RELIANCE OF THE FIELD SUPERVISORS ON EXPERIENCE-BASED TACIT KNOWLEDGE AND BARRIERS TO KNOWLEDGE SHARING

by

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Dedicated to my family and friends for their unconditional love and support.

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LIST OF ABBREVIATIONS

AEC	Architecture, Engineering & Construction
AGC	Associated General Contractors of America
BLS	Bureau of Labor Statistics
EDA	Exploratory Data Analysis
KM	Knowledge Management
NECA	National Electrical Contractors Association
PBO	Project-Based Organization
SECI	Socialization, Externalization, Combination & Internalization
SPSS	Statistical Package for the Social Sciences
TKML	Tacit Knowledge in Military Leadership

ABSTRACT

Generally, the trade supervisors are seen swapping stories about how they have done things differently in their previous projects that had resulted in saving manhours and resources. Since most of them are doing repetitive tasks for years, they rely mainly on their judgments and intuition while making decisions and have developed a plethora of knowledge throughout their experience. They often find it difficult to articulate the knowledge they have acquired most of which is tacit. There is a need to identify this tacit dimension of knowledge to harness it effectively as tacit knowledge is one of the factors determining the competitiveness of a construction firm. The skills shortage in the industry is further aggravated by the workforce attrition. Employee retirements and knowledge loss are compelling the specialty contracting firms to capture this tacit knowledge to prepare the future workforce. This study posits an instrument to gauge the reliance of the field supervisors on tacit knowledge and identifies barriers to knowledge sharing through case studies involving electrical contracting firms. The findings of this research clearly show that the experience level of an individual is related to the reliance on tacit knowledge. Most of the experienced field supervisors rely on the tacit dimension of knowledge to perform the major day-to-day routine tasks at the construction site. The education level of an individual seems to have no significant relation with the acquisition and usage of tacit knowledge. Findings also suggest that the viewpoint of the management and the field team are disparate regarding the barriers to knowledge sharing. Management feels that lack of formal processes prevents the trade professionals from sharing their knowledge among themselves whereas according to the field team lack of socialization is identified as the key barrier. Similarly, managers' resistance to change is identified by management as the key barrier that prevents supervisors or managers from sharing their knowledge with the subordinates whereas, for the field team it is the lack of encouragement from the management. Moreover, according to management, lack of formal processes is the key barrier at the organizational level but for the field team, it’s the silo mentality of the managers. The organizations must incorporate the feedback from the field team into the decision making related to knowledge management (KM). The developed framework will benefit the trade contractors to identify on what type of knowledge the field supervisors are relying to perform a particular task and eventually categorizing knowledge into explicit and tacit.

CHAPTER 1. INTRODUCTION

1.1 Introduction

According to Baker, Baker, Thorne, and Dutnell (1997), for effective knowledge management, there must be harmony between three key elements: human, process, and technology. However, in the construction sector, the human factor is often bypassed in knowledge management decisions which have significantly contributed to the underperformance in executing the projects (Pathirage, Amaratunga, & Haigh, 2007). Earlier the construction industry was known to deliver tangible products like roads, buildings, bridges, and similar structures, but nowadays it is widely recognized as a giant knowledge hub providing services to many stakeholders and hence laying more emphasis on knowledge capturing and sharing strategies (Egbu & Robinson, 2008). The knowledge generated in the construction sector is mostly experience-based which makes it quite challenging to transfer this knowledge to others (Kivrak, Arslan, Dikmen, & Birgonul, 2008). As explained by Nonaka and Takeuchi (1995) in their book "*The Knowledge-Creating Company*", capturing organizational knowledge is the biggest factor backing up the success of Japanese companies in the international market. Similarly, the competitive edge of a construction firm is determined by the effectiveness in capturing tacit hunches of the experienced professionals (Nesan, 2012). Tacit knowledge could play a vital role in the competitive market due to its relative immobility and unique nature as compared to explicit knowledge (Pathirage et al., 2007).

Unlike other industries, the construction industry relies on the skills and knowledge of the trade professionals as it is labor driven. It is characterized by its project-based nature where various teams work together for a common goal and often dissolve upon the completion of the project (Grover & Froese, 2016). There are several stakeholders associated with a construction project with different levels of expertise and knowledge, including multiple trade crews, office staff, managers, supervisors and many more and they work as an interdisciplinary team that converts a conceptualized intangible product on the drawings to an actual tangible construction product in the field. These stakeholders continuously interact and collaborate to put forward their expertise and generating better decisions. Similarly, on a construction site, specialty crews together form a temporary organization (Grover & Froese, 2016; Ninaus & Knapp, 2019) and interact continuously throughout the project and generate knowledge through the socialization process which plays a

crucial role in knowledge creation (Martin & Root, 2009). This social environment is an amalgamation of existing experience-based knowledge plus the knowledge that is developed continuously as the project progresses (Wilkinson, Farrell, & Sherratt, 2015).

Specialty contractors are responsible for executing the majority of the project work that requires specific skills like HVAC, electrical, roofing, plumbing, etc. and for which they employ trade professionals, acquire special equipment and tools, and possess special know-how (Tommelein & Ballard, 1997). Trade professionals are the people who perform the actual hands-on work in a construction project to get things done on time. The work performed by these craft people often consists of many routine steps (Ninaus & Knapp, 2019). Generally, emerging individuals who have gained much experience are promoted to higher positions like crew leaders or trade supervisors. When it comes right down to trade supervisors, a famous quote "*we can know more than we can tell*" (Polyani, 1966, p. 4) buttresses its validity. These trade supervisors have acquired a plethora of knowledge throughout their employment in the form of experience. They use this tacit knowledge in combination with engineering techniques to put forward solutions to different complex problems on the job site and to make other decisions (Sun & Ren, 2014). This experience-based or tacit knowledge is difficult to share in written or oral form (Nonaka & Takeuchi, 1995).

Capturing lessons learned at the end of the project is a common approach prevalent among many construction organizations but oftentimes it merely ends up being a formality since it usually happens by the end of the project when most of the people have stepped out of the project hence, ineffective in capturing the tacit knowledge generated throughout the project (Grover & Froese, 2016). There is a strong need for organizations specially engaged in the construction business to identify this intangible form of knowledge and formulate strategies to capture and harness it to sustain in the prevalent competitive market.

This chapter deals with an overview of the study, delineating the basic concepts related to the research. It also encompasses the Problem statement, Scope, Significance, Hypotheses, Assumptions, Limitations and Delimitations of this research in the coming sections.

1.2 Problem Statement

The construction industry is labor driven and skill-based. A construction site is a place where actual utilizable and context-specific knowledge is generated and applied practically (Wilkinson

et al., 2015). The knowledge of construction activities and procedures is an influential component of the organization's core competency. The construction operations substantially rely on the skills and experience of supervisors, trade professionals and managers in the construction field and the learning is mostly implicit (Bijleveld & Dorée, 2014). The construction industry is taking effective steps in capturing the explicit knowledge which is generated on the construction project, but it lacks efforts to capture tacit knowledge (Grover & Froese, 2016) which is still relatively unexplored (Khuzaimah & Hassan, 2012) when it comes to the construction field supervisors. Historically, most of these supervisors have attained their position in an organization based on their skills, expertise and technical know-how (Macneil, 2004) and they have further acquired an enormous amount of tacit knowledge especially know-how through their experience. To measure this work experience, most of the studies have adopted quantitative approaches like identifying years in an organization or particular role, how many times an individual has completed a particular task, etc. and still, the qualitative aspects, like the acquisition of tacit knowledge are relatively unexplored (Tesluk & Jacobs, 1998). It is challenging for organizations to identify this tacit knowledge (USAID, 2013). The contribution of a certain dimension of knowledge, explicit or tacit, can be reflected by identifying the activities that deal with it (Chen & Mohamed, 2010). Understanding the constituents of tacit knowledge would be key factors in its identification and effective management (Pathirage, Amaratunga, & Haigh, 2008). Hence, there is a need to identify construction activities that rely mostly on tacit knowledge so that organizations can better match workers to the task and formulate strategies for effective knowledge management (Chilton & Bloodgood, 2008). Also, there is a need to figure out a relation between an individual's experience and tacit knowledge.

Conversely, Limited research has been done in the field of assessing the degree to which the individuals rely on tacit knowledge to perform a specific task (Chilton & Bloodgood, 2008) and when comes to field supervisors, they are unable or unwilling to explain: how this tacit knowledge has been generated or used practically (Wilkinson et al., 2015). Also, there is a growing shortage of skills that the construction industry is facing along with the greater proportion of baby boomers in the workforce. According to the Bureau of Labor Statistics (2019), due to increased spending in the construction sector, employment of the construction trade workers is projected to grow by 10% from 2018 to 2028. Similarly, the projected employment growth of first-line supervisors of construction trades from 2018 to 2028 is 11% (Bureau of Labor Statistics, 2019a).

However, according to another survey, 80% of the contractors in the US are finding it difficult to fill the trade positions (AGC, 2020) and the problem that is further exacerbating this issue is the aging workforce (Brown, 2019). The median age of first-line trade supervisors is 45 and the overall construction industry is 41.3 (Bureau of Labor Statistics, 2020). 18% of the current workforce is projected to retire by 2021, 29% by 2026 and 41% by 2031 (National Center for Construction Education & Research, 2016). Also, the millennials are rarely considering trades as their long-time career (Dun & Bradstreet 2019). As the baby boomers (born between 1946 and 1964) are retiring, the individuals who are taking their positions are often criticized for the lack of skills and trade-based expertise (Wu et al., 2018) because of the knowledge gap that exists between the millennials and the baby-boomers along with their disparate approaches to learn new things (Swedberg, 2018). These baby boomers are taking along with them the experience-based knowledge and the key contacts that could be beneficial for the tradespeople who will fill in the positions for the retirees (Eisenberg, 2019). *The problem addressed in this research is the shortage of skills in the construction industry. Not only this industry is facing labor shortage, but the demographics also delineate that a major proportion of the workforce consist of the baby boomers who are going to retire soon which is further widening the skills gap.* There is a need to capture the experience-based knowledge from the potential retires to enhance the skillset of the existing workforce as well as the novices entering the trades. Also, for implementing effective KM strategies, it is equally important to identify the barriers that prevent the transfer of knowledge (Ahmad & An, 2008). Lack of knowledge sharing at the job site leads to rework, errors and wastage of resources (Wiewiora, Trigunarsyah, Murphy, & Liang, 2009).

Assessing the value of supervisors' experience-based knowledge is necessary to plan effective strategies for capturing and harnessing it to fill this growing skill-based knowledge gap that exists between the millennials entering the industry and the experienced supervisors who are retiring. For doing so we need a valid and reliable measure to assess the dependency of field supervisors on tacit knowledge to perform a specific construction task or decision making. The purpose of this study is to gauge the dependence of construction field supervisors on experience-based tacit knowledge by implementing a measure and identifying the barriers to knowledge sharing at three levels: *field team members, supervisor,* and *organization*. These three levels are adapted from a study by Sveiby (2007). The study also culminates through discussing ways to identify and harness this experience-based knowledge to narrow the knowledge gap between the

baby-boomers and the millennials and finally delineating the organizational value of tacit knowledge in the trades.

1.3 Research Questions

The questions that this research is intended to explore are:

1. To what extent do experienced field supervisors rely on tacit knowledge to perform daily tasks?
2. What are some of the barriers to knowledge sharing?
3. Do management and field teams agree on any barriers to knowledge sharing?

1.4 Scope

Experience plays a vital role in the construction industry. Capturing project-specific knowledge from the experts is important to train the novices. Through working experience, an individual acquires different forms of knowledge that are an amalgamation of both context-specific tacit hunches and explicit knowledge. This study involves assessing the extent to which trade supervisors use experience-based tacit knowledge to perform daily construction activities through a set of questionnaires (measure). The aim here is to gauge the supervisors' reliance on tacit or explicit knowledge in performing the routine construction tasks by testing in practice the measure developed by Chilton and Bloodgood (2008). The measure can also be used to analyze the distribution of knowledge among various construction activities i.e. which activities rely more on tacit knowledge and which on explicit.

To strengthen the existing knowledge management strategies, it is equally important to finding out the barriers that prevent knowledge sharing (Anwar, Rehman, Wang, & Hashmani, 2019). Therefore, potential hindrances to the process of knowledge sharing are also identified in the study. Knowledge sharing is important in the construction industry to prevent the issues and avoid mistakes that occurred in the previous projects to save time, cost and resources (Zhang, 2010). Conclusions are made regarding harnessing supervisors' tacit knowledge and utilizing the same to fill the knowledge gap between the baby boomers and the millennials and to enhance the skills of the existing workforce by sharing know-how. Regression analysis is used to figure out the relationship between an individual's tacit knowledge and work experience. The proposed research is limited to executives, project managers, and trade professionals. The data is collected through

surveys, site visits, and semi-structured interviews by phone. The study is divided into two parts: firstly, targeting field supervisors with a questionnaire (measure) to assess the tacit knowledge usage and secondly, identifying the key factors which hinder the process of knowledge sharing among the team members and crews through the survey. A similar survey is used among the project managers and executives to identify the factors which hinder knowledge sharing at construction job sites and comparisons are made based on the perspectives of both field and management from the obtained responses. Assumptions, Hypotheses, Limitations, and Delimitations related to this study are delineated in the forthcoming sections.

1.5 Significance

Knowledge management is key for any organization to sustain itself in a competitive market. The construction industry can be differentiated from other industries due to its project-based nature (Grover & Froese, 2016) and dependency on skills. Most of the construction workers enter the industry as unskilled and they learn through experience and instruction of the supervisors and by performing hands-on tasks. Knowledge management practices have been deployed in this sector and many of them are limited only to capture and assess the explicit dimension of knowledge. The tacit dimension is still relatively unexplored when it comes to a construction job site or field (Grover & Froese, 2016) and often 'the people factor' is ignored in this sector (Pathirage et al., 2005).

The construction field is the area where cost-related decisions are made and the conceptual models are turned to real structures by deploying knowledge and experiences of the personnel. Field supervisors can be compared to the managers and are responsible for looking after day-to-day construction activities in the field (Macneil, 2004). Many have acquired considerable knowledge through experience both as explicit and tacit. The explicit knowledge can be captured easily by codifying verbally or in writing in contrast, the know-how or tacit knowledge does not respond in the same way. The methodology framework and measure used in this research could be deployed by the construction firms at various intervals of the construction process to assess the dependency of field personnel on tacit knowledge to perform a routine construction activity. By doing so, the construction firms could identify the activities or decisions originated in the field where tacit knowledge is involved and incorporate effective strategies to capture and harness that

knowledge that ultimately aids the organizations in achieving profits in the long run (Chen & Mohamed, 2010).

According to Chilton and Bloodgood (2008), by identifying what kind of knowledge organizational members are using to perform a task, helps organizations to improve their existing knowledge management practices and to better match workers to tasks. These organizations can further utilize this captured knowledge to train their existing workforce or newcomers in the industry to enhance their skills and improve productivity. Also, by identifying the barriers which prevent the sharing of knowledge among the construction personnel, organizations could take necessary actions to shatter those barriers and implement efficient and effective knowledge management processes and strategies (Carrillo, Robinson, Al-Ghassani, & Anumba, 2004).

The purpose of this study is to assess the tacit dimension of knowledge among field personnel, identify the barriers to knowledge sharing and decipher the ways to enhance the skillset of construction workers and to close the boomer-millennial knowledge gap. The purposed measure is intended to aid construction organizations to prepare beforehand by identifying the routine activities that require a significant dependency on tacit knowledge and help them in strengthening existing strategies to capture the experience-based tacit knowledge of the field supervisors before it steps out of the door.

1.6 Hypothesis

The research gauges the reliance of experienced field supervisors on tacit knowledge used to perform day-to-day routine tasks at the job site. The hypothesis proposed for this research is:

> H_0: With experience, field supervisors rely more on their acquired tacit knowledge to perform day-to-day activities.

1.7 Definitions

Knowledge: In construction industry perspective Knowledge can be best defined as a set of personal capabilities, skills, information and experiences which an individual applies to solve a problem (Baker et al., 1997).

Knowledge Management: Knowledge management is defined as the process which includes creating, securing, capturing, coordinating, combining, retrieving and distributing knowledge (Tserng & Lin, 2004).

Tacit Knowledge: The best definition of tacit knowledge from the construction field perspective is "knowledge that people usually acquire individually or as a group in the workplace as in the process of learning by doing" (Panahi, Watson, & Partridge, 2013, p.384).

Explicit Knowledge: It is defined as "knowledge that can be expressed in a formal and a systematic language and shared in the form of data, scientific formulae, specifications, manuals and such like" (Nonaka et al., 2000, p. 7).

Experience: The well-suited definition of experience for this study is "Familiarity with a skill or field of knowledge acquired over months or years of actual practice and which, presumably, has resulted in superior understanding or mastery" (Business Dictionary, 2020).

Collaboration: The best definition of collaboration from the construction field perspective is "where workers share information and ideas with one another through interactions" (Joy & Haynes, 2011, p. 217).

Mentoring: The best definition of collaboration from the construction field perspective is "where knowledge workers share their experiences, usually from experienced to less-experienced staff" (Joy & Haynes, 2011, p. 217).

Field Supervisor: Field supervisors act as an interface between management and the trade professionals (Dowell & Wexley, 1978) that are responsible for supervising directly the daily construction activities and managing the construction trade workforce. In this research, the term 'Field Supervisor' encompasses superintendents, foreman, journeymen, and any other designated individuals who are directly responsible for overseeing various construction and trade activities in the field.

Baby Boomer: "Baby Boomer is the term used to describe a person who is born between 1946 and 1964" (Nafei, Khanfar, Kaifi, Nafei, & Kaifi, 2012, p. 88).

Millennials: Also called Generation Y, are the cohort of individuals born after 1980 (Nafei et al., 2012, p. 88).

Expert: The best definition of an expert from this research perspective is, Individuals who have developed knowledge, skills, and abilities required to be successful in a particular domain (Sternberg et al., 2000, p. 1).

1.8 Assumptions

Following are the assumptions that establish the basis of this study:

1. The participation is assumed to be voluntary and under no external or internal coercion.
2. It is assumed that the participants have acquired enough experience and knowledge in their respective fields and the responses are based on the same.
3. There is no significant amount of difference in the survey responses from the participants according to their organization, project, area of work and functional role.
4. The participants are assumed to understand the meaning of survey questions and the scale utilized the same way as the researcher intended.
5. Two dimensions of knowledge are taken into consideration: explicit and tacit. It is assumed that all forms of knowledge fall within this classification.
6. It is assumed that the participants are honest with their answers and the answers are not affected by the presence of other individuals or their state of mind during the survey.
7. It is assumed that the level of individual experience doesn't influence answers to the survey responses.
8. The survey generated uses online software that is assumed to be compatible with the devices being used by the participants.
9. The individuals answered the survey questions truly and without any biasing.

1.9 Limitations

The limitations of this study are:

1. Sometimes lack of knowledge about a specific construction activity may result in the proclivity of the answers in the semantic differential measure more towards the tacit side (Chilton & Bloodgood, 2008). Hence, it would be difficult to differentiate between experience-based answers or an answer based on just a lack of knowledge.
2. All the knowledge is thought to fall within the purview of tacit and explicit knowledge.
3. No specific sample size is selected for this research since the researcher implemented the snowball sampling technique to implement the proposed measure, and the participants were selected through referrals.

1.10 Delimitations

Following are the delimitations of this study:

1. Because of the time frame and for data collection, this study only considered the local specialty contractors in Indianapolis for implementing the survey measure to identify the extent to which field supervisors use tacit knowledge. This could impact the generalizability of the findings.
2. Participants below 18 years of age are not included in this study.
3. The research covers identifying the reliance of the field supervisors on tacit or explicit knowledge only for the activities or the situations dictated by the respondents during the semi-structured interviews.
4. Only two dimensions of knowledge are considered i.e. tacit and explicit. There may be other forms of knowledge that are not addressed in this research.
5. Contractors apart from specialty are not included in this study. This could also impact the generalizability of the overall findings.
6. Only union-based contractors are targeted as key participants for the second part of the study i.e. in identifying the potential barriers to knowledge sharing.

1.11 Summary

This chapter delineates the basic outline of this research. It provides a brief description of the study objective along with its context. By defining the assumptions, limitations, and delimitations, the researcher intends to define the boundary of the study. This chapter also provides definitions of some of the terms frequently used in the study. The forthcoming chapter deals with a theme-based literature review to provide more insights into various knowledge related terminologies and the previous efforts to harness tacit knowledge.

CHAPTER 2. REVIEW OF THE LITERATURE

2.1 Introduction

As a result of the economic recession at the beginning of the 21st century along with a relatively large cohort of baby boomers, the proportion of older trade professionals in the US construction industry has increased significantly. Reduction in the rate of younger workers' ingress in this industry due to their less proclivity for doing hands-on work and the larger proportion of baby boomers is a challenging issue (Schwatka, Butler, & Rosecrance, 2012). The construction industry is continuously facing a serious issue of the labor shortage. The shortage of workforce is impacting construction management too. Many specialty contractors are struggling to fill their trade positions. They have vacant managerial positions for which they are promoting experienced hourly trade professionals to salaried management positions and as a result, creating additional vacancies for skilled trade professionals (Bigelow, Perrenoud, Rahman, & Saseendran, 2019; Tagliaferre & Greenwood, 2002). As these baby boomers retire, they are leaving behind a gap which the millennials are uninterested in filling therefore, deepening further the labor shortage in construction management (Littman, 2017). With the retirement of senior trade supervisors and their promotions to managerial positions, there is a huge need to capture and share their experience-based knowledge or know-how to prepare the construction organizations for fluctuating and unstable labor markets and to keep the construction activities running on the job site. This experience-based tacit knowledge is of great strategic importance than the explicit one (Chen & Mohamed, 2010).

This research mainly focuses on identifying the extent of tacit knowledge usage among the trade supervisors, identifying the barriers in knowledge sharing followed by delineating some methods to capture tacit knowledge. This chapter deals with a thorough review of literature in the field of capturing tacit knowledge concerning the construction industry followed by identified gaps in the strategies of knowledge capturing and sharing in the construction industry, and the possible solutions to filling those gaps. This intent is to help the trade contractors to prepare for the unstable labor markets which fluctuate every year by making incremental adjustments in the individual's skills by identifying the know-how or the parcels of tacit knowledge through a measure and also

finding out the factors which hinder the process of knowledge sharing among the crew members and other teams.

2.2 Methodology for Conducting the Review

A meticulous literature review provides deep insights into what research has been done in this field with an opportunity to identify the voids in that research. The review of the literature incorporates a qualitative research approach. To conduct the review of the literature, the researcher used several databases including but not limited to the “Engineering Village”, “Scopus”, and “ProQuest Technology Collection” mostly with the range of last 20 years. The review includes highly ranked peer-reviewed journals, conference proceedings, and thesis. Also, a few construction magazines and web-based articles like the Electrical Contractor magazine, industry reports and organization survey statistics are used to reflect the current scenario of the industry. The key concepts for this literature review and their relationships are depicted in Figure 1 using the Venn diagram. The intersection point of all the Venn circles represents the area of concern for this study.

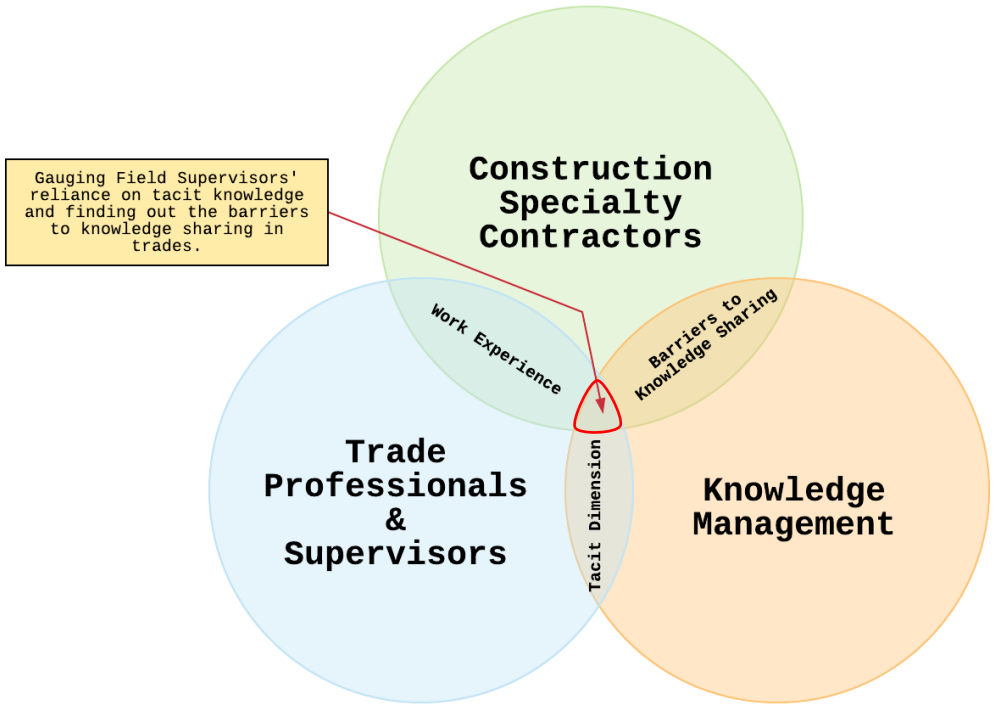


Figure 1- Key concepts and their relationships

Knowledge and its dimensions are identified in the first step to make a clearer picture of the tacit dimension of knowledge followed by the previous efforts in gauging tacit knowledge and identifying the gaps.

2.3 Knowledge and its Dimensions

What does it mean when someone says that I know how to do this or that? What are the dimensions of knowledge? To understand the knowledge, it's important to understand its basic classification. The intent here to explore several definitions of knowledge and its dimensions from various perspectives. Knowledge is one of the key factors behind human action. According to Albert Einstein, "*Knowledge is the experience. Everything else is just information."* Knowledge is a concept like gravity which cannot be seen but its impacts can be perceived (Hunt, 2003). One of the most agreed definitions of knowledge is "*justified true belief*" (Bolisani & Bratianu, 2018; Nonaka & Takeuchi, 1995, p. 21). It is a set of personal capabilities, skills, information and experiences which an individual applies to solve a problem (Baker et al., 1997). There are various definitions coined by several authors albeit this word "knowledge" remains fuzzy. Various cultures have contrasting perceptions of knowledge like western and eastern philosophers differ in their viewpoints regarding the extent to which it is possible to separate knowledge from the knowers. While westerns treat knowledge like a 'thing' which can be easily shared and traded among the users whereas, in the east, they consider knowing as a process that is inseparable from the users (Quintas, 2005). The western epistemology considers *truthfulness* as the main knowledge characteristic (Bolisani & Bratianu, 2018). There is no consensus in delineating the actual definition of knowledge. To some, it is just the art of knowing something while for others it is way more complex.

Polanyi (1966) classifies knowledge into two categories: *tacit* and *explicit* further highlighted by Nonaka and Takeuchi (1995), and Smith (2001). Tacit knowledge cannot be communicated smoothly to others as compared to explicit knowledge which can be easily codified and shared. Figure 2 depicts some of the characteristics of both tacit and explicit knowledge. These two dimensions of knowledge can also be viewed as the difference between "knowing that" and "knowing how" with regards to the work being performed (Wilkinson et al., 2015).

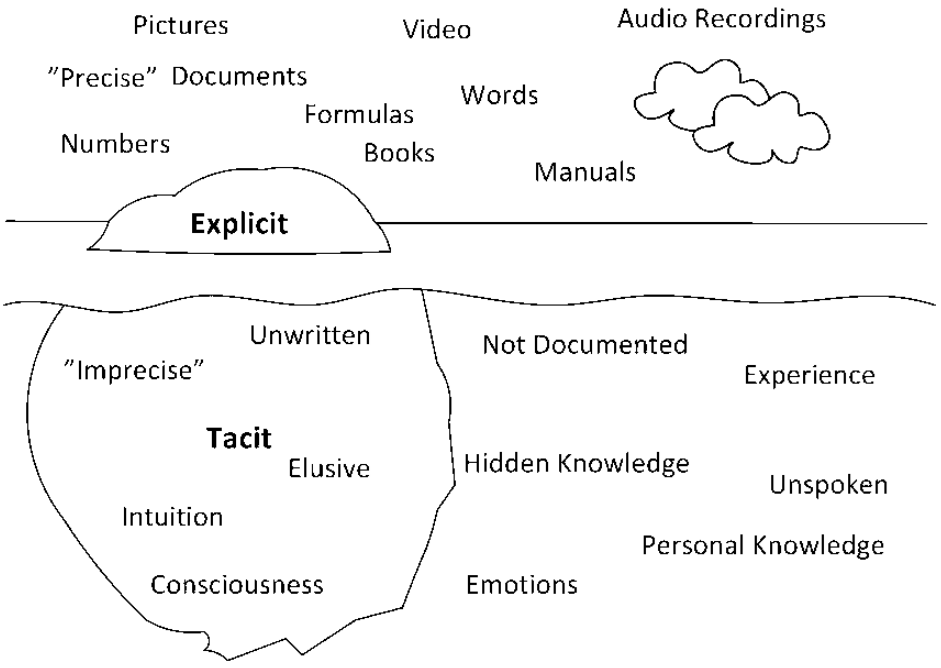


Figure 2- Tacit vs Explicit knowledge (Wikström, 2014)

Both tacit and explicit forms are essential for knowledge creation and are complementary to each other and their interactions ensue the knowledge creation process (Nonaka et al., 2000). There are many other classifications of knowledge like personal, public and shared; pragmatic and theory-based; hard and soft; internal and external, etc. but the classification by Polyani (1966) remains the most common (Pathirage et al., 2008).

2.3.1 The Explicit Dimension

The first dimension of knowledge taxonomy by Nonaka and Takeuchi (1995) is explicit knowledge. Explicit knowledge can be defined as codified knowledge that can be transferred easily and is transmittable systematically and formally (Woo, Clayton, Johnson, Flores, & Ellis, 2004). Organization's electronic and paper-based documents like contracts, specifications, online databases, manuals, and similar tools, constitute explicit knowledge (Ahmad & An, 2008). Similarly, in the construction sector, standard working procedures, contract documents, specifications, and other construction documents are perfect examples of explicit knowledge. This knowledge can be communicated to others in the form of symbols (Quintas, 2005) or the form of a formal and systematic language (Nonaka et al., 2000), for instance, laws of motion or

mathematical formulas. It can be disseminated or transferred in the form of email, meetings, documents and telephone meetings, and this knowledge is formal and public (Halonen & Laukkanen, 2008). Briefing in simpler terms, explicit knowledge can be captured easily in manuals, reference documents, similar likes and can be retrieved when required e.g. specifications, contract documents, standard working procedures, log sheets, etc.

2.3.2 Tacit Knowledge: What it is?

The other dimension of knowledge taxonomy by Nonaka and Takeuchi (1995) is what we call as tacit knowledge. To explain the concept of tacit knowledge, Polyani (1966) in his book "The Tacit Dimension" gave an example of riding a bicycle. To someone who doesn't know how to ride it, we could probably explain the procedure to ride but the individual has to physically ride a bicycle to synchronize pedaling with balance. Individuals acquire tacit knowledge through experience and it is difficult for them to explain it to someone who is not on the same wavelength or lack similar learning experiences (Quintas, 2005). Similarly in the construction industry especially if talking about trades, an individual must have hands-on experience with tools and equipment to perform the task. There is no beginner's luck in the construction industry. It's the experience that matters.

Tacit knowledge is gained through life experiences, training, and education which is beyond conscious awareness. It is the knowledge possessed by an individual which guide intuition and insights during making important decisions within seconds (Gasaway, 2017). Some relate tacit knowledge with wisdom (Smith, 2001) whereas others compared it to an iceberg where the floating part is explicit knowledge and the part beneath the seawater corresponds to tacit knowledge which is invisible and difficult to express (Pathirage et al., 2007). Tacit knowledge is based on an individual's experience which is hard to communicate and formalize. One can acquire tacit knowledge through observations, imitations, and practice (Teerajetgul & Chareonngam, 2008). Some definitions of tacit knowledge are: "knowledge that people usually acquire individually or as a group in the workplace as in the process of learning by doing" (Panahi et al., 2013, p. 384); "tacit knowledge is subjective knowledge that is difficult to formalize, articulate, and communicate to others, such as personal experiences, professional insights, and know-how in a specific area" (Huang, Hsieh, & He, 2014, p. 817); "tacit knowledge is the intangible elements of an organization, acquired through practice and they are adaptable to the situation" (Arduin, Mayag, Negre, & Rosenthal-Sabroux, 2014, p. 100). There are several definitions of tacit knowledge and there is

much consensus among them. To conclude in simpler terms, if the knowledge is difficult to codify, it's tacit. Some authors quote it as "elusive knowledge", or "collective wisdom", or inarticulate intelligence" (Stover, 2004).

There are two further dimensions of tacit knowledge: technical knowledge and cognitive knowledge (Nonaka & Takeuchi, 1995) as shown in Figure 3. Styhre (2009) used the term "*Aesthetic knowledge or sensible knowledge*" concerning trade professionals engaged in rock construction work. This aesthetic knowledge is considered as a special form of tacit knowledge and is embedded both in explicit and tacit knowledge i.e. a combination of both know-hows. According to Mahroeian and Forozia (2012), there are are many epitomes to define tacit knowledge in day-to-day working life e.g. gut-feeling, rule-of-thumb, intuition and individual skills and they together constitute the technical and cognitive dimensions. Smith (2001) also put forward Nonaka and Takeuchi's (1995) theory and delineates, when individuals master a certain body of knowledge or skills like those developed by master craftsmen, technical dimension is demonstrated whereas, imbibed perceptions, viewpoints, beliefs and mental models constitute cognitive dimension. To summarize, the cognitive dimension is the conception of reality (Pathirage et al., 2008) and is difficult to articulate. Winanti et al. (2020) stated that tacit knowledge can be measured form of these two dimensions: technical and cognitive, where the "technical dimension is in form of skills that are difficult to formalize" (p.184), and cognitive dimension that is hard to articulate represents trust attitudes, idealism, values, personal emotions, mental models, perceptions and solidarity. This further division of tacit knowledge can be explained by considering epistemological differences in Japanese and Western thinking on the codification and diffusion of tacit knowledge (Pathirage et al., 2008). These two schools i.e. Western and Japanese, have different viewpoints regarding codification and externalization, to one (Japanese) tacit knowledge can be made explicit for sharing whereas for other (Western) tacit knowledge always be tacit (Mahroeian & Forozia, 2012).

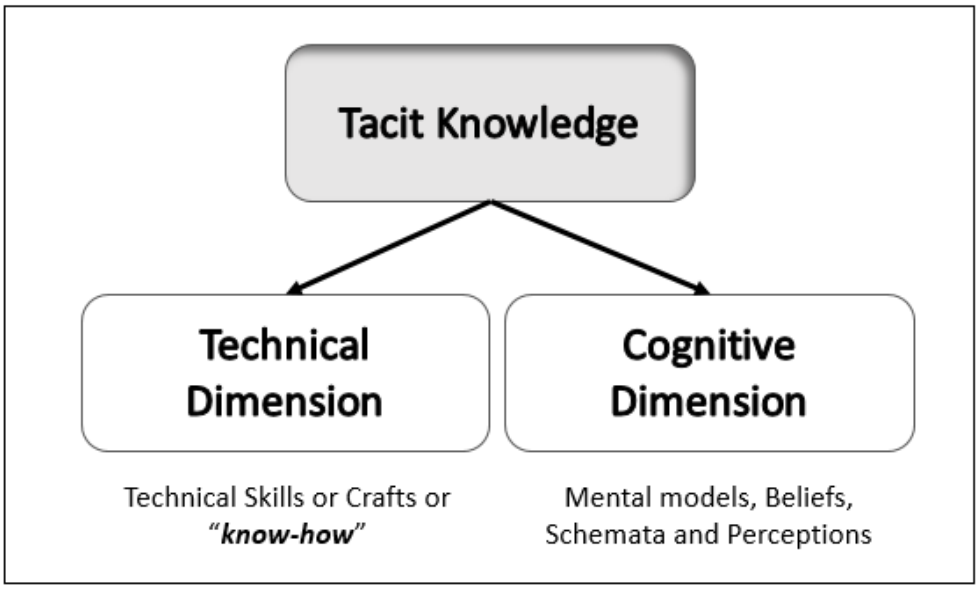


Figure 3- Two dimensions of Tacit Knowledge (Nonaka & Takeuchi, 1995)

According to Meloni and Villa (2007), by identifying the hidden tacit knowledge in the projects it can be used to enhance the project performance along with the development of new knowledge which can be reused in similar projects within the organization. The construction industry is characterized by its project-based nature which is constantly changing with the progress of the project. Many key players form temporary organizations and the creation of knowledge occurs at various levels. This temporary nature must be addressed while dealing with knowledge creation in construction (Martin & Hartmann, 2010).

2.4 How Knowledge is Created and Used?

The publication "Knowledge-Creating Company" by Nonaka and Takeuchi (1995) was a turning point in the field of knowledge management. They put forward the theory of knowledge creation according to which knowledge is created by following modes of interaction: Socialization: *tacit to tacit;* Externalization: *tacit to explicit*; Combination: *explicit to explicit*; Internalization: *explicit to tacit* (SECI). This model is known as the SECI model of knowledge creation (see Figure 4). The key elements of this model are SECI, Ba, and Basho.

SECI: According to Nonaka et al. (2000):

-through “Socialization”, individual experiences are shared with others which lead to the sharing of tacit knowledge employing apprenticeship training or informal gatherings. Through this process, experiences are disseminated and knowledge is created through sharing technical skills and mental models (Winanti et al., 2020).

-“Externalization” is the process through which tacit knowledge is converted to explicit form by using analogies, metaphors, images, and models. Conceptualization to generate a new product can be linked to externalization (Winanti et al., 2020).

-“Combination” is the conversion of explicit knowledge to a more structured and systematic form of explicit knowledge. Gathering knowledge from different sources on the web and then combining it in the form of a report is an example of a combination.

-The last element of the SECI model is “Internalization” which is the process to embody explicit knowledge into tacit knowledge. It is more about having hands-on experience or learning by doing.

The concept of *Ba*: Nonaka et al. (2000) differentiated knowledge from information by its context-based nature. Physical context is essential to create knowledge. “ba is the shared context in which knowledge is shared” (Nonaka et al., 2000). Ba is the shared space for emerging relationships. This space could be physical (e.g., construction field, office, etc.), virtual (e.g., e-mails, virtual 3d models, etc.), mental (e.g., work experiences, ideas, beliefs, etc.) or any combination of these three (Nonaka & Konno, 1998).

Basho: It is a greater place for interaction or greater ba (Nonaka & Konno, 1998).

This knowledge creation through the SECI process stimulates a new spiral knowledge creation as shown in Figure 4 which expands vertically as well as horizontally as it goes beyond the hierarchical boundaries in an organization (Takeuchi, 2006).

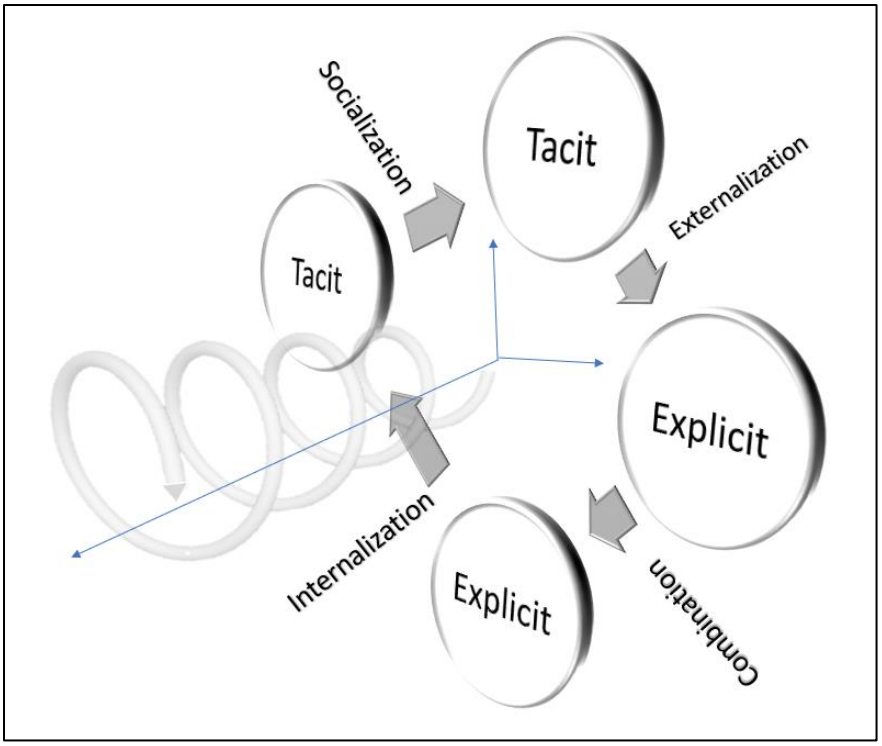


Figure 4- SECI model adapted from Nonaka and Takeuchi (1995); Takeuchi, (2006)

This model became the fundament of many knowledge models (Ninaus & Knapp, 2019). Martin and Root (2009) discussed the usability of the SECI model in the construction industry. They highlighted the project-based nature of the construction industry where several stakeholders continuously interact with each other like subcontractors, vendors, suppliers, and so on. This project-based nature of the construction industry along with the knowledge conversions of the SECI model makes it enter continuously the SECI spiral and hence creating and amplifying knowledge. However, this model failed to address well how these interactions generate knowledge in an organization (Martin & Hartmann, 2010).

For the construction industry, Socialization (tacit to tacit) plays a crucial role in knowledge creation (Martin & Root, 2009). Socialization captures knowledge from physical proximities. When an individual transfers one's ideas or experiences to another, there is a sharing of personal knowledge and according to Nonaka and Konno (1998), a common space/place or "ba" is created (see Figure 5). Ba is a Japenese term for "shared space of interaction" (Meloni & Villa, 2007). The key aspect of this common space is interaction. A similar type of interaction occurs when the construction crew and supervisors are working in the field. They share know-how and other

construction-related knowledge continuously. Communities of Practice (CoP) are similar to "ba" where knowledge sharing occurs among the individuals through interacting continuously. These types of places of knowledge can emerge between individuals, groups, organizations, project teams, temporary meetings, etc. (Nonaka & Konno, 1998). There are four types of *Ba*: Originating ba, Interacting ba, Cyber ba, and Exercising ba. Among these, originating ba enhances face-to-face interactions and hence sharing tacit knowledge through socialization (Meloni & Villa, 2007). When these participants (construction workers) in ba spend more time together, they interact and communicate, ask questions, observe other's actions and hence more knowledge is grasped (Skinnarland & Yndesdal, 2014).

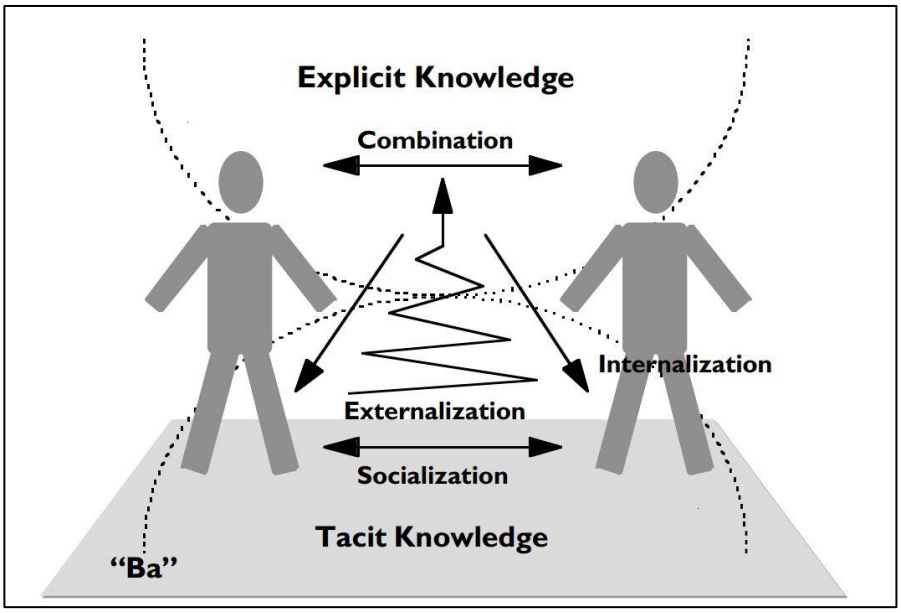


Figure 5- Ba and Knowledge Conversion adapted from Nonaka and Konno, (1998, p. 44)

Through their SECI model, Nonaka and Takeuchi (1995) did not differentiate between the implicit and tacit nature of the knowledge and they posited that this implicit knowledge can be made explicit through externalization (Pathirage et al., 2008). However, according to Polanyi (1966), there is a clear distinction between implicit and tacit nature of knowledge. Tacit knowledge is held in the mind of individuals in a non-verbal form and hence the holder of this knowledge cannot verbally communicate or express it to another individual (Pathirage et al., 2008). Based on the epistemological concepts of knowledge generation, autopoietic epistemology or autopoiesis is considered as the basis of tacit knowledge generation which delineates that knowledge is a self-

productive process (Pathirage et al., 2008) and in construction industry mostly the learning is project and experience-based (Bresnen, Edelman, Newell, Scarbrough, & Swan, 2003).

Another model for knowledge creation is Kolb's four-stage model (see Figure 6) based on the theory of learning from the experiences. This model has been rarely applied to the construction industry (Bijleveld & Dorée, 2014). Like the SECI model, Kolb's model has four stages: Experience; Reflection; Conceptualization and Implementation. A new experience is generated, or a new situation is encountered that acts as a stimulus followed by its understanding, conceptualizing and implementation by the learner to see the result. This process is cyclic and triggers experience-based learning (Kolb, 2014). According to this model, knowledge is created by the transformation of work experience which plays a central role in the process (Bijleveld & Dorée, 2014).

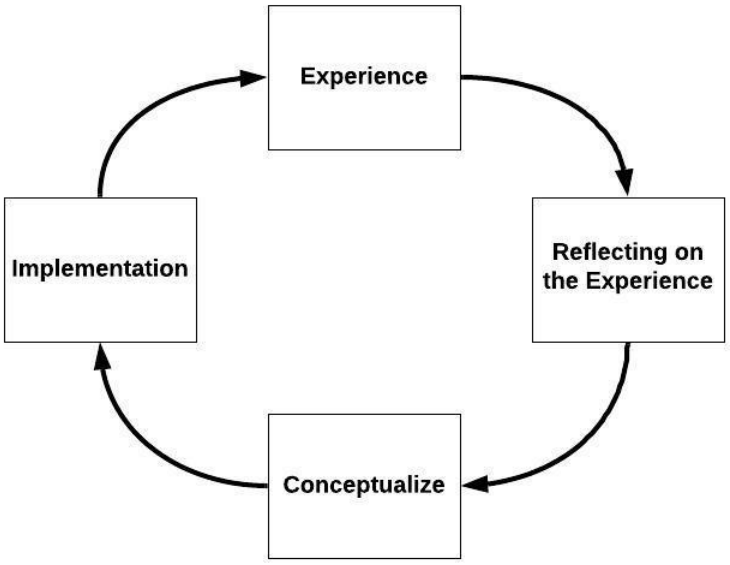


Figure 6- Kolb's Learning Model adapted from Kolb, (2014)

Pathirage et al. (2008) discussed the validity of Kolb's model in the generation of tacit knowledge in construction. Experience initiates tacit knowledge creation; Reflection helps in fathoming and processing it; Conceptualization dictates it into theory or concept and Implementation allows the user to act based upon the knowledge gained (Pathirage et al., 2008). Bijleveld and Dorée (2014) incorporated 'process monitoring' in Kolb's learning model to instigate change from tacit to explicit learning in a road construction project and to identify the

operator's experience-based knowledge. Highlighting the construction industry, reflection plays a vital role in learning from past experiences and implementing the lessons learned in future projects (Pathirage et al., 2008). Field supervisors and trade professionals similarly must learn from their past experiences for future decision-making in the field.

2.5 Knowledge in the Construction Industry

In the Information Technology (IT) sector, where most of the knowledge is codified, Knowledge management is a common term. It is a process that includes creating, securing, capturing, coordinating, combining, retrieving and distributing knowledge (Tserng & Lin, 2004). Potential knowledge is stored in the form of databases and this data can be retrieved when required. Coming to the construction industry, where most of the knowledge is experience-based and resides in the heads of people, it is important to reuse and share knowledge so that the construction processes could be improved with cutting off the extra cost and time required to solve the issues. Itis people who deliver construction projects, not the systems or processes (Pathirage et al., 2007). By reusing shared knowledge, management performance can be improved in terms of cost, time, and quality which further boosts the concept of knowledge management in construction (Hu, 2008). Construction-based Knowledge Management transfers and shares both knowledge and experience among engineers effectively and systematically (Lin & Lee, 2012). But this is not merely applicable to engineers only, it is equally related to supervisors, superintendents, trade professionals and other stakeholders associated with the project. Several methods are being employed at job sites where people share or transfer knowledge like face-to-face interactions, person-to-document, communities of practice, etc. Face-to-face interactions are the most direct method to transfer the experience-based or tacit knowledge among the workers (Sun & Ren, 2014). Construction industry's *raison d'être* is reinforced by the knowledge and skills possessed by its individuals. According to Kivrak et al. (2008), reducing rework is identified as the most important driver for knowledge management followed by responding to clients. In the AEC industry, not many efforts have been put forward to decipher the concept of tacit knowledge and knowledge worker (Pathirage et al., 2006).

According to Smith (2001), some companies practice knowledge management in two steps: first, they learn what local knowledge exists and second, they circulate the valuable knowledge and the processes involved are: Codification (person-to-document) approach to capture explicit

knowledge to create knowledge databases which can be extracted later by other employees and Personalization (person-to-person) to manage tacit knowledge with a focus on the dialogue between individuals rather than taking notes on a piece of paper. When knowledge is treated as an asset codification processes are considered whereas personalization processes dominate while considering knowledge as a process (Pathirage et al., 2008). Potentially useful knowledge can be stored and recorded in many ways like documents, videos, images, and databases. When tacit knowledge is captured and made explicit, it acts as the foundation of new knowledge in the form of images, concepts, codified construction documents, standard operating procedures, and similar (Teerajetgul & Chareonngam, 2008). This new form of knowledge can be utilized in several ways to train the workforce to enhance their skillset and to fill in the knowledge gap between the experts and the novices just stepping in the industry. Knowledge in the projects is transferred through several processes like social communication and explicit channels (Wiewiora et al., 2009).

2.6 Barriers to Knowledge Sharing

To implement effective knowledge management strategies, it is equally important to identify the barriers to knowledge sharing and capturing (Carrillo et al., 2004). Sveiby (2007) analyzed the issues that prevent knowledge sharing in organizations and targeted the knowledge workers as the key study participants. Lack of time to share knowledge followed by thinking that knowledge is power and can be used for promotion, are identified as the key barriers to knowledge sharing among the 'group of workers' context; managers not walking the talk followed by lack of management, are identified as the key barriers to knowledge sharing among the 'supervisor/manager behavior context'; and silo mentality of the managers followed by the unconcerned top management are identified as the key barriers to knowledge sharing among the 'organizational context' (Sveiby, 2007).

Carrillo et al. (2004) identified and ranked six major barriers to knowledge management in the UK construction industry (see Figure 7). A lack of standard work processes is identified as the key barrier in implementing knowledge management followed by a lack of time due to the project-specific nature of the construction industry (Carrillo et al., 2004). Small and medium-sized organizations lack resources both human and financial to implement formal processes to knowledge sharing and a substantial amount of knowledge management work is done ad-hoc without even proper planning and efforts (Zhang, 2010). Wiewiora et al. (2009) classified the

barriers related to knowledge sharing related to Project-Based Organizations (PBOs) in three different classes: social communication; inter-project lessons learned transfer; and project manager. Lack of social communication, insufficient time to produce lessons learned and project manager's priority to deliver the project are identified as the key barriers in each class respectively (Wiewiora et al., 2009). Akhavan, Zahedi, and Hosein (2014) also categorized the barriers to knowledge sharing in the Project-Based Organizations (PBOs) into five classes: individual barriers, organizational barriers, technological barriers, contextual barriers, and inter-project barriers. Fear of losing information to the competitors, insufficient knowledge management and lack of proper communication is identified as key individual barriers; lack of rewards and remuneration, lack of resources and inefficient integration of KM with company goals are identified as key organizational barriers; lack of integration to IT systems, inconsistencies among IT system and current organizational processes, and lack of technical support are identified as key technical barriers; lack of an effective mechanism to extracting knowledge, lack of content currency, and old processes of KM are identified as key contextual barriers; and extreme working pressure, lack of standard working processes, and the transient nature of projects are identified as key inter-project barriers (Akhavan et al., 2014).

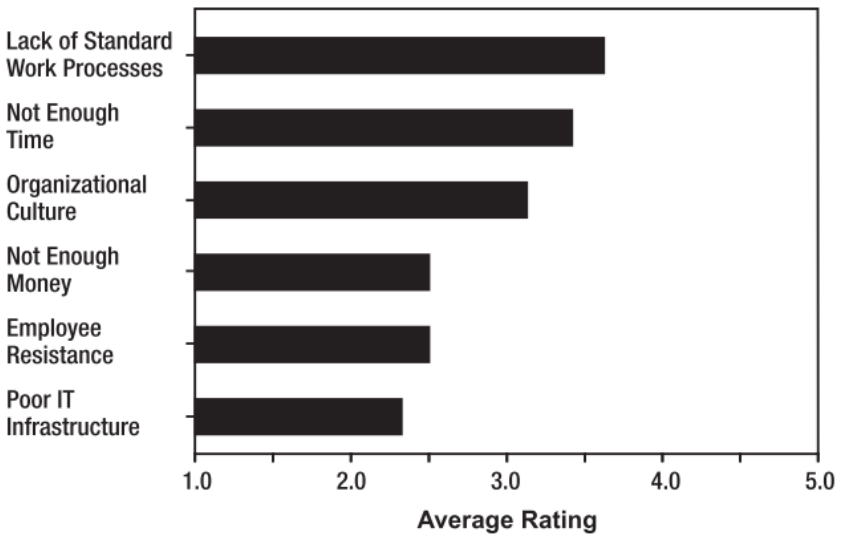


Figure 7- Barriers to implementing knowledge management (Carrillo et al., 2004, p. 53)

Anwar et al. (2019) through systematic literature review identified knowledge sharing barriers at various levels like the individual, technological, organizational, etc. in software

development organizations. Lack of trust, lack of social networking, personal fear and shyness, incompatible professional qualification, lack of time and motivation, and low awareness of self-knowledge are some of the identified individual barriers; lack and improper utilization of knowledge sharing tools, lack of training, contextual difference, lack of central knowledge repositories and templates, and technological knowledge gap are some of the identified technological barriers for knowledge sharing; Poor organizational culture, poor project handling, employee turnover, budget, competition and team growth, and lack of rewards and recognition are some of the identified organizational barriers in knowledge sharing; language difference and disparate cultural norms are some of the identified cultural barriers in knowledge sharing; and time zone difference and geographic distance are identified as geographical barriers (Anwar et al., 2019).

2.7 Transition from Novice to Expert

A novice can be considered as an entry-level individual in a trades profession who lacks basic skills to perform a specific construction task. Apprenticeship training, on-the-job learning, and hands-on-experience play a vital role in adding new skills throughout an individual's experience. The learning process follows an S-curve wherein the beginner stage individual lack competency and accumulates knowledge over time to enhance the capabilities by performing routine tasks (Johnson, 2018). The development of a profession-based skill is highlighted by the five-stage skill acquisition model proposed by Dreyfus and Dreyfus (1986). According to this model, the transition of novice to an expert occurs in five stages along the learning curve: novice, advanced beginner, competent, proficient, and expert (see Figure 8). The best definition of an expert from this research perspective is "individuals who have developed knowledge, skills, and abilities required to be successful in a particular domain" (Sternberg et al., 2000, p. 1). Malcolm Gladwell in his bestseller "Outliers" mentioned that it takes 10000 hours or 10 years of practice to become an expert in a field (Gladwell, 2008). However, in the technical field like construction, the process of becoming an expert is complex and it is difficult to identify the sequence of stages and time it requires to become an expert (Farrar & Trorey, 2008).

Figure 8- Model of skill acquisition adapted from Dreyfus and Dreyfus (1986)

Explicit and systematic learning procedures are required during the novice stage whereas, situation-based judgments and intuitions are more frequent among experts (Scott & Twumasi, 2018). During the learning process, novices and advanced beginners face real-time problems at the job site for which they find codified skills of less use and begin copying and reshaping these skills based on the situation. This context-specific knowledge generated cannot be generalized like standard codified working procedures and it becomes tacit (Boyd & Addis, 2011). Novices rely more on explicit knowledge whereas the experts aid their decisions by utilizing tacit knowledge and relying on intuitions and insights from their work experience.

2.7.1 Field Supervisors' Tacit knowledge and Experience

Field supervisors act as an interface between management and the trade professionals (Dowell & Wexley, 1978) responsible for supervising directly the daily construction activities. Project managers seldom pay visits to the construction site and these field supervisors are the ones who look after day-to-day field operations by managing the resources in the field. Historically, most of these supervisors have attained their position in an organization based on expertise and technical

know-how (Macneil, 2004). These field supervisors and the trade professionals have developed a plethora of knowledge through their experience which they have internalized, and they find it difficult to communicate or decipher this knowledge when asked (Skinnarland & Yndesdal, 2014). This experience-based knowledge is reflected in their relevant know-hows and skills that influence their job performance (Hedlund, Antonakis, & Sternberg, 2002). They use this experience-based knowledge in day-to-day routine decision making and when asked how they are so efficient in their jobs; they often reply that they have learned it through 'experience' or 'trial and error'. Learning from one's experience is a key to success and reflected in the form of acquisition of tacit knowledge (Hedlund et al., 2002). As per Joe, Yoong, and Patel (2013), "an expert demonstrates higher levels of efficiency, performs tasks with greater accuracy and cost-effectiveness and holds subject-specific knowledge, such as on methods and procedures, including knowledge of how to deal with problems and new solutions" (p. 915). These field supervisors being experts in their fields, upon retirement are taking away all their experienced-based knowledge along with them that if retained, could be beneficial to the employees filling in their positions and enhancing the skill set of the existing workforce through training. Hence, there is a huge need to identify, assess and capture this experience-based tacit knowledge.

2.8 Challenges to Manage Knowledge Sharing in the Construction Industry

A substantial amount of experience-based knowledge in the form of technical know-how, project-related issues, and decisions, lessons learned, best practices, and similar often resides in the heads of individuals (Khuzaimah & Hassan, 2012). Oftentimes the supervisors are unable or unwilling to explain: how this tacit knowledge has been generated or used practically (Wilkinson et al., 2015). Most of the initiatives so far have focused on capturing and managing explicit knowledge and the tacit dimension is relatively ignored (Khuzaimah & Hassan, 2012). The time essence of construction projects and the lack of processes to analyze the lessons learned from the previous projects are some of the challenges to share knowledge among the construction parties. Other factors that hinder the transfer of tacit knowledge in the construction industry are its transient nature, labor dependence, fragmented nature and some unprecedented problems which are unique to a project (Nesan, 2012). Due to geographic dispersion along with the time essence of the projects, there is a lack of social interaction that prevents the sharing of tacit knowledge (Wiewiora et al., 2009). The temporary and unique nature of construction projects along with the transient

nature of project teams leads to a substantial amount of knowledge loss which is termed as 'project-amnesia' by Sun and Ren (2014). Also, every construction project is unique with notable disruptions in the flow of manpower, materials, and knowledge. Various trade professionals together constitute the entire workforce with different knowledge bases and even language that make it challenging to codify knowledge (Bresnen et al., 2003).

2.9 Workforce Attrition and Brain-drain

The demand for construction labor is growing day-by-day among the trades' contractors and there aren't enough skilled people to satisfy it. According to the AGC 2018 data, 81% of the contractors are finding it difficult to fill in their trade positions. The proportion of the older trade professionals in the labor force is projected to increase from 23.1% in 2018 to 25.2% in 2028 (Bureau of Labor Statistics, 2019b). The median age of first-line trade supervisors is 45 and the overall construction industry is 41.3 (Bureau of Labor Statistics, 2020). Attrition is another challenge that is responsible for the growing departure of the skills and experience-based knowledge at the time when the US construction industry is experiencing a greater shortage in the workforce. According to the Bureau of Labor Statistics (2019a), the employment of the construction workforce is projected to grow by 11% from 2018 to 2028. However, 18% of the current workforce is projected to retire by 2021, 29% by 2026 and 41% by 2031 (National Center for Construction Education & Research, 2016). The brain-drain as a result of these retirements is the growing trend among several industries including construction where the organizations are often failing to have a succession plan to capture the boomer know-hows. These baby boomers upon retirement are taking along with them the experience-based knowledge and the key contacts that could be beneficial for the tradespeople who will fill in the for the retirees (Eisenberg, 2019).

The trade contractors like general commercial contractors are following the status quo where they are relying on the promotion of emerging people from the trades rather than following a systematic and strategic procedure to fill in their management positions hence, creating vacancies in the trades (Bigelow et al., 2019; Tagliaferre & Greenwood, 2002). Millennials are sparsely considering a "trade worker" as their long-term career (Netzer, 2019). Reduction in the rate of younger workers' ingress in the trades-based industry and the larger proportion of baby boomers in the workforce is a challenging issue for the US construction industry (Schwatka et al., 2012). At present, efforts are being made to assess the relationship between the apprenticeship training

and the rate of unemployment to enhance individual's skills during the times of economic decline and growth (Bilginsoy, 2018). With a large cohort of retiring baby boomers, construction organizations must incorporate necessary strategies to retain valuable experience-based knowledge to keep the construction operations running smoothly before it steps out of the door (Sheffield, 2019).

As a result of the economic recession at the beginning of the 21st century along with a relatively large cohort of baby boom generation, the proportion of older trade professionals in the US construction industry has increased significantly (Schwatka et al., 2012). Most of the US workforce is a cohort of persons born between 1946 and 1964 and they are approaching retirement age. As they retire, they carry away with them the experience-based knowledge which they have acquired throughout their employment. There is a need to identify this knowledge to formulate effective strategies to harness this experience-based knowledge.

2.10 Knowledge Transfer: A Construction Industry Perspective

Knowledge transfer occurs when knowledge is exchanged between the workers (Joy & Haynes, 2011). Following are the ways how knowledge is shared or transferred in a construction project:

2.10.1 Face-to-face interactions

The direct method to share tacit knowledge. Supervisors or engineers often termed as 'knowledge suppliers', use know-hows to make decisions in the field by integrating their experiences with engineering techniques whereas, the knowledge recipients like crew members or labor grasp this knowledge via face-to-face interactions and apply it in day-to-day construction activities (Sun & Ren, 2014). Workers can share knowledge via collaboration where they share ideas and information through interactions (Joy & Haynes, 2011). Mental models and technical skills can be shared by observations, imitations and joint practices (Meloni & Villa, 2007).

2.10.2 Documents

A common method to share explicit knowledge. This knowledge is further divided into specific knowledge and general knowledge. Specific knowledge consists of project drawings, construction organizational plan, project-specific documentation, and similar tools whereas, general knowledge

includes general contract specifications and organizational policies which are similar for multiple projects (Sun & Ren, 2014).

2.10.3 Communities of Practice

According to Khuzaimah and Hassan (2012), CoPs are the voluntary groups of individuals from inside and outside of the organization, interacting together openly and collaboratively to facilitate knowledge sharing and collective learning by developing shared repertoires of resources, procedures, tools, and similar to tackle recurring problems.

2.10.4 Mentoring

It is a process of knowledge transfer where experienced trade professionals share their experiences usually with less experienced staff (Joy & Haynes, 2011) by showing them the ropes (Smith, 2001). This is an effective way of sharing tacit knowledge.

2.10.5 Storytelling

Knowledge sharing is important for generating new knowledge and for the survival of a firm in a competitive market. Storytelling is one of the identified methods for tacit knowledge sharing. Leung and Fong (2011) asserted the effectiveness of storytelling to share knowledge in the construction industry. Stories are memorable, people-centered, encouraging creativity, emotion handling, entertaining, economical, and helping in making sense of complex situations; that coevolve along with the organization's culture (Leung & Fong, 2011). Highlighting construction industry and its project-based nature, learning histories or lessons learned is one of the examples to share knowledge in the project environment that can be deployed to manage the construction project knowledge (Leung & Fong, 2011).

2.11 Assessing Tacit Knowledge: Previous Efforts

Sternberg, et al. (2000) initiates the quantification of tacit knowledge to identify the relation between effective performance and tacit knowledge. There are several methods developed to measure real-world competencies like the critical incidence technique, simulation approach, and situational judgment techniques. To measure tacit knowledge, which is linked to practical

intelligence, Sternberg, et al. (2000) developed the 'tacit knowledge approach' based on the methods to measure real-world competencies. The framework for the developed approach by Sternberg, et al. is shown in Figure 9. In critical incidence technique, critical incidents are identified by interviewing the domain experts, after analysis, nature of the competencies to be successful are identified in each domain followed by categorization and drawing conclusions about ineffective and effective behaviors; in simulation approach, observations regarding people behavior are made based on the assigned realistic simulated situations, responses to these situations are considered as the responses to the real situations; and in situational judgment technique considered as a low-fidelity test, descriptions of work-related situations are provided, critical incident analysis is performed to select the critical situations followed by a set of options, respondents are asked to rate the effectiveness of each option (Sternberg, et al., 2000). The tacit knowledge approach combines critical incident analysis, simulation approach and situational judgment technique to develop a measure to quantify tacit knowledge (see Figure 9). The scoring of these measures relies on the judgments from the experts (Sternberg, et al., 2000).

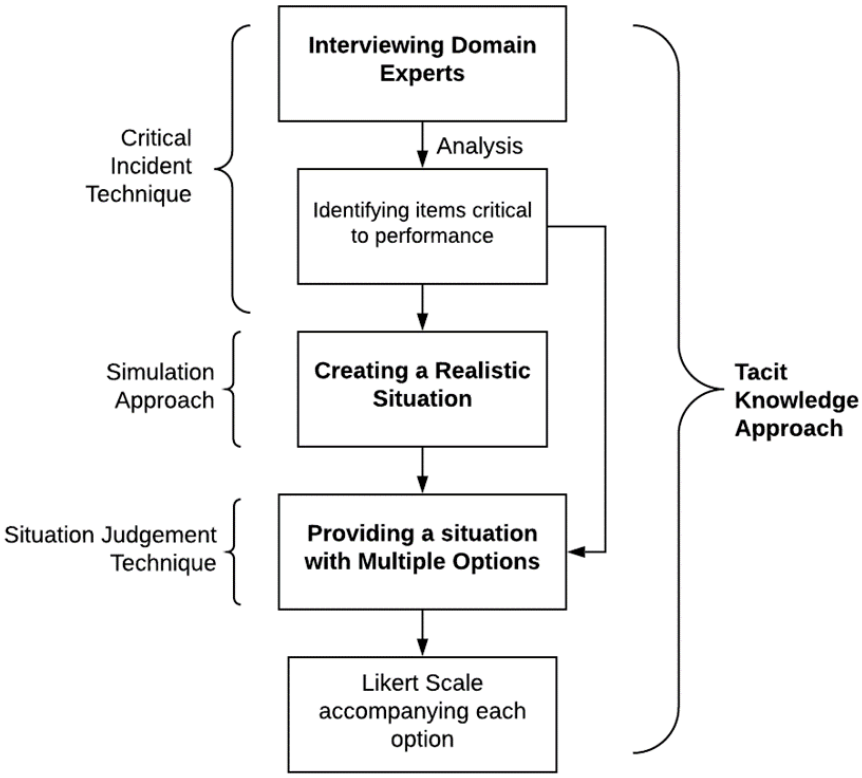


Figure 9- Tacit knowledge approach developed by Sternberg, et al. (2000)

2.11.1 In Academia

Various approaches have been adopted in academia to measure and identify tacit knowledge. Leonard and Insch (2005) formulated a six-factor model and a measure of tacit knowledge in academia based on the GPA as final performance indicator; implicit nature of tacit knowledge was incorporated using the social dimension along with technical and cognitive. The model developed was domain-general with self-motivation, self-organization, individual task, institutional task, task-related interaction, and social interaction being the six factors for measuring tacit knowledge (Leonard & Insch, 2005). Graduate students were interviewed regarding the knowledge which they felt important to success as undergraduates, followed by interviewing undergraduates; themes were created based on their responses with total 52 items; and finally, a semantic differential scale was used to create the measure based on the sorted themes and items (Leonard & Insch, 2005). Highlighting the construction industry, there is no specific performance measure like GPA to assess the tacit knowledge of the field supervisors.

Another research to measure tacit knowledge was conducted by Chilton and Bloodgood (2008). They developed a four-dimensional model based on the factors thought to be contributing to the tacitness of knowledge. The ideology behind developing the instrument to measure tacit knowledge was gauging the dimensions contributing to the tacitness of knowledge (Chilton & Bloodgood, 2008). Conscious awareness, Expressibility, Demonstrability, and Formal/Informal application were the four dimensions identified to generate a hypothesized model for measuring tacit knowledge. A 27-item pool was created, each accompanied with a semantic differential scale, with an electronic slider which was later converted to a 1 to 5 Likert scale for quantification (Chilton & Bloodgood, 2008). According to this instrument, the higher the score, the more they rely on explicit knowledge. Moreover, the model and instrument developed by Chilton and Bloodgood (2008) were deployed in academia where the subjects under consideration were engaged in relatively explicit tasks, the instrument is replicated in this study to verify the usefulness of this scale in construction and to assess the field supervisors' reliance on tacit knowledge which is further discussed in Chapter 3 in detail.

2.11.2 In Military

Tacit Knowledge inventories for Military Leaders (TKML) is a great example of research in the field of identifying and assessing tacit knowledge. Hedlund et al. (1998) established the TKML construct validity to assess the role of tacit knowledge in developing military leaders and identified that tacit knowledge plays a vital role in the effectiveness of leadership. The framework for the development of TKML inventory is shown in Figure 10.

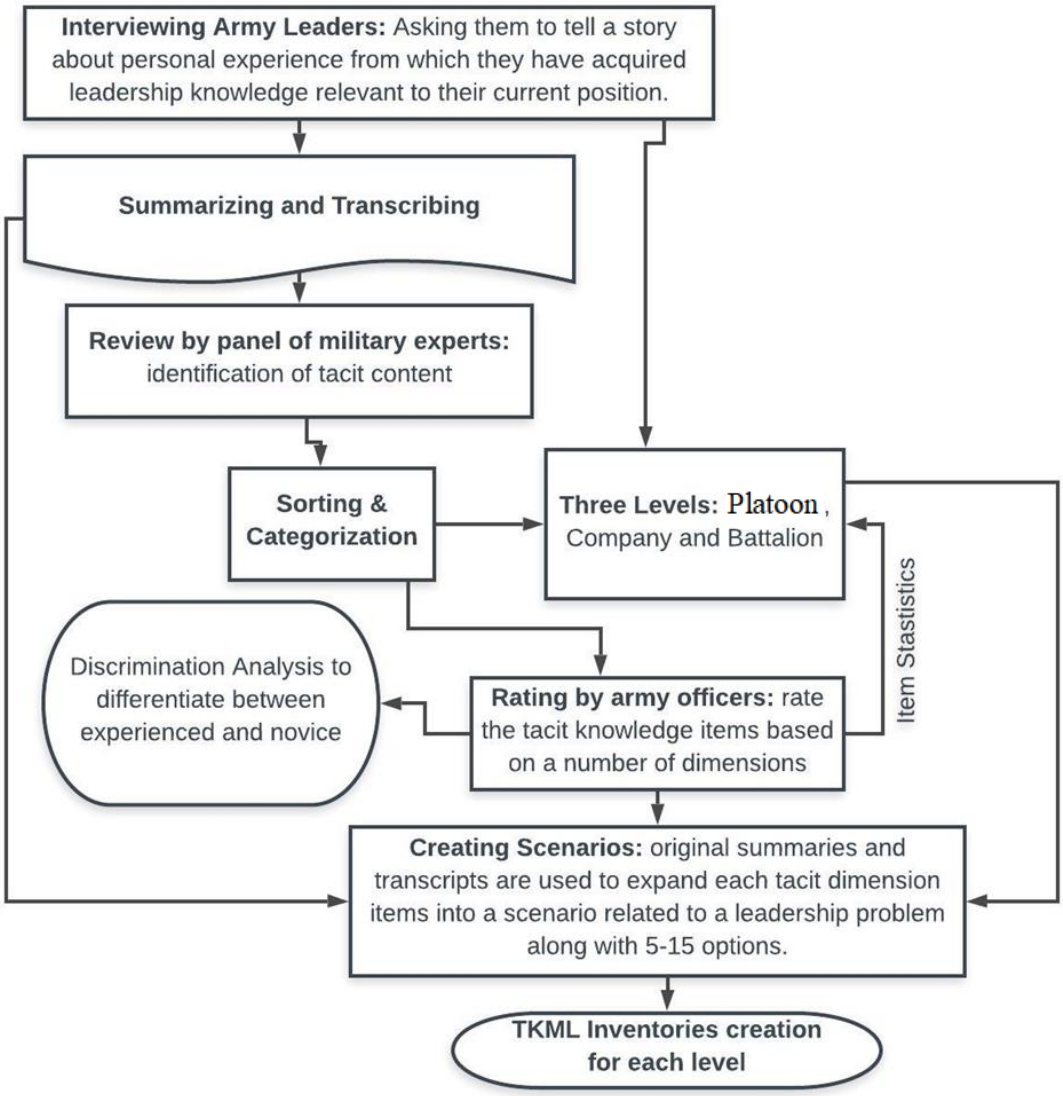


Figure 10- Framework: Tacit Knowledge Inventory for Military Leaders (Hedlund et al., 1998)

The scenarios developed were used to quantify the effectiveness of leadership among Army leaders. The key objectives behind the development of this TKML inventories were: identifying

and measuring tacit knowledge, validating the measures against the indices of leadership effectiveness to conclude how the Army might harness this tacit dimension of knowledge effectively and efficiently (Hedlund et al., 1998). Through TKML, participants are asked to rank or rate the appropriateness of the provided options and the level of knowledge is assessed based on the comparisons of their ratings against the standard experts (Hedlund et al., 2002).

2.12 Identified Gaps from the Literature

Most of the studies focusing on knowledge management in the construction industry have discussed only the ways to capture and harness explicit knowledge through several tools like IT. Limited research exists in the AEC literature to capture and harness the tacit dimension of knowledge. Also, there have been very few efforts for knowledge management at the construction field level where actual expertise is put together to churn out the final tangible product. This experience-based knowledge is relatively unexplored when it comes to the trade field supervisors. The larger proportion of old workers in trades is driving the construction firms to adopt strategies to capture and harness their know-how before these supervisors leave the organizations. To harness tacit knowledge, at first, it is important to identify it. Literature suggests that most of the studies to identify and access tacit knowledge have been conducted in the military and academia. This study aims to replicate an instrument from academia to the construction field to identify and assess the reliance of field supervisors on experience-based tacit knowledge.

2.13 Summary

This chapter sheds light on the literature about the previous efforts in assessing and harnessing tacit knowledge. In the literature search, a measure implemented in academia to identify the reliance of an individual on tacit knowledge has been discovered. Previous studies indicate that most of the research has been conducted in capturing and harnessing the explicit dimension of knowledge among several organizations. Moreover, existing research also indicates that not many efforts have been made in the field of the construction industry to identify and assess field supervisors' reliance on tacit knowledge in decision making related to day-to-day construction activities.

CHAPTER 3. METHODOLOGY

3.1 Introduction

Oftentimes, construction field supervisors swap stories on how the decisions made by them in their previous projects had resulted in saving a substantial number of man-hours or how they had learned from their past experiences. They generally rely on the knowledge gained through their experience to make routine decisions on the job site, and this experience becomes their general routine or habit (Chilton & Bloodgood, 2008). The purpose of this study is to assess the tacit dimension of knowledge among field supervisors, identify the barriers to knowledge sharing and decipher the ways through discussion, to enhance the skillset of construction workers to fill the boomer-millennial knowledge gap. The framework developed through this study can be used to identify the type of knowledge field supervisors use to perform any construction activity or in making construction-related decisions in the field. The study focusses on field supervisors from electrical contracting firms. The key idea behind the process is to gauge the usage of the tacit dimension of knowledge among field supervisors. To achieve it, a valid and reliable instrument is replicated based on the work of Chilton and Bloodgood (2008) which is modified to test its usefulness in the construction industry based on the feedback from two specialty contractors. The instrument used is a semantic differential scale. The second part of the methodology is to find the barriers to the knowledge sharing process at three different levels: field worker, supervisor, and organization. To achieve this, an online survey questionnaire is developed and distributed online.

The study focuses on electrical contracting firms. By identifying supervisors' reliance on tacit knowledge in the field for decision-making or in performing specific construction tasks; and by identifying the barriers to knowledge sharing at various organizational levels, the organizations can take better and effective knowledge capturing and management decisions. The organizations could also implement the proposed instrument to check the effectiveness of apprenticeship training in the job site at various intervals during the construction process. Based on the literature, a methodology framework is developed for data collection that is implemented among electrical contracting firms. This chapter deals with the methodology framework, proposed model, variables for the analysis, framework, and analysis methods in the forthcoming sections.

3.2 Typology of the Research

One of the most vexing questions for research is deciding what type of analysis is to be used. To decide an appropriate method for analysis in construction management depends on the nature of the research problem, and the choice made should be defensible and transparent in delineating the assumptions underlying it and the nature of the study (Wing, Raftery, & Walker, 1998). This research is an amalgamation of exploratory and explanatory methods to assess the reliance of field supervisors on tacit knowledge. The proposed methodology deploys a mixed approach that is a combination of both qualitative and quantitative or interpretive analysis. Adopting a mixed approach in research ensues methodological pluralism which results in broader perspectives than a single approach design (Molina-Azorin, Cameron, & Molina Azorín, 2010).

For assessing the reliance of field supervisors on tacit knowledge, a semantic differential scale with an electronic slider is adopted to accompany each of the survey questions. For quantitative analysis, this scale is converted to a Likert scale and the scores are analyzed based on the position of the slider. Based on the total score, supervisors' reliance on the tacit dimension of knowledge is assessed. Also, for identifying the barriers to knowledge sharing in three different contexts: a group of workers, supervisor/manager behavior and organization as a whole; descriptive statistical methods are adopted to perform the quantitative analysis based on the responses along with quantitative.

Also, the qualitative part of this research incorporates the key findings relevant to the study from the transcription of the voice recordings obtained through semi-structured interviews with trade professionals, and free-text entry options included in the surveys. This qualitative study aids in providing deeper insights into the participant's perception and viewpoint regarding experience-based knowledge and impediments to sharing it and paves a path to make comparisons with quantitative results. Some of the transcriptions are used to refute the outcomes from the quantitative analysis.

3.3 Adopted Model

The model deployed in this research is adopted from the work of Chilton and Bloodgood (2008). According to them, tacit knowledge can be gauged by measuring its constituent elements. Based on the literature, a four-dimensional model (see Figure 11) is generated and a survey questionnaire

is developed to measure tacit knowledge in academia (Chilton & Bloodgood, 2008). The same model from the study by Chilton and Bloodgood (2008) is replicated for this research. The four dimensions contributing to the degree of tacitness of the applied knowledge are discussed through this model, they are conscious awareness, codifiability, demonstrability, and formal/informal application.

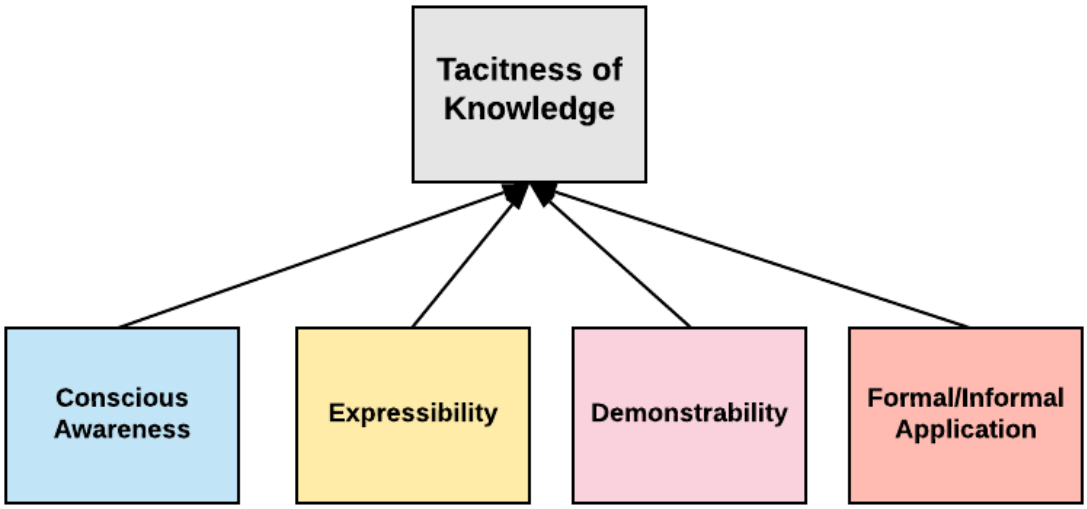


Figure 11- Model adapted from Chilton and Bloodgood (2008)

Conscious Awareness: The user when engaged in a work that uses tacit knowledge, is not much consciously aware of it (Chilton & Bloodgood, 2008). The field supervisors and trade professionals have been doing many of the routine construction tasks for many years that it has become their habit or secondary nature. They have acquired a plethora of tacit knowledge over their experience that even they find it hard to explicate. This knowledge is stored in an individual's memory in such a way that it is used automatically when required even without consciously thinking about it (Chilton & Bloodgood, 2008). For instance, an experienced reinforcement steel fitter who does not think consciously while tying reinforcement bars with steel wire but rather keep moving hands without being aware of it to tie different type of knots at various rebar positions.

Codifiability: It is difficult to express tacit knowledge to others either in verbal or in a written form (Polyani, 1966). The main issue with this experience-based tacit knowledge is that it is difficult to codify and communicate directly to other individuals (Chilton & Bloodgood, 2008)

due to its individual's mind-sticky nature and immobility. Consider an electrical field supervisor laying out overhead feeder conduit racks and who always spot opportunities to find a common path to group feeder conduits to cut material and labor cost. This supervisor has performed laying of overhead feeder conduit racks so many times that it has become the supervisor's habit or intuition that the supervisor is not able to express or codify. To justify their decision, these supervisors would likely be able to express it through a continuum with a purview of completely inexpressible to completely expressible (Chilton & Bloodgood, 2008).

Demonstrability: Chilton and Bloodgood (2008) referenced demonstrability as the ability of an individual to perform necessary steps of the task based on only seeing it performed or by seeing or visualizing the outcome or final product. The greater the demonstrability, the greater is the tacit knowledge and the user can better complete the task without relying on codified instructions (Chilton & Bloodgood, 2008). Similarly, consider an electrical apprentice who learns by observing the tasks performed by an electrical journeyman or supervisor either in the field or through apprenticeship training. Demonstrability is only meaningful if the steps are observable or something that can be imagined or visualized (Chilton & Bloodgood, 2008).

Formal/Informal application: This is based on the application of gained knowledge in performing a daily routine task. Initially, during training, an individual performs a task following step-by-step and organized procedures and the individual is consciously aware of the steps being performed but with experience, reliance on these steps becomes automatic without being much cognizant (Chilton & Bloodgood, 2008). Also, new learning is differentiated from prior learning or experience-based learning by the knowing reliance of an individual on explicit formal steps. Higher the reliance on experience-based learning, the higher the use of tacit knowledge (Chilton & Bloodgood, 2008)

3.4 Developed Methodology and Framework

3.4.1 Gauging Reliance of Field Supervisors on Tacit or Explicit Knowledge

As discussed in section 3.4, the hypothesized model developed by Chilton and Bloodgood (2008) is used in this study and a similar instrument is replicated to verify its usefulness in the construction

field by assessing the reliance of field supervisors on explicit or tacit knowledge. It is assumed that the instrument is reliable and valid. A few of the questions are modified, making them relevant to the construction industry especially the trades, followed by their validation to remove ambiguities as per the feedback from two major specialty contractors from the mid-west US region. The proposed methodology framework is shown in Figure 12. Let us recall one of the research questions:

"To what extent do experienced field supervisors rely on tacit knowledge to perform day-to-day tasks?'

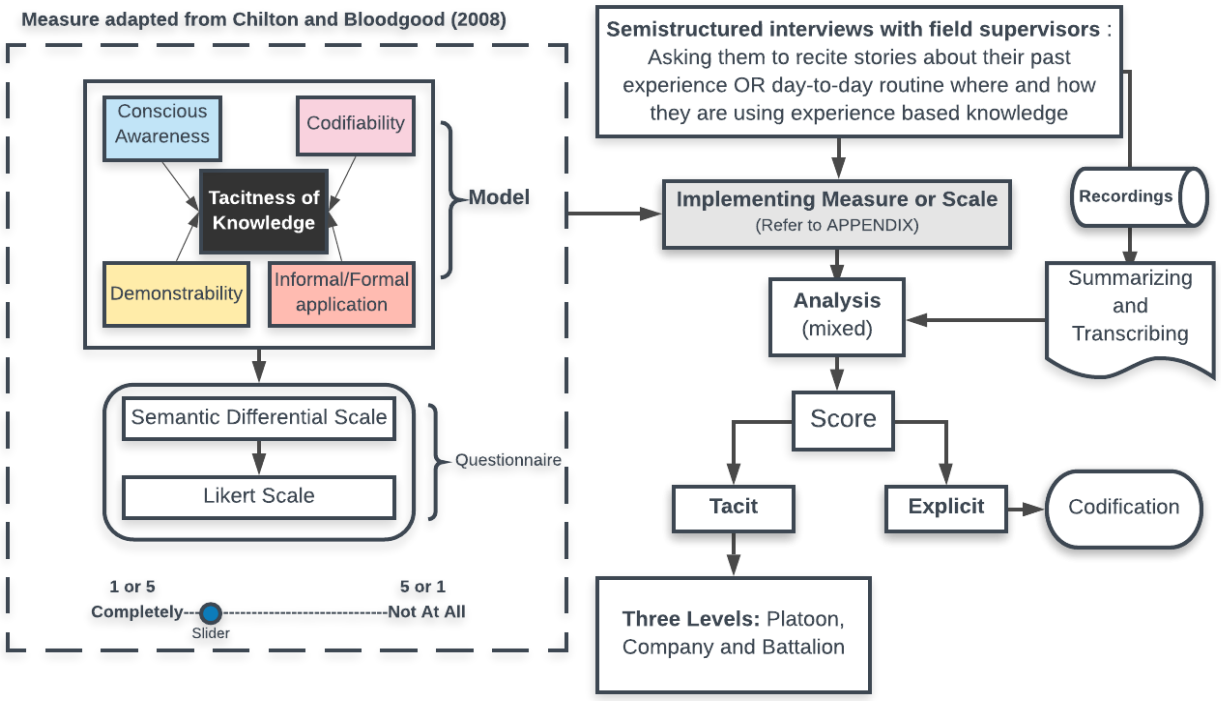


Figure 12- Proposed research framework

The solution to the above-mentioned research questions is generated by following the steps delineated in the proposed framework. The steps involved are:

1. Semi-structured interviews with field supervisors: asking them to recall an incident from their past or daily routine where they are using experience-based knowledge and how?

2. Recording the interviews to create summaries and transcriptions which are later be used to refute the results from the quantitative analysis.
3. Along with semi-structured interviews, the proposed measure is implemented to capture the viewpoint of the field supervisors related to their recited incidents.
4. Analysis of the collected responses.

3.4.2 Identifying Barriers to Knowledge Sharing

For the second part of the study, barriers to knowledge sharing are identified at three different levels. Let us recall another research question:

"What are the main impediments for knowledge sharing at different levels in the construction industry?"

To identify these barriers, an online questionnaire is created, asking the participants to rank the identified factors which prevent knowledge sharing at three different categories: a group of trade professionals, managerial role and organization. These categories were formulated based on the study by Sveiby (2007) which analyzed 691 free-text comments received from 848 participants throughout 92 business units (Sveiby, 2007). A few of the barriers with a high percentage of negative in each class are adopted from the study (Sveiby, 2007) and used in the questionnaire. These barriers are adopted to check their generalizability in construction organizations. Generalizability refers to the applicability of one research findings from one organizational setting to another (Sekaran & Bougie, 2016). The language of the questionnaire is modified and validated based on the feedback from two of the major electrical contracting firms from the mid-west region of the United States (see Table 1). Another intent of listing a few barriers in each category is to provide context for the participants before capturing their viewpoints if any through free-text entries.

Table 1- Barriers to knowledge sharing adapted from Sveiby (2007)

At the Level of Trade Professionals	At the Level of Managers	At the Level of Organization
Not enough time	Lack of encouragement	Managers are reluctant to share knowledge
Lack of Formal Processes	Managers are resistant to change	Apathetic nature of top management
Sharing happens only during the activity	Managers are unwilling to take risk	No formal process for knowledge sharing
A threat to job security	Managers not walking the talk	Retirees leave with their knowledge
Workers are poorly informed regarding knowledge sharing	Managers and staff are treated differently	Experience is not valued

Two free-text entry options are also be provided in the survey questionnaire with each question to capture viewpoints of the participants other than provided in Table 1 if any. The participants are asked to rank these factors based on their perspective and experience in the industry. A mixed-method analysis approach is adopted to analyze the results.

3.5 Target Population and Sampling

For the first part of the study i.e. assessing the reliance of field supervisors on experience-based knowledge, the snowball sampling technique is deployed. Various local electrical contractors are approached to interview their field supervisors based on their referrals. This sampling method generates a study sample through referrals, which are made among the persons who know of others possessing some research related characteristics (Biernacki & Waldorf, 1981). For the second part of the study which deals with identifying potential barriers to knowledge sharing, a combination of Simple Random Sampling (SRS) and snowball sampling is adopted. According to Groebner et al. (2010), a simple random sample is a sample where everybody has equal chances of getting selected. An online survey is created which is forwarded to all the National Electrical Contractors

Association (NECA) chapters across the United States, that they passed along to the associated member electrical contractors. The target population group for this part of the study are the electrical contractors who are directly associated with several NECA chapters. A similar survey is distributed to several field teams also during the semi-structured interviews to capture their viewpoint.

3.6 Variables and Constructs

A variable can be defined as a quantity that may change in size whereas a construct is an amalgamation of variables yielding a conglomerate phenomenon (Fellows & Liu, 2008). From the proposed model all the four dimensions representing the degree of tacitness i.e. conscious awareness, codifiability, demonstrability, and formal/informal application, can be considered as individual factors or attributes related to tacit knowledge measurement (see Figure 11). These factors behave as constructs independently having their theoretical meaning and imbibe cluster of variables within and can be quantified indirectly through the implemented semantic differential scale in combination with a Likert scale based on the survey questionnaire. Measurement instruments often termed as scales are a set of questions or items used to gauge variations in these theoretical constructs that can't be directly observed (Ding & Ng, 2008). Hence, the factors can be related to independent variables that can vary in quantity or score based on the position of electronic slider within the purview of 'completely' or 'not at all' (see Appendix B). Independent variables are the variables, the attributes of which are selected, controlled and measured by the researcher to examine the corresponding attributes of the dependent variable (Fellows & Liu, 2008). Other independent variables are the individual's age, work experience, gender, geographical region, and similar. According to the proposed model, by measuring or gauging these attributes, tacit knowledge can be measured, therefore, tacit knowledge here acts as a response variable or a dependent variable that relies on underlying dimensions for its quantification.

3.7 Proposed Assessment Instrument

For assessing the field supervisors' reliance on tacit knowledge, semi-structured interviews are conducted with field personnel either via conference calls or via project site visits. A semantic differential scale with an electronic slider is used to capture the answers for close-ended survey

questionnaire based on the construct (see Appendix B). The instrument implemented consists of 26 survey questions, each accompanying a seminal differential scale along with an electronic slider with "completely" and "not at all" as the two extremities. This scale is then converted to a 5-point Likert scale based on the position of the slider to calculate the score (see Figure 13). Scores have been assigned from 5-1 for some questions and 1-5 for others depending upon the proposed hypothesized model (see Appendix B).

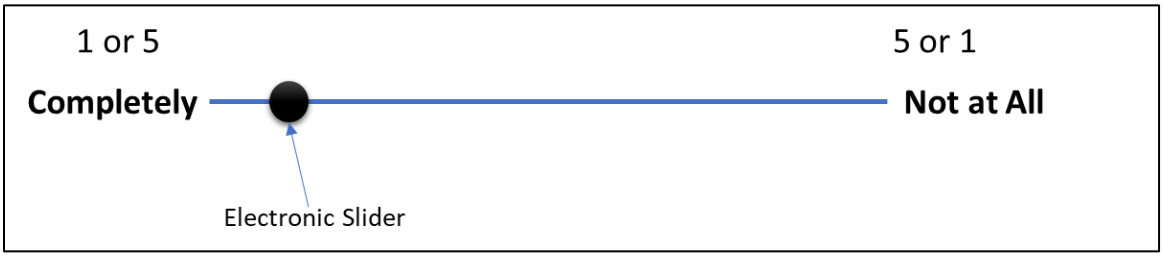


Figure 13- A semantic differential scale accompanying each survey question

A total score is calculated by summing up the scores from individual questions. A score of 26 means complete reliance on explicit knowledge whereas a total score of 130 depicts complete reliance on the tacit dimension. For identifying the barriers to knowledge sharing, an online survey is distributed to the managers and executives representing several Electrical Contracting firms, consisting of factors in random order that the participants are asked to rank. Two free-text entry options are provided with each question to capture their viewpoints if different from the listed ones.

3.8 Data Collection

To decide the inputs for the study, the outputs required must be delineated at first and these outputs are in the form of aims, objectives, hypothesis, and similar (Fellows & Liu, 2008). For the first part of the study i.e. assessing field supervisors' tacit knowledge, the researcher intends to identify the type of knowledge they are using in performing routine construction activities. For this purpose, semi-structured interviews are conducted with the field supervisors through either conference calls or visiting the job sites asking them to recall incidents from the past projects or day-to-day fieldwork where they are using their experience-based knowledge and how? An open-ended questionnaire approach is implemented in these semi-structured interviews. The interviews are

recorded for qualitative studies. The proposed instrument is implemented through an online survey questionnaire that the supervisors took parallelly during the semi-structured interviews. This type of non-linear method of data collection is a two-way approach that provides feedback along with gathering further data relevant to the research by probing the participants during semi-structured interviews (Fellows & Liu, 2008).

For the second part of the study i.e. identifying barriers to knowledge sharing, data is collected through online survey questionnaires distributed via anonymous survey link to the managers/executives representing various electrical contracting firms. A similar survey is distributed to the field supervisors and trade professionals during the semi-structured interviews. The perspectives of managers/executives are compared against the responses from the field to find out the congruence or differences in the opinions of management and the field team. Free-text entry options are also provided in the survey.

3.9 Method for Analysis

3.9.1 Gauging the Reliance on Tacit Knowledge

The data is collected through semi-structured interviews and conference calls with the Field personnel as mentioned in section 3.8. The survey incorporates a semantic differential scale with an electronic slider accompanying each questionnaire of the 26-item measure. This scale is then converted to a 5-point Likert scale based on the position of the slider to calculate the score. A final score is calculated. To analyze the data, exploratory and linear regression analyses are performed. "Regression analysis is a statistical methodology that utilizes the relation between two or more quantitative variables so that a response or outcome variable can be predicted from the other, or others" (Kutner, Nachtsheim, Neter, & Li, 2005, p. 2).

In this case, the linear regression technique is used to find out the relation between the dependent and the independent variable. Tacit knowledge score is the dependent variable whereas, an individual's experience and education are treated as independent categorical variables. The R-software tool is used to run the analysis.

Exploratory analysis is performed in the initial step to delineate basic summary statistics and plots. Linear regression is a handy tool for developing a relationship between the variables. The simplest equation of regression analysis in bivariate form is:

$$Y = \beta_0 + \beta_1 X + u \text{ .....1}$$

Where Y is a dependent variable, X is an independent variable, β_1 is slope parameter, β_0 is an intercept parameter, and u is an error term (Campbell & Campbell, 2008). Running regression analysis serves three purposes: description, control, and prediction (Kutner et al., 2005). It is worth noting that the intent here is only to check if the tacit knowledge score is related to the experience of field supervisors. Turkey test (Abdi & Williams, 2010) is conducted to group all the data into categories for developing the final regression model. Narrative analysis is also performed manually using the data from the recorded interviews and summaries.

3.9.2 Identifying Barriers to Knowledge Sharing

The survey to identify barriers to knowledge sharing incorporates ordinal scales asking the respondents to rank a few of the identified barriers in order eg. from 1 to 5. The same participants rated the barriers in three different categories. Friedman test is performed to determine the final or mean rank of the options in each category. Friedman test applies to the data which is not normally distributed, therefore, before applying Friedman test, the data is tested for normality using the Q-Q plot and Shapiro-Wilk test (Das, 2016; Shapiro & Wilk, 1965). Also, the Friedman test is a non-parametric test used for testing the hypothesis related to ordinal-scaled data; used when the data is not normally distributed; and also known as Friedman' two-way repeated-measures analysis of variance (Sheldon, Fillyaw, & Thompson, 1996). The null and alternate hypotheses adopted for each category are:

H_0: There is no difference in the survey respondents' ranking of barriers.

H_1: There is a difference in the survey respondents' ranking of barriers.

The software used to perform the analysis is SPSS which is known for performing advanced statistical analysis with a wide variety of options available like machine learning algorithms, analyzing text, etc. (IBM, 2020). The formula for calculating test statistics or χ^2_r for the Friedman test is:

$$\chi^2_r = \frac{12}{Nk(k+1)} \sum_{j-1}^{k} R_j^2 - 3N(k+1) \quad \ldots\ldots\ldots\ldots 2$$

where k is the total number of ranked observations or categories, N is the total number of responses, and R_j is the total sum of ranked scores in each category (Sheldon et al., 1996). Based on the analysis, χ^2 value and p-value are compared to test acceptance or rejection of the null hypothesis. The proposed null hypothesis is rejected if this χ^2_r value greater than the critical value and the p-value less than the critical value i.e. 0.05. If the null hypothesis is rejected, the Conover test is further carried out as a post hoc test to find if there is a significant difference in the ranking of barriers (Pohlert, 2016). R-software tool is used to perform the post hoc test. For the responses obtained from free-text entry options accompanying each survey, a thematic analysis is performed manually using MS Excel. The themes are adopted from the study by Akhavan et al. (2014). A few of the direct responses are also quoted in the analysis.

3.10 Summary

This chapter drafted the proposed research methodology phases and framework based on which the data obtained through semi-structured interviews and the online questionnaire is analyzed in the forthcoming chapter. The analysis is performed to answer the research questions. This chapter further delineates methods for data collection, variables, and constructs related to this study, and instrument that is implemented.

CHAPTER 4. PRESENTATION OF DATA & FINDINGS

This chapter deals with analyzing and evaluating the data collected through online surveys, site visits, and conference calls. The data has been analyzed in two parts i.e. one for gauging the reliance of the field supervisors on experience-based tacit knowledge and another to identify the barriers to knowledge sharing. This chapter includes assessing, cleaning and filtering the obtained data, performing analysis, classifying the data and presenting the outcomes.

4.1 Reliance of the Supervisors on Tacit Knowledge

4.1.1 Assessing and Analyzing the Data

To gauge the supervisors' reliance on tacit knowledge, semi-structured interviews were conducted through site visits, conference calls, and meetings. The key participants were electrical field supervisors, journeyman and apprentice electricians. These interviews were recorded to aid the transcriptions. A total of 25 complete responses were collected.

For analyzing the data, exploratory and linear regression techniques were adopted. Exploratory data analysis (EDA) was carried out first to get familiar with the data and to understand potential variables for running a regression analysis. "Regression analysis is a statistical methodology that utilizes the relation between two or more quantitative variables so that a response or outcome variable can be predicted from the other, or others" (Kutner et al., 2005, p. 2). 'R' software platform was used to run the analysis. The normality of the data was also tested as a requirement for the regression analysis. The observations are independent since these were recorded individually during face-to-face interactions or conference calls.

4.1.2 Exploratory Data Analysis

Exploratory data analysis was performed as the initial step to get familiar with the distribution of data through representations. It enables the researcher in understanding the data, visualizes potential relations, detecting outliers, developing models, and extracting relevant variables (Komorowski, Marshall, Salciccioli, & Crutain, 2016). The R-software tool was used to run the analysis. The box plot for experience vs tacit knowledge score is shown in Figure 14. From the

graph, the tacit knowledge score seems to vary with the experience level of the supervisors. Analysis results are shown in Appendix F. Further to statistically confirm the relation between experience and tacit knowledge score, linear regression analysis was performed in the forthcoming sections.

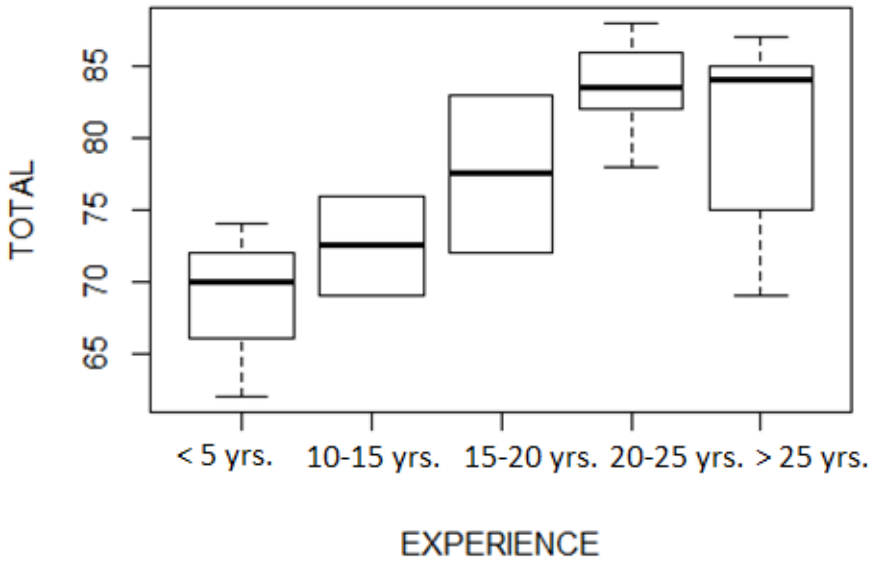


Figure 14- Box plots for Experience vs Tacit knowledge score

Similarly, box plots for an individual's education vs tacit knowledge score are shown in Figure 15. Graphically, education level does not seem to have a relation with the tacit score.

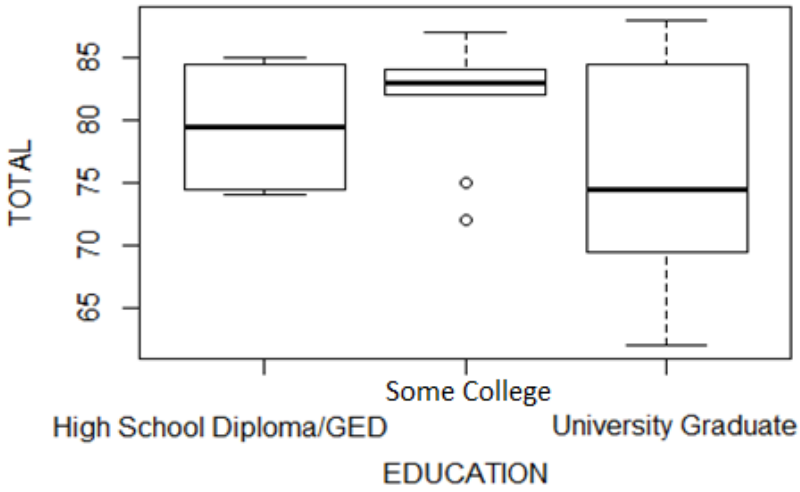


Figure 15- Box plots for Education level vs Tacit knowledge score

As a result of EDA, an individual's experience and education level were selected as two independent categorical variables and their relation to tacit knowledge score was statistically formulated using a linear regression technique.

4.1.3 Linear Regression and Model Building

The hypothesis proposed in this study is:

> H_0: With experience, field supervisors rely more on their acquired tacit knowledge to perform day-to-day activities.

To test this hypothesis, regression analysis was performed with an intent to find out the relation between an individual's experience and tacit knowledge score.

4.1.3.1 Model 1: Experience and Education as Variables

Initially, experience and education level were selected from EDA as two categorical independent variables. From figures 14 and 15, the experience level of an individual seems to have a significant relation with the total score (p-value < 0.05). This is further tested statistically by performing an analysis of variance (see Figure 16).

```
##            Df Sum Sq Mean Sq F value   Pr(>F)
## EXPERIENCE  4 627.01 156.753  5.2458 0.005576 **
## EDUCATION   2  71.35  35.677  1.1939 0.325916
## Residuals  18 537.87  29.882
```

Figure 16- Analysis of Variance (Experience + Education)

It is clear from the p-values that education level (p > 0.05) of an individual does not have a significant relation with the tacit knowledge score. Therefore, further analysis is carried out only with one variable i.e. experience level of an individual.

4.1.3.2 Model 2: Only Experience as a Categorical Variable

Using the only Experience as the key independent variable, analysis of variance further states that it is a significant predictor with a p-value less than 0.05 (see Figure 17) however, from the summary (see Figure 18) it seems that not all the experience levels are significantly different from the reference level i.e. less than 5 years.

```
##             Df Sum Sq Mean Sq F value  Pr(>F)
## EXPERIENCE  4 627.01 156.753   5.146 0.00513 **
```

Figure 17- Analysis of Variance (Only Experience)

The summaries table for all the experience levels is shown in Figure 18. As mentioned earlier, work experience less than 5 years is taken as reference by default and all the values are compared to it. It can be inferred that the experience categories 10-15 years and 15-20 years are not significantly different from the reference since they have a higher p-value (> 0.05). This could also be due to the small number of data points in some of the categories.

```
Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)              69.000      2.760  25.004  < 2e-16 ***
## EXPERIENCE10-15 years     3.500      4.780   0.732 0.472507
## EXPERIENCE15-20 years     8.500      4.780   1.778 0.090556 .
## EXPERIENCE20-25 years    14.500      3.563   4.070 0.000597 ***
## EXPERIENCE> 25 years     11.455      3.223   3.555 0.001987 **
```

Figure 18- Summary of Experience Levels

4.1.3.3 Model 3: Combining Experience Categories

Based on the earlier results and further analysis, all the categories of work experience are combined into two: less than 20 years and greater than 20 years based on Turkey test (see Appendix F) since Conover test was not applicable here due to the approach in data collection i.e. non-repetitive data since the observations were taken individually. It can be observed from the output of the Turkey test that there is no significant difference between the two groups (p-value >0.05). EDA was conducted and the box plots of the data are shown in Figure 19. Gaining expertise in a technical

field like construction is a complex process and it is not possible to measure an exact number of years or identify the stages to achieve it (Farrar & Trorey, 2008).

NOTE: The value '20 years' is selected based on the distribution of data (see EDA results in Appendix F) and Turkey test.

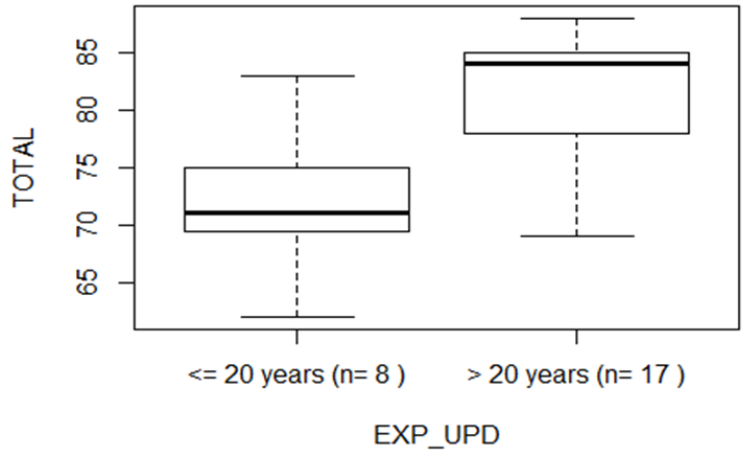


Figure 19- Exploratory Data Analysis Plot

The further summary suggests that there is a significant difference between the two categories of experience level (see Figure 20). Experience less than 20 years is taken as a reference.

```
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)         72.000      2.008  35.848  < 2e-16 ***
## EXP_UPD> 20 years    9.529      2.436   3.913 0.000699 ***
```

Figure 20- Summary for two Experience Categories

The final model is generated with an adjusted R^2 value of 0.3735 is:

Predicted tacit knowledge score = 72 + 9.529 (Exp. >20 years) + Error ……3

It can be inferred from the model that most of the supervisors with experience greater than 20 years have tacit knowledge scores 9.529 higher than those with less than 20 years. It is worth

noting that the tacit knowledge score is not a true measure of an individual's experience rather it only signifies the proclivity towards the usage of tacit knowledge in the task mentioned by the participant. Also, according to the feedback from two of the major Electrical contracting firms in the Midwest US region, it usually takes 15-20 years of experience for an electrician to become a field supervisor or superintendent. The hypothesis for this research is:

> H_0: With experience, field supervisors rely more on their acquired tacit knowledge to perform day-to-day activities.

From the above model (Equation 3), one group relies more on the tacit knowledge than another and hence, the hypothesis is validated as the usage of tacit knowledge is increasing with an increase in the experience level.

4.1.4 Model Diagnostics

4.1.4.1 Check for Normality

The normal Q-Q plots for model 3 is shown in Figure 21. It seems normally distributed since most of the points are closer to the reference line (Das, 2016).

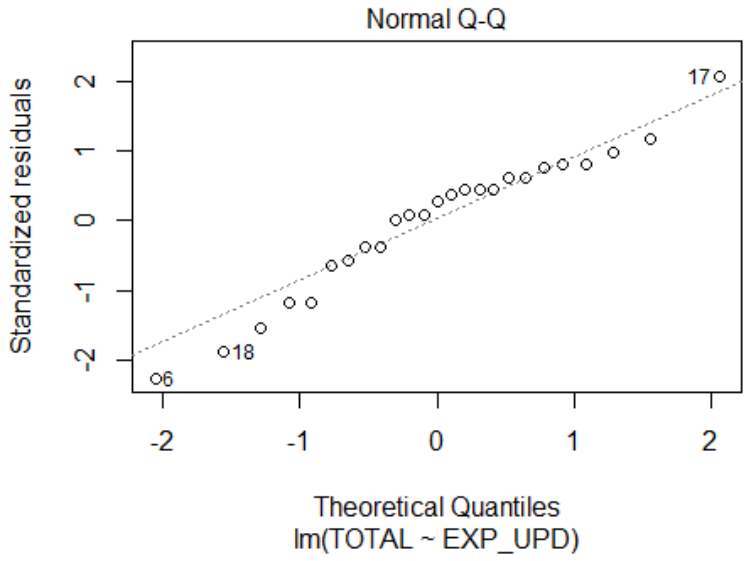


Figure 21- Q-Q plot of Experience level (model 3)

To test the normality, the Shapiro-Wilk normality test was also conducted which resulted in a p-value of 0.3541 (see Appendix F), so we failed to reject the null hypothesis i.e. sample is normally distributed (Shapiro & Wilk, 1965). Hence, the normality assumption for regression is validated. Further, the box-cox method (Box & Cox, 1985) is used to check if any transformation of the response variable i.e. tacit knowledge score is required. Since, 1 lies in the 95% Confidence Interval, there is no need to do any transformation on the response variable (see Figure 22).

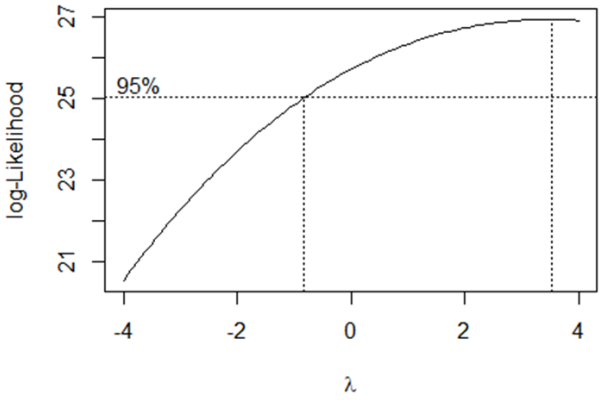


Figure 22- Box-cox Plot

4.1.4.2 Constant Variance

The constant variance plot of residual vs fitted variable is shown in Figure 23. There does not seem to have much difference in the variance.

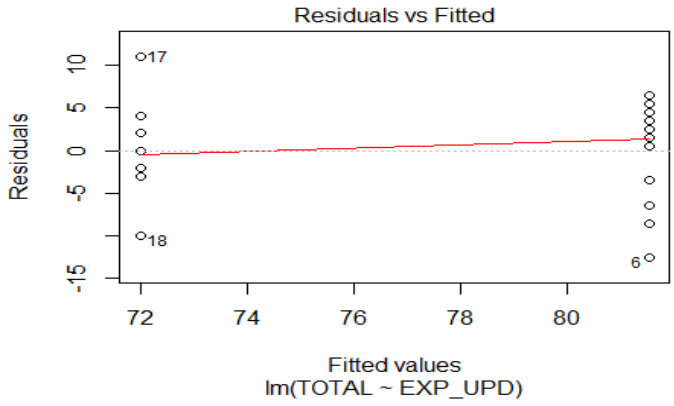


Figure 23- Residual vs Fitted Plot

4.1.5 Narrative Analysis

During data collection, the semi-structured interviews with the trade professionals and field supervisors were recorded to aid the transcriptions. Relying on hands-on experience than following the codified procedures was identified as a key learning aspect for the trade professionals and field supervisors. One of the field supervisors quoted, *"…I am not a bookish kind of a guy and I never was...I used repetitions…learned from experience".* Another field supervisor quoted regarding pre-planning that *"…how to do a layout…they don't teach in class…that's all you learn at the job"*. As per the journeymen and apprentice electricians, getting paired up with an experienced professional, on the job training, and mentoring are better ways to learn at the job site than relying on bookish knowledge. While answering the survey questions, most of the field supervisors mentioned that it is difficult for them to write down completely the procedures that they are using daily at the job site. These supervisors have imbibed the tacit dimension knowledge by doing repetitive tasks throughout their experience that it has become their habit of doing work or '*the secondary nature'* as mentioned by one of the field supervisors. A few of the construction activities were identified in common during the semi-structured interviews where these supervisors use their experience-based knowledge like laying out temporary lighting, running conduit through abandoned areas during restoration, performing job site layout, etc. Organizations should focus on identifying similar activities to harness tacit knowledge effectively.

4.2 Barriers to Knowledge Sharing

4.2.1 Assessing and Analyzing the Data

The survey related to the identification of potential barriers to knowledge sharing among the specialty contractors (see Appendix C) was sent to managers/executives of around 300 NECA member electrical contracting firms through an online anonymous link across the United States. Around 61% of the responses were obtained from the Midwest region, 16 % from the Northwest, 18% from the Southwest, 3% from the West, and 2% from the Southeast (see Figure 24). The description of these regions is shown in Appendix D.

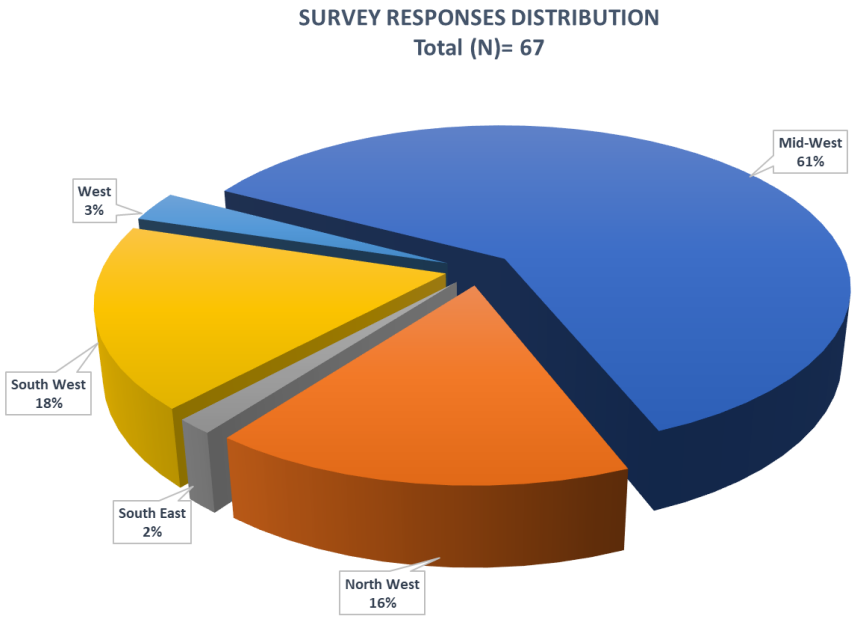


Figure 24- Distribution of the online survey responses

The first survey was directed towards the managers and executives representing these electrical contracting firms. A total of 67 usable responses are obtained from around out of total 101 responses representing about 22% of the response rate which is considered appropriate given its length (Deutskens, et al., 2004). By usable responses, the researcher means responses that are 100% complete.

A similar survey was distributed to the Field personnel alongside semi-structured interviews. Field supervisors, journeyman electricians, and apprentice electricians were the key participants in this survey. A total of 92 responses were obtained out of which 82 were complete or usable. The analysis is made based on 82 responses only.

For analyzing the identified barriers in each category, the Friedman test was adopted as mentioned in section 3.9. At first, data were tested for normality (see Appendix E). In the Friedman test, the null and alternate hypotheses adopted for each category are:

H_0: There is no difference in the survey respondents' ranking of barriers.

H_1: There is a difference in the survey respondents' ranking of barriers.

Chi-square and p-value are compared in each of the categories to check whether the null hypothesis is validated or not. If the null hypothesis is rejected, the Conover test was performed in each category to check any significant difference among the rankings by making pairwise comparisons. Bonferroni correction (Dunn, 1961; Pohlert, 2016) is used in the Conover test for the adjustment of p-value in each case.

4.2.2 The Management Perspective

As mentioned in section 4.2.1, an online survey was distributed to several electrical contractors who are members of several NECA chapters across the United States. The demographics are shown in Table 2 which highlights the age distribution, gender, position in the company, and ethnicity of the survey respondents. For analyzing the data, a Friedman test is conducted for determining whether the survey respondents have a different preference for orderly ranking all the barriers listed in each of the categories.

Table 2- Demographic Information of the respondents (N=67)

Demographics of the Survey Respondents	Frequency	Percentage
Age		
Less than 40 years	15	22
More than 40 years	52	78
Sex		
Male	64	96
Female	3	4
Role in the Company		
Executive/Director	12	18
President/Vice President	29	43
Managers	20	30
Others	6	9
Ethnicity		
White	63	94
Black/African American	1	1
Hispanic or Latino	2	3
Other	1	1

4.2.2.1 At Group of Trade Professionals Level

The results of the analysis also indicate that there is a difference in the preference of the participants to rank the barriers in the category 'Group of Trade Professionals' (see Table 3). The observed χ^2 value is 51.104 and the p-value is negligible which is less than 0.05.

Table 3- Test Statistics (group of trade professionals)

N	67
Chi-Square	51.104
df	4
Asymp. Sig.	0.000 (Negligible)

The mean ranks obtained from Friedman's analysis are shown in Table 4. As a result of the analysis, in the group of trade professionals category, 'lack of formal processes to share knowledge' is identified as the key barrier followed by 'lack of time to share knowledge' and 'sharing only happens during the activity' respectively.

Table 4- Mean Ranks (group of trade professionals)

CODE	BARRIER	MEAN RANK
A	Lack of Time	2.49
B	No Formal Processes	2.31
C	Sharing only happens during the activity	2.73
D	Job Security	3.60
E	Workers Poorly Informed	3.87

The Conover test was conducted as a post hoc test for the pairwise comparisons. The results are shown in Figure 25. Comparing the adjusted p-values, it can be inferred that A-D, A-E, B-D, B-E, C-D, C-E have significantly different ranks ($p < 0.05$).

```
##   A       B       C       D
## B 1.00000 -       -       -
## C 1.00000 1.00000 -       -
## D 0.00073 4.5e-05 0.01765 -
## E 9.9e-06 3.8e-07 0.00047 1.00000
##
## P value adjustment method: bonferroni
```

Figure 25- Pairwise comparisons using Conover Test (group of trade professionals)

4.2.2.2 At Managerial Level

The results of the analysis indicate that there is a difference in the preference of the participants to rank the barriers in the category 'Managerial Level' (see Table 5). The observed χ^2 value is 55.021 and the p-value is negligible which is less than 0.05.

Table 5- Test Statistics (managerial)

N	67
Chi-Square	55.021
df	4
Asymp. Sig.	0.000 (Negligible)

The mean ranks obtained from Friedman's analysis are shown in Table 6. As a result of the analysis, in the supervisory role category, 'resistance of managers towards change' is identified as the key barrier followed by 'lack of encouragement from the management' and 'unwillingness of managers to take the risk' respectively.

Table 6- Mean Ranks (managerial)

CODE	BARRIER	MEAN RANK
A	Lack of Encouragement	2.64
B	Mangers resistance to change	2.16
C	The unwillingness of managers to take risk	2.88
D	Managers not walking the talk	3.24
E	Managers and Staff treated differently	4.07

The Conover test was conducted as a post hoc test for the pairwise comparisons. The results are shown in Figure 26. Comparing the adjusted p-values, it can be inferred that A-E, B-D, B-E, C-E, D-E have significantly different ranks ($p < 0.05$).

```
##   A       B       C       D
## B 0.82485 -       -       -
## C 1.00000 0.09446 -       -
## D 0.30228 0.00112 1.00000 -
## E 3.5e-06 2.5e-10 0.00019 0.02518

##
## P value adjustment method: bonferroni
```

Figure 26- Pairwise comparisons using Conover Test (managerial level)

4.2.2.3 At the Organization Level

The results of the analysis also indicate that there is a difference in the preference of the participants to rank the barriers in the category 'Organizational level' (see Table 7) since the observed χ^2 value is 118.386 and the p-value is negligible which is less than 0.05.

Table 7- Test Statistics (organization)

N	67
Chi-Square	118.386
df	5
Asymp. Sig.	0.000 (Negligible)

The mean ranks obtained from Friedman's analysis are shown in Table 8. As a result of the analysis, in the organizational category, 'lack of formal processes' is identified as the key barrier followed by the 'disappearance of the retirees with knowledge' and 'reluctance of the managers to share knowledge with the employees' respectively.

Table 8- Mean Ranks (organization)

CODE	BARRIER	MEAN RANK
A	Reluctance of the managers to share knowledge	3.04
B	Apathetic top management	3.73
C	Lack of formal processes	2.09
D	Retirees disappear with knowledge	2.67
E	Experience not valued	4.40
F	Stringent policies	5.06

The Conover test was conducted as a post hoc test for the pairwise comparisons. The results are shown in Figure 27. Comparing the adjusted p-values, it can be inferred that A-E, A-F, B-C, B-D, B-F, C-E, C-F, D-E, D-F have significantly different ranks ($p < 0.05$).

```
##   A       B       C       D       E
## B 0.52629 -       -       -       -
## C 0.05203 1.0e-05 -       -       -
## D 1.00000 0.01807 1.00000 -       -
## E 0.00055 0.58834 9.5e-11 2.7e-06 -
## F 2.4e-08 0.00080 < 2e-16 2.2e-11 0.65651

##
## P value adjustment method: bonferroni
```

Figure 27- Pairwise comparisons using Conover Test (organization level)

4.2.3 The Field Perspective

A similar survey was distributed to the field trade professionals during the semi-structured interviews. The interviews with the Field personnel were conducted through site visits and conference calls with several locally organized electrical contractors and two apprenticeship training centers. The demographic information of the respondents is shown in Table 9. A similar Friedman testing is performed in each category to check whether the preference of the respondents differs or not and to find the mean ranking of the barriers.

Table 9- Demographic Information of the respondents (N=82)

Demographics of the Survey Respondents	Frequency	Percentage
Age		
Less than 40 years	58	71
More than 40 years	24	29
Sex		
Male	79	96
Female	2	4
NOTE: *There was one blank response (Total 79+2+1=82)*		
Ethnicity		
White	68	83
Black/African American	4	5
Hispanic or Latino	5	6
Other	5	6

4.2.3.1 At Group of Trade Professionals Level

The results of the analysis indicate that there is a difference in the preference of the participants to rank the barriers in the category 'Group of Trade Professionals' (see Table 10). The observed χ^2 value is 28.878 and the p-value is negligible which is less than 0.05.

Table 10- Test Statistics (group of trade professionals)

N	82
Chi-Square	28.878
df	4
Asymp. Sig.	0.000 (Negligible)

The mean ranks obtained from Friedman's analysis are shown in Table 11. As a result of the analysis, in the group of trade professionals category, 'sharing only happens during the activity' is identified as the key barrier followed by 'lack of formal processes to share knowledge' and 'lack of time to share knowledge' respectively.

Table 11- Mean Ranks (group of trade professionals)

CODE	BARRIER	MEAN RANK
A	Lack of Time	3.01
B	No Formal Processes	2.89
C	Sharing only happens during the activity	2.28
D	Job Security	3.32
E	Workers Poorly Informed	3.50

The Conover test was conducted as a post hoc test for the pairwise comparisons. The results are shown in Figure 28. Comparing the adjusted p-values, it can be inferred that C-A, C-D, C-E have significantly different ranks ($p < 0.05$).

```
##   A       B       C       D
## B 1.00000 -       -       -
## C 0.03346 0.14288 -       -
## D 1.00000 0.85612 0.00036 -
## E 0.49621 0.14288 1.3e-05 1.00000
##
## P value adjustment method: bonferroni
```

Figure 28- Pairwise comparisons using Conover Test (group of trade professionals)-Field

4.2.3.2 At Managerial Level

The results of the analysis indicate that there is a difference in the preference of the participants to rank the barriers in the category 'Managerial Level' (see Table 12). The observed χ^2 value is 22.195 and the p-value is negligible which is less than 0.05.

Table 12- Test Statistics (managerial)

N	82
Chi-Square	22.195
df	4
Asymp. Sig.	0.000 (Negligible)

The mean ranks obtained from Friedman's analysis are shown in Table 13. As a result of the analysis, in the managerial level category, ‘lack of encouragement from the management’ is identified as the key barrier followed by ‘resistance of managers towards change’ and ‘managers are not walking the talk’ respectively.

Table 13- Mean Ranks (managerial)

CODE	BARRIER	MEAN RANK
A	Lack of Encouragement	2.33
B	Mangers resistance to change	2.91
C	Unwillingness of managers to take risk	3.39
D	Managers not walking the talk	3.17
E	Managers and Staff treated differently	3.20

The Conover test was conducted as a post hoc test for the pairwise comparisons. The results are shown in Figure 29. Comparing the adjusted p-values, it can be inferred that A-C, A-D, A-E have significantly different ranks ($p < 0.05$).

```
##   A       B       C       D
## B 0.18633 -       -       -
## C 0.00024 0.55567 -       -
## D 0.00760 1.00000 1.00000 -
## E 0.00535 1.00000 1.00000 1.00000

##
## P value adjustment method: bonferroni
```

Figure 29- Pairwise comparisons using Conover Test (managerial level)-Field

4.2.3.3 At the Organization Level

The results of the analysis also indicate that there is a difference in the preference of the participants to rank the barriers in the category ‘Organizational Level’ (see Table 14) since the observed χ^2 value is 32.690 and the p-value is negligible which is less than 0.05.

Table 14- Test Statistics (organization)

N	82
Chi-Square	32.690
df	5
Asymp. Sig.	0.000 (Negligible)

The mean ranks obtained from Friedman's analysis are shown in Table 15. As a result of the analysis, in the organizational category, ‘reluctance of the managers to share knowledge with the employees’ is identified as the key barrier followed by ‘disappearance of the retirees along with their knowledge’ and ‘apathetic nature of the top-level execution’ respectively.

Table 15- Mean Ranks (organization)

CODE	BARRIER	MEAN RANK
A	Reluctance of the managers to share knowledge	2.98
B	Apathetic top management	3.24
C	Lack of formal processes	3.37
D	Retirees disappear with knowledge	3.12
E	Experience not valued	3.98
F	Stringent policies	4.32

The Conover test was conducted as a post hoc test for the pairwise comparisons. The results are shown in Figure 30. Comparing the adjusted p-values, it can be inferred that A-E, A-F, B-F, C-F, D-F have significantly different ranks ($p < 0.05$).

```
##   A       B       C       D       E
## B 1.00000 -       -       -       -
## C 1.00000 1.00000 -       -       -
## D 1.00000 1.00000 1.00000 -       -
## E 0.01064 0.19400 0.57155 0.05671 -
## F 9.4e-05 0.00426 0.01904 0.00082 1.00000

##
## P value adjustment method: bonferroni
```

Figure 30- Pairwise comparisons using Conover Test (organization level)- Fiel

4.2.4 Comparing Management v/s Field Perspectives

One of the research questions addressed in this research is- "*Is there any congruence of opinions between the management and field team regarding the barriers to knowledge sharing?*" To address this question, a comparison is made of the top three barriers in each category (see Table 16) after analyzing the responses from the management and the field team. There is a divergence of opinions for both the management and field teams.

Table 16- Management v/s Field Team: Top-ranked barriers in each of the category

		Management Perspective (N=67)			Field Perspective (N=82)		
CATEGORY ↓	**RANK →**	**1**	**2**	**3**	**1**	**2**	**3**
Barriers at the Level Trade Professionals		Lack of formal processes	Not enough time	Sharing only happens during the activity	Sharing only happens during the activity	Lack of formal processes	Not enough time
Barriers at Managerial Level		Managers are resistant to change	Lack of encouragement	Unwillingness of managers to take risk	Lack of encouragement	Managers are resistant to change	Managers not walking the talk
Barriers at Organization Level		No formal process	Retirees disappear with the knowledge	Reluctance of Managers to share knowledge	Reluctance of Managers to share knowledge	Retirees disappear with the knowledge	Apathetic nature of top management

4.2.5 Other Identified Barriers to Knowledge Sharing

A few other barriers are also identified based on the free text entry options accompanying each survey. These barriers are grouped into four different themes adopted from the study by Akhavan et al. (2014). The themes are individual barriers, organizational barriers, project-related barriers, and contextual barriers. A total of 92 responses were obtained in this category from both the surveys i.e. the survey directed towards the managers and the field team. These responses are manually categorized into themes in the forthcoming sections. The survey responses are tabulated in Appendix E.

4.2.5.1 Individual Barriers

Individual barriers are related to human behavior, actions and perceptions which differ from person to person (Akhavan et al., 2014). Most of the respondents mentioned certain barriers in common like the nonavailability of enough time for training and sharing lessons learned, job security, unwillingness to learn and to share knowledge, an individual's personality and character, and workers' attitude towards learning. As per one of the respondents highlighting the job security issue, *"people are very protective of their knowledge. They feel it keeps them more valuable and helps protect their job. By teaching what you know to someone else you have now become irrelevant and replaceable"* whereas others mentioned regarding an individual's attitude and lack of time that "*Journeyman not taking the time and having patience with apprentices. Possibly due to the stress of time from upper management*". The fear of losing the job to others is putting aside supervisors from sharing their acquired knowledge with their subordinates which is fatal for one of the most important resources in the construction industry i.e. tacit knowledge. This attitude of job security sometimes differs from union-based and non-union contractors. One of the supervisors who had worked for both union and non-union contractors mentioned, "*union is a family but non-union is a merit school*". A journeyman from union based electrical contracting firm stated, "*I believe that the only barriers I see in either sharing knowledge with someone or receiving knowledge are 'the person'. Our trade is built on sharing knowledge, which makes our union a union. If there's an issue with sharing knowledge, it's because the person doesn't want to share for personal reasons"*. The organizations need to decipher ways for the efficient flow of knowledge

among the project teams at the individual level. Employee motivation and encouragement could aid in shattering these barriers.

4.2.5.2 Organizational Barriers

The organizational barriers are related to the persistent environment, culture, and conditions within an organization (Akhavan et al., 2014). Some of the barriers identified in this category are profit motive of the employers, lack of resources, lack of appreciation and rewards for sharing knowledge, and non-involvement of the field team in the decision-making regarding knowledge management. As per one of the respondents, "*management just needs to listen to staff more on things that could be done differently when this happens it hinders the sharing of knowledge and stuff isn't getting done as efficiently as it should be*". Another respondent mentioned, *"companies don't build in time to share knowledge, i.e. don't want to pay the costs for the training"*. Lack of time is identified as the most common barrier to sharing knowledge due to the transient and unique nature of the construction projects (Carrillo et al., 2004). Generally, in construction projects, time is of the essence that ensues working pressure both on the management and the field team which sometimes hinders knowledge sharing. This is further buttressed by the responses that mention, *"Top-down focus of job completion overtraining the workforce. Training is best when it isn't pressured by time constraints and when the situation presents itself as a teaching opportunity"* and *"pressed to work faster and not enough competent workers with time to teach".* All these barriers could be tackled by removing the shortcomings in the organizational culture and strategies that hamper knowledge sharing.

4.2.5.3 Contextual Barriers

These barriers reflect an individual's perceptions and understanding of knowledge management (KM) and how it prevails among the individuals in an organization (Akhavan et al., 2014). Change in company focus, failure in identifying wisdom, etc. are some of the identified barriers in this category. As per one of the respondents, *"past generations were focused on building; new generations are focused on managing & technology. The simple change in industry focus leads to knowledge loss".* Another respondent mentioned, "*lack of knowledge categorization for ease of discussion*". Tacit hunches often remain unidentified in the construction industry as knowledge

management mainly focuses on codifying the explicit knowledge (Grover & Froese, 2016). Organizations must develop a strategy to categorize the different types of knowledge generated in the construction projects so that effective steps could be taken to capture and harness 'the tacit dimension of knowledge' before it steps out of the door.

4.2.5.4 Project Related Barriers

These barriers are specific to construction projects and may result due to the project-based structure of the organizations and the nature of the project (Akhavan et al., 2014). As per one of the respondents, *"People are typically focused on one project at a time and therefore, lessons learned on one job are not shared with a project team on a similar project"*. Similarly, as per another respondent, *"A particular project team may not be aware that another project team needs lessons learned"*. Sharing lessons learned is a great source of harnessing tacit knowledge. Transferring lessons learned from one project to another could save an ample amount of time and cost that the organizations are spending as a part of knowledge management (KM) processes.

4.3 Summary

This chapter delineated the process of collecting data and analyzing it using several analysis techniques like exploratory data analysis (EDA), regression, normality tests, and pairwise comparison tests. As a result of regression analysis, the experience of an individual had a relation with the tacit knowledge score. Several barriers were also identified in each class and the field to management perspective related to barriers to knowledge sharing was also compared. The contents of this chapter encompassed the presentation of the data and findings.

CHAPTER 5. SUMMARY, CONCLUSION AND FUTURE RECOMMENDATIONS

This chapter delineates the summary of the research, conclusions, potential limitations of the research and future recommendations.

5.1 Summarizing the Research

The construction industry amalgamates several stakeholders that play a crucial role in each step of the project cycle by interacting with each other. Oftentimes, the decisions made at the job site depend upon the judgment, intuition, and experience of the field supervisors which results in the generation of context-specific knowledge. Coming to specialty contractors, they do most of the hands-on work at the job site. The trade supervisors have imbibed a plethora of knowledge throughout their experience. This knowledge is a combination of both tacit and explicit knowledge. Explicit knowledge is easy to capture and codify but tacit knowledge is difficult to articulate. The growing need of skills along with the aging workforce are compelling the construction firms to take necessary steps to harness the knowledge of the potential retirees to enhance the skill set of the existing workforce through mentoring and training programs.

While talking about knowledge management (KM) practices in the construction industry, oftentimes the human factor is ignored. Construction Organizations are taking effective steps in capturing explicit knowledge through their documentation and databases, but the tacit dimension of knowledge is relatively unexplored hitherto. To effectively harness and utilize tacit knowledge it is necessary to identify it in practice. One of the goals of this research is to gauge the reliance of experienced field supervisors on tacit knowledge by deploying a reliable measure. For the same, the measure developed by Chilton and Bloodgood (2008) was replicated to test its usefulness in the construction industry. Slight modifications were made to the instrument based on the feedback from two of the major electrical contractors from Indiana. The data was collected through semi-structured interviews with the field personnel through site visits and conference calls.

Another goal of this research was to identify the potential barriers to knowledge sharing at the job site and comparing the management and the field perspectives related to it. It is important to identify the barriers to knowledge sharing so that the organizations could plan effective

strategies to strengthen the existing knowledge capturing strategies by shattering those barriers. For this part of the research, an online survey was developed that incorporated a few of the identified barriers to knowledge sharing from the literature along with a few free-text entry options. The survey asked the participants to rank the barriers based on their experience. The survey was distributed to both the management and the field team.

The data collection process went up to two months. A total of 25 observations were collected through semi-structured interviews with the field supervisors and trade professionals for the tacit knowledge survey. Similarly, for the barriers survey, 67 complete responses were obtained from the managers and executives whereas, 82 complete responses were obtained from the field team. Both qualitative and quantitative methods are deployed to analyzing the data. In the qualitative category, narrative analysis was used and in the quantitative category, linear regression, Friedman test, normality tests, and pairwise comparison tests were used. The conclusions drawn are summarized in the forthcoming section.

5.2 Conclusions

The analysis results are delineated in Chapter 4. Based on the analysis, the conclusions drawn from this research are summarized below:

5.2.1 Reliance of the Field Supervisors on Tacit Knowledge

The results of exploratory data analysis show that there is a significant relationship between the tacit knowledge score and an individual's experience. From figure 14 it can be inferred that the median tacit knowledge score increases with the increase in the experience. Generally, during earlier times, most of the supervisors have attained this position based on their skills and knowledge. By performing repetitive tasks every day, the trade field supervisors have become so efficient in the respective fields and they have internalized the knowledge generated throughout their experience (Skinnarland & Yndesdal, 2014) that has become their habit of doing work or secondary nature. They rely more on their judgment and intuition than the written procedures while performing daily construction activities. The education level of an individual does not have a significant relationship with the usage of tacit knowledge among the field personnel (see Figure

15). The relationship between experience and education with the usage of tacit knowledge is further validated using regression analysis.

The linear regression analysis results indicate that the effect of an individual's experience on the usage of tacit knowledge is significant (p-value < 0.05) whereas, for the education level it isn't (see Figure 16). Also, the regression analysis concluded the final model to predict the tacit knowledge score based only on one categorical variable i.e. experience level. Turkey Honest Significant Difference test indicated that there is no significant difference in the tacit knowledge scores of the individuals having 20-25 years of work experience and those with greater than 25 years (see Appendix F) hence, the final model is based on only two levels of work experience i.e. less than 20 years and greater than 20 years. The hypothesis is validated based on the final regression model. Most of the individuals with less experience rely more on explicit knowledge whereas the experienced individuals rely more on tacit knowledge at the construction job site. It can be concluded based on the data and results that the specialty contractors should prioritize developing strategies beforehand for capturing the tacit hunches from the field personnel who are having higher work experience say over 20 years since most of the individuals in this category seem to significantly rely on the tacit knowledge for performing the day-to-day construction tasks. The proposed methodology framework could be deployed by the firms to identify the reliance of the individuals on the tacit dimension of knowledge. It is worth noting

The narrative analysis also delineates that most of the field supervisors are relying on their experience-based knowledge than following standard written procedures. Getting paired up with the experienced professionals, apprenticeship training and mentorships are the best ways to transfer the tacit knowledge from the baby boomers to the millennials. Doing job layout at the site, running conduits, pulling cables, etc. are some of the identified activities that most of the supervisors mentioned where they are using experience-based knowledge. A similar instrument could also be deployed by the construction firms to identify the parcels of tacit knowledge at the job site. Also, by identifying the type of knowledge on which an individual is relying to perform a specific task could aid in better matching of workers with the jobs. The proposed instrument could also be used to check the effectiveness of the apprenticeship training programs.

5.2.2 Barriers to Knowledge Sharing

A total of 101 responses were obtained from the management team among which 67 useful responses were analyzed. It can be observed from the survey demographics data (see Table 2 and 9) that most of the respondents were ‘male’. This highlights that the ‘female group’ is relatively untapped while talking about workforce development in trades. This group could potentially benefit the industry in resolving the problem of existing skill-shortage if properly explored. Coming to further analysis, the results of Friedman's analysis show that the key barrier related to knowledge sharing among the group of trade professionals is the lack of formal processes and procedures for sharing knowledge. Organizations should formulate the knowledge sharing processes in their project execution plan. Failure to do so will result in a substantial loss of know-how from the construction job sites. Similarly, the resistance of managers to adopt a change is identified as a key barrier in the managerial category and again lack of formal processes is identified as the key barrier to knowledge sharing at the organizational level. The transient nature of the construction project teams and time essence of the projects affect the sharing of knowledge at the job site. There should be proper strategies and procedures to capture the knowledge generated during the lifecycle of a project.

Coming to the field team, a total of 82 useful responses were obtained. The results of Friedman's analysis show that ‘sharing only happens in the activity’ is identified as the key barrier to knowledge sharing among the group of trade professionals. In other words, sharing only happens when individuals socialize. The field supervisors should ensure that the workers should utilize effectively the knowledge gained during an activity. Organizations should take effective measures to promote socialization and gatherings at construction projects so that more and more knowledge could be shared among individuals for example during breaks, events, training programs, etc. In the managerial category, lack of encouragement from the top management is identified as the key barrier to the process of knowledge sharing. Generally, in the specialty contracting firms, profit maximization is the key motive and management sometimes feels that it will cost money to provide training to the trade professions. Organizations should provide resources and encourage the workers to share knowledge. Also, the reluctance of managers to share knowledge with the subordinates is identified as the key barrier at the organizational level. This is what Sveiby (2007) referred to as ‘the silo mentality’. This silo mentality of the managers is hampering the knowledge management (KM) at the construction job sites.

On comparing both the perspectives i.e. the management vs the field (see Table 16), it is clear that the field team doesn't think the same way as the management. The key barriers identified in each category were different for both. For the knowledge management to be successful at each level in an organization, it is equally important that the management should incorporate the feedback from the field team to strengthen the existing knowledge capturing and harnessing strategies. Often, the perspectives of the field team are ignored in decision making related to knowledge management (KM) policies and procedures. It is the collective effort of the field and management that results in the success of a project which eventually depends upon the type of knowledge being utilized. Tacit knowledge is what ensues the construction firms to sustain in this skill-seeking market and it is necessary to harness it effectively before an experienced employee leaves the organization.

Further, narrative analysis delineates that job security is one of the most negative individual factors that prevent a person from sharing knowledge. Organizations should motivate their employees to share the valuable knowledge they possess. Also, the opinions of union and non-union specialty contractors were found to be different during the field interviews. Most of the unions take knowledge sharing as a responsibility since lack of skills sometimes affects their retirement funds whereas non-unions stick to the concept of a merit-school i.e. the more you know, the more valuable you are. Organizations should keep aside special funds to boost the knowledge management process, especially at the site level like how they are putting efforts in safety and quality management. Organizations should categorize the different types of knowledge generated at the job site so that tacit hunches can be captured effectively. It doesn't mean that the organizations should not concentrate on harnessing the explicit knowledge. It is equally important, but it is not as difficult to identify and articulate as tacit. Explicit knowledge can be easily captured using documentation, databases, etc. that is traditionally being followed in the construction industry.

Moreover, the lessons learned approach is a great way to harness tacit knowledge if it is done properly. Generally, it is done at the end of the project when most of the teams have disintegrated or transferred to other projects (Grover & Froese, 2016). Capturing lessons learned continuously throughout the project life cycle and sharing it with the other project teams could be an effective way to share tacit knowledge. Implementation of other methods like Communities of Practice (CoP), storytelling, mentoring, socializing, and using technology like Virtual Reality (VR)

or Mixed Reality (MR) could strengthen the existing knowledge management strategies among the specialty contractors.

5.3 Potential Limitations

Some of the potential limitations of this study are:

- Only two dimensions of knowledge are considered, and all the knowledge is thought to occur in the purview of tacit and explicit. There may be other forms of knowledge that are not considered in this research.
- The tacit knowledge scores are calculated based on the feedback from the participants. No specific construction activity is used to compare an individual's reliance on tacit knowledge.
- The reliability and validity of the adopted instrument are not re-tested. It is assumed that the instrument adopted is reliable and valid. The intent is to test its usefulness in the construction industry.
- The surveys were conducted only with electrical contracting firms that may impact the generalizability of this research to other specialty contracting firms due to organizational culture, type of work, location, availability of resources, etc.
- The instrument (Chilton & Bloodgood, 2008) adopted in this study is assumed to be reliable and it is incorporated to check its usefulness in the construction industry. Based on the model adopted, the instrument is not tested for the individual impact of the four dimensions (conscious awareness, expressibility, codifiability, and formal/informal application) towards the tacitness of knowledge.
- Sometimes lack of knowledge about a specific construction activity may result in the proclivity of the answers in the semantic differential measure more towards the tacit side (Chilton & Bloodgood, 2008). Hence, it would be difficult to differentiate between experience-based answers or an answer based on just a lack of knowledge.
- Only 25 observations were used to build the final regression model. The model is not further tested for the average validity percent (AVP) and average invalidity percent (AIP) for its validation because of the small sample size. The model is only used to compare the two classes of individuals based on their experience levels.

- Only two variables were used initially to run the regression analysis i.e. education and experience, and eventually, the only experience of an individual is tested to have an impact on the overall tacit knowledge score based on the instrument.
- Experience is treated as a categorical variable in developing the regression model.
- Only a few of the barriers to knowledge sharing were adopted from the literature and arranged in categories asking the participants to rank them in order. The intent behind this was to keep the survey short mainly to capture the viewpoints of the managers, executives, and field personnel through the free-text entry options.
- Most of the interviews and surveys were conducted with the union-based electrical contracting firms. There are chances that the opinion of the non-union based firms might differ with the outcome of this research.
- The firms that are surveyed are not differentiated based on their size, location, organizational structure, and most of the participants were from different positions i.e. managerial and field.

5.4 Recommendations and Future Work

Some of the recommendations for future work are:

- The impact of each of the dimensions (conscious awareness, expressibility, codifiability, and formal/informal application) from the adopted model could be tested using statistical analysis towards the degree of tacitness of knowledge. This will ensure the reliability and validity of this measure in the construction industry.
- The final regression model could be further tested to check its validity given that the sample is large enough.
- The instrument could also be deployed to check the effectiveness of the apprenticeship programs by comparing the tacit knowledge scores of the apprentices with those of the experts.
- In the future, the study could be extended to different trades and even the general contracting firms to capture their opinion and perspectives and making the comparisons.

- This research proposed steps to identify the tacit dimension of knowledge at the construction job sites. Future studies could aim at how to capture this knowledge once identified and then implementing it in the training programs.

REFERENCES

Abdi, H., & Williams, L. J. (2010). Tukey's Honestly Significant Difference (HSD) Test. In *Encyclopedia of Research Design*. Retrieved from http://www.utd.edu/~herve

AGC. (2020). *2020 Construction Outlook Survey Results National Results*. Retrieved from https://www.agc.org/sites/default/files/Files/Communications/2020_Outlook_Survey_National.pdf

AGC of America. (2018). Worker Shortage Survey Analysis. Retrieved February 9, 2020, from https://www.agc.org/sites/default/files/2018_Worker_Shortage_Survey_Analysis.pdf

Ahmad, H. S., & An, M. (2008). Knowledge management implementation in construction projects: a KM model for Knowledge Creation, Collection and Updating (KCCU). *International Journal of Project Organization and Management*, *11*(2), 133–166. https://doi.org/doi:10.1504/IJPOM.2008.022189

Akhavan, P., Zahedi, M. R., & Hosein, S. H. (2014). A conceptual framework to address barriers to knowledge management in project-based organizations. *Education, Business and Society: Contemporary Middle Eastern Issues*, *7*(2), 98–119. https://doi.org/10.1108/EBS-10-2013-0040

Anwar, R., Rehman, M., Wang, K. S., & Hashmani, M. A. (2019). Systematic Literature Review of Knowledge Sharing Barriers and Facilitators in Global Software Development Organizations Using Concept Maps. *IEEE Access*, *7*. https://doi.org/10.1109/ACCESS.2019.2895690

Arduin, P.-E., Mayag, B., Negre, E., & Rosenthal-Sabroux, C. (2014). How to compromise on the best price? A group tacit knowledge-based multicriteria approach. *Journal of Decision Systems*, *23*(1), 99–112. https://doi.org/10.1080/12460125.2014.863592

Baker, M., Baker, M., Thorne, J., & Duntell, M. (1997). Leveraging Human Capital. *The Journal of Knowledge Management*, *1*(1), 63–74.

Biernacki, P., & Waldorf, D. (1981). Snowball Sampling Problems and Techniques of Chain Referral Sampling. *Sociological Methods & Research*, *10*(2), 141–163. https://doi.org/doi:10.1177/004912418101000205

Bigelow, F. F., Perrenoud, A. J., Rahman, M., & Saseendran, A. (2019). An Exploration of Age on Attraction and Retention of Managerial Workforce in the Electrical Construction Industry in the United States. *International Journal of Construction Education and Research*. https://doi.org/10.1080/15578771.2019.1611678

Bijleveld, F. R., & Dorée, A. G. (2014). Method-based learning: a case in the asphalt construction industry. *Construction Management and Economics*, *32*(7–8), 665–681. https://doi.org/10.1080/01446193.2014.887211

Bilginsoy, C. (2018). Unemployment, the Great Recession, and apprenticeship attrition in the U.S. *Journal of Vocational Education and Training*, *70*(2), 171–192. https://doi.org/10.1080/13636820.2017.1392999

Bolisani, E., & Bratianu, C. (2018). The Elusive Definition of Knowledge. In *Emergent knowledge strategies: Strategic thinking in knowledge management* (pp. 1–22). https://doi.org/10.1007/978-3-319-60656

Box, G. E. P., & Cox, D. R. (1985). An Analysis of Transformations. *The Collected Works of George E. P. Box: Volume II*, *26*, 463–495. https://doi.org/10.2307/2984418

Boyd, D., & Addis, M. (2011). *Moving from knowledge management to expertise management: a problem of contexts*. Centre for Environment and Society Research, Faculty of Technology, Engineering and the Environment.

Bresnen, M., Edelman, L., Newell, S., Scarbrough, H., & Swan, J. (2003). Social practices and the management of knowledge in project environments. *International Journal of Project Management*, *21*(3), 157–166. https://doi.org/10.1016/S0263-7863(02)00090-X

Brown, A. (2019). Construction's skills shortage. Retrieved February 14, 2020, from https://www.khl.com/international-construction/constructions-skills-shortage-/138380.article

Bureau of Labor Statistics. (2019a). Employment by detailed occupation : U.S. Bureau of Labor Statistics. Retrieved February 14, 2020, from https://www.bls.gov/emp/tables/emp-by-detailed-occupation.htm

Bureau of Labor Statistics. (2019b). Employment Projections 2018-2028. Retrieved February 9, 2020, from www.bls.gov/emp/tables/employment-by-major-industry-sector.htm.

Bureau of Labor Statistics. (2020). Employed persons by detailed occupation and age. Retrieved February 14, 2020, from https://www.bls.gov/cps/cpsaat11b.htm

Business Dictionary. (2020). What is experience? definition and meaning - BusinessDictionary.com. Retrieved February 3, 2020, from http://www.businessdictionary.com/definition/experience.html

Campbell, D., & Campbell, S. (2008). *Statlab Workshop Introduction to Regression and Data Analysis*. Retrieved from http://www.yale.edu/statlab

Carrillo, P., Robinson, H., Al-Ghassani, A., & Anumba, C. (2004). Knowledge management in UK construction: strategies, resources and barriers. *Journal of Project Management*, *35*(1), 46–56.

Chen, L., & Mohamed, S. (2010). The strategic importance of tacit knowledge management activities in construction. *Construction Innovation*, *10*(2), 138–163. https://doi.org/10.1108/14714171011037165

Chilton, M. A., & Bloodgood, J. M. (2008). The dimensions of tacit & explicit knowledge: A description and measure. *International Journal of Knowledge Management*, *4*(2), 75–91. Retrieved from https://search.proquest.com/docview/223090488?accountid=13360

Das, K. R. (2016). A Brief Review of Tests for Normality. *American Journal of Theoretical and Applied Statistics*, *5*(1), 5–12. https://doi.org/10.11648/j.ajtas.20160501.12

Ding, Z., & Ng, F. (2008). A new way of developing semantic differential scales with personal construct theory. *Construction Management and Economics*, *26*(11), 1213–1226. https://doi.org/10.1080/01446190802527522

Dowell, B. E., & Wexley, K. N. (1978). Development of a work behavior taxonomy for first-line supervisors. *Journal of Applied Psychology*, *63*(5), 563–572. Retrieved from http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=1&sid=8134108c-8883-4dc0-afec-2cfa63ba58d5%40sdc-v-sessmgr02

Dreyfus, H. ., & Dreyfus, S. E. (1986). *Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer*. New York: The Free Press.

Dunn, O. J. (1961). Multiple Comparisons Among Means. *Journal of the American Statistical Association*, *56*(293), 52–64.

Egbu, C. O., & Robinson, H. S. (2008). Construction as a Knowledge-Based Industry. *In*: Anumba, C. J., Egbu, C. & Carrillo, P. (eds.) *Knowledge Management in Construction* (pp. 31–49). Blackwell publishing. https://doi.org/10.1002/9780470759554

Eisenberg, R. (2019, January). Boomer Brain Drain: The Big Mistake Employers Are Making. *Forbes Magazine*. Retrieved from https://www.forbes.com/sites/nextavenue/2019/01/25/boomer-brain-drain-the-big-mistake-employers-are-making/#e4016d91ebee

Farrar, N., & Trorey, G. (2008). Maxims, tacit knowledge and learning: Developing expertise in dry stone walling. *Journal of Vocational Education and Training*, *60*(1), 35–48. https://doi.org/10.1080/13636820701828812

Fellows, R., & Liu, A. (2008). *Research Methods for Construction*. West Sussex, UK: Blackwell Publishing Ltd.

Gasaway, R. (2017). Tacit knowledge and situational awareness - Situational Awareness Matters!™. Retrieved February 3, 2020, from https://www.samatters.com/tacit-knowledge-and-situational-awareness/

Gladwell, M. (2008). *Outliers: The Story of Success*. Little, Brown and Company. https://doi.org/10.1017/CBO9781107415324.004

Groebner, D. F., Shannon, P. W., Fry, P. C., & Smith, K. D. (2010). *Business Statistics: A decision-making approach*. New Jersey: Pearson Publications.

Grover, R., & Froese, T. M. (2016). Knowledge Management in Construction Using a SocioBIM Platform: A Case Study of AYO Smart Home Project. *Procedia Engineering*, 1283–1290. https://doi.org/10.1016/j.proeng.2016.04.165

Halonen, R., & Laukkanen, E. (2008). Managing tacit and explicit knowledge in organisational teams. *3rd International Conference on Digital Information Management, ICDIM 2008*, (November 2008), 292–297. https://doi.org/10.1109/ICDIM.2008.4746707

Hedlund, J., Antonakis, J., & Sternberg, R. J. (2002). *Tacit Knowledge and Practical Intelligence: Understanding the Lessons of Experience*. Arlington, VA.

Hedlund, J., Horvath, J. A., Forsythe, G. B., Snook, S., Williams, W. M., Bullis, R. C., … Sternberg, R. J. (1998). *Tacit Knowledge in Military Leadership: Evidence of Construct Validity*. Alexandria, VA.

Hu, W. (2008). Framework of Knowledge Acquisition and Sharing in Multiple Projects for Contractors. *International Symposium on Knowledge Acquisition and Modeling*, 172–176. https://doi.org/DOI 10.1109/KAM.2008.112

Huang, X., Hsieh, J. J. P. A., & He, W. (2014). Expertise dissimilarity and creativity: The contingent roles of tacit and explicit knowledge sharing. *Journal of Applied Psychology*, *99*(5), 816–830. https://doi.org/10.1037/a0036911

Hunt, D. P. (2003). The concept of knowledge and how to measure it. *Journal of Intellectual Capital*, *4*(1), 100–113. Retrieved from https://search.proquest.com/docview/205543991/fulltextPDF/17C50A9599924BB7PQ/1?accountid=13360

IBM. (2020). SPSS Software. Retrieved March 11, 2020, from https://www.ibm.com/analytics/spss-statistics-software

Joe, C., Yoong, P., & Patel, K. (2013). Knowledge loss when older experts leave knowledge-intensive organisations. *Journal of Knowledge Management*, *17*(6), 913–927. https://doi.org/10.1108/JKM-04-2013-0137

Johnson, W. (2018). Build an A-Team. Retrieved February 4, 2020, from https://hbr.org/webinar/2018/12/https-hbrwebinars-wins-net-hbr1214181mweb

Joy, A., & Haynes, B. P. (2011). Office design for the multi-generational knowledge workforce. *Journal of Corporate Real Estate*, *13*(4), 216–232. https://doi.org/10.1108/14630011111214428

Khuzaimah, K. H. M., & Hassan, F. (2012). Uncovering Tacit Knowledge in Construction Industry: Communities of Practice Approach. *Procedia - Social and Behavioral Sciences*, *50*(2012), 343–349. https://doi.org/10.1016/j.sbspro.2012.08.039

Kivrak, S., Arslan, G., Dikmen, I., & Birgonul, T. M. (2008). Capturing Knowledge in Construction Projects: Knowledge Platform for Contractors. *Journal of Management in Engineering*, *24*(2), 87–95. https://doi.org/10.1061/ASCE0742-597X200824:287

Kolb, D. A. (2014). *Experience as the Source of Learning and Development* (Second). Pearson Education Inc.

Komorowski, M., Marshall, D. C., Salciccioli, J. D., & Crutain, Y. (2016). Exploratory Data Analysis. In *Secondary Analysis of Electronic Health Records* (pp. 185–203). https://doi.org/10.1007/978-3-319-43742-2

Kutner, M. H., Nachtsheim, C. J., Neter, J., & Li, W. (2005). Applied Linear Statistical Models. In *McGraw-Hill* (Fifth). https://doi.org/10.2307/2984653

Leonard, N., & Insch, G. S. (2005). Tacit knowledge in academia: A proposed model and measurement scale. *Journal of Psychology: Interdisciplinary and Applied*, *139*(6), 495–512. https://doi.org/10.3200/JRLP.139.6.495-512

Leung, J. K. L., & Fong, P. S. W. (2011). The power of stories in the construction industry: Lessons from other domains. *The Journal of Information and Knowledge Management Systems*, *41*(4), 466–482. https://doi.org/10.1108/03055721111188548

Lin, Y. C., & Lee, H. Y. (2012). Developing project communities of practice-based knowledge management system in construction. *Automation in Construction*, *22*(2012), 422–432. https://doi.org/10.1016/j.autcon.2011.10.004

Littman, J. (2017, August). Fountain Of Youth Running Dry For Construction Industry. *Forbes*. Retrieved from https://www.forbes.com/sites/bisnow/2017/08/16/fountain-of-youth-running-dry-for-construction-industry/#1af6e66b6b44

Macneil, C. M. (2004). Exploring the supervisor role as a facilitator of knowledge sharing in teams. *Journal of European Industrial Training*, *28*(1), 93–102. https://doi.org/10.1108/03090590410513901

Mahroeian, H., & Forozia, A. (2012). Challenges in Managing Tacit Knowledge: A Study on Difficulties in Diffusion of Tacit Knowledge in Organizations. In *International Journal of Business and Social Science*, *3*(19), 303-308.

Martin, L, & Root, D. (2009). Association of Researchers in Construction Management. In A. Dainty (Ed.), *Procs 25th Annual ARCOM Conference* (pp. 749–758). Nottingham, UK: Association of Researchers in the Construction Management.

Martin, Ludwig, & Hartmann, A. (2010). Understanding knowledge creation in construction: activity theory as an alternative approach. In C. Egbu (Ed.), *Procs 26th Annual ARCOM Conference* (pp. 737–746). Leeds, UK: Association of Researchers in Construction Management.

Meloni, G., & Villa, T. (2007). Uncovering tacit knowledge in projects. *PMI® Global Congress 2007—EMEA*. Retrieved from https://www.pmi.org/learning/library/uncovering-tacit-knowledge-projects-7378

Molina-Azorin, J. F., Cameron, R., & Molina Azorín, J. (2010). The Application of Mixed Methods in Organisational Research: A Literature Review. *The Electronic Journal of Business Research Methods*, *8*(2), 95–105. Retrieved from www.ejbrm.com

Nafei, W., Khanfar, N. M., Kaifi, B. A., Nafei, W. A., & Kaifi, M. M. (2012). A Multi-Generational Workforce: Managing and Understanding Millennials. *International Journal of Business and Management*, *7*(24), 88–93. https://doi.org/10.5539/ijbm.v7n24p88

National Center for Construction Education & Research. (2016). *The Cornerstone: A Construction publication for Workforce Development Professionals*. Retrieved from https://www.nccer.org/docs/default-source/pdfs/nccer-cornerstone-fall-winter-2017-final.pdf

Nesan, J. (2012). Factors Influencing Tacit Knowledge in Construction. *Construction Economics and Building*, *5*(1), 48–57. https://doi.org/10.5130/ajceb.v5i1.2943

Netzer, T. (2019). Baby Boomers retiring, leaving many open trades positions. Retrieved February 11, 2020, from Industrial Safety & Hygiene News website: https://www.ishn.com/articles/110888-baby-boomers-retiring-leaving-many-open-trades-positions

Ninaus, C., & Knapp, D. (2019). The potential of knowledge management on construction sites. *ISEC 2019 - 10th International Structural Engineering and Construction Conference*. Proceeding. ISEC Press.

Nonaka, I., & Takeuchi, H. (1995). *The Knowledge-Creating Company*. New York: Oxford University Press, Inc.

Nonaka, I., Toyama, R., & Konno, N. (2000). SECI, Ba and Leadership: A Unified Model of Dynamic Knowledge Creation. *Long Range Planning*, *33*(1), 5–34. https://doi.org/10.1016/S0024-6301(99)00115-6

Nonaka, Ikujiro, & Konno, N. (1998). The Concept of "Ba": Building a foundation for knowledge creation. *California Management review*, *40*(3), 40–54.

Panahi, S., Watson, J., & Partridge, H. (2013). Towards tacit knowledge sharing over social web tools. *Journal of Knowledge Management*, *17*(3), 379–397. https://doi.org/10.1108/JKM-11-2012-0364

Pathirage, C., Amaratunga, D., & Haigh, R. (2008). The role of tacit knowledge in the construction industry: towards a definition. *CIB W89 International Conference on Building Education and Research, in Conjunction with CIB W113, CIB TG53, CIB TG63, CIB TG67, CIB TG68, and CIB TG69, 11th - 15th February*, (March 2016).

Pathirage, C. P., Amaratunga, R. D. G., & Haigh, R. (2005). Importance of tacit knowledge towards company performance and its relevance to construction. *Queensland University of Technology Research Week International Conference, QUT Research Week 2005 - Conference Proceedings*, (December).

Pathirage, C. P., Amaratunga, R. D. G., & Haigh, R. P. (2006). A theoretical framework on managing tacit knowledge for enhancing performance in the construction industry. *COBRA 2006 - Proceedings of the Annual Research Conference of the Royal Institution of Chartered Surveyors*, (July 2016).

Pathirage, C. P., Amaratunga, R. D. G., & Haigh, R. P. (2007). Tacit knowledge and organisational performance: Construction industry perspective. *Journal of Knowledge Management*, *11*(1), 115–126. https://doi.org/10.1108/13673270710728277

Pohlert, T. (2016). *The Pairwise Multiple Comparison of Mean Ranks Package (PMCMR)*. Retrieved from http://cran.r-project.org/package=PMCMR.

Polyani, M. (1966). *The Tacit Dimension*. Garden City, New York: Doubleday and Company, INC.

Quintas, P. (2005). The Nature and Dimensions of Knowledge Management. In C. J. Anumba, C. Egbu, & P. Carrillo (Eds.), *Knowledge Management in Construction* (pp. 10–30). https://doi.org/10.1002/9780470759554.ch2

Schwatka, N. V, Butler, L. M., & Rosecrance, J. R. (2012). Epidemiologic Reviews An Aging Workforce and Injury in the Construction Industry. *Epidemiologic Reviews*, *34*, 156–167. https://doi.org/10.1093/epirev/mxr020

Scott, L., & Twumasi, E. A. (2018). Exploratory Study into Sustainability Expertise in the Irish Architecture, Engineering and Construction (aec) Sector. *4th International Sustainable E Cological Engineering Design for Society (SEEDS) Conference*, (9). Retrieved from https://arrow.tudublin.ie/beschreccon

Sekaran, U., & Bougie, R. (2016). *Research Methods for Business: a Skill Building Approach*. John Wiley & Sons, 2016. https://doi.org/10.1017/CBO9781107415324.004

Shapiro, S. S., & Wilk, M. B. (1965). An Analysis of Variance Test for Normality (Complete Samples). *Biometrika*, *52*(3/4), 591. https://doi.org/10.2307/2333709

Sheffield, L. (2019). Construction Grows, But Baby Boomers Retiring Leaves Gap. Retrieved February 9, 2020, from https://www.adp.com/spark/articles/2019/02/construction-grows-but-baby-boomers-retiring-leaves-gap.aspx#

Sheldon, M. R., Fillyaw, M. J., & Thompson, W. D. (1996). The use and interpretation of the Friedman test in the analysis of ordinal-scale data in repeated measures designs. *Physiotherapy Research International*, *1*(4), 221–228. https://doi.org/10.1002/pri.66

Skinnarland, S., & Yndesdal, S. (2014). Barriers to a Continuous Learning Process in Construction. *22nd Annual Conference of International Group for Lean Construction*, 1191–1201. Retrieved from http://www.oxforddictionaries.com/definition/english/barrier

Smith, E. A. (2001). The role of tacit and explicit knowledge in the workplace. *Journal of Knowledge Management*, *5*(4), 311–321. Retrieved from https://search.proquest.com/docview/230327996/fulltextPDF/E1B4EB0443E04290PQ/1?accountid=13360

Sternberg, R. J., Forsythe, G. B., Hedlund, J., Horvath, J. A., Wagner, R. K., Williams, W. M., … Grigorenko, E. L. (2000). *Practical intelligence in everyday life* (R. J. Sternberg, Ed.) [Book]. Cambridge, U.K. ; New York: Cambridge University Press.

Stover, M. (2004). Making tacit knowledge explicit: the Ready Reference Database as codified knowledge. *Reference Services Review*, *32*(2), 164–173. https://doi.org/10.1108/00907320410537685

Styhre, A. (2009). Tacit knowledge in rock construction work: a study and a critique of the use of the term. *Construction Management and Economics*, *27*(10), 995–1003. https://doi.org/10.1080/01446190903236379

Sun, J., & Ren, X. (2014). The Research on Knowledge Transfer of the Construction Project Network. *ICCREM 2014: Smart Construction and Management in the Context of New Technology*, 897–903.

Sveiby, K. E. (2007). Disabling the context for knowledge work: the role of managers' behaviours. *Management Decision*, *45*(10), 1636–1655. https://doi.org/10.1108/00251740710838004

Swedberg, C. (2018, September). Bridging the Gap: Millennials in Electrical Construction. *Electrical Contractor*, 70–74. Retrieved from http://www.ecmagdigital.com/ecmag/september_2018/MobilePagedReplica.action?pm=1&folio=6#pg10

Tagliaferre, L., & Greenwood, S. F. (2002). *Repositioning careers in electrical contracting (Feb. 2002)*.ELECTRI International Report. Bethesda, MD.

Takeuchi, H. (2006). The New Dynamism of the Knowledge-Creating Company. In H. Takeuchi & T. Shibata (Eds.), *Japan Moving Toward a More Advanced Knowledge Economy: Advanced Knowledge—Creating Companies*. Washington, D.C.: World Bank Institute (WBI).

Teerajetgul, W., & Chareonngam, C. (2008). Tacit knowledge utilization in Thai construction projects. *Journal of Knowledge Management*, *12*(1), 164–174. https://doi.org/10.1108/13673270810852467

Tesluk, P. E. ;, & Jacobs, R. R. (1998). Toward an integrated model of work experience. *Personnel Psychology*, *51*(2), 321–355. Retrieved from https://search.proquest.com/docview/220135248/fulltextPDF/1D384D2B490D4855PQ/1?accountid=13360

Tommelein, I. D., & Ballard, G. (1997). *COORDINATING SPECIALISTS*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=50EF81C7F0ECE98E8706F518E3A1898A?doi=10.1.1.42.9008&rep=rep1&type=pdf

Tserng, H. P., & Lin, Y. C. (2004). Developing an activity-based knowledge management system for contractors. *Automation in Construction*, *13*(6), 781–802. https://doi.org/10.1016/j.autcon.2004.05.003

USAID. (2013). *Tacit Knowledge: Knowledge Management Briefs*. Retrieved from https://usaidlearninglab.org/sites/default/files/resource/files/ppl_guidance_docs_tacit_knowledge_final.pdf

Wiewiora, A., Trigunarsyah, B., Murphy, G. D., & Liang, C. (2009). Barriers to effective knowledge transfer in project-based organisations. *Proceedings of the 2009 International Conference on Global Innovation in Construction Proceedings*, (May 2014). Holywell Park, Loughborough university.

Wikström, R. (2014). *Fuzzy Ontology for Knowledge Mobilisation and Decision Support* (Åbo Akademi University). https://doi.org/10.13140/2.1.4324.0329

Wilkinson, R., Sherratt, F., & Farrell, P. (2015). Knowledge management on site: a case study project. *Institution of Civil Engineers- Management, Procurement and Law*, 99–109. https://doi.org/10.1680/mpal.14.00022

Winanti, Gaol, F. L., Kosala, R., Supangkat, S. H., & Ranti, B. (2020). A survey of tacit knowledge in community learning based on measurement dimensions. In *Studies in Computational Intelligence* (Vol. 830, pp. 179–190). https://doi.org/10.1007/978-3-030-14132-5_14

Wing, C. K., Raftery, J., & Walker, A. (1998). The baby and the bathwater: Research methods in construction management. *Construction Management and Economics*, *16*(1), 99–104. https://doi.org/10.1080/014461998372637

Woo, J. H., Clayton, M. J., Johnson, R. E., Flores, B. E., & Ellis, C. (2004). Dynamic Knowledge Map: Reusing experts' tacit knowledge in the AEC industry. *Automation in Construction*, *13*(2), 203–207. https://doi.org/10.1016/j.autcon.2003.09.003

Wu, W., Tesei, A., Ayer, S., London, J., Luo, Y., & Gunji, V. (2018). Closing the Skills Gap: Construction and Engineering Education Using Mixed Reality – A Case Study. *2018 IEEE Frontiers in Education Conference (FIE)*, 1–5. https://doi.org/10.1109/FIE.2018.8658992

Zhang, J. (2010). *A social semantic web system for coordinating communication in the architecture, engineering & construction industry* (Graduate Department of Civil Engineering, University of Toronto). Retrieved from https://search.proquest.com/docview/869988990/4C62DB95634A4BFCPQ/4?accountid=13360

APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL

Purdue Institutional Review Board approval:

PURDUE
UNIVERSITY

This Memo is Generated from the Purdue University Human Research Protection Program System, Cayuse.

Date: October 7, 2019
PI: Anthony Sparkling
Department: PWL CONST MGMT TECH
Re: Initial - IRB-2019-304
Harnessing Supervisors' Tacit Knowledge among Specialty Contractors

The Purdue University Human Research Protection Program (HRPP) has determined that the research project identified above qualifies as exempt from IRB review, under federal human sub jects research regulations 45 CFR
46.104. The Category for this Exemption is listed below. Protocols exempted by the Purdue HRPP do not require regular renewal. However, the administrative check-in date is **October 7, 2022**. The IRB must be notified when this study is closed. If a study closure request has not been initiated by this date, the HRPP will request study status update for the record.

Specific notes related to your study
are found below. **Decision:** Exempt
Category: Category 2.(i). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording).
The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

Findings:
Research Notes:

Any modifications to the approved study must be submitted for review through Cayuse IRB. All approval letters and study documents are located within the Study Details in Cayuse IRB.

What are your responsibilities now, as you move forward with your research?

Document Retention: The PI is responsible for keeping all regulated documents, including IRB correspondence such as this letter, approved study documents, and signed consent forms for at least three (3) years following protocol closure for audit purposes. Documents regulated by HIPAA, such as Release Authorizations, must be maintained for six (6) years.

Site Permission: If your research is conducted at locations outside of Purdue University (such as schools, hospitals, or businesses), you must obtain written permission from all sites to recruit, consent, study, or observe participants. Generally, such permission comes in the form of a letter from the school superintendent, director, or manager. You must maintain a copy of this permission with study records.

Training: All researchers collecting or analyzing data from this study must renew training in human subjects research via the CITI Program (www.citiprogram.org) every 4 years. New personnel must complete training and be added to the protocol before beginning research with human participants or their data.

Modifications: Change to any aspect of this protocol or research personnel must be approved by the IRB before implementation, except when necessary to eliminate apparent immediate hazards to subjects or others. In such situations, the IRB should still be notified immediately.

Unanticipated Problems/Adverse Events: Unanticipated problems involving risks to subjects or others, serious adverse events, and
noncompliance with the approved protocol must be reported to the IRB immediately through an incident report. When in doubt, consult with the HRPP/IRB.

Monitoring: The HRPP reminds researchers that this study is subject to monitoring at any time by Purdue's HRPP staff, Institutional Review Board, Research Quality Assurance unit, or authorized external entities. Timely cooperation with monitoring procedures is an expectation of IRB approval.

Change of Institutions: If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study or transferred to a new IRB. Studies without a Purdue University PI will be closed.

Other Approvals: This Purdue IRB approval covers only regulations related to human subjects research protections (e.g. 45 CFR 46). This determination does not constitute approval from any other Purdue campus departments, research sites, or outside agencies. The Principal Investigator and all researchers are required to affirm that the research meets all applicable local, state, and federal laws that may apply.

If you have questions about this determination or your responsibilities when conducting human subjects research on this project or any other, please do not hesitate to contact Purdue's HRPP at irb@purdue.edu or 765-494-5942. We are here to help!

Sincerely,

Purdue University Human Research Protection Program/ Institutional Review Board

APPENDIX B: TACIT KNOWLEDGE INSTRUMENT

Survey Questionnaire/Instrument:

The following measure is implemented in the study (through an online survey):

Drag the "***slider***" along the line that conforms to your opinion regarding each item.

Here is an example scenario based on the conversation with one of the field supervisors: "*During estimating, I always spot opportunities to run our conduit underground to save on material and labor cost*."

Now you have talked about these challenges and how you have tackled them, to what extent….

1. Did you rely on written procedures?
Completely +----------+Not at all

2. Did you rely on the construction documents provided?
Completely +----------+Not at all

3. Did you rely on the knowledge gained from outside this project?
Completely +----------+Not at all

4. Could the knowledge you used be written down?
Completely +----------+Not at all

5. Would you have difficulty in explaining the procedures?
Completely +----------+Not at all

6. Would viewing the final product allow you to understand the procedures involved?
Completely +----------+Not at all

7. Were you conscious of the procedures required?
Completely +----------+Not at all

8. Did you utilize formal procedures?
Completely +----------+Not at all

9. Did you organize the procedures you used?
Completely +----------+Not at all

10. Did you rely on what you have learned from your past experience?
Completely +----------+Not at all

11. Could the procedures be written down so that anyone could follow them?
Completely +----------+Not at all

12. Could you explain those procedures so that anyone could follow them?
Completely +----------+Not at all

13. Did the solutions come to you in a logical sequence?
Completely +----------+Not at all

14. Would you have difficulty writing down the procedures you used?
Completely +----------+Not at all

15. Would it be easier to demonstrate than telling others?
Completely +----------+Not at all

16. Did you feel you knew how to do this without thinking about it?
Completely +----------+Not at all

17. Did your actions seem instinctive instead of reasoned?
Completely +----------+Not at all

18. Were you already familiar with how to do this?
Completely +----------+Not at all

19. Did you spend more time planning the necessary steps in the procedure?
Completely +----------+Not at all

20. Were you able to do this without thinking about it?
Completely +----------+Not at all

21. Did you feel that you were repeating certain procedures?
Completely +----------+Not at all

22. Did you have to invent new processes or procedures?
Completely +----------+Not at all

23. Are you clear about your success in your finished project?
Completely +----------+Not at all

24. Could you explain why you did better or worse on this job than others?
Completely +----------+Not at all

25. Did you rely on your intuition?
Completely +----------+Not at all

26. Did you change your typical approach to solving problems?
Completely +----------+Not at all

Note:

Each of these questions was represented in the form of a semantic differential scale with "completely" and "not at all" representing the two extremities. Scores (1 to 5) were assigned corresponding to the position of the slider. Hence, the total score ranges from 130 (complete reliance on tacit knowledge) to 26 (complete reliance on explicit knowledge). Questions 3, 5, 6, 10, 14,15,16, 17, 18, 20, 21 and 25 were scored reverse i.e. 5 to 1 based on the model used for the study.

APPENDIX C: BARRIERS TO KNOWLEDGE SHARING SURVEY

Survey for Knowledge Sharing Barriers:

1. Drag the following factors in order of priority that you think prevent knowledge (know-how or know-what) sharing among a **Group of Trade Professionals**:

(Rank from 1 to 7, with 1= most important factor and 7= least important factor)

There is not enough time available to share knowledge

There are no formal processes to share knowledge

Sharing happens only when the workers work together in an activity

Some think that knowledge is power and can be used to get a promotion

Workers are poorly informed regarding knowledge sharing

Other 1 _____

Other 2 _____

2. Drag the following factors in order of priority that you think prevent knowledge (know-how or know-what) sharing based on **Managerial Role**:

(Rank from 1 to 7, with 1= most important factor and 7= least important factor)

Lack of encouragement from the management

Managers are resistant to change

Managers are unwilling to take risk

Managers not walking the talk

Managers and staff are treated differently

Other 1 _____

Other 2 _____

3. Drag the following factors in order of priority that you think prevent knowledge (know-how or know-what) sharing based on the **Organization as a whole**:

(Rank from 1 to 8, with 1= most important factor and 8= least important factor)

Managers are reluctant to share knowledge with employees

Top-level execution is apathetic towards the workers

No formal process for sharing knowledge

Retirees disappear with the knowledge which they acquired by experience

Experience is not valued

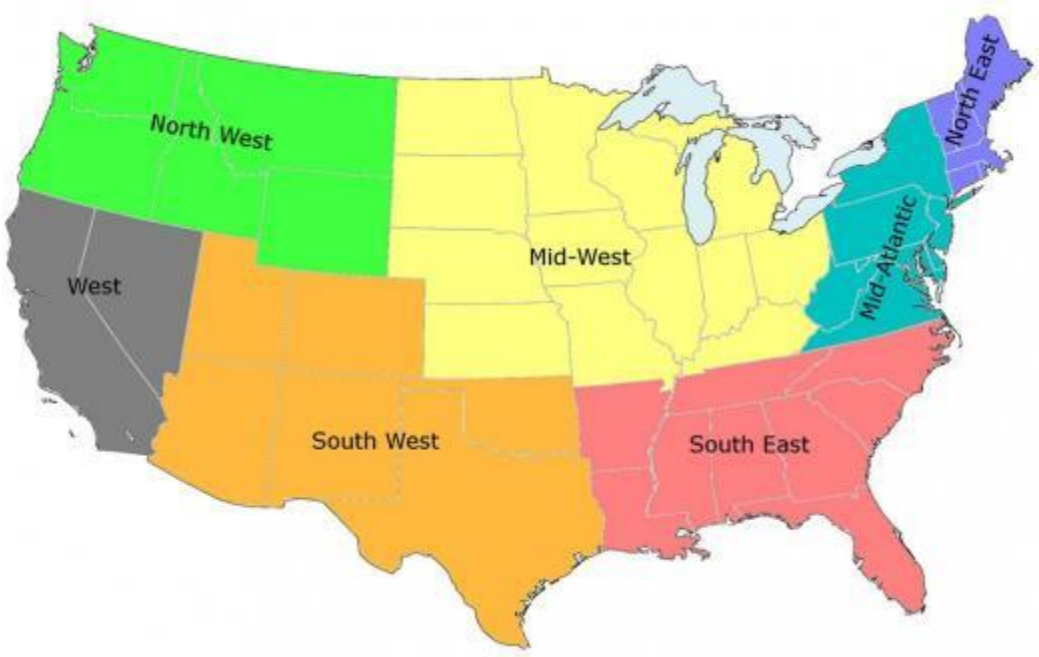
Stringent policies and procedures

Other 1 _____

Other 2 _____

APPENDIX D: REGIONAL MAP USED IN SURVEY

Map of different regions of the United States which accompanied one of the online survey questions in the survey to identify the barriers to knowledge sharing and is intended for managers/executives of Electrical contracting firms:



APPENDIX E: BARRIERS ANALYSIS RESULTS

SPSS Outcomes: barriers to sharing knowledge:

1. **Management (N=67):**

Ranks

	Mean Rank
Lack_of_time	2.49
No_formal_processes	2.31
Sharing_only_in_activity	2.73
Job_security	3.60
Workers_poorly_informed	3.87

Test Statistics[a]

N	67
Chi-Square	51.104
df	4
Asymp. Sig.	.000

a. Friedman Test

Ranks

	Mean Rank
Lack_of_encouragement	2.64
Managers_resistance_to_change	2.16
Managers_unwilling_to_take_risks	2.88
Managers_not_walking_the_talk	3.24
Managers_staff_treated_different	4.07

Test Statistics[a]

N	67
Chi-Square	55.021
df	4
Asymp. Sig.	.000

a. Friedman Test

Ranks

	Mean Rank
Managers_reluctant_to_share_knowledge	3.04
Apathetic_top_management	3.73
Lack_of_formal_processes	2.09
Retirees_disappear_with_knowledge	2.67
Experience_not_valued	4.40
Stringent_policies	5.06

Test Statistics[a]

N	67
Chi-Square	118.386
df	5
Asymp. Sig.	.000

a. Friedman Test

2. **Field (N=82):**

Ranks

	Mean Rank
Lack_of_time	3.01
No_formal_processes	2.89
Sharing_only_in_activity	2.28
Job_security	3.32
Workers_poorly_informed	3.50

Test Statistics[a]

N	82
Chi-Square	28.878
df	4
Asymp. Sig.	.000

a. Friedman Test

Ranks

	Mean Rank
Lack_of_encouragement	2.33
Managers_resistance_to_change	2.91
Managers_unwilling_to_take_risks	3.39
Managers_not_walking_the_talk	3.17
Managers_staff_treated_different	3.20

Test Statistics[a]

N	82
Chi-Square	22.195
df	4
Asymp. Sig.	.000

a. Friedman Test

Ranks

	Mean Rank
Managers_reluctant_to_share_knowledge	2.98
Apathetic_top_management	3.24
Lack_of_formal_processes	3.37
Retirees_disappear_with_knowledge	3.12
Experience_not_valued	3.98
Stringent_policies	4.32

Test Statistics[a]

N	82
Chi-Square	32.690
df	5
Asymp. Sig.	.000

a. Friedman Test

Running Post Hoc analysis in R-software tool:

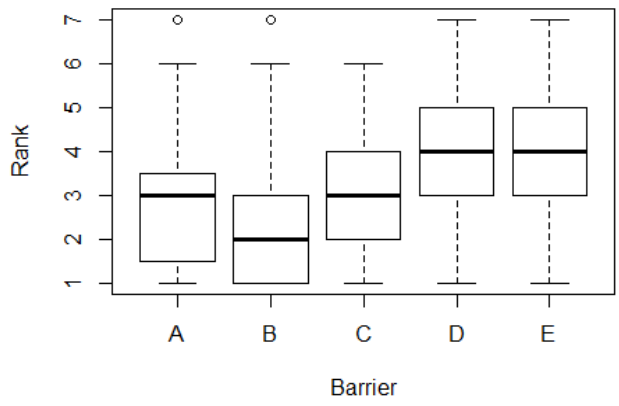
1. **Management Perspective:**

Loading data and converting to required form

```
library(PMCMRplus)

## Warning: package 'PMCMRplus' was built under R version 3.6.3

barriers <- read.csv('barriers_office.csv',header = T)
q1<-data.matrix(barriers[,5:9])
q2<-data.matrix(barriers[,10:14])
q3<-data.matrix(barriers[,15:20])
r1 = c(t(as.matrix(q1)))
r2 = c(t(as.matrix(q2)))
r3 = c(t(as.matrix(q3)))
f1 = c("A", "B", "C", "D","E")
f2 = c("A", "B", "C", "D","E")
f3 = c("A", "B", "C", "D","E","F")
k1 = 5
k2 = 5
k3 = 6
n = 67
tm1 = gl(k1, 1, n*k1, factor(f1))
tm2 = gl(k2, 1, n*k2, factor(f2))
tm3 = gl(k3, 1, n*k3, factor(f3))
blk1 = gl(n, k1, k1*n)
blk2 = gl(n, k2, k2*n)
blk3 = gl(n, k3, k3*n)
q1_anova <- data.frame(r1,tm1,blk1)
q2_anova <- data.frame(r2,tm2,blk2)
q3_anova <- data.frame(r3,tm3,blk3)
```

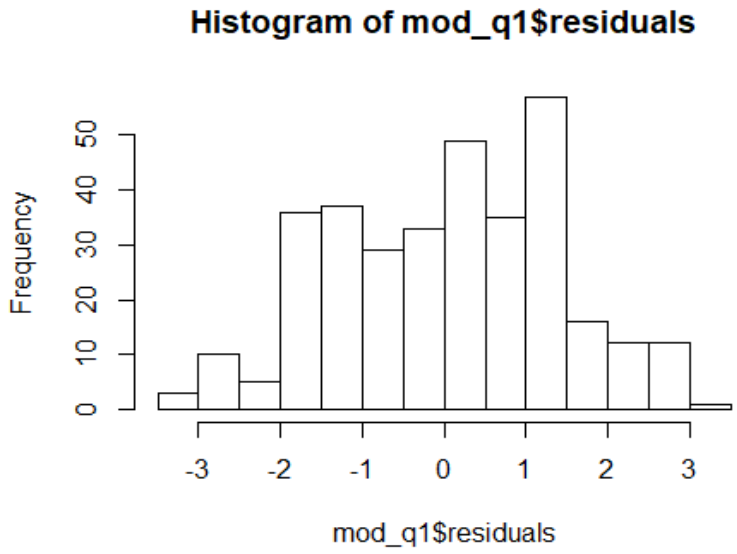
Group of Trade Professionals

```
boxplot(q1_anova$r1~q1_anova$tm1, xlab='Barrier', ylab='Rank')
```

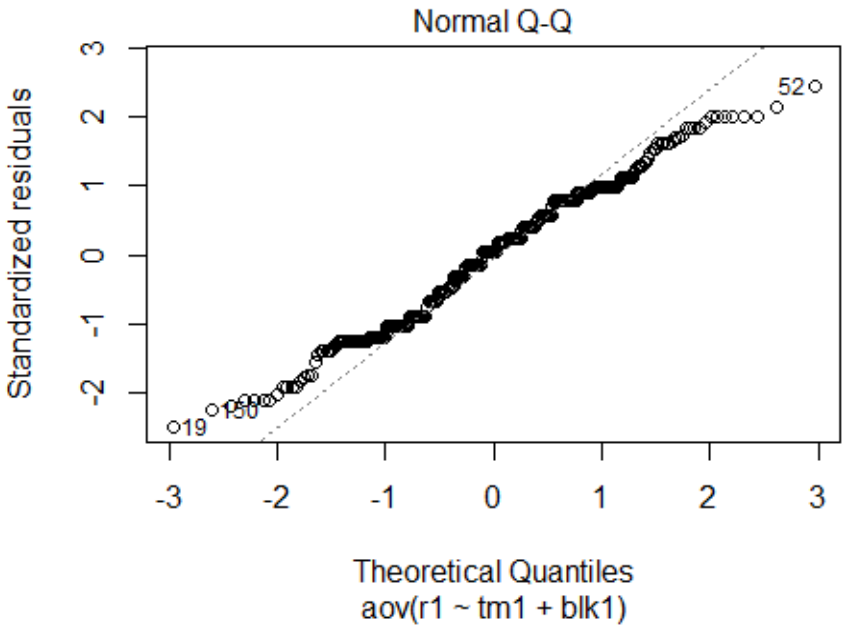


Checking for normality:

```
mod_q1 = aov(r1 ~ tm1 + blk1, data = q1_anova)
hist(mod_q1$residuals)
```




```
plot(mod_q1,which = 2)
```




```
shapiro.test(mod_q1$residuals)

##
##  Shapiro-Wilk normality test
##
## data:  mod_q1$residuals
## W = 0.98471, p-value = 0.001271
```

Nonparametric Test

Since normality is invalidated, we move on to Non-parametric test: Friedman Test

```
friedman.test(r1,tm1,blk1,r1~tm1|blk1, data=q1_anova)

##
##  Friedman rank sum test
##
## data:  r1, tm1 and blk1
## Friedman chi-squared = 51.104, df = 4, p-value = 2.123e-10
```

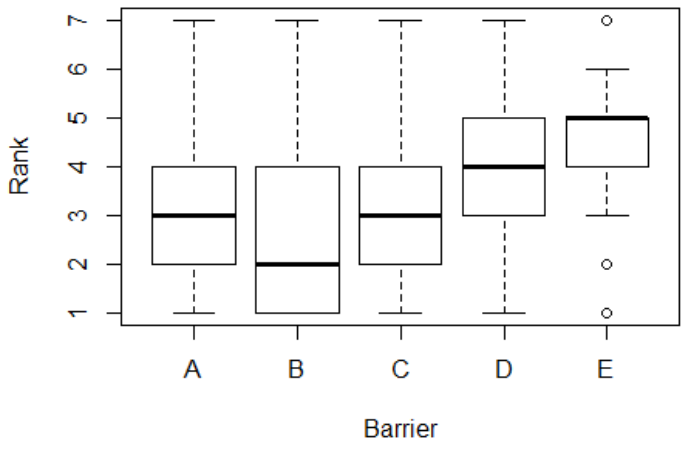
significant p-value which means there is a difference among ranks

Now for post-hoc we use "Conover Test" for all pairs with bonferroni adjustment to control for family type 1 error rate

```
frdAllPairsConoverTest(r1,tm1,blk1,r1~tm1|blk1, data=q1_anova,
p.adjust = "bonferroni")

##
##  Pairwise comparisons using Conover's all-pairs test for a two-way
balanced complete block design

## data: y, groups and blocks

##   A       B       C       D
## B 1.00000 -       -       -
## C 1.00000 1.00000 -       -
## D 0.00073 4.5e-05 0.01765 -
## E 9.9e-06 3.8e-07 0.00047 1.00000

##
## P value adjustment method: bonferroni
```

Managerial Role

```
boxplot(q2_anova$r2~q2_anova$tm2, xlab='Barrier', ylab='Rank')
```



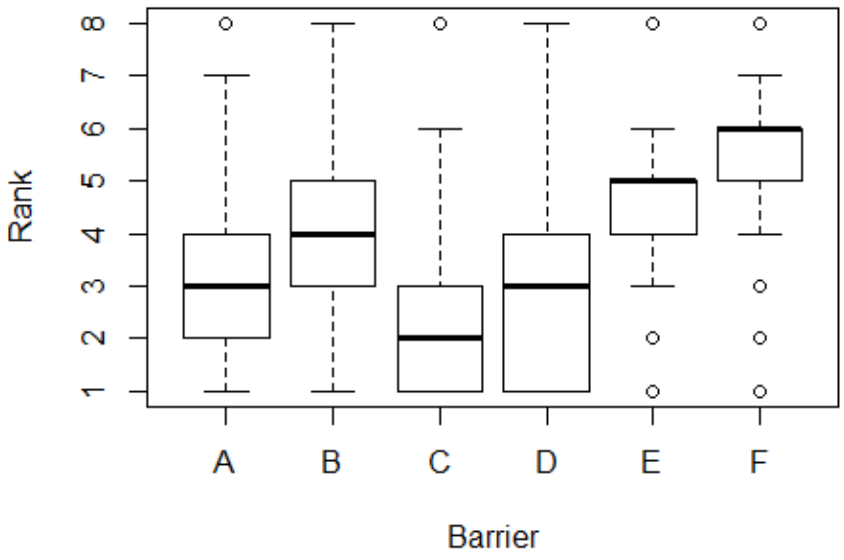
Nonparametric Test

Friedman Test

```
friedman.test(r2,tm2,blk2,r2~tm2|blk2, data=q2_anova)

##
##  Friedman rank sum test
##
## data:  r2, tm2 and blk2
## Friedman chi-squared = 55.021, df = 4, p-value = 3.216e-11

frdAllPairsConoverTest(r2,tm2,blk2,r2~tm2|blk2, data=q2_anova,
p.adjust = "bonferroni")

##
##  Pairwise comparisons using Conover's all-pairs test for a two-way
balanced complete block design

## data: y, groups and blocks

##   A       B       C       D
## B 0.82485 -       -       -
## C 1.00000 0.09446 -       -
## D 0.30228 0.00112 1.00000 -
## E 3.5e-06 2.5e-10 0.00019 0.02518

##
## P value adjustment method: bonferroni
```

Organization Level

```
boxplot(q3_anova$r3~q3_anova$tm3, xlab='Barrier', ylab='Rank')
```



Nonparametric Test

Friedman Test

```
friedman.test(r3,tm3,blk3,r3~tm3|blk3, data=q3_anova)

##
##  Friedman rank sum test
##
## data:  r3, tm3 and blk3
## Friedman chi-squared = 118.39, df = 5, p-value < 2.2e-16

frdAllPairsConoverTest(r3,tm3,blk3,r3~tm3|blk3, data=q3_anova,
p.adjust = "bonferroni")

##
##  Pairwise comparisons using Conover's all-pairs test for a two-way
balanced complete block design

## data: y, groups and blocks

##   A       B       C       D       E
## B 0.52629 -       -       -       -
## C 0.05203 1.0e-05 -       -       -
## D 1.00000 0.01807 1.00000 -       -
## E 0.00055 0.58834 9.5e-11 2.7e-06 -
## F 2.4e-08 0.00080 < 2e-16 2.2e-11 0.65651

##
## P value adjustment method: bonferroni
```

2. **Field Perspective:**

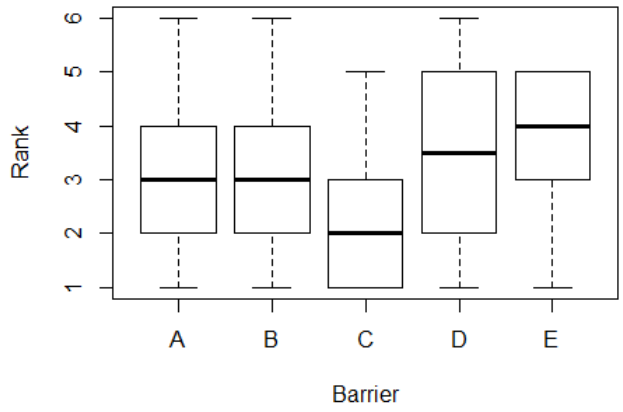
Loading data and converting to required form

```
library(PMCMRplus)

## Warning: package 'PMCMRplus' was built under R version 3.6.3

barriers <- read.csv('barriers.csv',header = T)
q1<-data.matrix(barriers[,5:9])
q2<-data.matrix(barriers[,10:14])
q3<-data.matrix(barriers[,15:20])
r1 = c(t(as.matrix(q1)))
r2 = c(t(as.matrix(q2)))
r3 = c(t(as.matrix(q3)))
f1 = c("A", "B", "C", "D","E")
f2 = c("A", "B", "C", "D","E")
```

```
f3 = c("A", "B", "C", "D","E","F")
k1 = 5
k2 = 5
k3 = 6
n = 82
tm1 = gl(k1, 1, n*k1, factor(f1))
tm2 = gl(k2, 1, n*k2, factor(f2))
tm3 = gl(k3, 1, n*k3, factor(f3))
blk1 = gl(n, k1, k1*n)
blk2 = gl(n, k2, k2*n)
blk3 = gl(n, k3, k3*n)
q1_anova <- data.frame(r1,tm1,blk1)
q2_anova <- data.frame(r2,tm2,blk2)
q3_anova <- data.frame(r3,tm3,blk3)
```

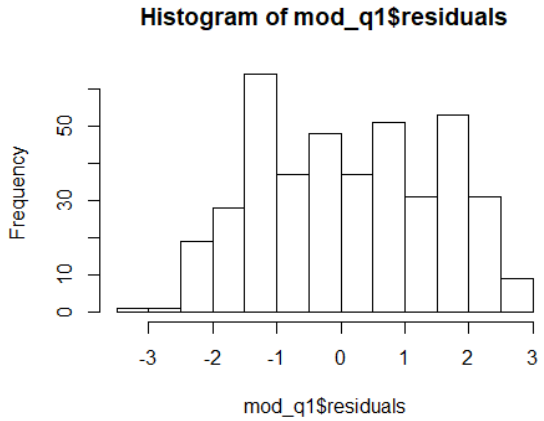
Group of Trade Professionals

```
boxplot(q1_anova$r1~q1_anova$tm1, xlab='Barrier', ylab='Rank')
```

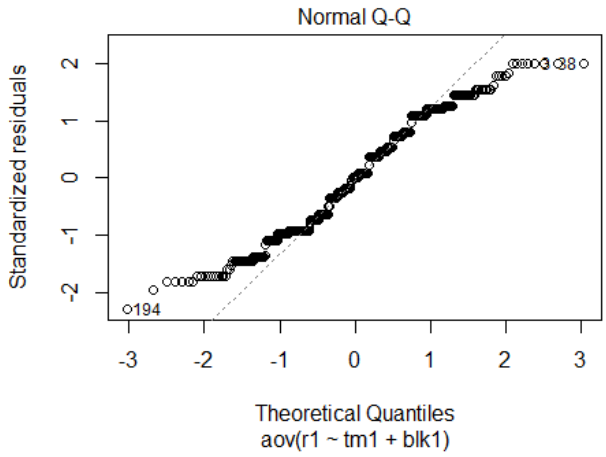


Checking for normality

```
mod_q1 = aov(r1 ~ tm1 + blk1, data = q1_anova)
hist(mod_q1$residuals)
```




```
plot(mod_q1,which = 2)
```




```
shapiro.test(mod_q1$residuals)

##
##  Shapiro-Wilk normality test
##
## data:  mod_q1$residuals
## W = 0.96838, p-value = 9.555e-08
```

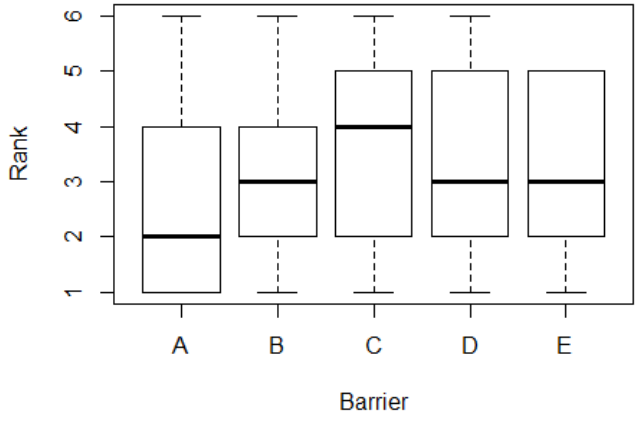
Nonparametric Test:

Since normality is invalidated, we move on to Non-parametric test: Friedman Test

```
friedman.test(r1,tm1,blk1,r1~tm1|blk1, data=q1_anova)

##
##  Friedman rank sum test
##
## data:  r1, tm1 and blk1
## Friedman chi-squared = 28.878, df = 4, p-value = 8.276e-06

frdAllPairsConoverTest(r1,tm1,blk1,r1~tm1|blk1, data=q1_anova,
p.adjust = "bonferroni")

##
##  Pairwise comparisons using Conover's all-pairs test for a two-way
balanced complete block design

## data: y, groups and blocks

##   A       B       C       D
## B 1.00000 -       -       -
## C 0.03346 0.14288 -       -
## D 1.00000 0.85612 0.00036 -
## E 0.49621 0.14288 1.3e-05 1.00000

##
## P value adjustment method: bonferroni
```

Managerial Level

```
boxplot(q2_anova$r2~q2_anova$tm2, xlab='Barrier', ylab='Rank')
```



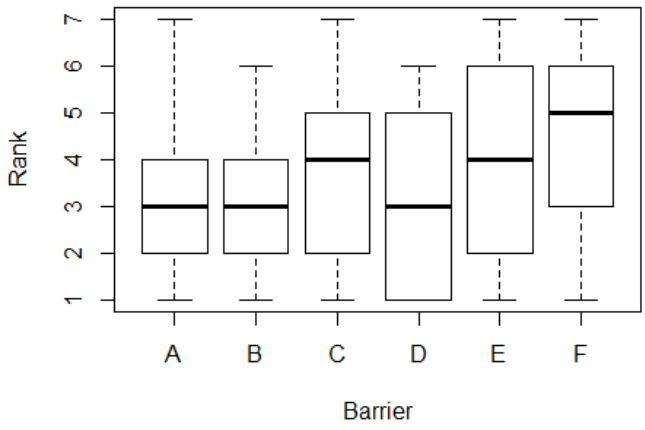
Nonparametric Test

Friedman Test

```
friedman.test(r2,tm2,blk2,r2~tm2|blk2, data=q2_anova)

##
##  Friedman rank sum test
##
## data:  r2, tm2 and blk2
## Friedman chi-squared = 22.195, df = 4, p-value = 0.0001833

frdAllPairsConoverTest(r2,tm2,blk2,r2~tm2|blk2, data=q2_anova,
p.adjust = "bonferroni")

##
##  Pairwise comparisons using Conover's all-pairs test for a two-way
balanced complete block design

## data: y, groups and blocks

##   A       B       C       D
## B 0.18633 -       -       -
## C 0.00024 0.55567 -       -
## D 0.00760 1.00000 1.00000 -
## E 0.00535 1.00000 1.00000 1.00000

##
## P value adjustment method: bonferroni
```

Organization Level

```
boxplot(q3_anova$r3~q3_anova$tm3, xlab='Barrier', ylab='Rank')
```



Nonparametric Test

Friedman Test

```
friedman.test(r3,tm3,blk3,r3~tm3|blk3, data=q3_anova)

##
##  Friedman rank sum test
##
## data:  r3, tm3 and blk3
## Friedman chi-squared = 32.69, df = 5, p-value = 4.336e-06

frdAllPairsConoverTest(r3,tm3,blk3,r3~tm3|blk3, data=q3_anova,
p.adjust = "bonferroni")

##
##  Pairwise comparisons using Conover's all-pairs test for a two-way
balanced complete block design

## data: y, groups and blocks

##   A       B       C       D       E
## B 1.00000 -       -       -       -
## C 1.00000 1.00000 -       -       -
## D 1.00000 1.00000 1.00000 -       -
## E 0.01064 0.19400 0.57155 0.05671 -
## F 9.4e-05 0.00426 0.01904 0.00082 1.00000

##
## P value adjustment method: bonferroni
```

Barriers classification (free-text entry options):

	Survey Response	Individual	Organizational	Contextual	Inter-Project
1	Insecurities of being replaced	x			
2	No time allotted to share lessons learned from different jobs	x			
3	Don't set aside time for training	x			
4	Not allocating resources to do so		x		
5	Lack of compensation for training time		x		
6	Past generations were focused on building, new generations are focused on managing & technology. The simple change in industry focus leads to knowledge loss.			x	
7	Management feels profits are more important than training		x		
8	Not right people in the right seat		x		
9	Companies don't build in time to share knowledge, i.e. don't want to pay the costs for the training.		x		
10	Failure to identify key "wisdom"			x	
11	Managers think training cuts into profits		x		
12	Failure to want to move from good to great		x		
13	Companies often give the hardest project to the most seasoned people, but don't always put the understudy on that job		x		
14	no one to manage the process		x		
15	none of these our organization encourages all workers to share knowledge with each other to help the team thrive and be the best		x		
16	Managers think experienced worker cost the company more money		x		
17	Org. exhibits 5 dysfunctions of a team		x		
18	Time constraints	x			
19	Top-level executives want knowledge sharing as long as the bottom line isn't affected		x		
20	don't want to empower others	x			
21	Managers lack the skill to train others effectively		x		
22	Managers are too busy to pass along the knowledge they have gained	x			
23	Too many meetings	x			
24	Managers focusing on the moment and not the future		x		
25	none of these management encourages training		x		
26	Lack of Time	x			
27	The activities and skills relied on now are different from what they were in the past generation so the skills being discussed (past on) most are not the same skills being lost.			x	
28	Management thinks that the training will cost them production		x		
29	Not understanding leading and influencing	x			
30	Managers don't make the time to share knowledge	x			
31	fulling unappreciated by their employer		x		
32	Not enough young workers to retain knowledge		x		
33	Workers don't show up for training session	x			
34	Unwillingness to lead		x		
35	Lack of younger workers stepping up to the invest in time needed to grow in a leadership position		x		
36	A particular project team may not be aware that another project team needs lessons learned				x
37	Failure to incorporate retired workers as guest instructors in our apprenticeship programs		x		
38	No buy-in		x		
39	No formal sharing groups		x		
40	Training is the job of all in our trade, Contractors, Apprenticeships and experienced Journeyman	x			
41	Capability interferes with sharing of knowledge	x			
42	Each feel their ideas are valued	x			
43	Workers are afraid they will be replaced	x			
44	Workers are told, but not given a chance to practice the knowledge		x		
45	Lack of knowledge categorization for ease of discussion.			x	
46	Some withhold information to make others look incompetent	x			
47	Young workers uninterested in learning	x			
48	Workers don't want to learn	x			
49	Some workers just don't care and there for won't share ideas	x			
50	Unwillingness to learn	x			
51	Lack of willingness and confidence by Baby boomers to give the younger generation the opportunity	x			
52	People are typically focused on 1 project at a time and therefore, lessons learned on one job, is not shared with a project team on a similar project				x
53	Workers fear someone will take their job	x			
54	Poor communication	x			
55	personality conflicts prevent staff from being willing to share with others	x			
56	Not enough Key People to actually provide global acquired knowledge		x		
58	Training is our Trades Future		x		
59	Personality interferes with sharing of knowledge	x			
60	Not a group! All are individuals	x			
61	Workers don't take the time to be informed	x			
62	Scared they will lose their job to younger generation	x			
63	Pride to admit when they don't know something	x			
64	Potential highly qualified High School Candidates are not interested in working in construction, diluted labor pool	x			
65	Most are too concerned about themselves	x			
66	Negative Personality of field trainer.	x			
67	Top down focus of job completion over training the workforce. Training is best when it isn't pressured by time constraints AND when the situation presents itself as a teaching opportunity.		x		
68	Guys don't care	x			
69	Bad at sharing knowledge	x			
70	People not having the right knowledge to pass on	x			
71	Jobs are rushed to make money, and workers are pressed to do shotty work		x		
72	splitting up apprentices and journeyman before third year in order to boost efficiency and then accepting sub- par results.		x		
73	Managers not allowing an apprentice to work on a specific job to gain knowledge.		x		
74	Managers don't want to take the time to teach	x			
75	Managers need to stay in the office not the job site	x			
76	Not enough time to teach	x			
77	Lack of appreciation		x		
78	Managers press for it to be finished quickly and save money, not quality		x		
79	foremen are generally good in my experience so far, project managers undervalue the tradesperson's point of view				
80	Poor communication skills.	x			
81	Employees aren't paid to teach. They are paid to perform their job. A "stay in your lane" mentality."		x		
82	They don't care, as long as the job gets done	x			
83	There is a flow chart pm to foreman to jw to apprentice		x		
84	Pressed to work faster and not enough competent workers with time to teach		x		
85	I believe that the only barriers I see in either sharing knowledge with someone or recieving knowledge is the person. Our trade is built on sharing knowledge, which makes our union a union. If there's an issue with sharing knowledge it's because the person doesn't want to share for personal reasons.			x	
86	Company culture, identity the learning approach of the learner,		x		
87	To find right people to share, trade personal shuffle	x			
88	Journeyman not taking the time, and having patience with apprentices. Possibly due to the stress of time from upper management.	x			
89	People are very protective of their knowledge. They feel it keeps them more valuable and helps protect their job. By teaching what you know to someone else you have now become irrelevant and replaceable.	x			
90	Employees need to be pushed out of their comfort zone to learn new knowledge, experience a new situation to learn from it and take that knowledge forward.	x			
91	There is not a formal way to share knowledge. Life lessons and learning. Plan your work and work your plan!		x		
92	management just needs to listen to staff more on things that could be done differently when this happens it hinders the sharing of knowledge and stuff isn't getting done as efficient as it should be		x		

APPENDIX F: GAUGING TACIT KNOWLEDGE ANALYSIS

Gauging Tacit Knowledge: R software Tool

Loading data

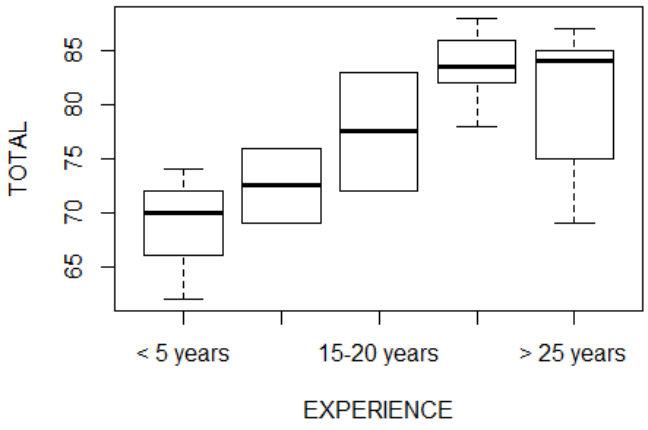
```
library(MASS)
tacit <- read.csv('TACIT.csv', header=T)
tacit$EXPERIENCE <- factor(tacit$EXPERIENCE,
                           levels = c('< 5 years',
                                      '10-15 years',
                                      '15-20 years',
                                      '20-25 years',
                                      '> 25 years'))
```

Step 1: EDA

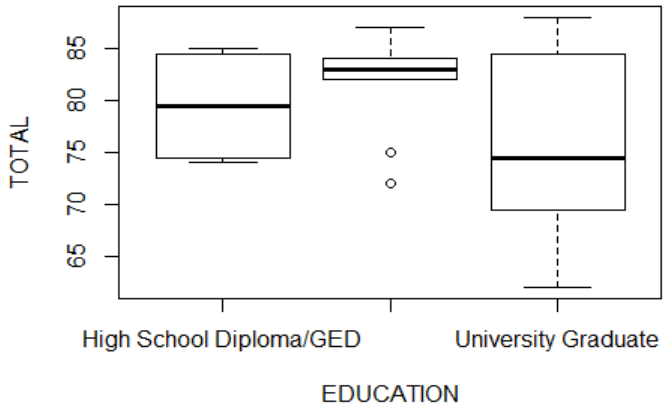
```
summary(tacit)
```

```
##           ï..AGE   GENDER                        RACE
##  18- 30      :5   Male:25   Asian                  : 1
##  31-40       :2             Black/African American: 1
##  41-50       :7             Hispanic or Latino     : 1
##  51-60       :8             White                  :22
##  61 and above:3
##
##                     EDUCATION        EXPERIENCE     TOTAL
##  High School Diploma/GED: 4   < 5 years  : 4   Min.   :62.00
##  Some College           : 9   10-15 years: 2   1st Qu.:73.00
##  University Graduate    :12   15-20 years: 2   Median :82.00
##                               20-25 years: 6   Mean   :78.48
##                               > 25 years :11   3rd Qu.:84.00
##                                                Max.   :88.00
```

```
boxplot(TOTAL~EXPERIENCE, data=tacit)
```



```
boxplot(TOTAL~EDUCATION, data=tacit)
```



Step 2: Linear Models

Model 1: EXPERIENCE & EDUCATION

```
mod1 <- lm(TOTAL~EXPERIENCE+EDUCATION, data = tacit)
anova(mod1)
```

```
## Analysis of Variance Table
##
## Response: TOTAL
##            Df Sum Sq Mean Sq F value   Pr(>F)
## EXPERIENCE  4 627.01 156.753  5.2458 0.005576 **
## EDUCATION   2  71.35  35.677  1.1939 0.325916
## Residuals  18 537.87  29.882
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 2: Only EXPERIENCE

```
mod2 <- lm(TOTAL~EXPERIENCE, data = tacit)
anova(mod2)
```

```
## Analysis of Variance Table
##
## Response: TOTAL
##            Df Sum Sq Mean Sq F value  Pr(>F)
## EXPERIENCE  4 627.01 156.753   5.146 0.00513 **
## Residuals  20 609.23  30.461
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod2)
```

```
##
## Call:
## lm(formula = TOTAL ~ EXPERIENCE, data = tacit)
##
```

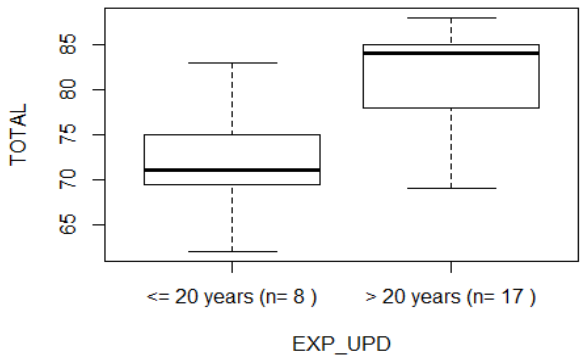
```
## Residuals:
##     Min      1Q  Median      3Q     Max
## -11.454  -5.455   1.000   4.500   6.545
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)                69.000      2.760  25.004  < 2e-16 ***
## EXPERIENCE10-15 years       3.500      4.780   0.732 0.472507
## EXPERIENCE15-20 years       8.500      4.780   1.778 0.090556 .
## EXPERIENCE20-25 years      14.500      3.563   4.070 0.000597 ***
## EXPERIENCE> 25 years       11.455      3.223   3.555 0.001987 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.519 on 20 degrees of freedom
## Multiple R-squared:  0.5072, Adjusted R-squared:  0.4086
## F-statistic: 5.146 on 4 and 20 DF,  p-value: 0.00513
```

```
anova(mod1,mod2)
```

```
## Analysis of Variance Table
##
## Model 1: TOTAL ~ EXPERIENCE + EDUCATION
## Model 2: TOTAL ~ EXPERIENCE
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1     18 537.87
## 2     20 609.23 -2   -71.354 1.1939 0.3259
```

Model 3: Combining experience categories

```
tacit$EXP_UPD<-factor(ifelse(tacit$EXPERIENCE == '< 5 years' |
                        tacit$EXPERIENCE == '10-15 years' |
                        tacit$EXPERIENCE == '15-20 years',
                      '<= 20 years','> 20 years'))
mod3 <- lm(TOTAL~EXP_UPD, data = tacit)
b<-boxplot(TOTAL~EXP_UPD, data=tacit)

boxplot(TOTAL~EXP_UPD, data=tacit,
        names=paste(b$names, "(n=", b$n, ")"))
```



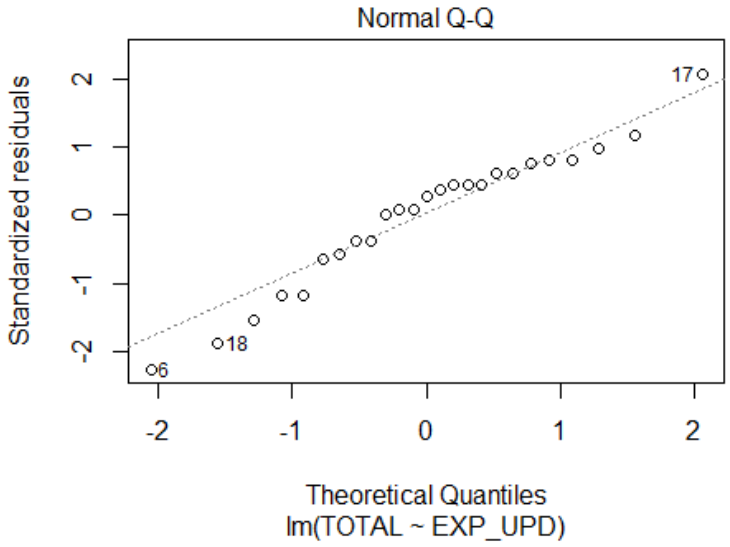
```
summary(mod3)
```

```
##
## Call:
## lm(formula = TOTAL ~ EXP_UPD, data = tacit)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.529  -3.000   1.471   3.471  11.000
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)         72.000      2.008  35.848  < 2e-16 ***
## EXP_UPD> 20 years    9.529      2.436   3.913 0.000699 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.681 on 23 degrees of freedom
## Multiple R-squared:  0.3996, Adjusted R-squared:  0.3735
## F-statistic: 15.31 on 1 and 23 DF,  p-value: 0.0006988
```

Step 3: Model Diagnostics

Normality

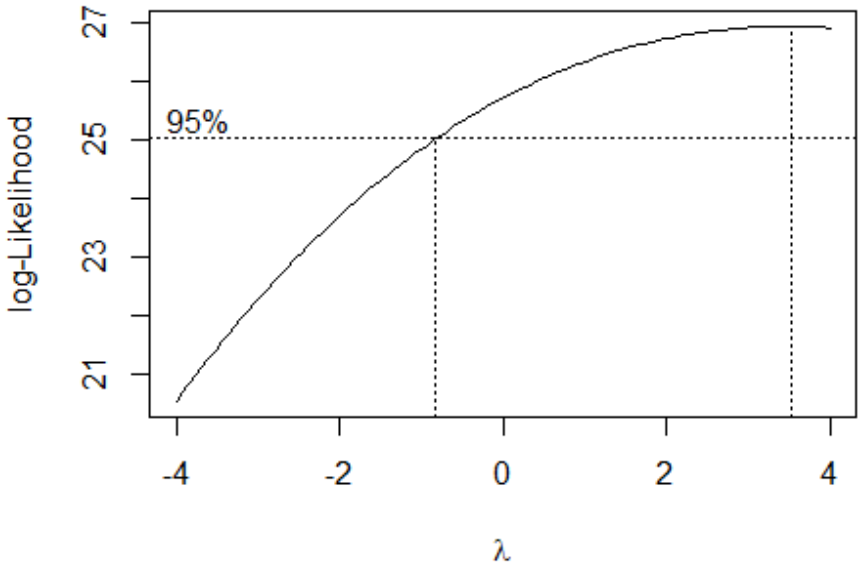
```
plot(mod3,which=2)
```




```
shapiro.test(mod3$residuals)
```

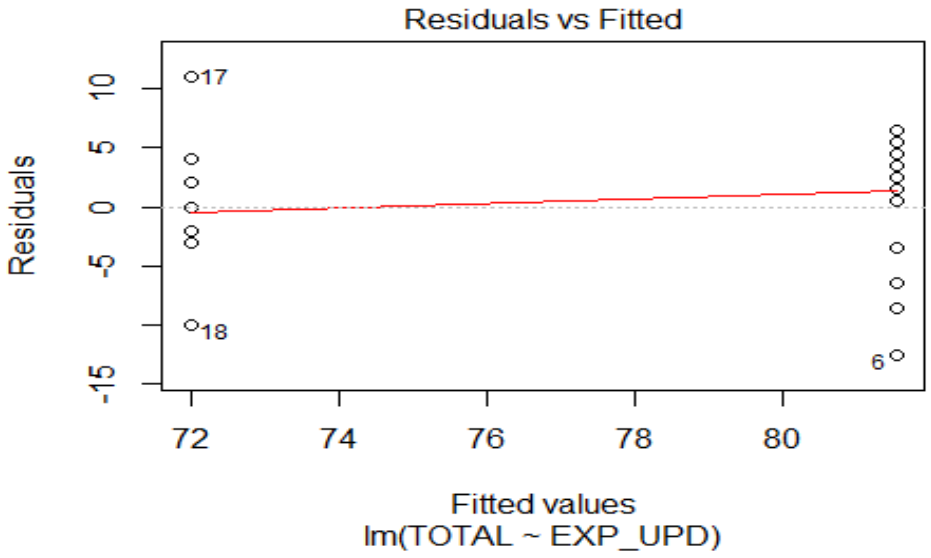
```
##
##  Shapiro-Wilk normality test
##
## data:  mod3$residuals
## W = 0.95678, p-value = 0.3541
```

```
boxcox(mod3, lambda = seq(-4,4))
```



Constant Variance

```
plot(mod3, which=1)
```



PAIRWISE COMPARISON USING TURKEY TEST TO FINALIZE THE TWO CATEGORIES:

$EXPERIENCE	diff	lwr	upr	p adj
10-15 years-< 5 years	3.500000	-10.802806	17.802806	0.9463458
15-20 years-< 5 years	8.500000	-5.802806	22.802806	0.4125139
20-25 years-< 5 years	14.500000	3.839318	25.160682	0.0048144
> 25 years-< 5 years	11.454545	1.811595	21.097495	0.0151430
15-20 years-10-15 years	5.000000	-11.515458	21.515458	0.8912707
20-25 years-10-15 years	11.000000	-2.484815	24.484815	0.1451309
> 25 years-10-15 years	7.954545	-4.740988	20.650079	0.3617364
20-25 years-15-20 years	6.000000	-7.484815	19.484815	0.6756852
> 25 years-15-20 years	2.954545	-9.740988	15.650079	0.9549205
> 25 years-20-25 years	-3.045455	-11.427367	5.336458	0.8109180

- The two p-values highlighted in yellow are with a p-value <0.05. This means "20-25 years" is significantly different from "< 5 years" and ">25 years" is significantly different from "< 5 years". (Similar result to what we get from model 2 regression summary).

- The 3 p-values highlighted in red (>0.05) are also important. They show that these two groups are not significantly different. The last one shows than ">25 years" and "20-25 years" can be combined.