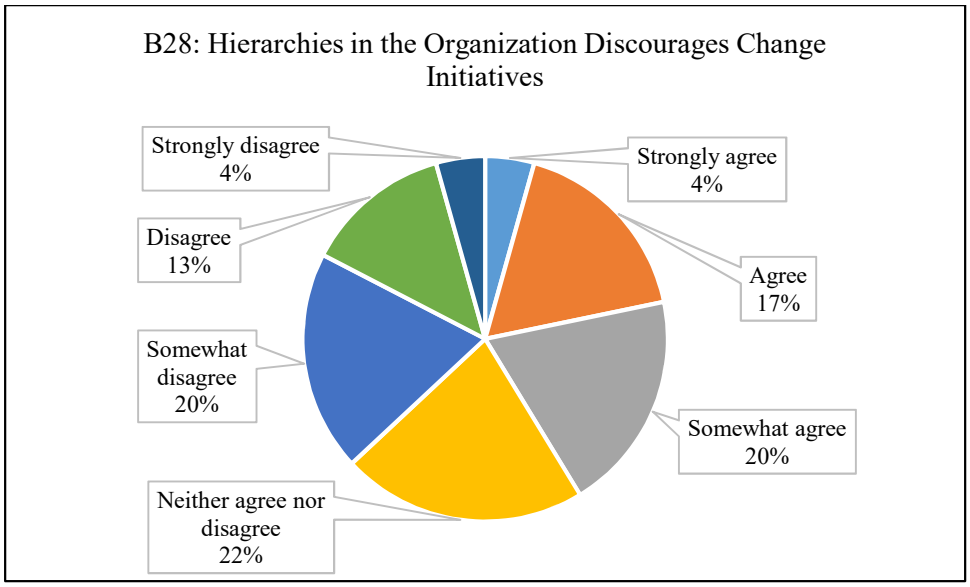

Figure 4.35 Participants' Opinion on B28: Hierarchies in the organization discourage change initiatives

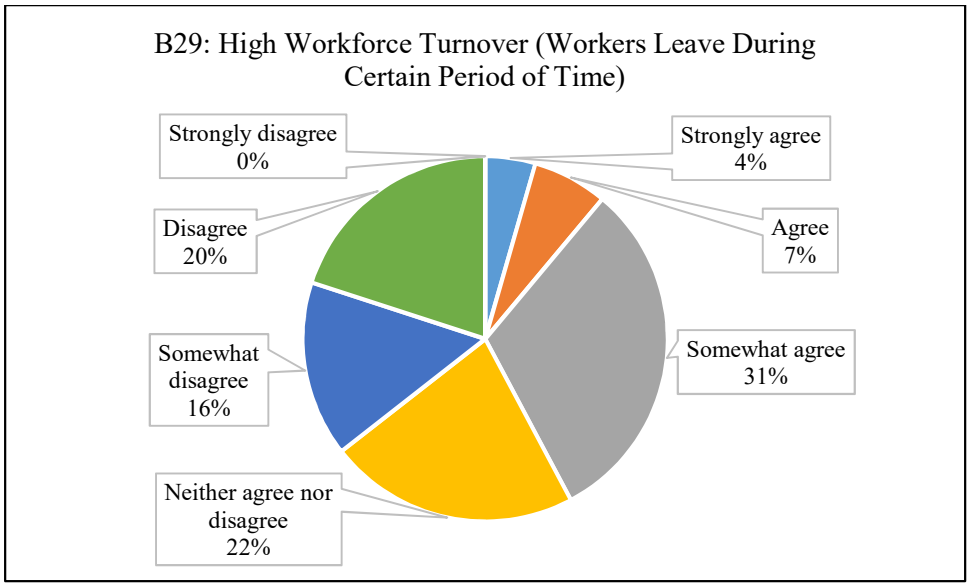

Figure 4.36 Participants' Opinion on B29: High workforce turnover

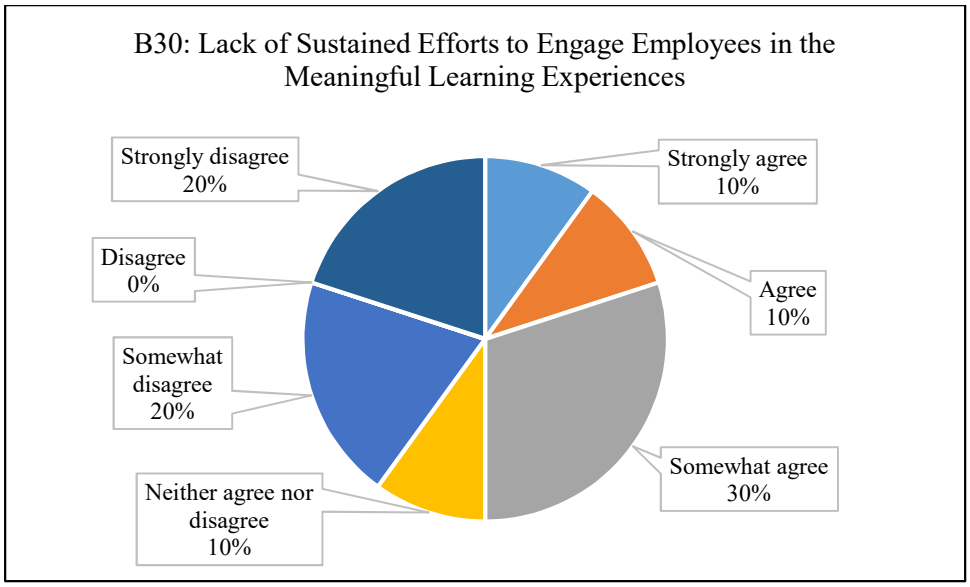

Figure 4.37 Participants' Opinion on B30: Lack of sustained efforts to engage employees in the meaningful learning experiences

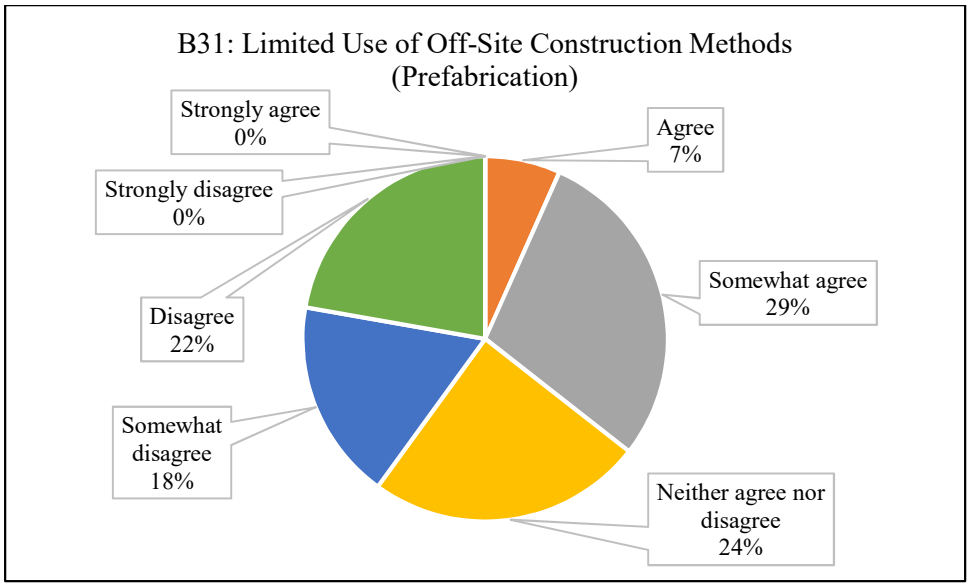

Figure 4.38 Participants' Opinion on B31: Limited use of off-site construction methods

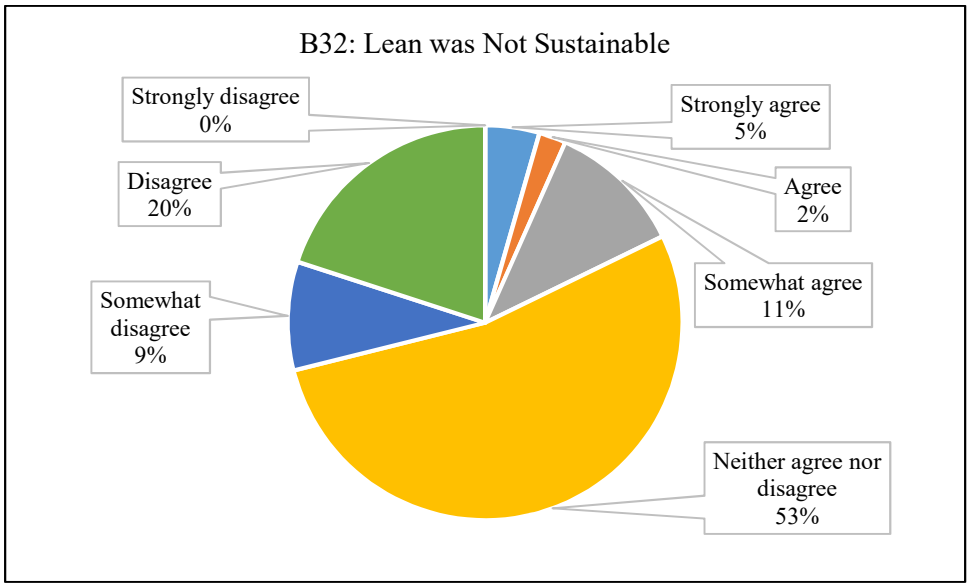

Figure 4.39 Participants' Opinion on B32: Lean was not sustainable

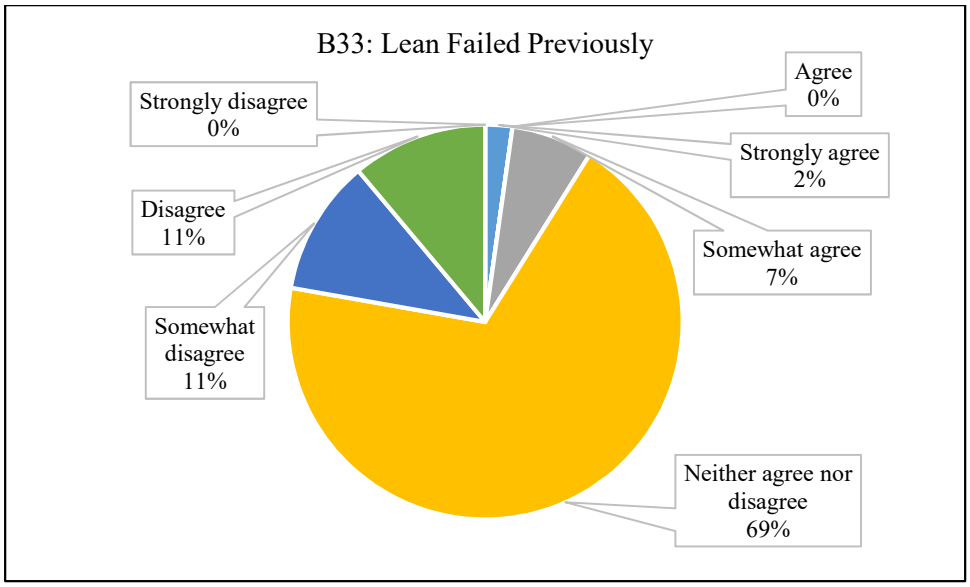

Figure 4.40 Participants' Opinion on B33: Lean failed previously

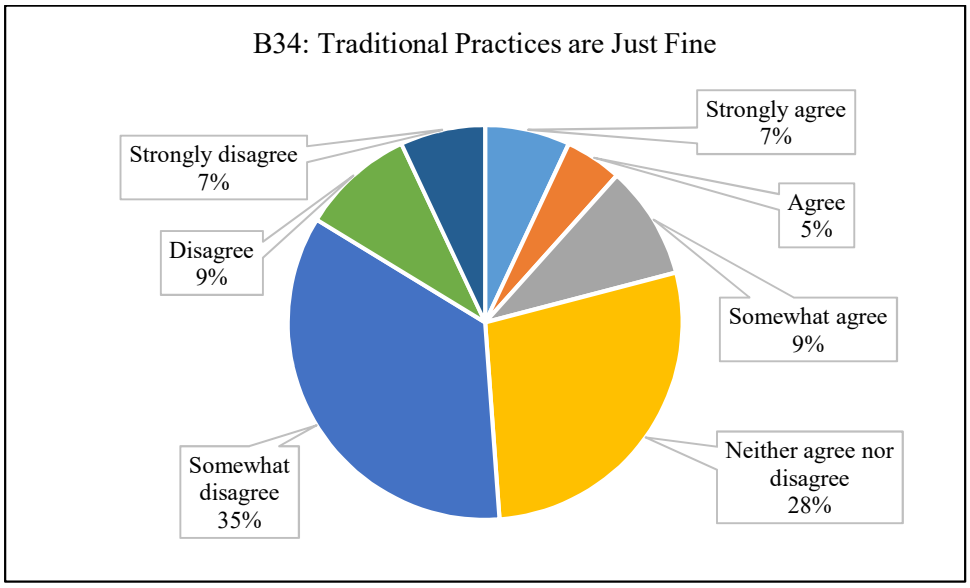

Figure 4.41 Participants' Opinion on B34: Traditional practices are just fine

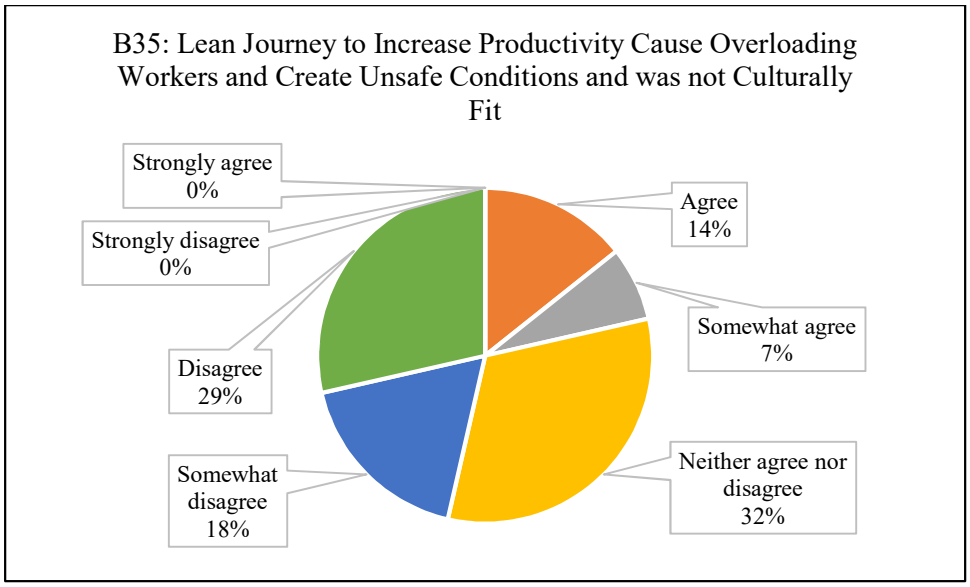

Figure 4.42 Participants' Opinion on B35: Lean journey cause overloading workers and create unsafe conditions and was not culturally fit

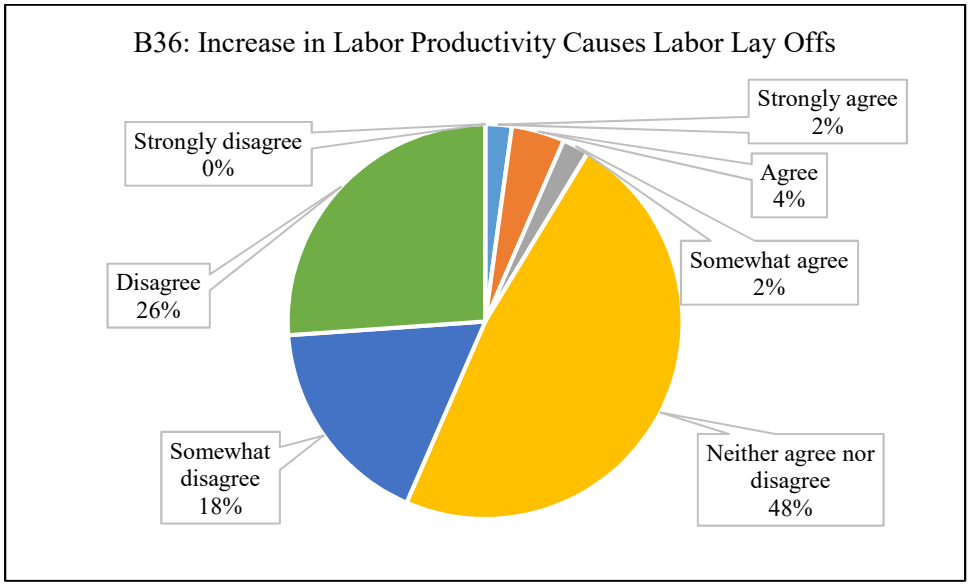

Figure 4.43 Participants' Opinion on B36: Increase in labor productivity causes labor layoffs

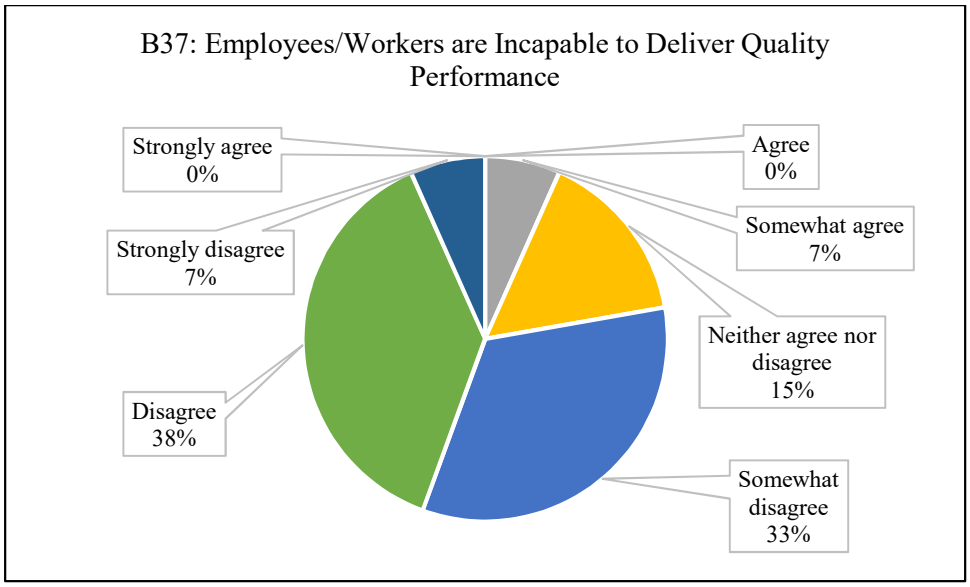

Figure 4.44 Participants' Opinion on B37: Incapability of employees/workers to deliver quality performance

APPENDIX F – Analysis of the Nature of Barriers

Table 4.5 Respondents' Opinions on Knowledge and Skills Related Barriers in Lean Implementation

#	Question	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	Employees/workers are not aware of Lean methods	8	18	14	6	-	1	-	47	5.532
2	Management/supervisory skills are insufficient to implement Lean	2	6	15	10	6	7	1	47	4.213
3	There are misconceptions about lean methods; e.g., Lean was a gimmick	3	12	9	21	-	2	-	47	4.809
4	There was a lack of training and mentoring for Lean methods	8	22	8	8	1	-	-	47	5.596
5	Lack of sufficient workforce skills to implement Lean	1	7	11	15	8	5	-	47	4.213
6	Wrong methods of Lean tools are selected	3	4	6	32	1	-	-	46	4.478

The participants' responses for barriers related to knowledge and skills are shown in Table 4.5. In this group type, the average value indicates that lack of training and mentoring for Lean methods was the top barrier, while lack of sufficient workforce skills to implement Lean methods, and insufficiency of managerial and supervisory skills, are the least important barriers in this group type.

Table 4.6 Respondents' Opinions on Commitment and Support Barriers in Lean Implementation

#	Question	Strongly Agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	Senior management was not supportive and committed enough	5	5	6	18	4	7	1	46	4.217
2	Employees/workers are resistant to change	5	9	15	9	5	3	-	46	4.804
3	Subcontractors/suppliers are not participating and are not collaborative	2	5	14	19	4	2	-	46	4.478
4	There was insufficient time and money to implement lean methods	3	7	9	18	5	4	-	46	4.413

Participants' perceptions on commitment and support barriers lean toward neutrality and expressing some agreement, as shown in Table 4.6. Employees/workers' resistance to change scores a higher average value than insufficient time and money to implement Lean methods.

However, when it comes to structural and organizational barriers, the top barrier was that employees/workers are not rewarded as shown in Table 4.7. The respondents in this barrier believe that increase in labor productivity causes labor layoffs.

Table 4.7 Respondents' Opinions on Structural and Organizational Barriers in Lean Implementation

#	Question	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	Employees/workers are often not empowered enough	3	9	18	7	3	5	1	46	4.630
2	Employees/workers are not rewarded	5	14	13	9	3	2	-	46	5.065
3	Hierarchies in the organization discourages change initiatives	2	8	9	10	9	6	2	46	4.087
4	Multi-functional layout of the job sites	-	4	6	31	4	1	-	46	4.174
5	Multi-layer subcontracting	-	5	14	20	6	1	-	46	4.348
6	Increase in labor productivity causes labor lay offs	1	2	1	22	8	12	-	46	3.478
7	High workforce turnover (workers leave during certain period of time)	2	3	14	10	7	9	-	45	4.022

Table 4.8 Respondents Rank Communication Barriers in Lean Implementation

#	Answer	Rank1	Rank2	Rank3	Responses	Mean
1	Lack of communication between management and employees/workers	12	14	10	36	2.056
2	Incapability of project teams to maintain alignment with each other	18	6	12	36	2.167
3	Lack of communication between management and subcontractors/suppliers	6	16	14	36	1.778
	Total	36	36	36	-	-

When respondents were asked to rank communication barriers, shown in Table 4.8, it was found that "Incapability of project teams to maintain alignment with each other" ranked the first, while "Lack of communication between management and employees/workers" ranked second. It can be inferred that there was an issue of teams' capability, and not the lack of communication between project stakeholders.

When the respondents' opinions on the cultural aspects of the barriers were considered, a majority of respondents believe that the "Lack of shared vision, consensus, and group culture" was the top barrier. The cultural differences between project stakeholders was the next important barrier in this group, as shown in Table 4.9. It can be inferred from the degree of respondents' disagreement on "Traditional practices are just fine," that project stakeholders, in general, are open change and acknowledge that shortfall in labor productivity.

Table 4.9 Respondents' Opinions on Cultural and Attitudinal Barriers in Lean Implementation

#	Question	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	Lack of sustained efforts to engage employees in the meaningful learning experiences hinders the implementation of Lean Construction	1	1	3	1	2	-	2	10	4.000
2	Employees/workers do not participate in continuous improvement processes	1	3	6	8	7	2	-	27	4.148
3	Lack of Lean culture in subcontractors/suppliers leads to barrier in Lean Construction implementation	1	1	6	4	2	1	-	15	4.467
4	Lack of shared vision, consensus, and group culture in the organization hinders the implementation of Lean Construction	5	8	6	3	1	-	-	23	5.565
5	There's a cultural difference between project stakeholders	4	8	12	1	4	-	1	30	5.100
6	Lean journey to increase productivity cause overloading workers and create unsafe conditions and was not culturally fit	-	4	2	9	5	8	-	28	3.607
7	Traditional practices are just fine	3	2	4	12	15	4	3	43	3.651

Table 4.10 Respondents' Opinions on Governmental and Legislative Barriers in Lean Implementation

#	Question	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	There are liability consequences over implementing Lean project delivery	3	7	12	16	5	2	-	45	4.578
2	Federal and or State agencies do not support lean projects	6	7	4	21	7	1	-	46	4.587
3	Lean methods can be applied in parallel with traditional project delivery methods	-	11	15	13	4	-	3	46	4.522

As shown in Table 4.10, participants' in the governmental and legislative barriers category generally agree that there are liability consequences over implementing Lean project delivery, and federal and state agencies do not support Lean projects; however, their responses' average was in the range between neutrality and agreeing somewhat.

Table 4.11 Respondents Rank Logistical Barriers in Lean Implementation

#	Answer	Rank1	Rank2	Rank3	Rank4	Responses	Mean
1	Material delivery just when required	12	12	9	5	38	2.842
2	Lack of public infrastructure in transportation	9	5	14	10	38	2.368
3	Material quality	3	11	10	14	38	2.105
4	Suppliers are not aligned with the project due to absence of a sound strategic (long-term) relationship	14	10	5	9	38	2.789
	Total	38	38	38	38	-	-

As shown in Table 4.11, respondents believe that the just-in-time (JIT) approach, which requires material to be delivered just when it was required, was the top logistical barrier to implementing Lean Construction followed by unalignment of suppliers. Respondents do not believe that material quality was a major logistical barrier. When it comes to the project technical complexity, as shown in Table 4.12, most respondents believe that failing to document Lean benefits was hindering its implementation and generally disagree that employees/workers are incapable of delivering quality performance.

Table 4.12 Respondents' Opinions on Projects' Technical Complexity Barriers in Lean Implementation

#	Question	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	There was no actual performance measurement system	3	4	14	15	4	4	1	45	4.356
2	Employees/workers are incapable to deliver quality performance	-	-	3	7	15	17	3	45	2.778
3	Limited use of off-site construction methods (prefabrication) deter the implementation of Lean Construction	-	3	13	11	8	10	-	45	3.800
4	Limited involvement of construction firm in the design obstruct the implementation of Lean Construction	4	10	15	10	2	5	-	46	4.761
5	Failure to document Lean benefits challenges the implementation of Lean Construction	4	13	15	12	-	1	-	45	5.133
6	Project complexity and lack of technical knowledge was a barrier to the implementation of Lean Construction	2	8	14	11	6	2	1	44	4.523

Table 4.13 Respondents' Opinions on Miscellaneous (Other) Barriers in Lean Implementation

#	Question	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
1	Lack of long-term continuous improvement strategy	2	12	13	13	4	1	-	45	4.822
2	Lack of client support	4	11	12	15	1	2	-	45	4.911
3	Lean was not sustainable	2	1	5	24	4	9	-	45	3.800
4	Lean failed previously	1	-	3	31	5	5	-	45	3.800

Those four barriers, which the researcher believed did not fit in any other abovementioned barrier types, are shown in Table 4.13. Respondents generally disagree that Lean's unsustainability or Lean's previous failure are barriers to its implementation; they show some degree of agreement with the suggestion that lack of a long-term continuous improvement strategy and lack of client support may hinder implementation of Lean Construction methods and principles.

APPENDIX G – Prioritized List of Barriers

Table 4.14 Total Barriers Prioritization List

#	Barrier Description	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree	Response	Average Value
B1	There was a lack of training and mentoring for Lean methods	8	22	8	8	1	0	0	47	5.596
B2	Lack of shared vision, consensus, and group culture in the organization hinders implementation of Lean Construction	5	8	6	3	1	0	0	23	5.565
B3	Employees/workers are not aware of Lean methods	8	18	14	6	0	1	0	47	5.532
B4	Failure to document Lean benefits challenges implementation of Lean Construction	4	13	15	12	0	1	0	45	5.133
B5	There's a cultural difference between project stakeholders	4	8	12	1	4	0	1	30	5.100
B6	Employees/workers are not rewarded	5	14	13	9	3	2	0	46	5.065
B7	Lack of client support	4	11	12	15	1	2	0	45	4.911

Table 4.14 (Cont'd)

B8	Lack of long-term continuous improvement strategy	2	12	13	13	4	1	0	45	4.822
B9	There are misconceptions about lean methods; e.g., Lean was a gimmick	3	12	9	21	0	2	0	47	4.809
B10	Employees/workers are resistant to change	5	9	15	9	5	3	0	46	4.804
B11	Limited involvement of construction firm in the design obstruct implementation of Lean Construction	4	10	15	10	2	5	0	46	4.761
B12	Employees/workers are often not empowered enough	3	9	18	7	3	5	1	46	4.630
B13	Federal and or State agencies do not support lean projects	6	7	4	21	7	1	0	46	4.587
B14	There are liability consequences over implementing Lean project delivery	3	7	12	16	5	2	0	45	4.578
B15	Project complexity and lack of technical knowledge was a barrier to implementation of Lean Construction	2	8	14	11	6	2	1	44	4.523
B16	Lean methods can be applied in parallel with traditional project delivery methods	0	11	15	13	4	0	3	46	4.522
B17	Wrong methods of Lean tools are selected	3	4	6	32	1	0	0	46	4.478

Table 4.14 (Cont'd)

B18	Subcontractors/suppliers are not participating and are not collaborative	2	5	14	19	4	2	0	46	4.478
B19	Lack of Lean culture in subcontractors/suppliers leads to barrier in Lean Construction implementation	1	1	6	4	2	1	0	15	4.467
B20	There was insufficient time and money to implement lean methods	3	7	9	18	5	4	0	46	4.413
B21	There was no actual performance measurement system	3	4	14	15	4	4	1	45	4.356
B22	Multi-layer subcontracting	0	5	14	20	6	1	0	46	4.348
B23	Senior management was not supportive and committed enough	5	5	6	18	4	7	1	46	4.217
B24	Management/supervisory skills are insufficient to implement Lean	2	6	15	10	6	7	1	47	4.213
B25	Lack of sufficient workforce skills to implement Lean	1	7	11	15	8	5	0	47	4.213
B26	Multi-functional layout of the job sites	0	4	6	31	4	1	0	46	4.174
B27	Employees/workers do not participate in continuous improvement processes	1	3	6	8	7	2	0	27	4.148
B28	Hierarchies in the organization discourages change initiatives	2	8	9	10	9	6	2	46	4.087

Table 4.14 (Cont'd)

B29	High workforce turnover (workers leave during certain period)	2	3	14	10	7	9	0	45	4.022
B30	Lack of sustained efforts to engage employees in the meaningful learning experiences hinders implementation of Lean Construction	1	1	3	1	2	0	2	10	4.000
B31	Limited use of off-site construction methods (prefabrication) deter implementation of Lean Construction	0	3	13	11	8	10	0	45	3.800
B32	Lean was not sustainable	2	1	5	24	4	9	0	45	3.800
B33	Lean failed previously	1	0	3	31	5	5	0	45	3.800
B34	Traditional practices are just fine	3	2	4	12	15	4	3	43	3.651
B35	Lean journey to increase productivity cause overloading workers and create unsafe conditions and was not culturally fit	0	4	2	9	5	8	0	28	3.607
B36	Increase in labor productivity causes labor lay offs	1	2	1	22	8	12	0	46	3.478
B37	Employees/workers are incapable to deliver quality performance	0	0	3	7	15	17	3	45	2.778

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