CHALLENGES PREVENTING THE CONSTRUCTION INDUSTRY FROM FULLY UTILIZING PREVENTION THROUGH DESIGN

By

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ABSTRACT

The construction industry plays a major role in shaping the building environment, yet it is one of the most hazardous industries when it comes to worker safety. Prevention through design (PtD) is a method that aims to apply safety into the design and planning phases of construction projects. Despite its potential to reduce hazard risks and enhance safety, the construction industry faces challenges when utilizing PtD.

The purpose of this research is to investigate the challenges preventing the implementation of Prevention through Design (PtD) in the construction industry. This study aims to identify, analyze, and address the various challenges that hinder the full utilization of PtD practices within construction projects. By examining these challenges, including those related to contract language changes, professional roles, and industry wide practices, the research seeks to contribute insights and recommendations that can enhance the adoption of PtD and promote a safer and more proactive approach to design and construction in the industry. The research provides a comprehensive approach, combining a systematic literature review and an online survey of industry professionals.

A systematic literature review was conducted, following PRISMA guidelines, and eight relevant existing papers published between 2010 and 2023 were identified. The existing papers were analyzed to provide information on PtD challenges, creating the basis for the study. An online survey was created to provide insights from industry professionals on the challenges that prevent the industry from implementing PtD, necessary contract language changes and whether an architect or engineer is more equipped with implementing PtD practices, resulting in 58 valid responses. The survey identified 12 challenges preventing the implementation of PtD including, the increase in cost, lack of knowledge, lack of training programs, project delivery method influence, awareness, increase in design time, lack of laws and industry standards, lack of motivation and incentives, clients attitude towards PtD implementation, fear of liability, absence of PtD related contractual clauses, and others. These results indicated that the major challenge faced with PtD practices is the increase in cost with 45 references. Future research recommendations based on the results and findings of the study are provided.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

According to the U.S. Bureau of Labor Statistics (BLS), the construction industry has one of the highest injury rates and one of the worst fatality rates among the main U.S. sectors (Helmick et al., 2022). The U.S. Bureau of Labor Statistics reported a total of 976 fatal injuries in 2020 (Helmick et al., 2022). Additionally, it was reported that from 2019 to 2020, the incidence rate for nonfatal work-related illnesses and injuries that required time off work increased from 94.8 cases per 10,000 full-time workers across all occupations to 127.2 cases (Helmick et al., 2022).

An approach known as "Prevention through Design" (PtD) aims to avoid or minimize occupational injuries, illnesses, and fatalities by including preventative measures into all designs that have an impact on workers (Bach, 2023). PtD was developed many years ago, but it has only just begun to gain popularity (Hermreck, 2023). Designing for occupational hazards and dangers is the most efficient technique to protect workers considering it incorporates preventative measures into all designs that have an influence on workers. Figure 1 displays the hierarchy of controls, a method to identify and rank safeguards to protect workers from hazards (OSHA, 2023).

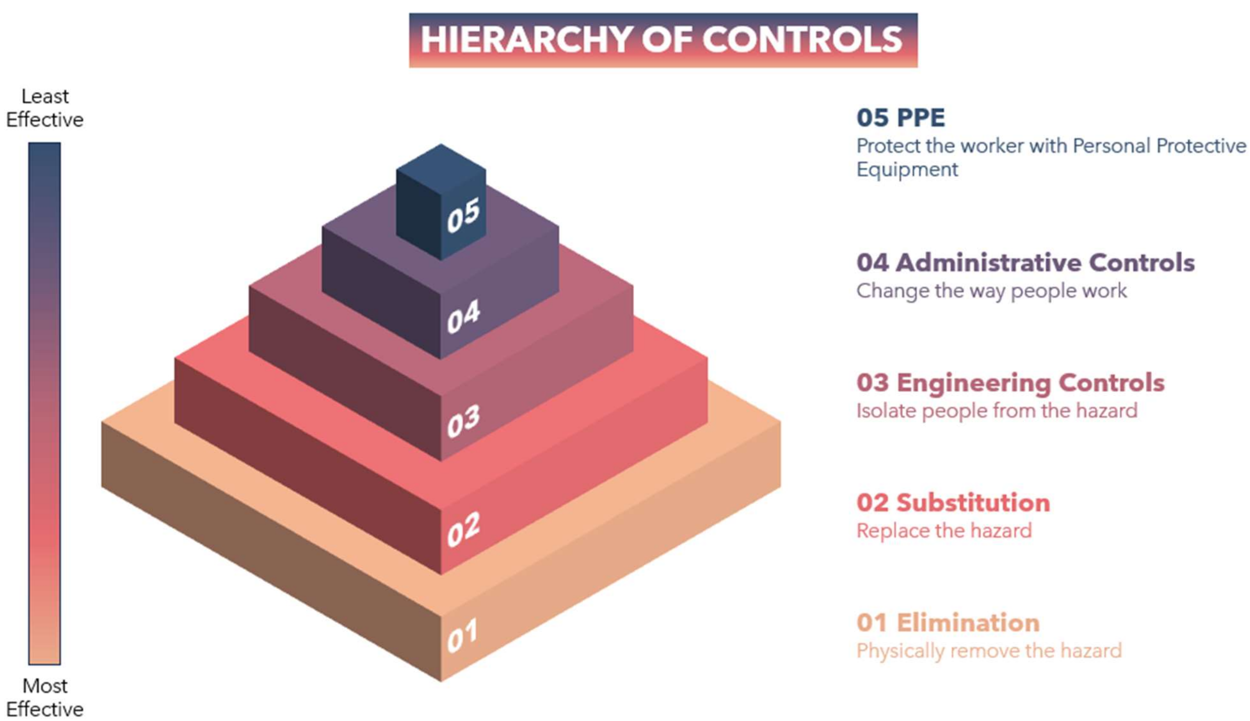

Figure 1: Determining Actions to Best Control Hazard Exposures

The safeguards are arranged from the most effective to least effective and include elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE) (OSHA, 2023). An understanding of the safeguards listed in the hierarchy of controls, as described below (OSHA, 2023):

- **Elimination:** Make sure the hazard no longer exists.
- **Substitution:** Change out a material or process to reduce a hazard.
- **Engineering Controls:** Reduce the exposure by preventing hazards from coming into contact with workers
- **Administrative Controls:** Change the way work is done or give workers more information by providing workers with relevant procedures, training, or warnings.
- **Personal Protective Equipment (PPE):** Provide clothing and devices to protect workers.

A new concept of hierarchy of controls was developed and labeled as the hierarchy of risk treatment (HORT) strategies hierarchy model, Figure 2. This concept was developed in order to provide OSH (Occupational Safety and Health) professionals with a broader range of risk reduction strategies that include inherently safer design concepts (Lyon et al., 2019). The objective of changing the concept of hierarchy of controls was to implement appropriate risk reduction plans to reduce risks associated with each decision made to achieve an acceptable risk level (Lyon et al., 2019).

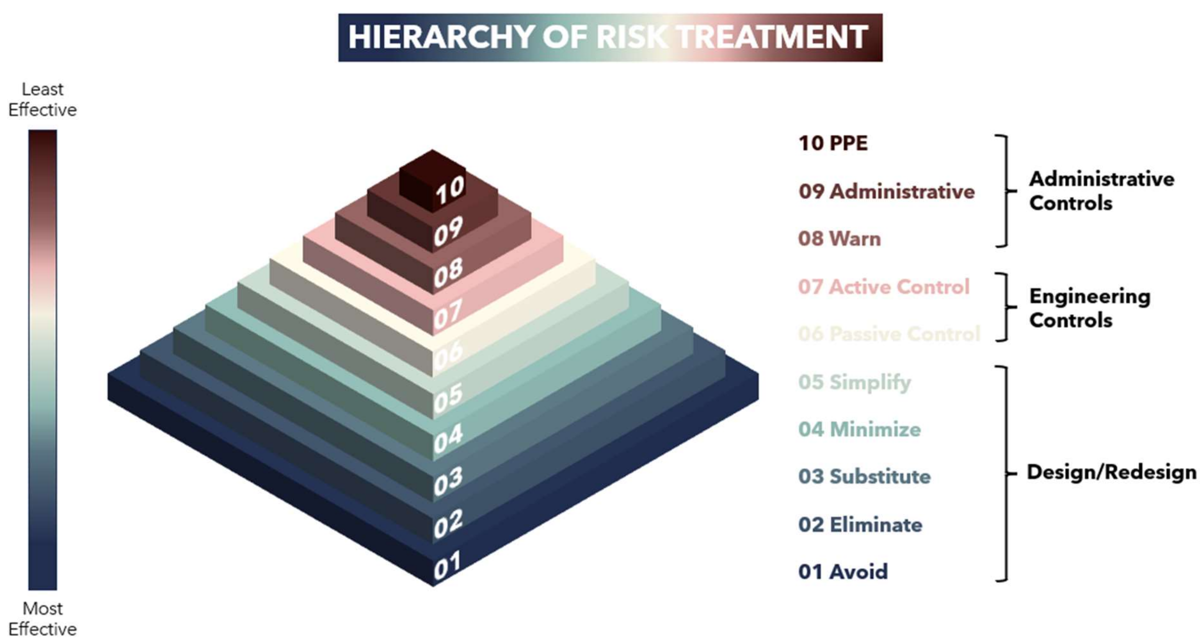

Figure 2: A Hierarchy of Risk Treatment Incorporating Inherently Safer Design Concepts

The new model provides a total of 10 risk treatment strategies that are divided into 3 different categories including design/redesign, engineering controls, and administrative controls. The first category of risk treatments, which includes design/redesign risk treatments, is the only type of risk treatment that is long lasting and does not degrade over time, claiming that hazards avoided, eliminated, or substituted by design will not change unless the design feature is changed (Lyon et al., 2019). The second and third categories, on the other hand, are less resilient and likely to deteriorate, wear out, or lose efficacy, requiring constant inspections, testing, maintenance, and repair (Lyon et al., 2019). Provided below is a brief description of each risk treatment strategy as stated within "Risk Treatment Strategies Harmonizing the Hierarchy of Controls & Inherently Safer Design Concepts" (Lyon et al., 2019):

- **Design/Redesign:** Long lasting and does not degrade overtime.
  - **Avoid:** In new designs, as well as redesigns, modifications, and additions to existing systems and workplaces, new hazards/risks are intentionally avoided.
  - **Eliminate:** Through redesign, existing hazards/risks are reduced or removed from systems/workplaces.
  - **Substitute:** New or existing hazards/risks are intentionally replaced with less hazardous materials that meet the system's or workplace's needs.
  - **Minimize:** A particular hazard's amount or quantity minimized to a level that presents a lower severity risk.
  - **Simplify:** By simplifying systems or workplace processes and controls, the likelihood of error or occurrence is reduced.
- **Engineering Controls:** Tend to degrade and wear out or lose effectiveness.
  - **Passive Control:** Passive engineering controls that protect and function without activation control or contain hazards. Example: Guardrails.
  - **Active Control:** Active engineering controls that need activation to protect or function are used to control hazards. Example: Sensing devices, fire suppression systems.
- **Administrative Controls:** Least effective and degrade more quickly.
  - **Warn:** By sight, sound, or touch, an awareness device informs or warns of residual risks.

- **Administrative:** Work procedures and worker training are used to control hazards in order for the system or workplace to operate safely.
- **PPE:** Hazards are managed by putting on and wearing protective clothing and equipment in order to prevent or reduce contact, exposure, impact, or harm from hazards.

The goal of this research is to identify the challenges to PtD adoption in the construction industry and provide ways to overcome them so that PtD may be further adopted by the whole industry. To determine the full potential of applying PtD in the industry and how familiar industry designers are with the technique, a questionnaire/survey was be developed and sent to industry professionals within the construction industry.

1.2 BACKGROUND

PtD is a practice that focuses on implementing safety into project design in order to prevent or minimize occupational hazards and risks. To prevent workplace injuries, illnesses, and fatalities, it is necessary to start with the root cause, which includes the risks and hazards associated with work; here is where PtD comes into play. The NSC's 1955 Accident Prevention Manual made the case for the need for Prevention through Design (PtD) but was not until the 1990s that PtD was used in the U.S. construction industry, following research sponsored by the Construction Industry Institute and conducted by Professors Jimmie Hinze and John Gambatese (Toole, 2017b). Over the past 20 years, the PtD idea has gradually gained acceptance and application in the U.S. (Toole, 2017b). PtD programs have been formed by major design-build companies including URS, Parsons, and Jacobs Engineering, and Kiewit, Fluor, Mustang Engineering, and Zachry Engineering have started the process of putting one into place (Toole, 2017b). The National Occupational Research Agenda (NORA) Construction Sector Council added PtD as one of its ten focus topics in 2006 (Toole, 2017b). PtD workshops were held by NIOSH in 2007 and 2011, and several hundred people from eight different industry sectors attended (Toole, 2017b). To examine the relationship between occupational safety and health and sustainable building practices, USGBC published a new (pilot) credit in 2015 that aims to promote the implementation of PtD practices (Langford, 2015). This credit was produced with the assistance of NIOSH (Langford, 2015). The credit addresses safety in both the operations and maintenance as well as the design and construction phases to prevent hazards and risk exposures to workers (Langford, 2015). Additionally, USGBC and NIOSH have collaborated on a course to raise awareness of occupational safety and health in the design, construction, and operation of green buildings (Langford, 2015).

In conclusion, PtD has progressed over the years to become a crucial practice for minimizing occupational hazards and risks. From its introduction in the NSC's Accident Prevention Manual in 1955 to its growing acceptance and implementation in the United States construction industry, PtD is currently utilized by major design-build companies. The collaboration between USGBC and NIOSH, as seen by the 2015 pilot credit and the development of educational courses, goes to show an effort in integrating PtD into sustainable building practices, promoting worker health and safety across various project phases.

1.3 RESEARCH OBJECTIVES

The objectives of this research are to assess the challenges that prevent the construction industry from fully utilizing the implementation of Prevention through Design by addressing, but not limited to, the following:

a) Identify the challenges and barriers that hinder the utilization of PtD within the construction industry.
b) Understand and identify the necessary contract language challenges that are needed.
c) Determine whether professional architects or engineers are more suited in applying PtD within the industry.
d) Provide suggestions to address the challenges faced to promote the utilization of PtD within the industry.

CHAPTER 2: METHODOLOGY

To achieve the studies objectives, the following steps were followed:

2.1 LITERATURE REVIEW

A literature review is an efficient way of learning about a certain study topic and assessing what is presently known. This part of the work aims to provide a systematic literature review on finding barriers/challenges that prevent the implementation of PtD. As a result, this study examined the literature on the challenges/barriers to implementing PtD throughout the construction industry. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart is utilized in this study to identify the publications. PRISMA is an evidence-based minimal set of components for systematic review and meta-analysis reporting (PRISMA, 2015). The technique of the research as indicated in Figure 3, consists of four primary steps: identification, screening, eligibility, and inclusion steps (PRISMA, 2020).

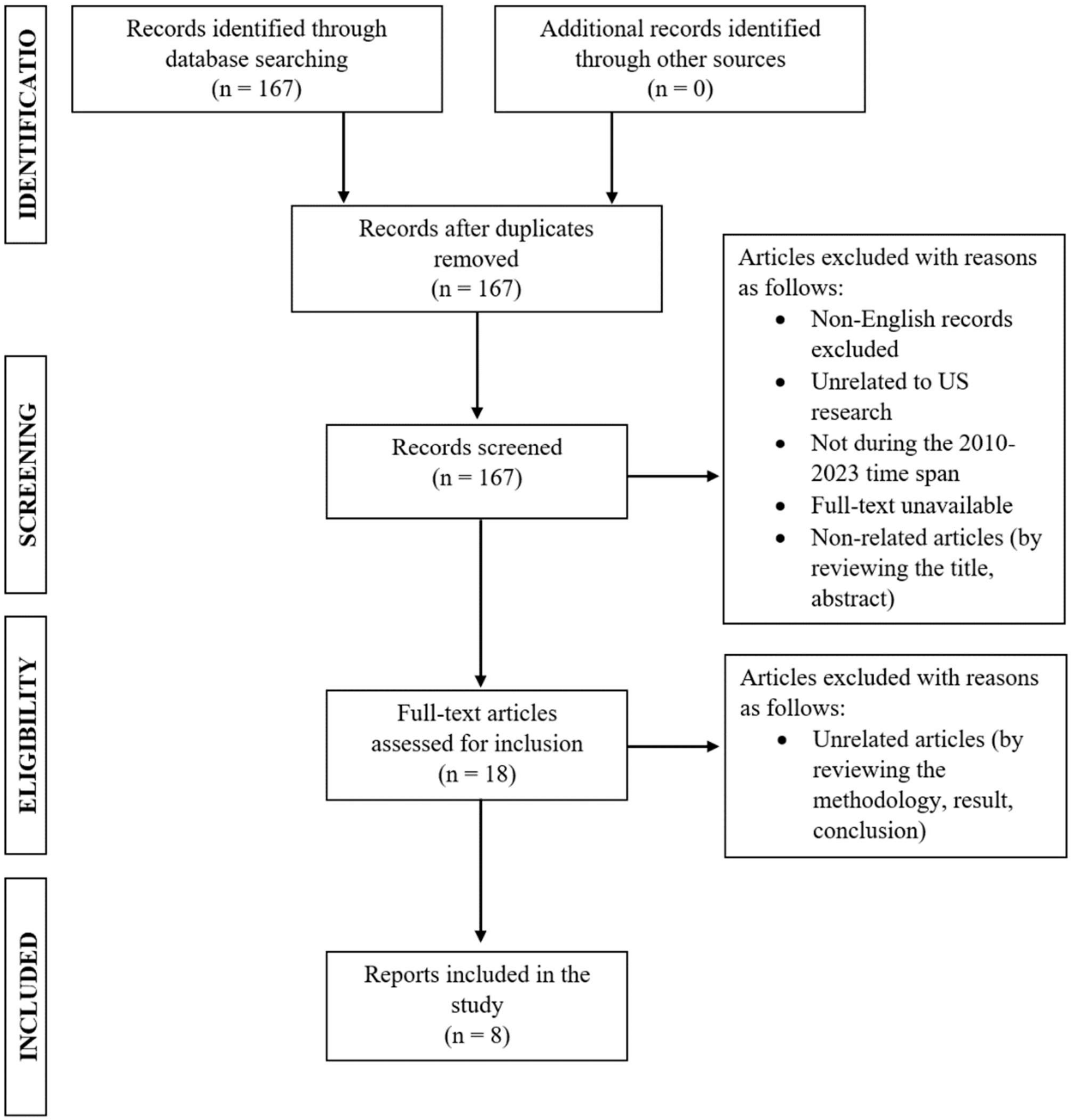

Figure 3: Research Methodology Flowchart

In the first phase, two databases were used to identify the most relevant papers which are American Society of Civil Engineers' (ASCE) online library and Science Direct. As a starting point, a web search was conducted with keywords related to the subject, such as "PtD", "Prevention through Design" and "PtD + Construction". The first phase of the literature review resulted in 167 papers that were published between 2010 and 2023 and focused on research related to the US. In the second phase, initial review of the articles' titles was conducted which resulted in a total of 167 research articles as shown in Figure 3. In the third phase, a content analysis was performed by skimming the articles' titles and an abstract. The third phase resulted in 18 papers. Accordingly, in-depth content analysis was conducted on the resulting 18 focusing on the methodology, results and conclusion sections which resulted in 8 related papers that were fully reviewed. Ten articles were not eligible out of the 18 total records evaluated and appraised for inclusion through eligibility. A few paper samples will be presented, along with the reasons for why they were not included in the research. For example, a research article titled "Identification, Quantification, and Classification of Potential Safety Risk for Sustainable Construction in the United States" assesses and categorizes occupational safety and health (OSH) risks associated with the construction, operation, and maintenance of sustainable projects in the construction industry within United States. It also detects and compares OSH hazards to those found in non-sustainable buildings. This paper was not accepted as an included article due to the lack of outlining what risks and barriers designers face while using PtD in the United States related to construction. Another article, "Design Resources for Incorporating PtD," discusses the many types of solutions accessible to designers as well as current techniques for informing and educating designers on PtD solutions. Although this article gives a decent grasp of the methods that may be utilized to implement PtD, it does not highlight the barriers/challenges that designers experience when using this technique. This article might be used to do more research into what solutions could be employed to address the highlighted barriers/challenges in Table 1. Finally, the article "A Simulation and visualization-based framework for labor efficiency and safety analysis for prevention through design and planning" examines the integration of ergonomics and efficiency analysis into the design process and provides a framework for concurrently planning efficient and safe operations. Upon a closer examination of the article and the material it contains, no barriers/challenges encountered by designers while using PtD were observed.

2.2 SURVEY METHODOLOGY

An online survey was created and administered to achieve this step of the research. Screening questions were created to determine whether a respondent is qualified to proceed with the survey. These questions included a total number of years of construction industry experience, with respondents requiring a minimum of 5 years' experience. Further screening questions included whether or not the respondents were aware of the concept of PtD. If the respondent was not aware or did not have a minimum of 5 years' experience in the construction industry they were excluded. The survey consisted of 5 open-ended questions where respondents answered in an open-text format to allow for answers based on their knowledge and experience. These questions included the following:

1) Based on your experience, list the three most challenges that prevent the construction industry from fully utilizing PtD?
2) Please briefly explain what kind of contract language changes are needed.
3) Please list any other high or extremely high-impact challenges that may hinder the utilization of PtD, if any.
4) Why do you believe that engineers are more equipped to implement PtD?
5) Why do you believe that architects are more equipped to implement PtD?

In June 2023, Lawrence Technological University's Human Subject Institutional Review Board (HSIRB) reviewed and approved the research survey. The survey was administered over a three-month period, beginning in June 2023, and ending in August 2023, and 58 valid responses were collected. The survey questions can be seen in Appendix A.

2.3 QUALITATIVE DATA COLLECTION AND ANALYSIS

Qualitative data analysis is a research method used to understand non-numerical information. Unlike quantitative data analysis, which deals with quantities, qualitative data analysis focuses on exploring and understanding the patterns and themes within gathered research data. The process of data analysis was used to organize, analyze, and interpret data obtained from survey results. This analysis included a code frequency analysis and word frequency analysis to thoroughly examine the data collected from survey responses. In this section we will explore the process of conducting data analysis using NVivo. The approach involves organizing data, importing it into the software, creating and customizing codes, analyzing code and word frequencies, visualizing attributes, and constructing charts to identify patterns.

2.3.1 DATA ORGANIZATION AND SOFTWARE CHOICE

Following the collection of the survey responses on the challenges encountered while implementing PtD in the construction industry, a qualitative data analysis was conducted. To begin the process of conducting a qualitative data analysis on the survey data obtained, all the survey data was organized in Microsoft Excel. Once all the data was organized in Microsoft Excel, it was time to upload it into a qualitative data analysis software to begin the study. NVivo, a program that allows for qualitative data and mixed methods research, was utilized to conduct the analysis.

- All survey data was organized in Microsoft Excel for data management.
- NVivo was chosen for qualitative data analysis given it can manage this type of research.

2.3.2 IMPORTING DATA INTO NVIVO

After downloading and running NVivo, a new project was initiated, and an introduction/tour of the software and its useful functions was provided. It was then time to transfer the Microsoft Excel file into NVivo to begin the analysis. To do so, the toolbar contained an "Import" button that, when selected, presented a toolbar with several options. Since a survey had been conducted for this research, the survey option was chosen as the best fit. The survey option offered multiple alternatives dependent on the type of file utilized, which in this case was an Excel file. When the file was first uploaded, a survey import wizard (Figure 4) appeared, explaining that respondents would be saved as cases, closed-ended questions would be created as attributes to the cases, and open-ended questions would be created as codes. After selecting the "Next" option and verifying the data format, "Next" was clicked one final time. Next, it was critical to determine if a question was closed-ended or open-ended. NVivo automatically read the imported data and classified the questions, but it was essential to check and verify if the questions lined up. Finally, after selecting "Next" one more time, NVivo provided the option of having the program auto coded all the responses to the open-ended questions. Initially, the choice was made to have NVivo automatically code the responses to the questions, but the generated codes were not exactly what was needed, so they were deleted, and new ones were created.

- Launched a new project in NVivo to create a workspace.
- Imported survey data from Microsoft Excel.
- Used NVivo's survey import wizard to automatically sort respondents into cases, attributes (closed-ended questions), and codes (open-ended questions).

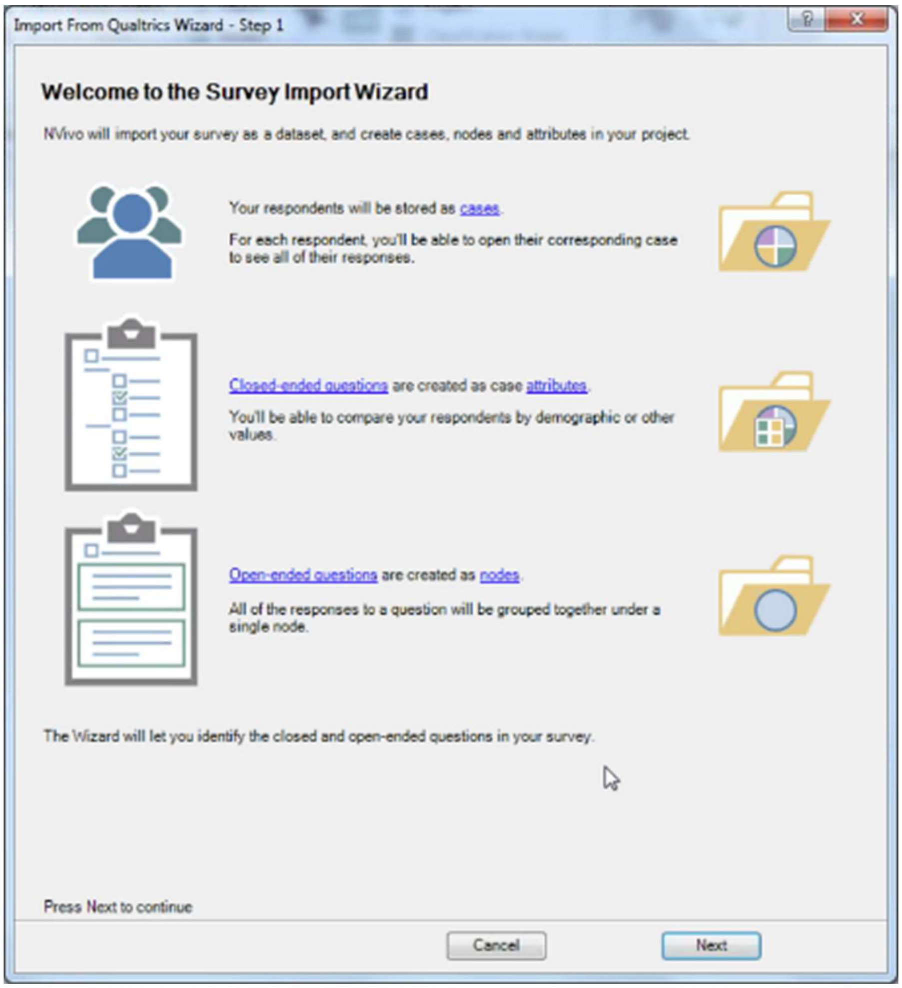

Figure 4: NVivo Survey Import Wizard

2.3.3 CREATING AND CUSTOMIZING CODES

To begin the first code, the first step involved right-clicking on the first open-ended question and selecting "New Code." This allowed for naming the code and choosing "Create." Now that the first code, "Awareness," had been created, all the responses related to awareness were added to the created code. To add a response to a code, the response was simply highlighted and dragged to the corresponding code. Instead of developing codes as the process continued, a decision was made to skim through all the replies and create the necessary codes before going through and adding responses to the corresponding codes. Both methods were found to be effective, but it was observed that developing the codes first made it more efficient, as it allowed going through all the replies at once rather than working with one code at a time. In total, 12 codes were created, and all the replies were read through and added to the appropriate codes. Once all the responses were sorted into the appropriate codes, the next step involved identifying how many references each code had. This enabled determining the most frequently mentioned response to the following open-ended question, "Based on your experience, list the three most significant challenges that prevent the industry from fully utilizing PtD?" The code with the highest number of references to this question was "Increase in Cost" with 45 references, followed by "Lack of Knowledge" with 20 references. These processes were repeated for the remaining open-ended questions to complete the coding process, and the study of the gathered coded data was initiated.

- ❖ Open-ended questions were reviewed to find themes.
- ❖ Created codes representing these themes.
- ❖ For increased efficiency, codes were created prior to adding responses.
- ❖ Using NVivo's drag and drop feature, I assigned responses to their appropriate codes.

2.3.4 ANALYZING CODE AND WORD FREQUENCIES

It was time to analyze the created codes and their word frequencies. The goal was to understand the word frequencies for each open-ended question. The "Explore" option was selected, and then "Word Frequency" was chosen. A window labeled "Word Frequency Criteria" (Figure 5) appeared. In this window, the settings were adjusted in an attempt to find the ideal word frequency for preferences. "Selected Items" was chosen, which opened a window where the project titled "PtD Survey" was selected from the code drop-down. The open-ended question or questions to conduct a word frequency analysis on were also selected, in this case, it was done for each question separately. "Display Words" was set to the top 50 most frequent words with a minimum length of 4, and the grouping was set to "With Generalizations" before clicking the "run query" button. After running the word frequency query, a table summary was provided, containing the word, length of the word, count, weighted percentage (%), and similar words used by the respondents. It was discovered that for the question "Based on your experience, list the three most significant challenges preventing the industry from fully utilizing PtD?" The term with the largest weighted percentage was "demands" (6.80%), followed by "cost" (4.65%) and "process" (4.77%). In addition to the table summary, a visualization of a word cloud for the 50 most frequently used terms was constructed using the criteria that were set. To do so, on the right side of the word frequency window, there was a vertical toolbar with the option of choosing "Word Cloud." Clicking this re-ran the data to generate a word cloud graphic, which could be customized by changing the theme.

- ❖ Analyzed each code's frequency of occurrence to identify recurring themes.
- ❖ Determined, for example, the most frequently used responses to certain questions.
- ❖ Analyzed word usage patterns using NVivo's "Word Frequency" function.
- ❖ Criteria such as word length and frequency limitations were adjusted.
- ❖ Developed a word cloud graphic displaying frequently utilized words for visual data.

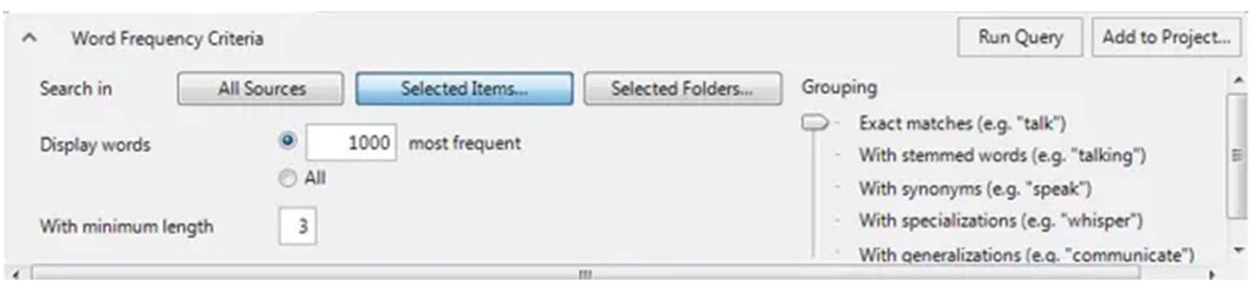

Figure 5: Word Frequency Criteria

2.3.5 DISPLAYING RESPONDENT ATTRIBUES

Apart from word frequency tables and word clouds, key attributes were desired that were important in determining which respondents qualified for the survey data collection. Pie charts and bar graphs were created to provide information on the percentage and the number of respondents in each category. These criteria included respondents' total years of industry experience, job title, and field specializations. To achieve this, "Case Classifications' were selected under the Cases header on the left, which opened up the attributes associated with respondents. The desired characteristics were chosen for analysis and a more detailed examination. Right-clicking on the attribute and selecting "Visualize" followed by "Chart Cases by Attribute Value" was done to create an attribute chart that required revision before completion. "Select Data" in the toolbar was clicked, and the X-axis property was changed to "All attribute values except 'Unassigned', 'Not Applicable'" before clicking "OK." Finally, the number of respondents per category was displayed in the chart by enabling data values.

- Essential respondent attributes were examined, including job titles, field specializations, and total years of industry experience.
- To display the percentage distribution and the number of respondents in each group, pie charts and bar graphs were made.
- Modified these visual representations to exclude unnecessary information.

2.3.6 CREATING HIERARCHY CHARTS

The development of a hierarchy chart was started to allow the depiction of a hierarchy, aiding in the identification of patterns in the attribute values of cases. NVivo included two types of hierarchy charts: Tree map and Sunburst. The Tree map Chart was chosen, displaying data as a series of rectangles of increasing sizes. The sizes of the rectangles represented a quantity when compared to one another. The process began with clicking "Explore" and then "Hierarchy Chart" to create a hierarchy chart for attribute comparison. In this situation, the focus was on the attribute values given to cases. "Cases" were selected under attribute values, followed by "Next." For categorization, "Survey Respondents” and the desired attributes were chosen. In this case, three different attributes were being compared. After selecting these attributes, "Finish" was selected, providing a Hierarchy Chart breaking down the attributes based on the total number of years the respondents worked in the industry, followed by a breakdown of the respondents' specializations and each respondent's job title.

- Used hierarchy diagrams for analyzing patterns among respondent attribute data.
- Selected a Tree map hierarchy chart type to represent data visually.
- The attributes were broken down to acquire insights into patterns connected to years of experience, specialization, and job titles.

2.3.7 SUNBURST HIERARCHY CHART FOR OPEN-ENDED QUESTIONS

Finally, a sunburst hierarchy chart was constructed for a combination of all open-ended questions. A sunburst hierarchy chart displayed data in the form of rings, with the innermost ring representing the top level of hierarchy and the outermost rings representing contributing segments. The process of creating a hierarchy chart for open-ended questions was quite like the process used when a hierarchy was created for respondent attributes. To begin, "Explore" and then "Hierarchy Chart" were chosen. Unlike the attributes portion, the quantity for coding for "Codes" was selected, followed by "Next" and "Finish." The chart was set to open as a Tree Map by default, however, changing to a Sunburst chart was simple. To modify this, the Toolbar was used to pick between the two; if Sunburst was selected, NVivo automatically generated the Sunburst chart. A few changes were made, such as changing the representation to code references, which darkened the section colors to highlight which segment had the most references cited throughout the survey. In this case, the code with the most references was the "Increase in Cost," which received 45 references from 58 respondents.

- ❖ Created a sunburst hierarchy chart to display relationships between codes based on open-ended questions.
- ❖ This chart type displays data in inner and outer rings, making it clear to visualize coding links.
- ❖ Highlighted the code with the highest number of references to identify key themes within the responses.

By carefully following this process, a thorough qualitative data analysis using NVivo was successfully completed, allowing for the collection of insightful survey responses and the identification of significant patterns in the data.

CHAPTER 3: FINDINGS

In this section the results from both PRISMA and Survey methods will be discussed:

3.1 PRISMA FINDINGS

The authors of the 8 articles had researched the factors for barriers/challenges that prevent the implementation of PtD. The article analysis identified 10 barriers/challenges that the construction industry faces while implementing PtD on a project. Two of the barriers/challenges include sub barriers/challenges that break down the categories into additional categories for understanding. The 10 barriers/challenges were categorized into 3 categories – General Barriers, Designer Related Barriers, and Client Related Barriers – in accordance with its characteristics.

1. General Barriers
    a. Lack of Laws and Industry Standards
    b. PtD Increases the Costs and Time of Design Work
    c. Project Delivery Method Influence
    d. The Absence of Contractual Clauses that Organize PtD
2. Designer/Engineer Related Barriers
    a. A/Es Fear of Liability
    b. Lack of PtD Knowledge among A/Es
        i. Construction Means and Methods
        ii. Safety Requirements
    c. The Absence of Motivation and Incentives for A/Es
    d. The Absence of PtD Educational Programs
        i. The Absence of PtD Training
        ii. The Absence of PtD Professional Development programs
        iii. The Absence of PtD Education in Colleges
3. Client Related Barriers
    a. Lack of Understanding of PtD among Project Owners/Clients
    b. Clients' Attitude Towards PtD Implementation is not Encouraging.

3.1.1 GENERAL BARRIERS

The first category of barriers, General Barriers, focuses on barriers including the absence of PtD-related contractual clauses, cost and design time increases, lack of regulations and industry standards, and project delivery method influence. Because there are no regulations or industry standards requiring construction worker safety to be considered in project designs, the implementation of PtD is a voluntary practice (Gambatese et al. 2017). Most of the time, designers delegate health and safety concerns to the contractors. Increased costs and design time represent the second barrier. Designers stated that there is occasionally insufficient funding or time available for designing for worker health and safety since they must take other important elements into account during the design process (Karakhan et al. 2017). The idea of implementing PtD on a project would result in excessive costs and minimize the owner's advantages (Gambatese et al. 2017). Due to poor communication between designers and builders, the third barrier, project delivery method influence, particularly affects the Design-Bid-Build project delivery method. Designers stated that standard project management techniques encourage industrial separation between designers and contractors and discourage collaboration, often determining the contractor once the design is complete (Karakhan et al. 2017). Communication between designers and builders is limited throughout the design phase by the conventional design-bid-build project delivery method as well as the fragmented and disconnected nature of the construction industry (Gambatese et al. 2017). The last barrier in this category is the absence of PtD-related contractual agreements; there are worries about scope modifications, change orders, dispute resolution clauses, and greater responsibility for the designer. The employment of contractual approaches, according to designers, is a significant obstacle to their capacity to properly participate in safety constructability evaluations or other safety efforts required for PtD implementation (Karakhan et al. 2017).

3.1.2 DESIGNER-RELATED BARRIERS

The second category of factors, designer-related barriers, focus on barriers including, liability concerns, lack of knowledge of safety regulations and construction means and methods, lack of incentives and motivation, and the absence of PtD educational programs including training, professional development programs and education in colleges. First, designers assert that addressing workplace safety issues would increase their professional responsibility and may cause problems with their insurance providers (Karakhan et al. 2017). Designers also claimed that their lawyers advised them not to take part in safety procedures or be in charge of workplace safety in order to avoid legal liability for safety injuries (Karakhan et al. 2017). Designers have typically steered away from involvement in safety due to liability worries because of traditional practices in the design and construction industries that explicitly outsource responsibility for site safety to the constructor (Gambatese et al. 2017). The second obstacle is that designers do not understand or are not aware of the PtD knowledge and tools that are available for planning safe and healthy building projects. PtD procedures may still be ineffective if the contractor chooses the wrong ones since, according to designers, eliminating building dangers is mostly based on construction means and processes (Karakhan et al. 2017). Moreover, designers said that they did not receive any PtD-related training or continuous education (Karakhan et al. 2017). The third barrier, the lack of motivation and incentives, might make it difficult for designers to prioritize safety over other project objectives if they have no rewards or incentives for doing so. The absence of PtD implementation in the AEC sector led to designers' lack of interest in participating in the safety initiative (Karakhan et al. 2017). The absence of PtD educational programs for designers is the final barrier in this category. It has been discovered that traditionally, the architecture/engineering (AE) communities lack training in building safety through education or professional development prohibits them from carrying out PtD implementation (Gambatese et al. 2017a). Lastly, PtD is not frequently taught on the job outside of the process construction industry, is rarely taught to graduate engineers through continued education courses and is never required in undergraduate civil engineering curriculum (Toole et al. 2019).

3.1.3 CLIENT-RELATED BARRIERS

The client-related category of barriers, which focuses on the client's understanding of and attitude toward PtD implementation, is the last one. This is a result of owners' or clients' knowledge of the advantages brought on by PtD implementation. Implementing PtD is significantly influenced by the owners' mentality. It appears that owners are often positive people. If AEs were made aware of the significant owner's interest in PtD, they would probably react by incorporating it into their design procedure (Gambatese et al. 2017). It was found that AEs are crucial to PtD implementation, and if they have a bad opinion of PtD, owners will likely become unable or unwilling to overcome AE opposition (Gambatese et al. 2017). In-depth barriers and explanations of the challenges encountered with PtD implementation in the United States are provided in Table 2, "Barriers/Challenges Faced with the Deployment of PtD."

Table 1:Results and Analysis

#	Author(s)/ Year	Purpose of Article	Sample Size (Targeted Population)	Research Methods	Barriers Preventing the Implementation of PtD
1	Gambatese et al. (2017a)	Examines the findings of a two-year research study on how employees in owner enterprises view potential hurdles to PtD.	182 workers (Case-Study Surveys: 79 owners in various industries including hospital group (26), microchip manufacturer (7), power-generating company (12), energy company (34) Industry Surveys: Construction Industry Institute Member Companies (4%), Members of a National Association of Owner Companies (6%), Federal Agencies (41%), ASCE Construction Institute (2%), PennDOT (37%), ODOT (11%))	• Industry Surveys • Case-Study Surveys	1. There are no existing standards that require construction worker safety to be addressed in project design. 2. Fear of responsibility related with safety involvement. 3. No prior construction safety training. 4. Excessive costs connected with PtD on a project. 5. The DBB technique restricts design cooperation between AEs and Constructors.
2	Toole & Erger (2019)	Examines both the challenges and the opportunities presented by PtD, attempting to give a balanced set of viewpoints on the new safety management approach.		• Literature Review	1. Risk of lawsuits. 2. Risk of destroying statutory protection against injured worker lawsuits. 3. Risk of liability for post construction activities. 4. Risks associated with lack of designer expertise. 5. Risks associated with increased design fees. 6. Risk of exposure to OSHA citations.

3	Gambatese et al. (2017b)	Investigate the types and amounts of resources used to put PtD into effect on projects, as well as the strategies and tools often used to address safety in design and personal project, organizational, and industry barriers to PtD implementation.	228 Workers (IOSH (30%), APS (11%), CIOB (10%), IStructE (8%), Principal contractors (21%), CDM coordinators (15%), Architects (5%))	• Question naire Survey	1. Designers who lack the necessary knowledge and capabilities. 2. Other project objectives prioritized by project owner/client. 3. Construction techniques and procedures unknown during design. 4. Other project objectives prioritized by designer.
4	Karakhan & Gambatese (2017b)	Support the idea that worker health and safety should be incorporated into the design process as part of the innovation process.		• Literature Review	1. Fear of Liability 2. Lack of Education & Regulatory Requirements 3. Limited Knowledge 4. Absence of Collaboration Between Contractors and Designers.
5	Karakhan & Gambatese (2017a)	Investigate and identify current barriers to PtD implementation in the AEC industry, as well as possible enablers	- 101 Designers - 21 Constructors	• Question naire survey	1. Fear of Liability 2. Contractual Methods 3. Lack of Knowledge 4. Economic Reasons 5. No Motivation 6. Other

6	Jin et al. (2022)	Identify and solve present PtD study constraints, as well as broaden the area of PtD research, for use by industry experts when assessing and selecting PtD resources/tools in practice.		• Literature Review	1. Economic Barriers (additional costs associated with PtD implementation) 2. Contractual Barriers (changes in contract clauses) 3. Knowledge/Information (designer lack of knowledge about safety or construction means and methods) 4. Safety is not given a higher priority. 5. Clients attitude towards PtD 6. Lack of Motivation 7. Schedule and budget concerns
7	Toole et al. (2017a)	Increase awareness of the role that facility owners may play in implementing PtD in their capital projects.	247 workers (65 face-to-face interviews, 79 anonymous surveys at 4 case study organizations, 103 surveys completed by members of national construction associations and organizations)	• Interviews • Case Study Surveys • Industry Surveys	1. Lack of Knowledge
8	Ibrahim et al. (2022)	Provides a way for the client, designer, or design organization to conduct an initial assessment of the designer's PtD construction competency.	59 Experts	• Delphi Survey	1. Fear of liability 2. Contractual methods 3. Lack of safety knowledge

Table 2: Barriers/Challenges Faced with the Implementation of PtD

Barrier Category	Barriers/Challenges	Barrier Explanation
General Barriers	**F01. Lack of Laws and Industry Standards**	• No existing regulations that mandate addressing construction worker safety in the design of a project (Gambatese et al. 2017a; Gambatese et al. 2017b; Jin et al. 2022) • Regulatory requirements in the United States, such as Occupational Safety and Health Administration (OSHA) regulations, place the responsibility on contractors, and exclude designers from such responsibility (Karakhan et al. 2017) • No laws related to PtD (Toole et al. 2017a) • The absence of PtD regulations was recognized as one major barrier to PtD implementation (Jin et al. 2022)
	F02. PtD Increases the Costs and Time of Design Work	• There is sometimes insufficient funding and time available for designing for worker health and safety as designers are obligated to address other important criteria in the design process (Karakhan et al. 2017a) • Inadequate design time (Gambatese et al. 2017b) • Perceptions that the costs associated with performing PtD on a project would be excessive and outweigh the benefits received by the owner (Gambatese et al. 2017a) • Schedule and budget concerns (Jin et al. 2022) • Additional costs associated with PtD implementation (Jin et al. 2022) • The diffusion of PtD to increase design costs (Toole et al. 2017a)
	F03. Project Delivery Method Influence (e.g., Design-Bid-Build Vs. Design-Build)	• Designers contended that traditional project delivery methods inhibit collaboration and foster segregation of the industry (designers versus contractors) in addition to the fact that, in many cases, the contractor is not identified until the design is complete (Karakhan et al. 2017a) • The typical design-bid-build method of project delivery and the fragmented and disjointed nature of the construction industry, limited collaboration between AEs and constructors during design (Gambatese et al. 2017a) • The DBB project delivery method is used by most public agencies and introduces fewer opportunities for collaboration between project reams because in most cases the contractor is identified after the project design is complete (Karakhan et al. 2017b) • The traditional design-bid-build process can make it difficult to secure safety constructability input from contractors because the project general contractor and

		subcontractors are not identified until the end of the bid stage (Toole et al. 2019)
	F04. The Absence of Contractual Clauses that Organize PtD	• Changes in contract clauses (Jin et al. 2022) • Design firms typically enter into contracts that expressly disclaim responsibility for job site safety and assign that duty solely to the construction contractor (Toole et al. 2019) • The contract between the owner and design firm is a standard industry contract, including a provision stating that the design firm is not responsible for job site safety (Toole et al. 2019) • Designers do not get involved in overseeing safety on the site during construction due to contractual obligations (Gambatese et al. 2017a)
Designer Related Barriers	**F05. A/Es' Fear of Liability**	• Designers indicated that liability issues are the main reason why PtD implementation may not be feasible. Many designers stated that their involvement in addressing workplace safety would increase their professional liability and may cause problems with their insurance carriers (Karakhan et al. 2017a) • Some designers claimed that their lawyers advised them not to be involved in safety efforts or presume responsibility for workplace safety to avoid potential liability for safety injuries (Karakhan et al. 2017a) • In response to advice from their legal counsel, design professionals often cite the potential for increased liability as a reason for not becoming involved in construction worker safety in and way, including pursuing PtD thinking in their designs (Gambatese et al. 2017b) • Within the industry, insecurity associated with becoming involved in construction safety to an extent is a product of current legal and insurance practice in the construction industry (Gambatese et al. 2017b) • Adopting PtD revealed that the number of adopters is small due to the liability issue (Gambatese et al. 2017b) • Traditional practice within the design and construction industry separates AEs from site safety, a responsibility explicitly given to the constructor. As a result, AEs fear liability associated with any involvement in safety (Gambatese et al. 2017a) • Given the number of lawsuits by injured construction workers against other entities involved in projects, designers understandably fear being held liable for any safety-related activity they might undertake (Gambatese et al. 2017a) • Designers expected PtD to increase organizational liability for owners (Gambatese et al. 2017a) • Fear of professional liability (Toole et al. 2019; Ibrahim et al. 2022) • Potential legal liability is identified as one of the most prominent impediments for designers to implement PtD in countries/regions without PtD regulations (Jin et al. 2022)
	F06. Lack of PtD Knowledge	• **Construction** • Lack of knowledge in construction safety and limited resources were

	among A/Es:	**Means and Methods**	identified as the third most prevalent obstacle to the acceptance of PtD practices among those in the design community (Karakhan et al. 2017a) • Construction means and methods not known during design (Gambatese et al. 2017b) • Lack of knowledge of construction means and methods (Gambatese et al. 2017b)
		• **Safety Requirements**	• Many designers claimed that they did not receive any training or continuing education about PtD (Karakhan et al. 2017a) • Designer lacking requisite PtD knowledge and skills (Gambatese et al. 2017b) • Insufficient design for safety knowledge and skills (Gambatese et al. 2017b) • Designers typically lack sufficient knowledge about construction safety to adopt PtD in designs, as well as to identify and assess hazards during the design/planning phase (Jin et al. 2022) • Designers struggle with identifying and analyzing risks and hazards during the design process due to the lack of skills and exposure to the PtD practice (Ibrahim et al. 2022)
	F07. The Absence of Motivation and Incentives for A/Es	• Designer responses indicated that the lack of PtD adoption in the AEC industry contributed to the lack of motivation for designers to be involved in the safety effort (Karakhan et al. 2017a) • Other project objectives given higher priority by designers (Gambatese et al. 2017b; Jin et al. 2022) • Lack of motivation (Jin et al. 2022) • Without owner involvement and insistence, AEs may be unwilling to change traditional understandings of onsite safety responsibility and implement PtD (Gambatese et al. 2017a)	
	F08. The Absence of PtD Educational programs including:	• **PtD Training**	• Lack of PtD education/training and resources (Jin et al. 2022) • Majority of designers in the country have not yet participated in hands-on PtD training (Ibrahim et al. 2022) • Traditionally AEs are not trained in construction safety, through either education or professional development, thus inhibiting their performing PtD (Gambatese et al. 2017a) • Designers claimed that they did not receive any training or

		• **PtD Professional Development Programs**	continuing education about PtD (Karakhan et al. 2017a) • Education on PtD is rarely offered and never required in undergraduate civil engineering curricula, rarely offered to graduate engineers through continuing education courses, and often not learned on the job outside of the process construction sector (Toole et al. 2019)
		• **PtD Education in Colleges**	
Client Related Barriers	**F09. Lack of Understanding of PtD among Project Owners/Clients**	• Owner's lack of knowledge regarding benefits resulting from implementation of PtD (Gambatese et al. 2017a)	
	F10. Clients' Attitude towards PtD Implementation is not Encouraging	• Other project objectives given higher priority by project owner/client (Gambatese et al. 2017b) • Owner attitude has a significant impact on implementing PtD. It seems that owners, in general, have a positive attitude. If AEs become aware of the significant owner's interest in PtD, AEs will likely respond by including it as part of their design services (Gambatese et al. 2017a) • AEs play an integral role in PtD implementation, and if they view PtD negatively, its implementation is unlikely where owners themselves are unwilling or unable to overcome AE resistance (Gambatese et al. 2017a) • Clients attitude toward PtD (Jin et al. 2022)	

3.1.4 LITERATURE REVIEW DISCUSSION

A variety of challenges, each connected and requiring a detailed approach, stand in the way of efficient implementation of Prevention through Design (PtD) in the construction industry. The lack of laws and industry standards makes it difficult to implement PtD in the construction industry. Although PtD stresses incorporating safety issues into the earliest stages of project design, there is a chance that safety may be neglected or implemented inconsistently in the absence of clear regulations. Because there are no set standards for safety procedures, there may be variations in these processes among different building projects, which could risk worker safety. According to existing literature, there are no existing regulations that mandate addressing construction worker safety in the design of a project (Gambatese et al. 2017a; Gambatese et al. 2017b; Jin et al. 2022). Additionally, in the absence of legal laws, certain stakeholders might put cost and scheduling concerns ahead of safety ones, as we shall discuss in the paragraph that follows. It is essential for the construction industry to encourage the development and implementation of laws and industry standards focused on safety to increase PtD adoption and worker safety.

Another challenge relates to the rise in both the cost and time of design work when implementing PtD in the construction industry. PtD requires careful planning of safety precautions and risk-reduction techniques throughout the design process, which could demand additional resources and knowledge. This might result in longer project deadlines and more expensive design processes. There is sometimes insufficient funding and time available for designing for worker health and safety as designers are obligated to address other important criteria in the design process (Karakhan et al. 2017a; Gambatese et al. 2017b). Additionally, perceptions that the costs associated with performing PtD on a project would be excessive and outweigh the benefits received by the owner (Gambatese et al. 2017a). However, it is critical to understand that these initial safety expenses are meant to pay off overall by lowering accidents, injuries, and related expenses throughout construction and over the course of the project. PtD can therefore lead to significant cost savings and increased worker safety over the course of the project, even though it may increase initial design costs.

The choice of project delivery method presents a significant challenge when implementing PtD in the construction industry. Different project delivery methods, such as design-bid-build, design-build, and construction management at-risk (CM@R), can influence the incorporation of safety considerations in the design phase. In traditional design-bid-build contracts, the designer may not have direct input into construction and safety planning, potentially limiting the effectiveness of PtD. Designers contended that traditional project delivery methods inhibit collaboration and foster segregation of the industry (designers versus contractors) in addition to the fact that, in many cases, the contractor is not identified until the design is complete (Karakhan et al. 2017a). The typical design-bid-build method of project delivery and the fragmented and disjointed nature of the construction industry limits collaboration between AEs and constructors during design (Gambatese et al. 2017a). The DBB project delivery method is used by most public agencies and introduces fewer opportunities for collaboration between project teams because in most cases the contractor is identified after the project design is complete (Karakhan et al. 2017b). In contrast, design-build and CM@R approaches allow for collaboration between designers and contractors, facilitating the integration of safety measures from the start. However, this also requires a more proactive commitment to PtD from all project stakeholders. Therefore, successfully implementing PtD requires aligning the chosen project delivery method with a shared commitment to prioritize safety in the design process, regardless of the contractual arrangement.

An overlooked challenge in implementing PtD in the construction industry is the absence of contractual clauses specifically organizing and mandating PtD practices (Jin et al. 2022). Traditional construction contracts often lack provisions that clearly outline the responsibilities and expectations related to safety integration during the design phase. This gap in contractual language can lead to uncertainty and disputes among project stakeholders regarding who holds responsibility for PtD. Design firms typically enter into contracts that expressly disclaim responsibility for job site safety and assign that duty solely to the construction constructor (Toole et al. 2019). The contract between the owner and design firm is a standard industry standard contract, including a provision stating that the design firm is not responsible for job site safety (Toole et al. 2019). This contractual arrangement makes the situation more difficult, as designers do not get involved in overseeing safety on the site during construction due to contractual obligations (Gambatese et al. 2017a). To address this challenge, it is essential for contracts to incorporate explicit language and clauses that promote the inclusion of safety measures in the design process. Such provisions can help establish accountability and ensure that PtD principles are followed, contributing to improved worker safety and project outcomes. However, achieving widespread adoption of these contractual changes may require industry-wide advocacy and collaboration to establish best practices and standards for PtD in construction contracts.

Architects and engineers (A/Es) struggle with the fear of liability (Karakhan et al. 2017a; Gambatese et al. 2017b; Toole et al. 2019; Ibrahim et al. 2022). PtD encourages these professionals to take a proactive role in identifying and mitigating safety hazards during the design phase. However, the heightened responsibility for safety can be intimidating, as A/Es may worry about potential legal consequences if safety issues arise later in the project. Some designers indicated that liability issues are the main reason why PtD implementation may not be feasible, as their involvement in addressing workplace safety could increase their professional liability and cause problems with their insurance carriers (Karakhan et al. 2017a). In response to advice from their legal counsel, design professionals often cite the potential for increased liability as a reason for not becoming involved in construction worker safety, including pursuing PtD thinking in their designs (Gambatese et al. 2017b). Traditional practice within the design and construction industry separates A/Es from site safety, a responsibility explicitly given to the constructor, and A/Es fear liability associated with any involvement in safety (Gambatese et al. 2017a). Given the number of lawsuits by injured construction workers against other entities involved in projects, designers understandably fear being held liable for any safety-related activity they might undertake (Gambatese et al. 2017a). Designers expected PtD to increase organizational liability for owners (Gambatese et al. 2017a). Potential legal liability is identified as one of the most prominent impediments for designers to implement PtD in countries/regions without PtD regulations (Jin et al. 2022). This fear of liability can sometimes lead A/Es to adopt an overly cautious approach when designing safety features, potentially increasing project costs and complicating construction. To address this challenge, it is essential to establish clear legal frameworks and industry standards that define the roles and responsibilities of A/Es in PtD, providing them with a sense of confidence and assurance that their efforts to enhance safety will not result in major legal repercussions.

Another challenge in the implementation of PtD in the construction industry is the lack of PtD knowledge among A/Es (Karakhan et al. 2017a; Gambatese et al. 2017b; Jin et al. 2022). Not all A/Es possess the necessary understanding of PtD principles, which can set back its implementation. This knowledge gap may result from inadequate education or training on PtD concepts and practices, or simply a lack of awareness about the importance of early safety integration in construction projects. Construction means and methods not known during design (Gambatese et al. 2017b), and designers typically lack sufficient knowledge about construction safety to adopt PtD in designs, as well as to identify and assess hazards during the design/planning phase (Jin et al. 2022). Lack of knowledge in construction safety and limited resources were identified as the third most prevalent obstacle to the acceptance of PtD practices among those in the design community (Karakhan et al. 2017a). Many designers claimed that they did not receive any training or continuing education about PtD (Karakhan et al. 2017a). Designers lacking requisite PtD knowledge and skills, as well as insufficient design for safety knowledge and skills, contribute to the overall challenge (Gambatese et al. 2017b). Designers struggle with identifying and analyzing risks and hazards during the design process due to the lack of skills and exposure to the PtD practice (Ibrahim et al. 2022). Addressing this challenge requires industry-wide efforts to enhance education and awareness among A/Es, ensuring they have the knowledge and tools to confidently embrace PtD principles and contribute to safer construction practices.

The lack of motivation and incentives for A/Es wanting to actively engage in PtD practices poses a challenge for its implementation (Karakhan et al. 2017a; Gambatese et al. 2017b; Jin et al. 2022). A/Es may feel like they will not be rewarded for the excessive amounts of work that comes with implementing PtD and achieve no direct benefit. In some cases, design professionals may give higher priority to other project objectives, such as design or cost, over safety due to tight project timelines and budget constraints (Gambatese et al. 2017b; Jin et al. 2022). Designer responses indicated that the lack of PtD adoption in the AEC industry contributed to the lack of motivation for designers to be involved in the safety effort (Karakhan et al. 2017a). Without owner involvement and insistence, AEs may be unwilling to change traditional understandings of onsite safety responsibility and implement PtD (Gambatese et al. 2017a). To address this challenge effectively, it's essential to promote a culture of safety within design teams and emphasize the long-term benefits of PtD, such as reduced construction delays and lower accident-related costs. Providing A/Es with tangible benefits, such as financial incentives or professional recognition, for successfully implementing PtD can also motivate them to prioritize safety in their designs.

In addition to these challenges in the implementation of PtD in the construction industry is the absence of educational programs that include PtD training, professional development programs, and education within colleges and universities (Jin et al. 2022; Ibrahim et al. 2022; Gambatese et al. 2017a; Karakhan et al. 2017a; Toole et al. 2019). Many architects, engineers, and construction professionals lack adequate training in PtD principles and practices. This knowledge barrier can lead to the inability to apply PtD effectively, restricting its adoption in real-world construction projects. The absence of PtD training programs and professional development opportunities means that industry professionals may not be aware of the latest PtD techniques and best practices (Ibrahim et al. 2022). Lack of PtD education/training and resources is a significant challenge identified in recent studies (Jin et al. 2022). Designers claimed that they did not receive any training or continuing education about PtD (Karakhan et al. 2017a). Education on PtD is rarely offered and never required in undergraduate civil engineering curricula, rarely offered to graduate engineers through continuing education courses, and often not learned on the job outside of the process construction sector (Toole et al. 2019). This lack of awareness can lead to missed opportunities for improving safety in project designs. Furthermore, the exclusion of PtD education in colleges and universities continues the cycle of inadequate PtD knowledge, as emerging professionals are not adequately prepared to implement PtD principles in their careers. To overcome this challenge, there is a need for the development of PtD training programs and professional development initiatives within the construction industry. Additionally, integrating PtD education into college and university curricula can help ensure that future architects, engineers, and construction professionals are well-equipped with the knowledge and skills needed to prioritize safety in design from the jump. These educational efforts are essential steps toward enhancing safety practices and encouraging a culture of safety within the construction industry.

The lack of understanding of PtD principles among project owners/clients is another challenge faced when implementing PtD (Gambatese et al. 2017a). Many project owners and clients may not fully understand the importance and potential benefits of this approach. Often, their primary concerns revolve around project cost and schedule, with safety considerations not receiving much thought. This lack of understanding can lead project owners and clients to prioritize cost-cutting measures over safety enhancements during project planning and design. As a result, there may be resistance in gathering resources for PtD implementation, potentially affecting worker safety in the long run. Addressing this challenge requires education and awareness-building efforts aimed at project owners and clients. By effectively communicating the advantages of PtD, such as reduced accidents, lower insurance costs, and improved project outcomes, stakeholders can be encouraged to prioritize safety in project planning.

Lastly, owners/clients' attitude towards PtD implementation is another challenge faced (Gambatese et al. 2017b; Jin et al. 2022). Many owners and clients feel the need to give higher priority to other project objectives (Gambatese et al. 2017b). This attitude can create a barrier to effective PtD adoption, as resources and efforts may be directed away from safety precautions. It seems that owners, in general, have a positive attitude. If AEs become aware of the significant owner's interest in PtD, AEs will likely respond by including it as part of their design services (Gambatese et al. 2017a). AEs play an integral role in PtD implementation, and if they view PtD negatively, its implementation is unlikely where owners themselves are unwilling or unable to overcome AE resistance (Gambatese et al. 2017a). Owners and clients sometimes view PtD as an additional expense or a potential delay in project completion, leading to reluctance in committing to its implementation. Changing these perceptions through education and demonstrating the long-term benefits of PtD is crucial for encouraging a safer construction industry.

3.2 SURVEY FINDINGS

The results portion of the NVivo qualitative data analysis focuses on the findings that have developed from the surveys thorough study. With the use of NVivo it was possible to examine each aspect of the survey. This section provides an overview of the patterns, themes, and important results that resulted from the analysis. In addition to helping understand research topics, the qualitative data analysis provided an understanding of the individual thoughts on PtD and industry experiences of the survey respondents. The section also provides an overview of the findings that were acquired and the contributions that the study has made to the overall understanding of the topic.

Respondents came from various types of construction specializations throughout the United States, including residential construction (24.14%), construction of buildings (37.93%), civil and heavy construction (32.76%), and industrial construction (5.17%). The following job titles were included: architectural engineer (24.14%), other (1.72%), civil: structural engineer (48.28%), architect (24.14%), civil: other (1.72%). Finally, answers to the question about respondents' years of experience indicated that 58.62% had more than 10 years of experience and 41.38% had 5 - 10 years of experience. Table 3 provides an overview of respondent attributes.

Table 3: Survey Respondent Attributes

#	Specialization	Number of Matching Cases	Weighted Percentage (%)	Job Title	Number of Matching Cases	Weighted Percentage (%)	Years of Experience	Number of Matching Cases	Weighted Percentage (%)
1	Residential Construction	14	24.14%	Architectural Engineer	14	24.14%	More than 10 Years	34	58.62%
2	Construction of Buildings	22	37.93%	Other	1	1.72%	5 – 10 Years	24	41.38%
3	Civil and Heavy Construction	19	32.76%	Civil: Structural Engineer	28	48.28%	-	-	-
4	Industrial Construction	3	5.17%	Architect	14	24.14%	-	-	-
5	-	-	-	Civil: Other	1	1.72%	-	-	-
-	**Total**	**58**	**100%**	**Total**	**58**	**100%**	**Total**	**58**	**100%**

3.2.1 PTD CHALLENGES

Based on a survey with 58 respondents, the coding findings provide important insights on the challenges preventing the construction industry from utilizing Prevention through Design (PtD) practices. Respondents were asked to list the three most challenges that prevent the construction industry from fully utilizing PtD, resulting in a total of 158 listed challenges from all respondents categorized into 12 themes. Figure 6 and Figure 7 provide a percentage and reference count breakdown of each challenge mentioned by respondents. A qualitative data analysis revealed that the major challenge faced in the industry when implementing PtD is an increase in cost, with 45 references. This makes sense given that owners/clients want to save as much money as possible and would prefer to avoid any additional costs**.** Figure 8 illustrates an understanding of word frequency based on replies from respondents. The word cloud visualizes word data; the larger the term in the word cloud, the more frequently the word happens to be mentioned in the respondents' responses. The determined challenges were also included in the conducted literature review, along with additional challenges like awareness and others. The results of this study showed that, in line with the complexities of the construction industry, there were a total of twelve challenges to the implementation of PtD. The challenges provided were categorized into several themes:

- **Increase in Cost (45 References):** One of the most significant challenges was the increasing cost of PtD implementation, which highlighted the financial barrier that the construction industry was facing. The respondents expressed concerns over challenges in managing and controlling projects due to limited budgets and increasing costs, as well as resistance from lenders and design limitations.
- **Lack of Knowledge (20 References):** A lack of knowledge of PtD practices and principles was a recurring challenge mentioned. The respondents stated education, designers' lack of familiarity with occupational safety and health hazards, and a lack of understanding of integrated safety and prevention as parts of this challenge. Programs for education and initiatives to spread information could help in reducing this knowledge gap.

- **Lack of Training Programs (16 References):** Respondents mentioned that there were not enough training programs available to offer professionals PtD expertise. Respondents stated that a shortage of a skilled workforce is caused due to a lack of training and educational programs. Making it essential to increase the availability of training programs.
- **Project Delivery Method Influence (15 References):** The adoption of PtD was shown to be impacted by the methods selected for project delivery. Respondents who were asked to identify the reasons for the effect of project delivery methods mentioned a few themes, including lack of communication and barriers to collaboration among stakeholders. It is essential to understand how various project delivery methods affect safety concerns.
- **Awareness (14 References):** A considerable percentage of the respondents indicated the industry's low knowledge of PtD concepts. Many respondents stated that the unawareness of safety risks and concerns resulted from a lack of knowledge, from inadequate safety training to a lack of experience in risk management. Increasing awareness seems to be an essential first step toward solving this problem.
- **Increase in Design Time (13 References):** When using PtD, respondents often mentioned the extra time needed for design. Respondents also said that time limitations and restrictions result from clients wanting projects completed in a certain amount of time. It is essential to find a balance during the design phase between efficiency and safety.
- **Lack of Laws and Industry Standards (10 References):** One challenge was the lack of clear PtD specific laws and industry standards. Respondents stated that PtD implementation was not considered or managed in standard practice, and that there were no regulations or clear standards or guidelines. The development and implementation of PtD specific laws could provide helpful guidance.
- **Lack of Motivation and Incentives (9 References):** Lack of motivation and incentives for PtD implementation was a recognized challenge. Many respondents noted that there is strong opposition to changing how they carry out projects; few others said that companies and organizations lacked the motivation to embrace PtD and that there were insufficient rewards available. It is important to look at ways of encouraging industry stakeholders.

- **Others (9 References):** Respondents also mentioned a range of additional challenges, including difficulty in managing and integrating multidisciplinary project teams in PtD, improper handling of rules, cooperation, lack of innovation, acceptance, limited scalability of PtD technologies for large-scale projects, difficulty in managing change and stakeholder engagement, and issues related to compliance.
- **Client Attitude Towards PtD Implementation (4 References):** It was discovered that client attitudes and viewpoints impacted PtD adoption. Gaining the support of clients and educating them about the advantages of PtD may be necessary.
- **Fear of Liability (2 References):** Although it was not mentioned as much as expected, designers' fear of liability was recognized as a major challenge based on results found within the literature review. The respondents stated that they were worried about increasing their responsibility by taking on additional unnecessary responsibilities related to worker safety. Addressing this issue would benefit from the clarification of laws, industry standards, and liability concerns.
- **Absence of PtD Related Contractual Clauses (1 Reference):** One reference brought attention to the lack of PtD related contractual clauses, stating that PtD is inadequately integrated with legal and contractual frameworks emphasizing the need of incorporating PtD considerations into contractual agreements.

All these results highlighted the variety of challenges that the construction industry faces when implementing PtD into practice. Effectively addressing these challenges would be essential to raising safety standards, cutting expenses, and encouraging proactive and preventative construction project designs. Table 4 provides an understanding of the number of references and weighted percentages based on responses from respondents.

Table 4: Challenges

#	Challenges	# of References	Weighted Percentage (%) Based on # of References	Weighted Percentage (%) Based on # of Respondents
1	Increase in Cost	45	28.48%	77.59%
2	Lack of Knowledge	20	12.66%	34.48%
3	Lack of Training Programs	16	10.13%	27.59%
4	Project Delivery Method Influence	15	9.49%	25.86%
5	Awareness	14	8.86%	24.14%
6	Increase in Design Time	13	8.23%	22.41%
7	Lack of Laws and Industry Standards	10	6.33%	17.24%
8	Lack of Motivation and Incentives	9	5.70%	15.52%
9	Others	9	5.70%	13.79%
10	Clients Attitude Towards PtD Implementation	4	2.53%	6.90%
11	Fear of Liability	2	1.27%	3.45%
12	Absence of PtD Related Contractual Clauses	1	0.63%	1.72%
	TOTAL	**158**	**100%**	**-**

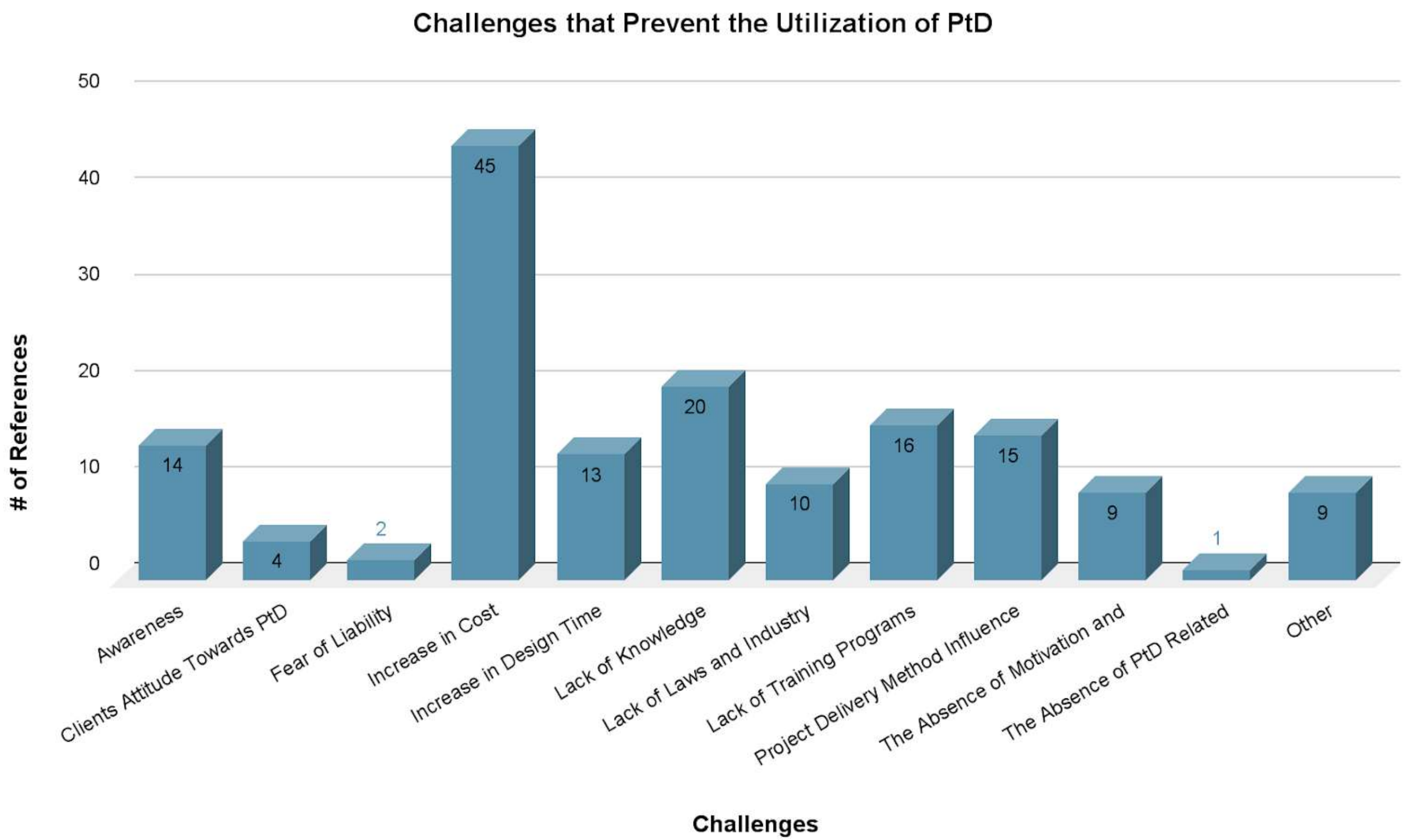

Figure 6: Challenges that Prevent the Utilization of PtD

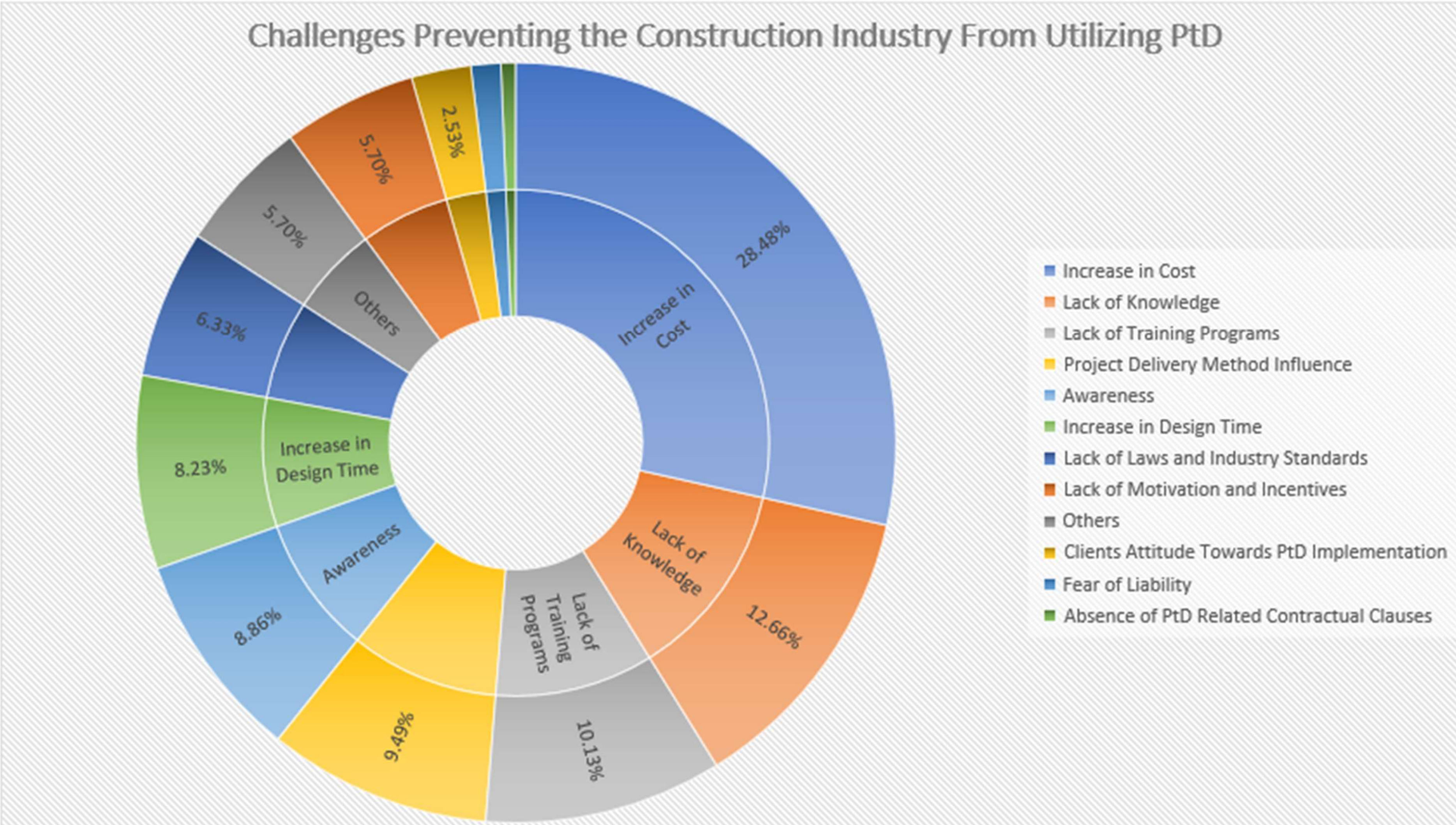

Figure 7: Sunburst Hierarchy Chart on the Challenges that Prevent the Construction Industry from Utilizing PtD

Figure 8: PtD Challenges Word Frequency Word Cloud

3.2.2 CONTRACT LANGUAGE CHANGES

The coding findings provide important insights on the necessary contract language changes needed to implement PtD efficiently. Respondents were asked to briefly explain what kind of contract language changes are needed, resulting in a total of 29 listed contract language changes from all respondents categorized into 10 themes. Figure 9 and Figure 10 provide a percentage and reference count breakdown of each contract language change mentioned by respondents. The qualitative data analysis revealed that the most significant contract language changes were the inclusion of liability, definition section clarification, and inclusion of PtD. Figure 11 illustrates an understanding of word frequency based on replies from respondents. The word cloud visualizes word data; the larger the term in the word cloud, the more frequently the word happens to be mentioned in the respondents' responses. The results of this study showed that, in line with the difficulties of the construction industry, there were a total of 10 necessary contract language changes to implement PtD. The contract language changes provided were categorized into several themes:

- **Liability (7 References):** The inclusion of liability within contract language was recognized as the most significant contract language change by respondents. Respondents stated that expanding and narrowing indemnification language for a clearly addressed language was required to clarify which stakeholder the liabilities and responsibilities fall on. Few other respondents stated that companies should be held accountable and penalized for failing to follow PtD practices, and that force majeure clauses should be revised to account for unforeseen events or circumstances beyond their control.
- **Definition Section Clarification (6 References):** Clarification of the definition section was the second most often mentioned contract language change. To minimize ambiguity or misrepresentation, respondents felt that contract language needed to be clarified or expanded. Respondents also stated that clauses and line definitions were necessary.
- **Inclusion of PtD (5 References):** The third most often stated contract language change was the inclusion of PtD in contract language. Respondents said that specific PtD clauses were required for builders and contractors to abide by the rules. One respondent stated that a specific PtD language is required so that the contract is enforceable to specific requirements.

- **Code Requirements (3 References):** Code requirements were identified as contract language changes required for PtD implementation. Respondents stated that it should be made necessary and required by state and federal codes, and that wording to determine how work will be carried out should be included. According to one reply, designers, builders, and owners must meet code requirements while designing and building with PtD principles at the most foundational level, otherwise permits will not be approved.
- **Coordination Between Stakeholders (2 References):** Another contract language change mentioned by respondents was the coordination between stakeholders. Respondents stated that the contract language should emphasize the importance of coordination between architects, engineers, and contractors to ensure that safety considerations are integrated seamlessly into the design.
- **Safety Responsibility on the Contractor (2 References):** Two respondents mentioned that the safety responsibilities should fall down to the contractor. One respondent stated that the contract language between the designer and the owner, and between the owner and the contractor clearly mandate the responsibility of safety to the contractor. The other respondent stated that the contractual responsibility for safety lays with the contractor, who was required to "Take all necessary precautions for the safety of employees on the work".
- **Change Management Procedure (1 Reference):** One respondent mentioned that a change in management procedures a needed contract language change. The respondent stated that contract language can address change management procedures to ensure that any modifications or revisions to the design during the project adhere to PtD principles.
- **Importance of PtD Measures (1 Reference):** A respondent mentioned the need for the importance of PtD measures within contract language. The respondent stated constructing language spelling out not only the theories and methods but also the importance of preventative measures.
- **Needs for Involvement in PtD (1 Reference):** The needs for involvement in PtD was mentioned by one respondent. The respondent stated that the changes needed should specify the needs involved with PtD and what it encompasses.
- **PtD Policies (1 Reference):** PtD policies were mentioned once within the survey responses. The respondent stated that policies and a few other issues need to be addressed.

Table 5 provides an understanding of the number of references and weighted percentages based on responses from respondents.

Table 5: Necessary Contract Language Changes

#	Contract Language Changes	# of References	Weighted Percentage (%)
1	Liability	7	24.14%
2	Definition Section Clarification	6	20.69%
3	Inclusion of PtD	5	17.24%
4	Code Requirements	3	10.34%
5	Coordination Between Stakeholders	2	6.90%
6	Safety Responsibility on the Contractor	2	6.90%
7	Change Management Procedure	1	3.45%
8	Importance of PtD Measures	1	3.45%
9	Needs for Involvement in PtD	1	3.45%
10	PtD Policies	1	3.45%
	TOTAL	**28**	**100%**

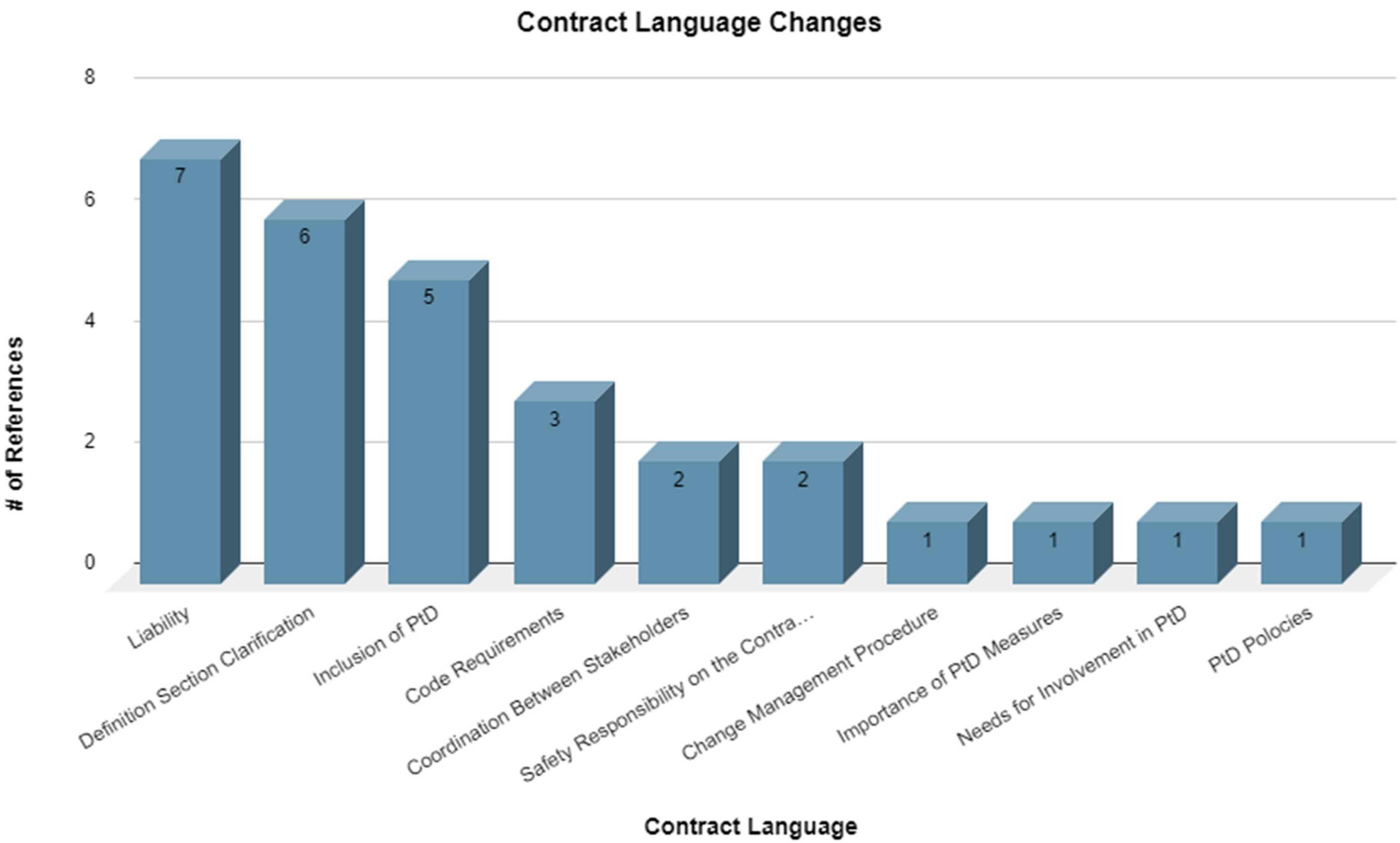

Figure 9: Necessary Contract Language Changes

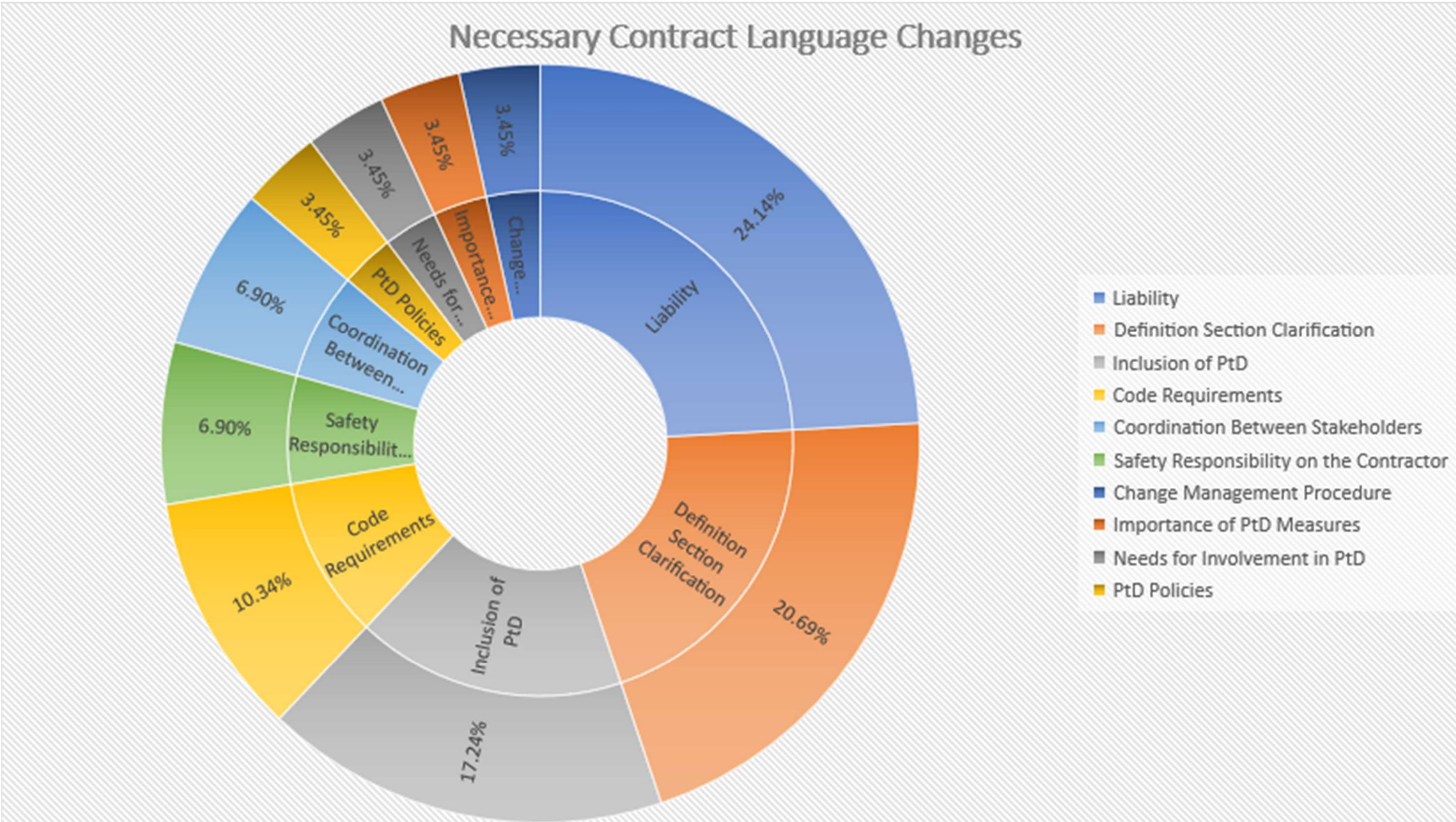

Figure 10: Sunburst Hierarchy Chart on the Necessary Contract Language Changes

Figure 11: Contract Language Changes Word Frequency Word Cloud

3.2.3 HIGH OR EXTREMELY HIGH CHALLENGES

The coding findings provide important insights on high or extremely high impact challenges that prevent the industry from utilizing PtD efficiently. Respondents were asked to list any other high or extremely high-impact challenges that may hinder the utilization of PtD, if any, resulting in a total of 54 listed high or extremely high impact challenges from all respondents categorized into 17 themes. Figure 12 and Figure 13 provide a percentage and reference count breakdown of each high or extremely high impact challenge mentioned by respondents. The qualitative data analysis revealed that the most significant high or extremely high impact challenges were the increase in cost, lack of knowledge, and increase in time. Figure 14 illustrates an understanding of word frequency based on replies from respondents. The word cloud visualizes word data; the larger the term in the word cloud, the more frequently the word happens to be mentioned in the respondents' responses. The results of this study showed that, in line with the difficulties of the construction industry, there were a total of 17 high or extremely high impact challenges that prevent the industry from implementing PtD. Some challenges were found to be repeated from the previous question for list 3 challenges that prevent the construction industry from fully utilizing the implementation of PtD but did also shed light on more challenges that weren't previously mentioned. The high or extremely high impact challenges provided were categorized into several themes:

- **Awareness (1 Reference):** One respondent stated that there is limited awareness of the implementation of PtD. Providing awareness to current and upcoming professionals would allow for professionals to understand the benefits of PtD.
- **Client Expectations (1 Reference):** One respondent mentioned client expectations. The respondent stated that there are expectations from clients. This could be in regard to meeting deadlines as well as staying on budget. Clients always want work to be completed as quickly and efficiently as possible without the need for additional work and methods to be added to the workload.
- **Clients Attitude (2 References):** Client's attitude was mentioned by a few respondents. Respondents stated that designers/builders may not want to scare off a client with such approaches or methods. Clients may not have any background knowledge and may feel

overwhelmed with the idea of applying a new approach as stated by another respondent, resistance from stakeholders who are comfortable with existing approaches.

- **Clients Understanding (2 References):** Client's understanding is an effect that may hinder the utilization of PtD, this is because some clients may have never heard of the method of PtD. Respondents stated that business owners just do not know enough about it and that there is a lack of customer understanding of it. Providing a client with full insight on the benefits of PtD in the industry could potentially move a client to go forward with applying the approach.
- **Cost (9 References):** Based on the responses to a previous question asked as well as this specific question, it has been identified that the major challenge with the implementation of PtD is the increase in cost. Many respondents stated repeatedly that there would be higher costs as well as budget constraints due to the implementation of PtD. Ultimately PtD could potentially save costs due to considerations of health and safety to all that are involved by reducing mistakes and making it easier for workers to get work done efficiently.
- **Designers Liability (1 Reference):** Designers' liability was identified as a challenge affecting the implementation of PtD. Although it was mentioned once in response to this question, respondents stated that there is nothing to protect a designer. Designers may fear that if any complications were to happen during the construction phase, they will be held accountable.
- **Improper use of Procedures (1 Reference):** Improper use of procedure was mentioned as a high or extremely high challenge affecting the implementation of PtD. One respondent stated that the arrogance in architects and or contractors thinking they could cut corners and knowingly ignore and refuse to follow proper procedures. If this was to happen with the approach of PtD, this could harm many different stakeholders and workers within the project, implying complete negligence from the architect or contractor.
- **Lack of Communication (1 Reference):** The lack of communication was mentioned once but was not fully explained. The respondent stated lack of communication, this could be among all stakeholders. Communication is a huge aspect of working within the construction industry.

- **Lack of Educational Programs (5 References):** The lack of educational programs was mentioned five times by respondents. Respondents stated that there is a lack of knowledge being provided by the school systems and or education departments, insufficient training and education programs for workers and professionals on PtD principles. This is a major problem because workers and professionals must understand a concept in order to apply it. In order to avoid this problem educational programs should start to incorporate the education and training of PtD as it would benefit all participants.
- **Lack of Knowledge (6 References):** Many respondents mentioned that the lack of knowledge is a challenge faced when implementing PtD methods. Respondents stated that there is a lack of proper knowledge among designers and clients, many construction professionals may not be familiar with PtD principles or may not fully understand their importance, and that there is not much participation in PtD practices. The idea of incorporating educational programs into schooling systems would break this barrier.
- **Lack of Motivation for Change (4 References):** Stakeholders may lack the motivation for change as mentioned by 4 respondents. Respondents stated that there is a resistance to change and reluctance to adopt new practices. It was also stated that construction industry practices and norms can be resistant to change and that stakeholders cannot change the habits or the way they think about changing.
- **Limited Adoption of Resources and Technologies (4 References):** Four respondents mentioned that there is limited adoption of resources and technologies. Respondents stated that the construction industry has been relatively slow in adopting advanced technologies, lack of resources to implement PtD practices, and that economic demands might limit the allocation of resources to adopting PtD measures. With the design of tools and software's, including tools to allow for a gathering of necessary resources as well as PtD equipped software that may further the application could greatly benefit any architect/engineer with the intent of following PtD measures.
- **Limited Research to Prove Benefits (1 Reference):** One respondent mentioned that there is limited research to prove the benefits of implementing PtD within the construction industry. The respondent stated there is limited evaluation and documentation of PtD benefits. As days progress further benefits and research will begin to emerge within the industry on PtD.

- **Project Delivery Influence (4 References):** Project delivery influence is a major challenge due to the fact that stakeholders do not hold contracts with one another in order to fully communicate based on the type of project delivery method used. Respondents stated that there is inadequate collaboration between designers and end-users, resistance from the traditional design-bid-build process, and the challenge includes communication, negotiation, and approval of application among many others to be agreed upon given the particular design circumstances.
- **Regulations and Standards (4 References):** Regulations and standards were among these challenges faced when implementing PtD. Respondents stated that there are no laws forcing these changes, the absence of standardized guidelines for PtD implementation, and local regulations not enforcing PtD. Because there are no regulations or standards for architects/engineers to follow, there may be confusion over what exact specifications are necessary depending on local locations and the overall application of PtD.
- **Time (6 References):** Time was repeatedly mentioned by respondents. Respondents stated that there may be tight schedules, time constraints, and time of work and planning would increase with the implementation of PtD. Stakeholders are working to meet all deadlines and work within budget, with the addition of a new approach it may take designers/engineers a longer time to fully develop a design that utilizes PtD practices possibly affecting their clients' deadlines.
- **Trust (2 References):** Considering trust plays a huge role in the construction industry it was found as a barrier/challenge when implementing PtD. Respondents stated that there is a lack of trust, and that there is a high reliance on subcontractors. Stakeholders need to feel secure when following an approach, especially one they have not worked with or have prior knowledge to.

Table 6 provides an understanding of the number of references and weighted percentages based on responses from respondents.

Table 6: High or Extremely High Challenges

#	High or Extremely High Challenges	# of References	Weighted Percentage (%)
1	Awareness	1	1.85%
2	Clients Expectations	1	1.85%
3	Clients Attitude	2	3.70%
4	Clients Understanding	2	3.70%
5	Cost	9	16.67%
6	Designers Liability	1	1.85%
7	Improper use of Procedures	1	1.85%
8	Lack of Communication	1	1.85%
9	Lack of Educational Programs	5	9.26%
10	Lack of Knowledge	6	11.11%
11	Lack of Motivation for Change	4	7.41%
12	Limited Adoption of Resources and Techniques	4	7.41%
13	Limited Research to Prove Benefits	1	1.85%
14	Project Delivery Influence	4	7.41%
15	Regulations and Standards	4	7.41%
16	Time	6	11.11%
17	Trust	2	3.70%
	TOTAL	**54**	**100%**

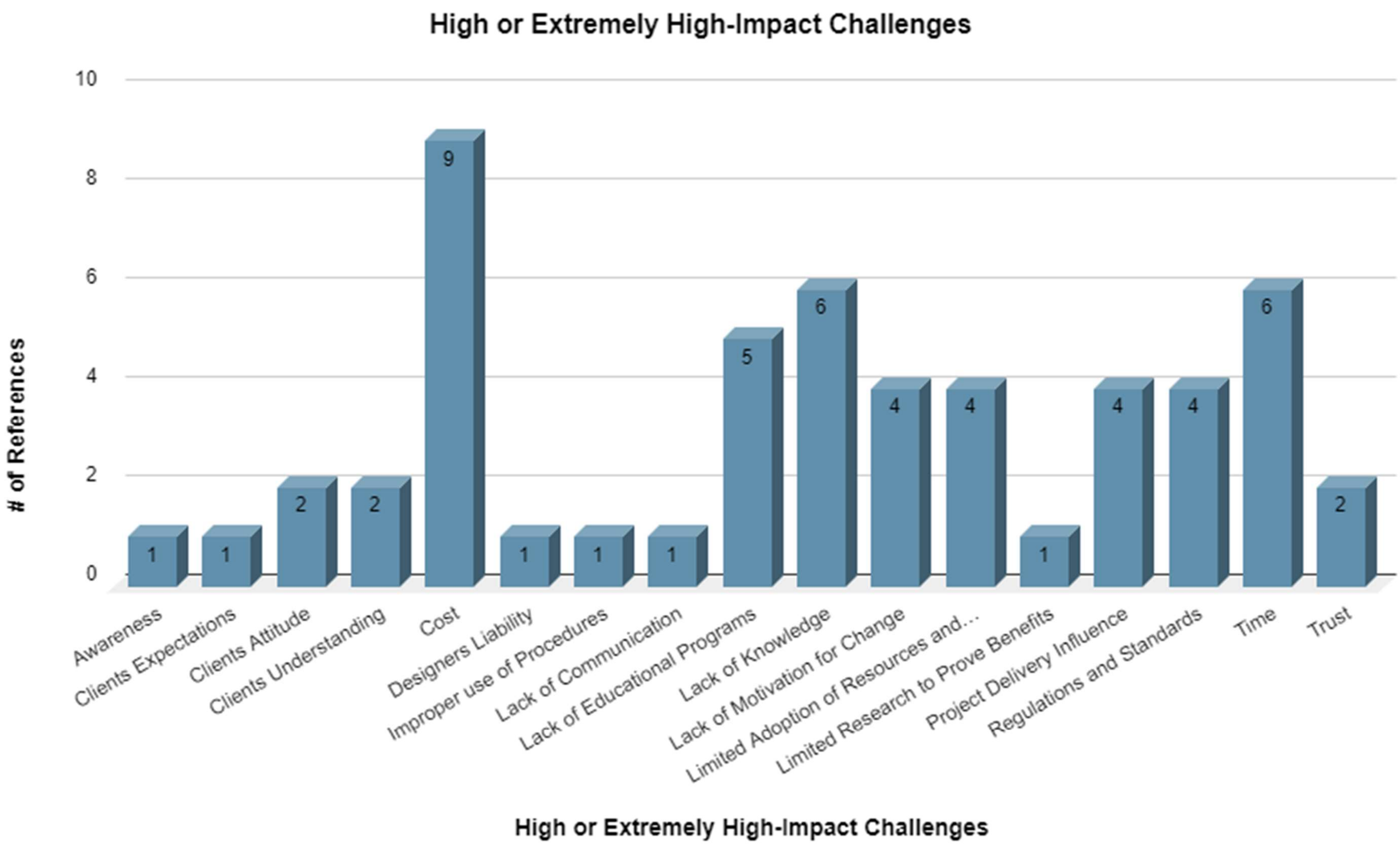

Figure 12: High or Extremely High-Impact Challenge

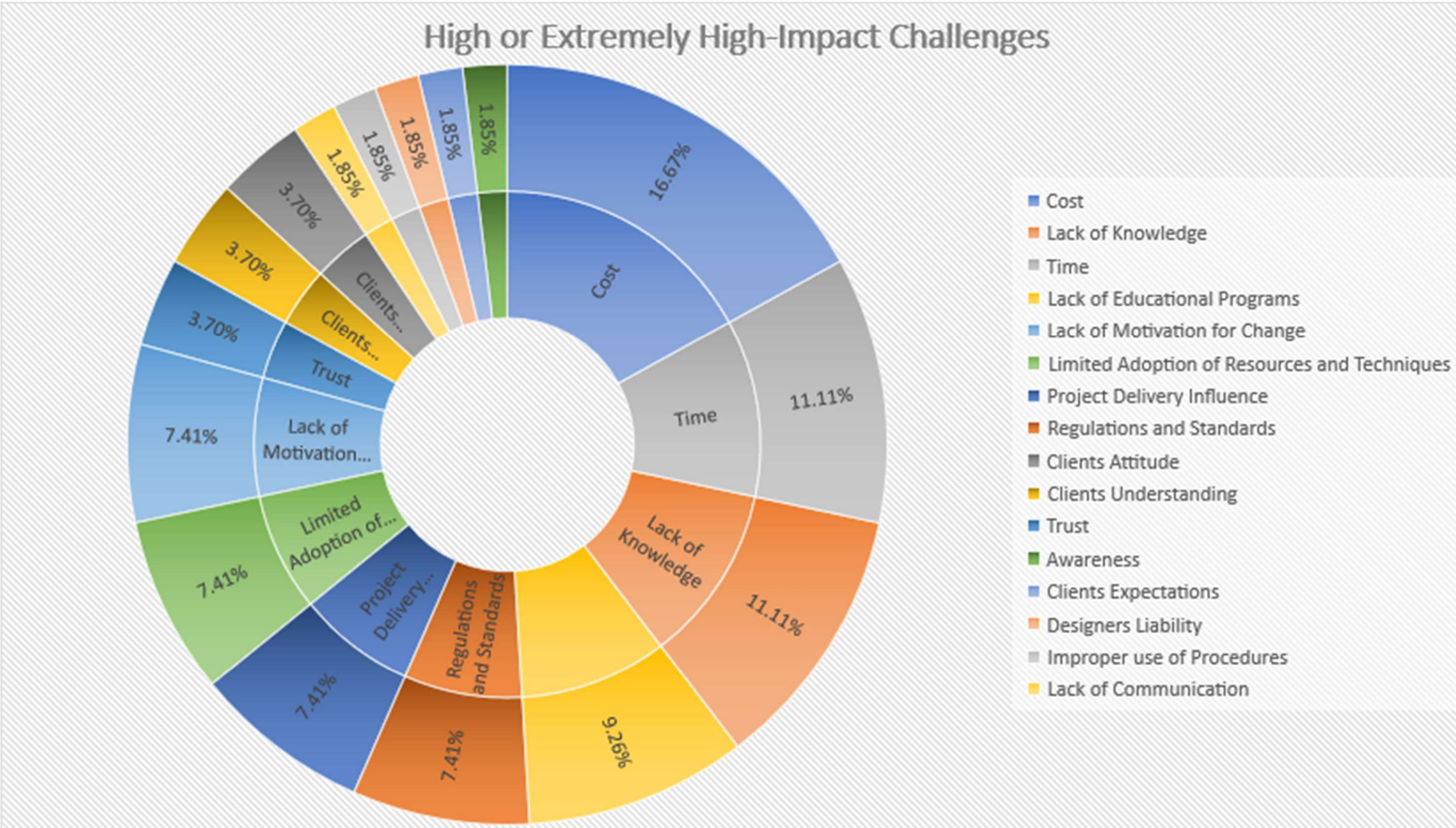

Figure 13: Sunburst Hierarchy Chart on High or Extremely High-Impact Challenges

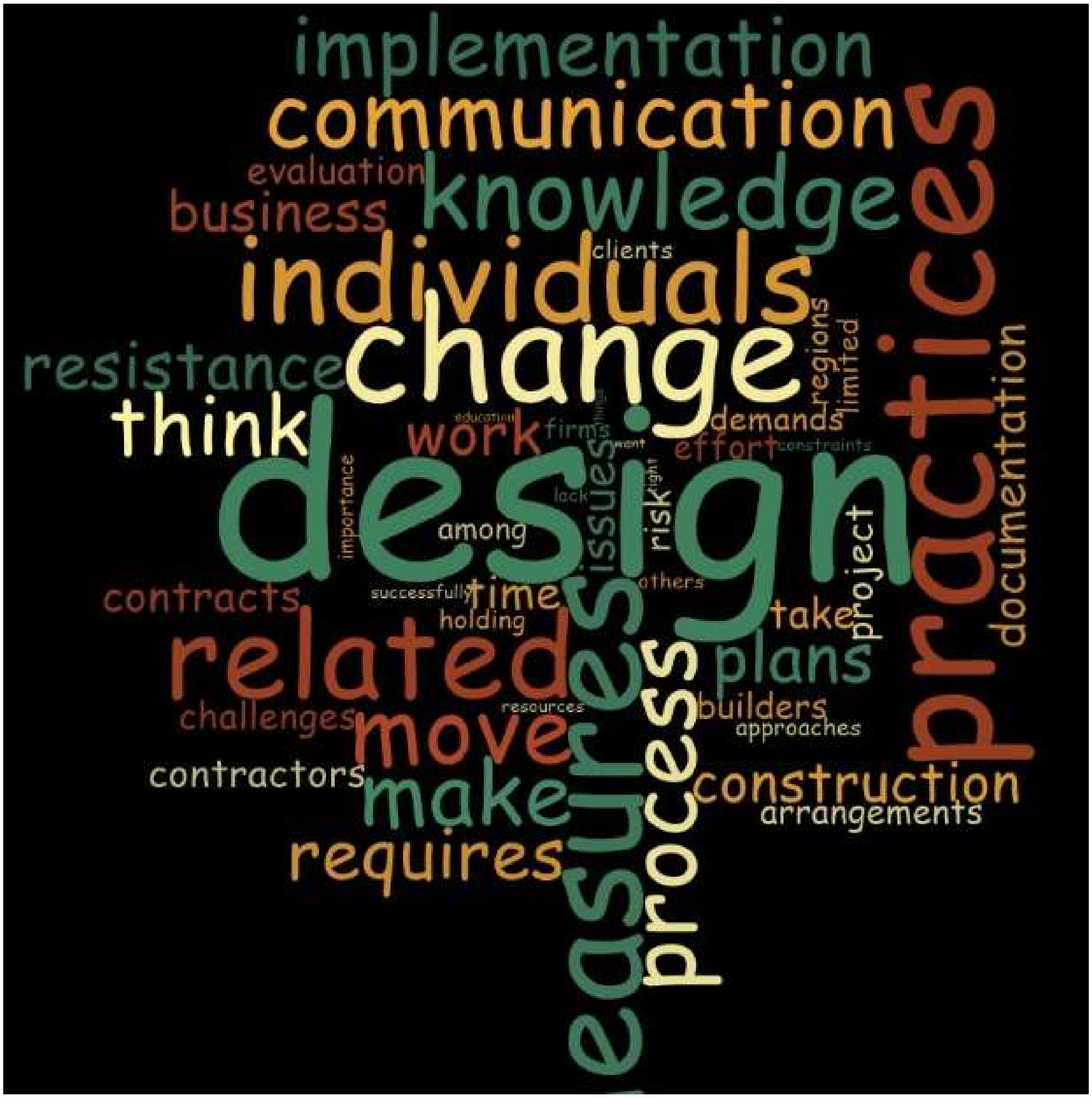

Figure 14: High or Extremely High-Impact Challenges Word Frequency Word Cloud

3.2.4 ENGINEERS: KEY ATTRIBUTES TO IMPLEMENTING PTD

The coding findings provide important insights on why engineers are more equipped to implement PtD compared to architects. Respondents were asked why they believe that engineers are more equipped to implement PtD, resulting in a total of 20 listed reasons as to why engineers are more equipped to implement PtD from all respondents categorized into 4 themes. Figure 15 and Figure 16 provide a percentage and reference count breakdown of each reason as to why engineers are more equipped with implementing PtD mentioned by respondents. The qualitative data analysis revealed that the most significant reason was because of engineers working closely with the project, and that they offer problem solving skills. Figure 17 illustrates an understanding of word frequency based on replies from respondents. The word cloud visualizes word data; the larger the term in the word cloud, the more frequently the word happens to be mentioned in the respondents' responses. The results of this study showed that there was a total of 4 reasons why engineers are more equipped with implementing PtD practices compared to architects. Reasons as to why engineers are more equipped with implementing PtD were categorized into several themes:

- **Ability to Assess Potential Risks and Hazards (4 References):** Engineers are found to have the ability to assess potential risks and hazards as mentioned by respondents. Respondents stated that engineers have the ability to assess potential risks and hazards associated with a project, enabling them to design and implement preventative measures to mitigate those risks. Another respondent stated that engineers are trained to think systematically, which allows them to assess the potential hazards associated with different design choices.
- **Problem Solving Skills (5 References):** Considering engineers study problem solving skills within their education programs, it was found by respondents that this is a reason as to why engineers are more equipped to implement PtD practices compared to architects. One respondent stated that engineers undergo rigorous training that equips them with the expertise to tackle intricate challenges and devise groundbreaking solutions. In the context of PtD, this skill set proves invaluable as engineers are adept at proactively recognizing and mitigating potential hazards, aligning with the fundamental principles of

hazard prevention. Another respondent stated that engineers are more equipped to implement PtD because they have the technical knowledge and expertise to understand.

- **Understanding Codes and Standards (2 References):** Two respondents mentioned that engineers have a better understanding of codes and standards. One respondent stated that engineers have better knowledge in codes and standards compliance and usually follow analytics-based approaches. The other respondent stated that engineers have a solid understanding of safety regulations and codes, ensuring compliance with legal requirements and industry standards.
- **Working Closely with the Project (9 References):** The most significant reason why engineers are more equipped in implementing PtD practices was because they work closely with the project. A total of 9 respondents mentioned this reasoning, stating that engineers work more closely with the core of the project. One respondent stated that engineers tend to be on site considerably more often than that of architects.

Table 7 provides an understanding of the number of references and weighted percentages based on responses from respondents.

Table 7: Reasons Engineers are more Equipped with Implementing PtD

#	Contract Language Changes	# of References	Weighted Percentage (%)
1	Ability to Assess Potential Risks and Hazards	4	20%
2	Problem Solving Skills	5	25%
3	Understanding Codes and Standards	2	10%
4	Working Closely with the Project	9	45%
	TOTAL	**20**	**100%**

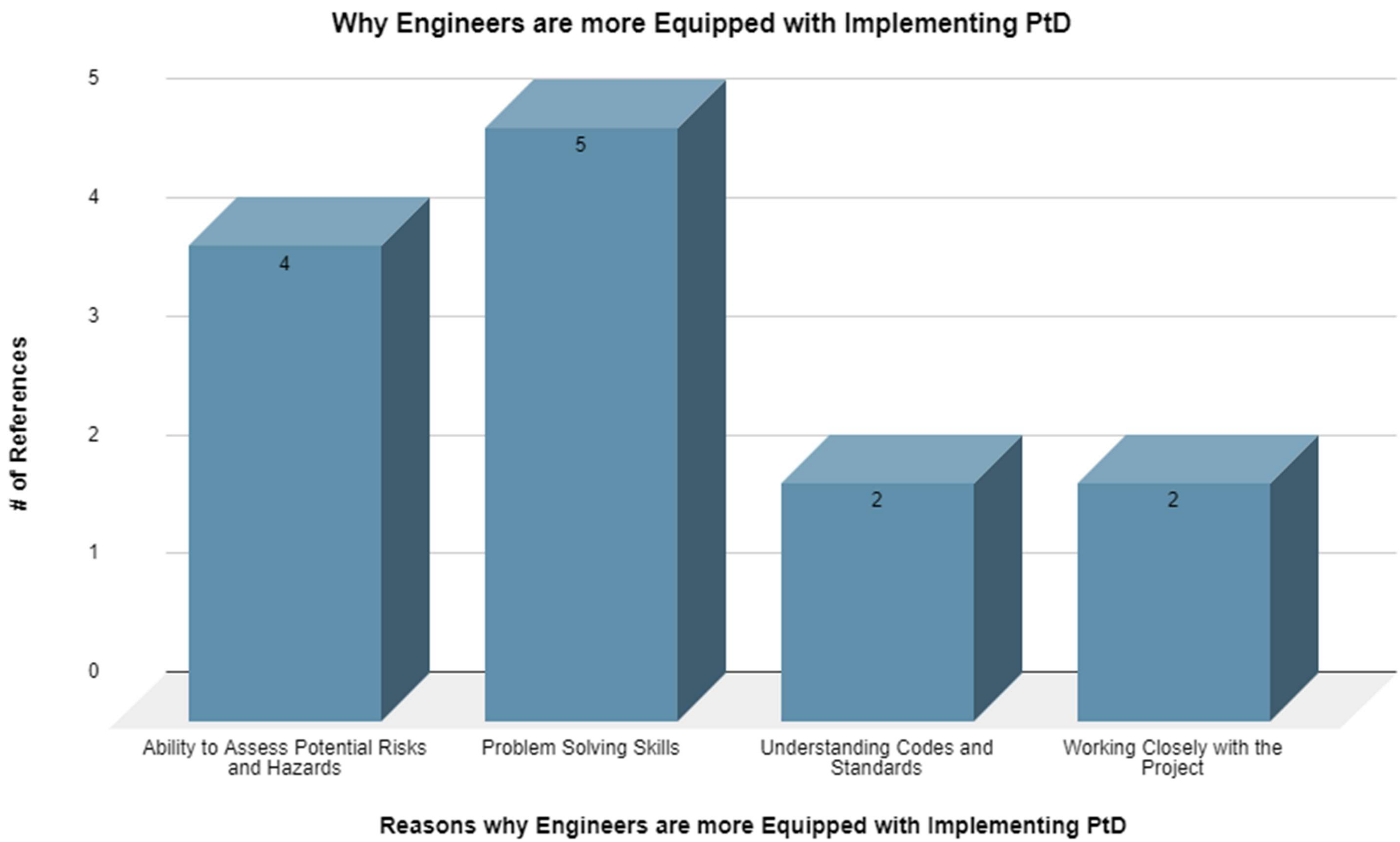

Figure 15: Reasons why Engineers are more Equipped with Implementing PtD

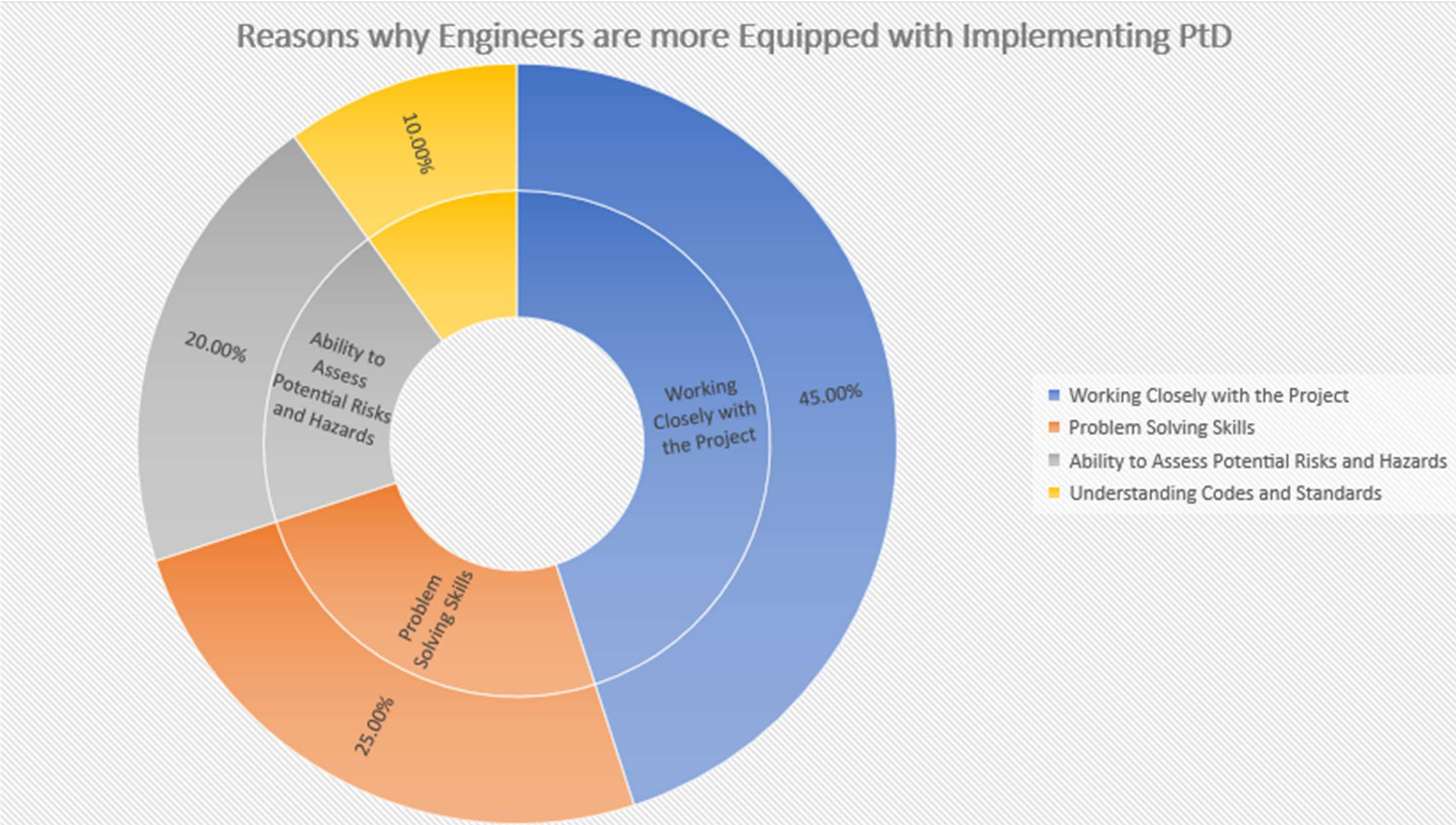

Figure 16: Sunburst Hierarchy Chart on Reasons why Engineers are more Equipped with Implementing PtD

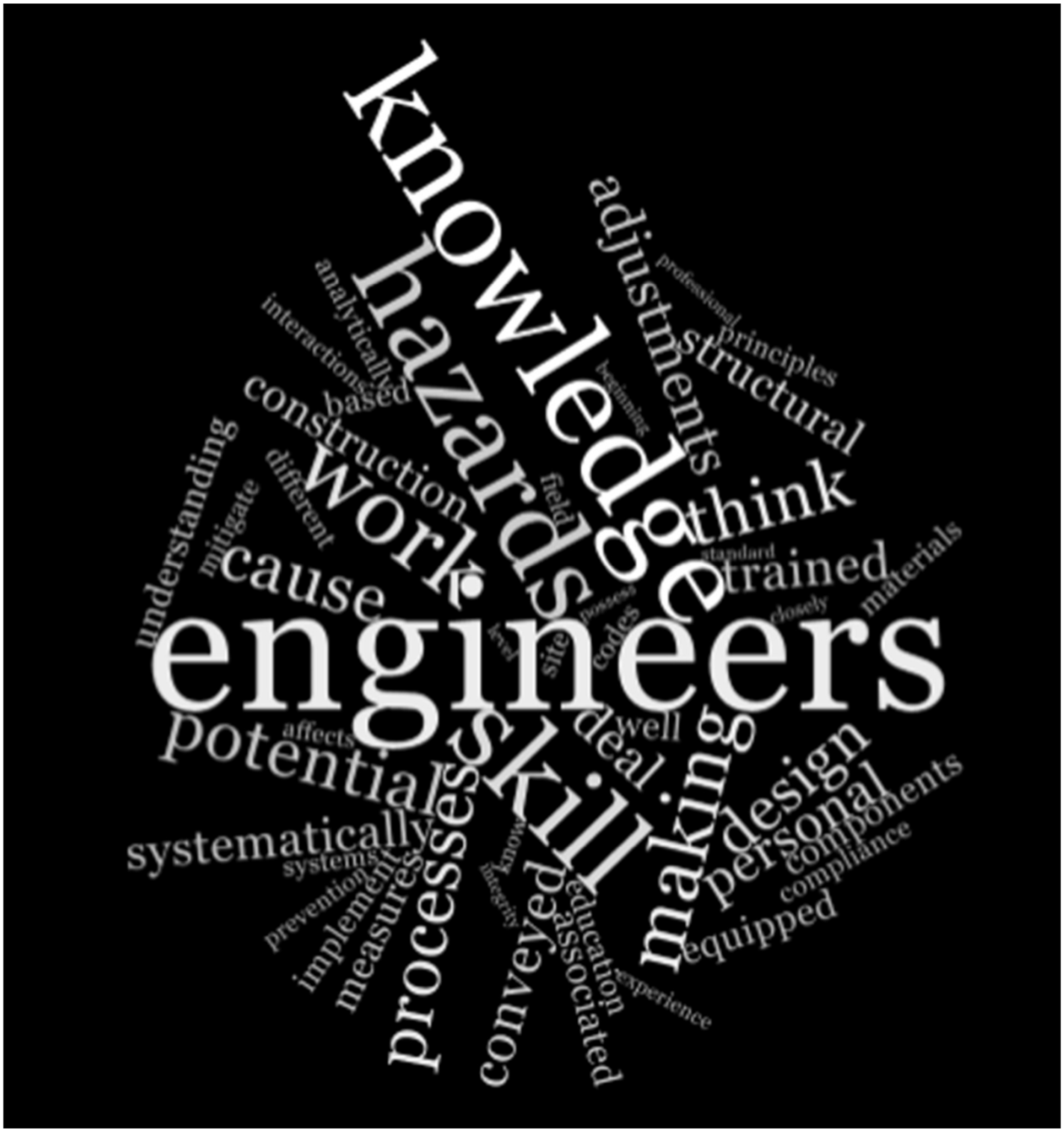

Figure 17: Why Engineers are more Equipped with Implementing PtD Word Frequency Word Cloud

3.2.5 ARCHITECTS: KEY ATTRIBUTES TO IMPLEMENTING PTD

The coding findings provide important insights on why architects are more equipped to implement PtD compared to engineers. Respondents were asked why they believe that architects are more equipped to implement PtD, resulting in a total of 24 listed reasons as to why architects are more equipped to implement PtD from all respondents categorized into 4 themes. Figure 18 and Figure 19 provide a percentage and reference count breakdown of each reason as to why architects are more equipped with implementing PtD mentioned by respondents. The qualitative data analysis revealed that the most significant reason was because architects have more expertise in designing and overseeing, and that they offer effective communication and coordination. Figure 20 illustrates an understanding of word frequency based on replies from respondents. The word cloud visualizes word data; the larger the term in the word cloud, the more frequently the word happens to be mentioned in the respondents' responses. The results of this study showed that there was a total of 4 reasons why architects are more equipped with implementing PtD practices compared to engineers. Reasons as to why architects are more equipped with implementing PtD were categorized into several themes:

- **Effective Communication and Coordination (6 References):** Architects were found to have more effective communication and coordination skills as mentioned by respondents. One respondent stated that architects work closely with engineers' contractors, and other professionals, facilitating effective communication and coordination of safety measures throughout the project.
- **Expertise in Designing and Overseeing (9 References):** The most significant reason why architects are more equipped with implementing PtD was due to their expertise in designing and overseeing as mentioned by respondents. Respondents stated that architects are trained to understand and conceptualize the design of buildings and structures. Another respondent stated that architects possess a comprehensive understanding of design principles, including spatial planning, structural systems, material selection, and building codes, allowing them to identify potential safety hazards and develop design solutions that mitigate risks.
- **Involvement in Initial Design Process (6 References):** Architects are known to have the majority of the involvement of a project during the initial design process. Respondents

stated that architects have a significant influence and key role during the design process. One respondent stated that architects know the design of the building more than the engineer.

- **Understanding of Codes Regulations, and Industry Standards (3 References):** The least significant reason as to why architects are more equipped with implementing PtD practices was the understanding of codes, regulations, and industry standards. Respondents stated that architects, as experts in the building environment, have a thorough understanding of building codes, regulations, and industry standards. Another respondent stated that architects play a crucial role in PtD considering their expertise in space planning, building codes, aesthetics, and functionality allows them to influence the design process to minimize hazards and promote safety.

Table 8 provides an understanding of the number of references and weighted percentages based on responses from respondents.

Table 8: Reasons Architects are more Equipped with Implementing PtD

#	Contract Language Changes	# of References	Weighted Percentage (%)
1	Effective Communication and Coordination	6	25%
2	Expertise in Designing and Overseeing	9	37.50%
3	Involvement in Initial Design Process	6	25%
4	Understanding of Codes, Regulations, and Industry Standards	3	12.50%
	TOTAL	**24**	**100%**

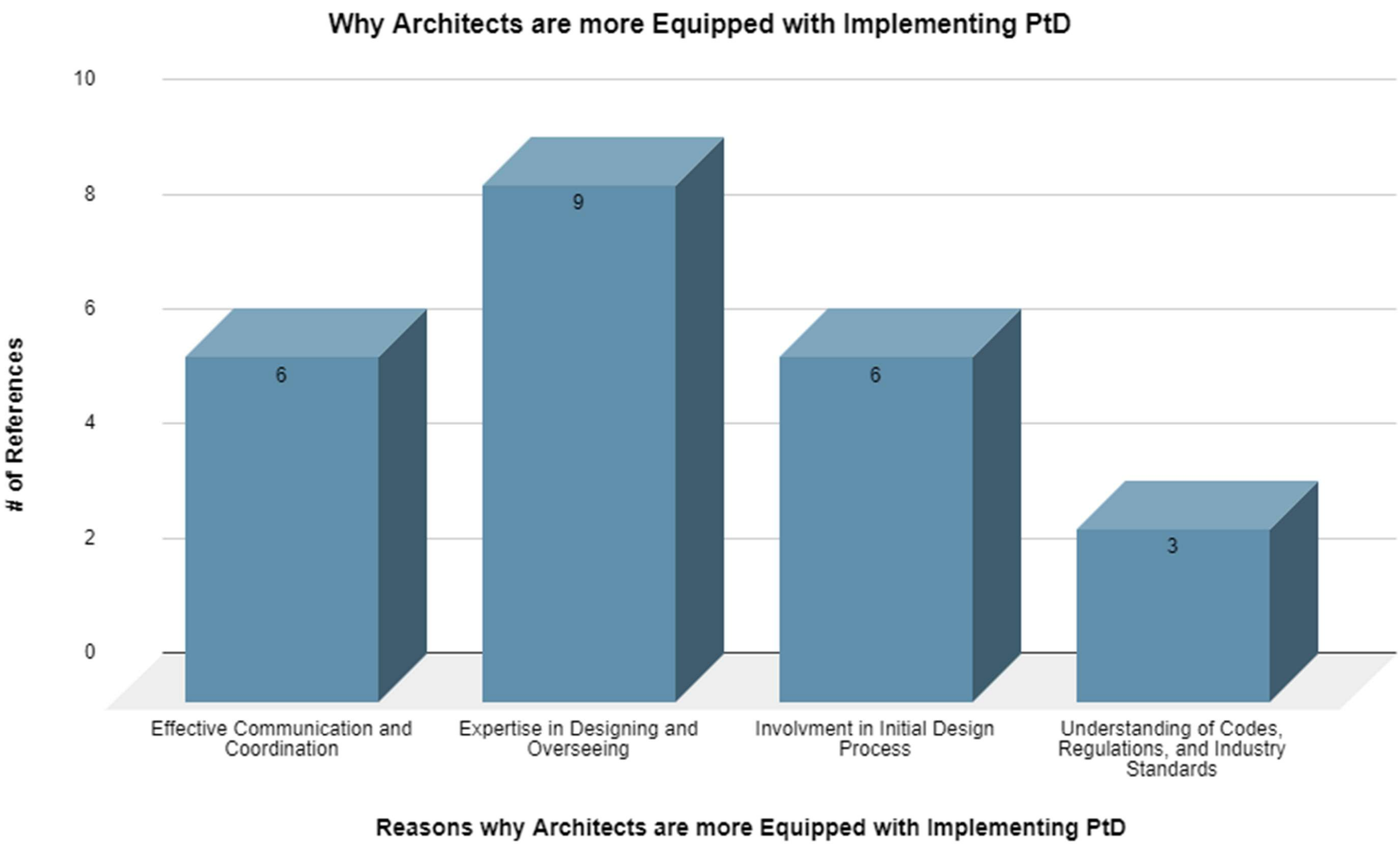

Figure 18: Reasons why Architects are more Equipped with Implementing PtD

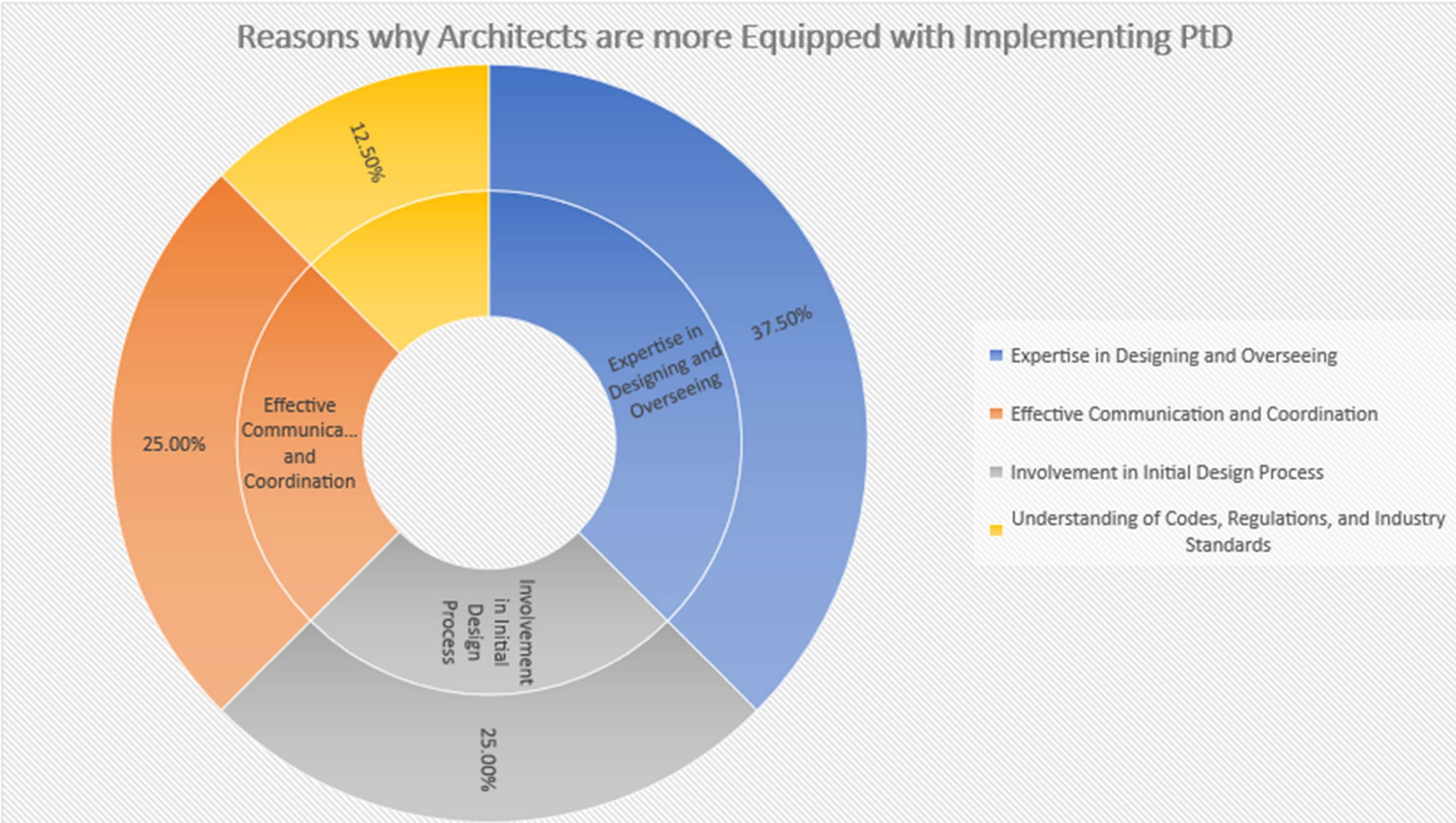

Figure 19: Sunburst Hierarchy Chart on Reasons why Architects are more Equipped with Implementing PtD

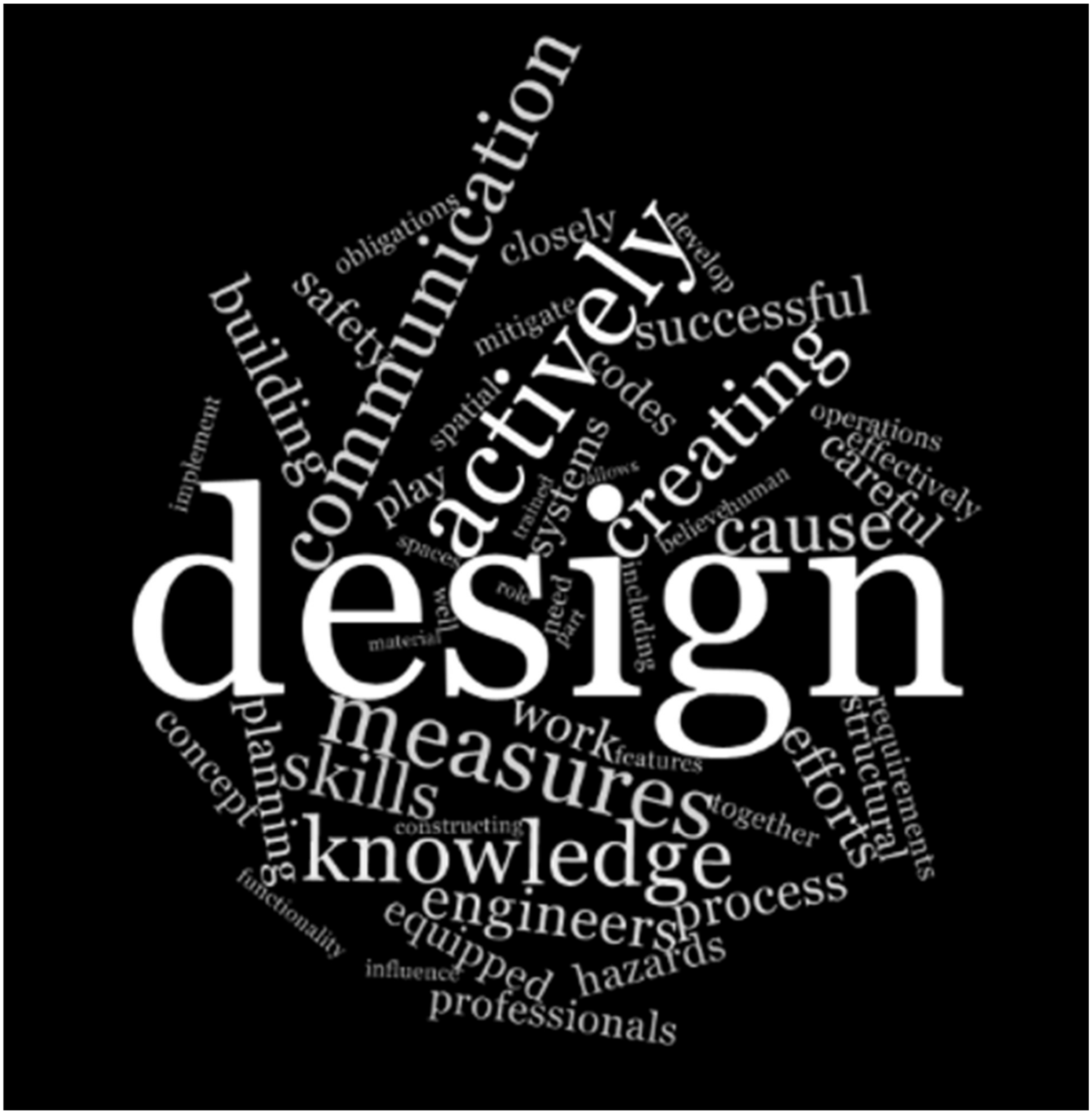

Figure 20: Why Architects are more Equipped with Implementing PtD Word Frequency Word Cloud

CHAPTER 4: CONCLUSION/RECOMMENDATIONS

This chapter provides a brief summary of the work done as part of this research, its results, and recommendations.

4.1 INTRODUCTION

The study was conducted to identify the challenges and barriers to PtD implementation in the construction industry. A literature review was conducted on existing literature in order to gather data and conduct research on the topic of PtD. This provided a better understanding of current PtD research. A survey was then created to help in the identification of relevant data, including the challenges that prevent the construction industry from implementing PtD practices, contract language changes that are necessary, and which professional (architect or engineer) is more equipped to implement PtD practices. After the survey results were gathered, a qualitative data analysis was performed using the NVivo software to identify patterns and themes in the analysis results.

4.2 CONCLUSION

To gather data on challenges faced when implementing PtD in the construction industry, an online survey was created and administered using Qualtrics. The survey included open-ended questions to gather information from respondents based on their knowledge and experience. Over a three-month period, 58 valid responses were gathered. The following questions were asked to respondents:

1) Based on your experience, list the three most challenges that prevent the construction industry from fully utilizing PtD?
2) Please briefly explain what kind of contract language changes are needed.
3) Please list any other high or extremely high-impact challenges that may hinder the utilization of PtD, if any.
4) Why do you believe that engineers are more equipped to implement PtD?
5) Why do you believe that architects are more equipped to implement PtD?

Respondents of the survey went through screening questions before being able to continue with the survey. This was necessary to allow the most qualified respondents to take part in the survey.

Respondents were required to have a minimum of 5 years' experience as well as having worked with PtD practices.

The use of the NVivo qualitative data analysis resulted in findings regarding the challenges that prevent the construction industry from fully implementing PtD practices. The survey resulted in a total of 58 valid responses from respondents from various construction specializations within the United States. The respondent group specialized in fields including industrial construction, residential construction, construction of buildings, and civil and heavy construction, with job titles including architectural engineers, civil: structural engineers, architects, and others.

The results from the survey responses identified many challenges hindering the utilization of PtD in the construction industry. The primary challenge referenced 45 times was the increase in cost, highlighting the financial barriers faced by the construction industry. Other major challenges included a lack of knowledge (20 references), pushing the need for education and awareness programs; the lack of training programs (16 references), indicating a lack of development of skilled professionals; and project delivery method influence (15 references), proving the impact of communication and collaboration challenges among stakeholders.

The survey also revealed obstacles relating to awareness, increased design time, a lack of laws and industry standards, a lack of motivation and incentives, and various other challenges. The survey also resulted in providing insights on important aspects of PtD including necessary contract language changes (29 references), and high or extremely high impact challenges (54 references) affecting the implementation of PtD within the industry.

In addition, the study looked at why engineers and/or architects are more equipped to implement PtD practices. Engineers were seen as more equipped due to their ability to assess risks, problem solving skills, understanding codes, and their close involvement in projects. Architects, on the other hand, were also considered more equipped due to their effective communication and coordination skills, expertise in designing and overseeing, involvement in the initial design process, and their understanding of codes, regulations, and industry standards.

In conclusion, these findings point out the various challenges that the construction industry faces when trying to implement PtD and offer useful insights into potential solutions. Addressing these challenges is important for improving safety standards, lowering costs, and motivating proactive and preventative construction project designs. The study's findings include identifying necessary contract language changes and high impact challenges, creating a foundation for future research in improving PtD practices within the construction industry.

4.3 Recommendations

The following recommendations for future research are based on the research's concluding results and findings:

- ❖ Identify solutions on how the construction industry can avoid the identified challenges and make for a better workplace for all stakeholders.
- ❖ Investigate how changing contract language can help with the implementation of PtD.
- ❖ Investigate the impact of PtD on project timelines and costs and how to balance safety with efficiency and cost effectiveness.
- ❖ Further investigate whether an architect or engineer is more equipped to implement PtD, and why.

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APPENDIX A: SURVEY QUESTIONS

PtD Barrier

Prevention through Design (PtD) is defined as the elimination of construction hazards or hazard design-out as a method to prevent or reduce occupational injuries, illnesses, and fatalities. Because hazards are eliminated or managed "at the source," or as early as possible in the project life cycle, PtD is the most reliable and effective prevention measure. PtD is achieved by incorporating prevention considerations into all designs that may impact workers' safety.

Designers and engineers are considered the primary initiators of PtD in the construction industry, with the ability to educate project owners and construction practitioners about its benefits and importance. This survey aims to understand the barriers and drivers that influence PtD integration into the Design process.

There are no anticipated risks from participating in this research. Your participation is voluntary, and no compensation will be provided. When you begin the survey, you consent to participate in the study. If, after beginning the survey, you decide that you do not wish to continue, you may stop at any time. If you have any questions prior to or during your participation in the study, you may contact Dr. Ahmed Al-Bayati at 248-204-2586 or aalbayati@ltu.edu at Lawrence Technological University. You may also contact the Lawrence Technological University Institutional Review Board by calling (248) 204-3096 or emailing irb@ltu.edu.

By choosing "yes" below, you indicate that you understand what is expected of you if you participate in this survey. You also indicate that you have been given the opportunity to ask questions and that you understand participation is voluntary. Thus, you hereby individually and on behalf of your heirs, executors, and assignees release and hold harmless Lawrence Tech, its officials, employees, and agents and waive any right of recovery that you might have to bring a claim or a lawsuit against them for any personal injury, death, or other consequences arising out of your volunteer activities. **Are you willing to help?**

- Yes
- No

1. How old are you?
   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 64
   - 65 - 74
   - 75 - 84
   - 85 or older

2. How many years of experience do you have in the design of construction projects?
   - Less than five years
   - 5-10 years
   - More than ten years

3. What best describes your job title out of the following?
   - Architectural Engineer
   - Civil: Structural Engineer
   - Civil: Transportation Engineer
   - Civil: Geotechnical Engineer
   - Architect
   - Other

4. Did you ever receive a request from construction crews to revise a design in order to improve workers' safety?
   - Yes
   - No

5. Please enter your job title.

   ____

6. Which of the following specializations most closely matches your design work?
   - Industrial
   - Residential
   - Utility
   - Construction of Buildings
   - Civil and Heavy Construction
   - Other

7. Were you aware of the PtD concept before this survey?

- Yes
- No

8. Did you or currently practice the PtD in your work?

- Yes
- No

9. Based on your experience, list the three most challenges that prevent the industry from fully utilizing PtD?

1. ____
2. ____
3. ____

10. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"Lack of Laws and Industry Standards"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

11. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"PtD Increases the Costs and Time of Design Work"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

12. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"Project Delivery Method Type (e.g., Design – Bid – Build Vs. Design – Build)"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

13. What is the project delivery method that you most utilize in your practice?

- Design – Bid – Build
- Design – Build
- CM@Risk
- I Do Not Know

14. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"The Absence of Contractual Clauses that Organize PtD"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

15. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"PtD Lack of Knowledge among Designers"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

16. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"Designers' and Engineers' Fear of Liability"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

17. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"The Absence of Motivation and Incentives for Designers"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

18. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"The Absence of PtD Training for Designers"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

19. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"The Absence of PtD"
Select Minor Impact for this Question (Attention Check Question)

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

20. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"The Absence of PtD Education in Colleges"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

21. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

"The Absence of PtD Professional Development Training"

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

22. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

“Lack of Understanding of PtD Among Project Owners/Clients”

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

23. Based on your experience, rate the impact of the following **on limiting the PtD implementation:**

“Clients’ Attitude Towards PtD Implementation is not Encouraging”

- Minor Impact
- Normal Impact
- High Impact
- Extremely High Impact

24. In order to implement PtD, was there a need to change or add new language to the contract document?

- Yes
- No

25. Please briefly explain what kind of contract language changes are needed.

____

____

____

26. Please list any other high or extremely high – impact challenges that may hinder the utilization of PtD, if any.

____

____

____

____

____

27. Are you a registered Professional Engineer (PE)?

- Yes
- No

28. How many employees work at your establishment?

- Less than 10
- 10 – 50
- 51 – 100
- 101 – 250
- More than 250

29. Who is more equipped to implement PtD in the Industry?

- Architect
- Engineer
- Both

30. Why do you believe that engineers are more equipped to implement PtD?

____

____

31. Why do you believe that architects are more equipped to implement PtD?

____

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