INVESTIGATING THE PERSUASIVENESS OF FORENSIC INFORMATION MODELS FOR JURORS IN CONSTRUCTION DISPUTES

A Dissertation

by

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ABSTRACT

Effective communication has always been challenging in the process of resolving disputes. The seriousness of this difficulty is exacerbated when a jury with little or no knowledge of construction engages in dispute resolution trials.

Forensic Information Modeling (FIM) is an advanced BIM technique and specialized for forensic investigations. FIM combines the inspection data required for forensic investigation with a three-dimensional computer model. This techniques was used, for example, to explain a bridge collapse in Minneapolis.

FIM is expected to allow forensic engineers to explain to a jury vividly and interactively the data collected or the cause of the accident analyzed. However, there is no evidence that FIM is actively being applied to settle construction disputes in courts. Due to the severe consequences of risky decisions in litigation and the uncertainties associated with the creation and use of FIM, attorneys may not be active in the use of this technology despite the potential benefits of FIM.

This study attempts to demonstrate experimentally how effectively FIM could explain to a jury the results of a hypothetical forensic investigation of a structure damaged by fire. More specifically, this study seeks to identify how the visual tools used to describe forensic investigations of structures damaged by fire could make a difference in enhancing jury understanding. To design this experiment, eight forensic engineers and four construction lawyers were interviewed. Using the data obtained from interviews, an FIM model was produced that describes a fire in a virtual pump station.

The experiment involved 120 students from Texas A&M University. These students were randomly divided into four groups. Each group was asked to answer questions designed to assess how well they understood the fire that occurred at the pump station after watching one of the four videos including:

- A video explaining the plaintiff's argument using PowerPoint
- A video explaining the plaintiff's argument using FIM
- A video explaining the defendant's argument using PowerPoint
- A video explaining the defendant's argument using FIM

According to the statistical analysis, using FIM assisted students participating in this experiment to significantly have a better comprehension of the plaintiff's arguments, to be able to visualize the plaintiff's arguments easier, and to become persuaded to support the plaintiff in this dispute at a 95 percent confidence interval. However, when watching the defendant's claim video, using FIM compared to the PowerPoint-based presentation did not affect the participants' understanding of the argument, their ability to visualize the case, nor their persuasion to support the defendant.

The inconsistencies in the findings of this case-based study might be rooted in the difference between the content of the arguments made by each argumentative side. According to the results, FIM seems to have a positive impact on the persuasiveness of the argument when it is more technical and unfamiliar to the participants when considering their background and experience. Otherwise, using BIM to explain the forensic findings in a dispute does not seem very effective. In other words, when the argument is compressible for the audience, a three-dimensional presentation is not more persuasive than using 2D CAD drawings in PowerPoint slides.

DEDICATION

This dissertation is dedicated to my family and parents for their endless love and sacrifices, and to my husband who supported me throughout past twelve years with his love and devotion.

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1. INTRODUCTION AND LITERATURE REVIEW

1.1. Forensic Information Modeling

Information and communication technologies such as Building Information Modeling (BIM), Virtual Design and Construction technology (VDC), along with Geographic Information Systems (GIS) have revolutionized the Architecture, Engineering, and Construction (AEC) industry (Cheng et al., 2016).

BIM has been defined in different ways in the literature depending on people's approach to implementation of BIM to overcome their never-ending challenges in such a project-oriented industry. BIM is appreciated as an assisting technology for industry practitioners to achieve their objectives, which is mainly delivering the final product on time within budget and with accepted and also expected quality for the project stakeholders (Azhar, 2011). BIM is a very popular device in AEC for various purposes over projects' life cycles, such as visualization, fabrication/shop drawings, code review, cost estimating, construction sequencing conflict, interference and collision detection, facilities management, and quantity project breakdown structure (Azhar, 2011). With BIM, information is easily shared, value-added, and reused. Environmental performance is more predictable and life-cycle costs are better realized. Building proposals can be rigorously understood through accurate visualization by BIM. Simulations can be performed quickly, and performance can be benchmarked, thus enabling improved and innovative solutions. Digital product data can be exploited in downstream processes and used for manufacturing and assembly of structural systems. Additionally with BIM, all requirements, design, construction, and operational information is transferrable for more efficient facilities management (CRC Construction Innovation, 2007).

The all-encompassing application of BIM in the AEC industry is rooted in its potential to improve the ability to integrate information and share knowledge through visualization (Jane Matthews et al., 2018). By using BIM, the flow of information can be visualized, which results in escalating the level of perception of the decision makers and facilitates integrating people, systems, and business structures and practices into a collaborative process to reduce waste and optimize efficiency through all phases of the project lifecycle (Glick and Guggemos, 2009& Goh et al., 2014). Based on the survey research conducted by Sattineni et al. (2011), uses for BIM in U.S. construction in the order of frequency include: visualization; architectural design; collision detection; estimating; mechanical, electrical, plumbing (MEP) design; structural design; marketing; and scheduling. This result emphasizes that BIM is mostly appreciated for its visualization power.

Relying on its power in visualization and data sharing, new applications of BIM in construction projects have been introduced in the literature in recent years. For example, Nadeem et al. (2018) studied the application of BIM in site management. Their findings showed that the visualization from BIM 3D/4D model helps engineers or planners to become more confident about real happenings on the construction site. Li et al. (2018) proposed the safety risk identification system (SRIS) and early warning system (SREWS) for China's metro construction on a BIM platform. Adoption of BIM in lean construction, sustainability, and energy efficiency is also a new research trend in recent years and extends the application of BIM in the AEC industry (L. Sonhudo, 2018; Saieg, 2018). Another creative application of Building Information Modeling in the literature is Forensic Information Modeling (FIM). In this approach, a 3D model of a structure is tied to the results obtained during the forensic analysis. In other words, since this 3D model includes the forensic investigation results, it is

called Forensic Information Modeling (FIM). Forensic analysis is the process of understanding, re-creating, and analyzing arbitrary events that have previously occurred. Forensic analysis also refers to the derivation of information for use in courts (Peisert et al., 2007).

FIM can be described as a dynamic representational tool that serves to highlight both geographical and chronological patterns in inspection or repair data. FIM assists forensic investigation teams to interactively communicate their findings with other parties during a dispute resolution process (Keranci, 2012). The examples of using FIM in the literature include the litigation of the 2007 I-35 Minneapolis bridge collapse, in which using FIM proved critical to the case (Malsch et al. 2011 & Brando et al. 2013). As another example of using BIM in forensic engineering matters, an FIM was created by Thornton Tomasetti to investigate the deflation of the fabric roof at the Metro Dome Stadium in Minneapolis as part of an insurance claim (Keranci, 2012). Improved visualized data besides the organizational configuration of a back-end database are key factors in the effectiveness of FIM as a communication tool in construction dispute resolution, which contributes to its extension in various types of projects.

Legal conflicts between owners, developers, general contractors, and subcontractors are important issues in the construction industry. Construction disputes can be considered as part of a project's life cycle. As the complexity of the industry caused by the adoption of emerging technology, innovative construction techniques, and new contracting and delivery methods increases, the number of disputes increases and the adoption of effective tools and methods in dispute resolution process becomes more prominent (Koc et al., 2014). According to Global Construction Disputes (2017), failure to properly administer the

contract, poorly drafted or incomplete and unsubstantiated claims, employer/contractor/subcontractor failing to understand and/or comply with its contractual obligation, errors and/or omissions in the contract document, and incomplete design information or employer requirements (for design-build and design & construction) are important causes of disputes. Disputes can be resolved between parties through the Alternative Dispute Resolution (ADR) process or, in extreme occasions, might end up in courtrooms, where jurors might be in charge of the judgments for the cases. In the legal system, jurors are composed of nontechnical and lay individuals who do not have any experience or background about the matters to which they decide upon a verdict.

Regardless of how far a claim goes in the resolution process and who are involved in a dispute, communication is the cornerstone of dispute resolution processes. This is not surprising at all when one recognizes that many disputes and claims arise because of poor communications and ineffective information exchanges between parties in the verbal or textual formats.

In engineering related failures and claims, forensic engineers are responsible for finding the causes of failures. According to the American Society of Civil Engineers (ASCE) definition, *forensic engineering* is the "application of engineering principles to the investigation of failures or other performance problems." Also, forensic engineers serve as expert witnesses to communicate their findings with judges and jurors during trials if disputes are not resolved through negotiation, mediation, and arbitration. In performing their profession, forensic engineers face two major challenges:

1) Organizing and managing the information and documents they collect during the investigation period in an effective and logical manner.

2) Communicating their technical findings with nontechnical people, including clients or jurors in trials, in a user-friendly and explicit way.The Forensic Information Modeling (FIM) approach has proven to be an effective solution to address challenges regarding the organizing and managing of information during an investigation and seems potentially beneficial for transmitting findings to nontechnical people, especially jurors in a court setting. However, there are still uncertainties about its persuasiveness for jurors that needs more in-depth study. These uncertainties prevent lawyers from adopting this new instrument and make its admissibility challenging for the judiciary system. Visual displays, however, can have positive impacts on learning due to vividness, yet can also prevent people from learning because of the mental processing efforts required due to their complexities, especially when the audience does not have a rich background about the topic (Mayer, 2001). Also using visual aids may negatively affect jurors' perceptions of expert witnesses' credibility that conflicts with persuasiveness (Morrison, 1998).

1.2. Problem Statement

The uncertainties in the persuasiveness of Forensic Information Models for jurors hinders the adoption of FIM in spite of its advantages as a convenient, multi-dimensional visualization tool with interactivity and a data-sharing function. The lack of knowledge about the outcome of using FIM in explaining technical concepts for jurors not only prevents attorneys from using this technology in construction disputes, but negatively affects its admissibility in the litigation system (Dun& Kassin, 2006).

In addition to the uncertain outcomes, the challenges of creating FIM models for existing buildings, besides the financial resources and the level of expertise required for creating and

using these models, necessitate experimenting with the impact of FIMs on jurors for more informed decision making.

Hence, to address the above-mentioned problem, this study tends to answer the following question:

Would using FIM as a presentation tool impact jurors' persuasion compared to a two-dimensional presentation of building and facilities on PowerPoint slides as a conventional presentation technology?

1.3. Research Objective and Hypothesis

Following is the general hypothesis in this research to address the problem and answer the research question:

H_0: Forensic Information Model and PowerPoint based presentation are equally persuasive for jurors.

H_a: Forensic Information Model and PowerPoint based presentation are not equally persuasive for jurors.

The above described hypothesis is broken down to five sub hypotheses as follows:

Sub-H_1

FIM significantly affects working memory (free recall) of jurors compared to a 2D presentation using PowerPoint slides.

According to the story model theory, jurors construct a mental story based on the evidence they hear and remember during trials. The more jurors remember, the easier they make their story and the more persuaded they are. In other words, persuasiveness of a presentation method is the function of its influence on jurors' working memory. The higher level of

complexity of a presentation tool may lead to bad cognitive loads on working memory and negatively affect the persuasiveness.

Sub-H_2

FIM significantly affects jurors' comprehension of the case compared to a PowerPoint-based presentation.

According to the story model theory of jurors' decision making, persuasion is the function of comprehension of the evidence by jurors. Based on the Morrison's model of persuasion, (1998) comprehension and learning attention (free recall) are considered as two different elements of the persuasion in this study.

Sub-H_3

FIM significantly affects jurors' agreement with the argumentative sides compared to a PowerPoint-based presentation.

According to the story model theory, jurors support the argumentative side that helps them create their mental story about the case with less effort. Therefore, agreement can be another measure of persuasiveness of the presentation methods or visual aids.

Sub-H_4

FIM significantly affects the confidence level of jurors in their supporting verdicts compared to a PowerPoint-based presentation.

According to the story model theory, making it easiest for jurors to construct their mental story not only would help argumentative sides prevail, but would make jurors more confident about their supporting verdict.

Sub-H_5

FIM significantly affects jurors' ability in visualizing the argumentative sides' story compared to a PowerPoint- based presentation.

According to the vividness studies conducted by Bell & Loftus (1985, 1988, 1989), the vivid descriptions presented to participants provided information that made it easier to imagine by jurors. Therefore, ease of visualizing indicates better perception, resulting in persuasion.

1.4. Research Approach

To achieve the research objective and answer the research question, retention, comprehension, agreement, confidence, and vividness were measured using a 2 by 2 factorial experiment, (plaintiff BIM, plaintiff PowerPoint) by (defendant BIM, defendant PowerPoint), which produces four treatments as listed below:

1. Treatment#1: Plaintiff/PowerPoint vs. Defendant/PowerPoint
2. Treatment#2: Plaintiff/PowerPoint vs. Defendant/BIM
3. Treatment# 3: Plaintiff/BIM vs. Defendant/PowerPoint
4. Treatment#4: Plaintiff/BIM vs. Defendant/BIM

This study was performed in following steps:

1. Face-to-face interviews with forensic engineers and construction law attorneys
2. Forensic Information Modeling
3. Test material preparation
4. Experiment and data analysis
5. Results interpretation

2. BACKGROUND

2.1. Jurors' Decision Making

Psychologists are interested in jurors' judgments because the jurors' task is an inherently complex one that involves almost all higher-order thought processes of interest to cognitive psychologists. Multiple cognitive factors affect jurors' abilities to process complex and lengthy trial information and judgment based on the evidence available to them in light of the legal parameters available to them. Jury selection happens in two parts, including random selection and voir dire (speak the truth). In random selection, people are selected for the jury pool using a random method. Voir dire refers to the process by which the court and the attorneys narrow down the pool of juries to six or twelve people that will decide the case (www.americanbar.org). According to Hastie (1993) models, the jurors' decision-making process tends to fall into one of two categories:

1. Mathematical approaches.
2. Explanation-based approaches.

Three different models exemplify the mathematical approach:

1. Probability Theory (Schum & Martin, 1993).
2. Algebraic Theory (Anderson, 1981; Ostorm, Werner& Saks, 1978).
3. Stochastic Processes (Kerr, 1993).

In all three mathematical models, jurors are thought to engage in a series of "mental" calculations in which they weigh the relevancy and strength of each independent piece of trial evidence and translate the resulting score into an evaluation of the defendant's guilt or liability. This score is then compared to the criterion needed to find the defendant guilty or

liable. If the weight of the evidence meets the legal threshold for finding the defendant responsible, the juror will render that verdict. Similarly, Probability Theory relies on jurors' preconceptions about the defendant's guilt, factoring in subjective links between pieces of evidence.

Explanation-based approaches, including story models and heuristic-systematic models that emphasize jurors' cognitive organization or representation of the evidence, have been favored by jury researchers in recent years. These models illustrate jurors as the active decision-makers who interpret, evaluate, and elaborate on the trial evidence information rather than as passive recipients who solely weigh each piece of evidence as a discrete entity and combine these elements in some probabilistic fashion. The most widely cited, comprehensive, and detailed explanation-based approach to jurors' cognitive behavior, is the story model developed by Pennington and Hastie (1981, 1986, 1988, and 1993). This theory posits that jurors construct a narrative storyline out of the evidence presented during the trial. This model is called "story model" because it claims that central cognitive processes in jurors' decision making lead to story construction or creation of the narrative summary of the events under dispute (Hastie, 1993). There are three stages in this model:

1. Evaluating the evidence through story construction
2. Learning about the various verdict options available
3. Deciding by fitting the story to the most appropriate verdict category

Pennington and Hastie (1988) through their empirical studies not only realized that subjects spontaneously evaluated evidence in a legal judgment task by constructing explanatory representation in the form of a narrative story, but also figured that an item's membership in the story is related to the chosen or rejected verdict predicted subjects' ratings of its

importance as evidence. In one of their experiments, subjects listened to testimony from criminal trials presented in various orders designed to manipulate the ease with which a particular explanatory summary of the evidence (story) could be constructed. The order manipulation shifted verdict choices in the direction of the more easily constructed story, indicating that story structure affects decisions. Also, the coherence of the explanatory story structure and the strength of alternative stories were significant determinants of perceptions of the strength of evidence and confidence in the decision.

Based on their following studies, Pennington and Hastie (1993) proposed that the constructive nature of story-generating is based on jurors' prior experiences, knowledge of the world, their ability to deal with the legal constraints placed upon them, and varying degrees of experience with issues related to the facts of a case. This experience affects how a juror interprets both the trial evidence and the judge's instructions. According to this theory, the mental story that jurors construct consists of a combination of information and inferences they receive and, when needed, the information they provide themselves. Pennington and Hastie's (1993) later studies conclude that this is central to juror learning models. Based on their findings, whichever party makes it easiest for the jurors to construct a story that makes sense is the party most likely to prevail. The story model concept provides litigation teams a simple yet powerful structure to develop their trial presentations. According to cognitive principals, use of different tools and combination of presentations can have different effects on people's knowledge retention. The knowledge retention accrues when people can recall more information about the evidence. The jurors' task according to Hastie (1993) is illustrated in Fig.1.

2.2. Courtroom Evidence Visualization

Visualization in general assists humans with a better understanding of data by representing information in a visual format. This assistance is also called *cognitive support*. Visualization empowers users by providing valuable insight that assists them to define new questions, hypothesis, and better modeling of data. Visual displays often can act to improve the viewer's ability to retain the evidence, maintain an interest in the proceedings, and help them better digest the nature of the evidence (Leader and Schofield, 2006). A survey by the American Bar Association found that members of a jury are often confused, bored, frustrated, and overwhelmed by technical issues or complicated facts (Kuehn, 1999). Other research has shown the attention span of the average member of a jury in a standard trial in court may be as little as seven minutes (Devine et al., 2001). Also, previous research in the U.S. has examined how members of a jury retain details in their memory from different forms of evidence. For example, this survey showed that members of a jury would retain twice the amount of information when using a visual presentation in comparison to an oral presentation (Krieger, 1992).

The continuing technology advancement has had an enormous impact on the way forensic evidence is collected, analyzed, and interpreted. In a modern courtroom, the presentation of forensic evidence by an expert witness can raise the need for arduous descriptions in different formats by lawyers and experts to explain the specifics of complicated scientific, spatial, and temporal data (Schofield, 2009).

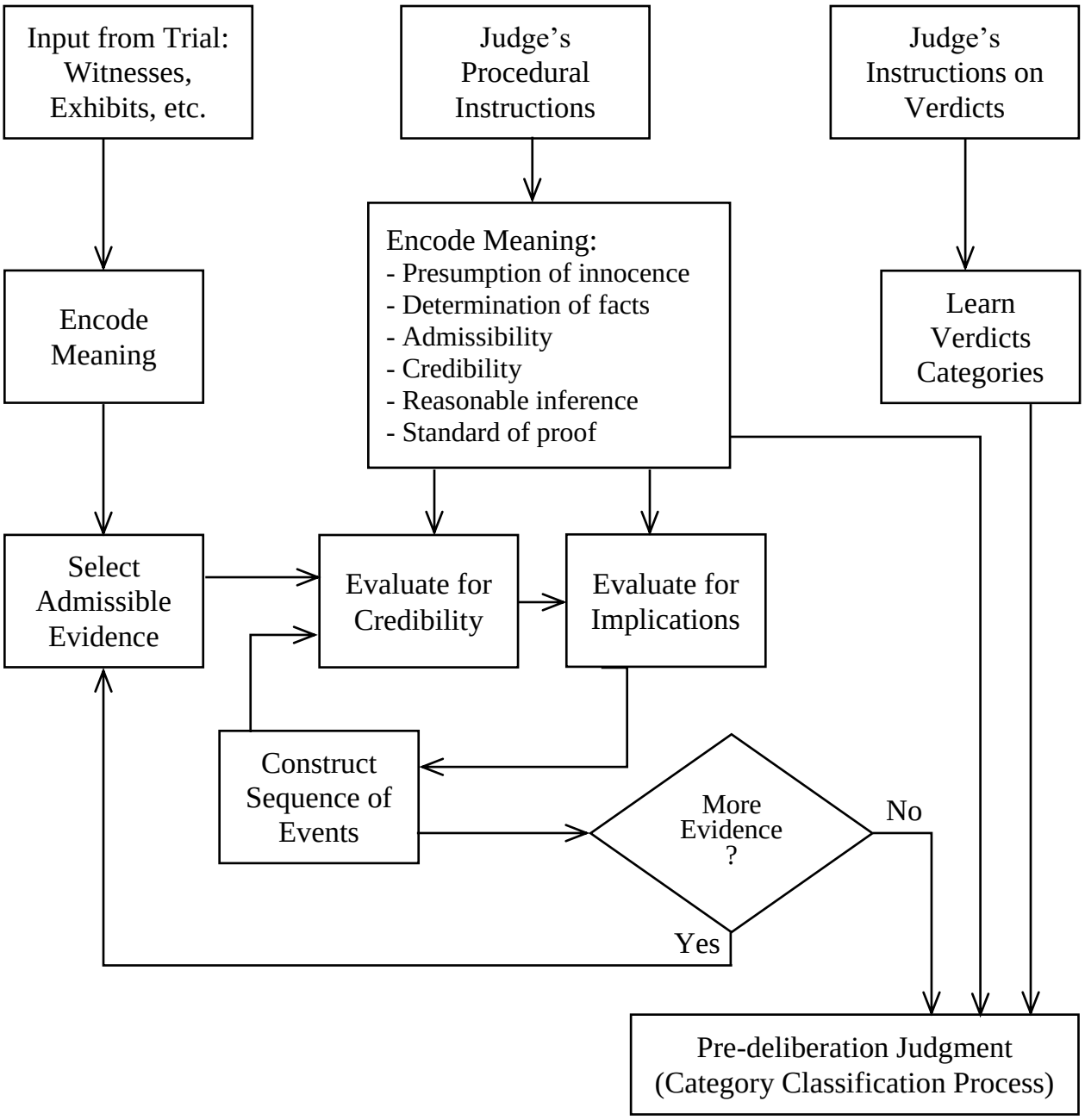

Figure 1. The jurors' task (Hastie, 1993)

So far many researchers have explored the influence of different combinations of pictorial, textual, and verbal information provisions on learning enhancement. Some of the notable theories on this matter that were the foundation of the empirical studies regarding data

presentation methods in legal settings include Schema Theory, Cognitive Load Theory, and Multi-Media Learning Theory.

Schema theory suggests that knowledge is stored in a format of schemas and explains how material that is stored in the memory is connected (Sweller, Van Merrienboer, & Paas, 1998). Schemas are understood as abstract conceptual structures that are arranged hierarchically and are retained in memory in the form of top-down frameworks.

In other words, when people recognize elements of a bigger unit, the whole schema is activated. Activation of a schema is an important element of maximizing the learning effects from a task because it reduces a load in working memory and automates commonly used strategies towards a recognized task. As schema theory suggests, its activation takes place due to a reconstructive nature of memory (Sweller, 1998). In short, this theory suggests that each individual has generalizations regarding every particular domain of knowledge (Alba, & Hasher, 1983). Hence, schemas also set up a context for inferences needed to make sense of novel information. In addition to schemas, or large generic representations in memory, people's declarative and procedural knowledge contain scripts and systems of concepts that also contribute to storing knowledge in memory.

In application to the legal scenario, it can be argued that a jury can activate the schema and thus anticipate it with a certain attitude. People evoke and recall the schema on the ascribed situation because of certain conceptual cues in the narrative or some visual cues in the graphic. Collective sensory modalities activate an audiovisual comprehension process and contribute to the mental model formation of text and graphic.

Cognitive Load Theory (CLT) was built on the premise of limited working memory capacity. Therefore, the cognitive load theory deals with an ability to retain information in working

memory and construct knowledge that further is stored in long-term memory (Chandler, & Sweller, 1991; Sweller, 2008). Hence, this process of knowledge construction is directly related to schemas, as the CLT assumes that knowledge is preserved in schemas. Cognitive Load Theory understands a perspective of the limited capacity of short-term memory and concentrates on efficiency and productivity of a learning process as well as extraction of new knowledge from offered study materials. According to this theory, when learners approach a task, a mental model is required to understand this task. Thus, the process of mental model construction requires cognitive allocation in working memory. If cognitive demands are high, learners fail to understand (Sweller, van Merri¨enboer, & Paas, 1998). In this regard, theory suggests reducing a "bad" cognitive load along with increasing a "good" type of a cognitive load.

The cognitive theory of multimedia learning (Mayer, 2001; 2009; 2005) is based on major ideas of dual coding theory by Paivio (2006), dual processing assumption of working memory by Baddeley (1992), and a limited cognitive capacity in terms of the informational load (Sweller et al 1998; Chandler, & Sweller, 1991). In the cognitive theory of multimedia learning, Mayer (2001) suggested the major multimedia principle of learning, that is, learning from visuals paired with text (words), is better than learning only from text (words). This principle embraces several other principles of multimedia design for instruction purposes: spatial contiguity, temporal contiguity, coherence, modality, redundancy, and the individual differences principle.

The spatial contiguity principle suggests that pictures and accompanying text or words should be placed near each other rather than far apart in a document, on a page, or on a screen. Temporal contiguity principle describes how words and corresponding visual

materials should be presented at the same time. This principle works better in the application of instructional animations rather than for static visuals. The coherence principle suggests that unrelated words or unconnected visuals are not included into the presented combination of words and pictures. Modality principle claims that better learning takes place when a narration and an animation are presented together rather than animation and “on-screen text.” Redundancy principle describes that when too many alternatives for representation of what needs to be learned are presented, it can be overwhelming for a learner. This means that an effect of better learning can be lost if we present information in a variety of formats, for example, a format of animation, narration, and on-screen text. Therefore, a choice of formats is suggested: animation and narration rather than all at once (Mayer, 2001).

The individual differences principle describes how “low-knowledge learners” benefit from instructive multimedia designs in comparison with “high-knowledge learners” who may view presented instructions in multimedia as redundant. Also, the individual differences principle suggests that “high-spatial learners” learn better than “low-spatial learners” (Mayer, 2001).

Historically, static images such as diagrams and charts have been used to explain the complex testimony of an expert witness. The use of computer animation techniques to reconstruct crime scenes is beginning to replace the traditional illustration photo, graphs, and verbal description and is becoming popular in today’s forensics (Ma et al., 2010). Since the mid-1980s, forensic animation technologies are acknowledged as a true paradigm shift and have been increasingly employed by attorneys to present demonstrative evidence in U.S. courts (Burton, Schofield, & Goodwin, 2005). Forensic animation refers to computer-generated "movies" created for courtroom presentations. Forensic animations are distinct

from most other visual technologies because they are entirely orchestrated by one party to integrate all relevant evidence. In other words, they are designed to present a party's story in a visually compelling narrative format (Sainato, 2009).

Animation advantages include the ability of triers to comprehend spatial and temporal data, in effect decreasing the length of a trial by making the translation of complex information more efficient. It is also inherently clear, which can increase the triers' attention to the more persuasive details of a party's narrative. One reason vivid presentations have an impact on social judgments is that they help individuals visualize the scenario described (Dunn, 2006). In the classic vividness studies (Bell & Loftus 1985, 1988, 1989), the vivid descriptions presented to participants provided information that made it easier to imagine the scene. Thus, animations may be persuasive courtroom tools because they help jurors visualize what is being described by witnesses. The study of narratives also offers clues as to why jurors may be persuaded by computer-animated displays. To make sense of the events described in the trial, jurors construct a narrative story to fit the evidence presented (Pennington & Hastie 1986). Jurors order and incorporate the unorganized trial presentation into a narrative story that allows for better comprehension and matches that story with the verdict alternatives provided in the judge's instructions to arrive at a final verdict. Pennington and Hastie's (1986, 1988) research indicates that computer-animated displays may impact jurors' cognitive organization of the evidence presented at trial. Without the aid of computer animation, jurors are forced to organize the various strands of evidence into a coherent, plausible narrative. The introduction of computer animation alters that process, removing the juror's effortful contribution. When an attorney introduces a computer-animated display, the jury is provided with a ready-made narrative account of the event in question. Because

jurors are no longer required to build their narratives when faced with computer animation, they may be unusually willing to accept the scenario depicted by the animated display, especially when the scenario is an unfamiliar one.

However, there are many concerns regarding the use of forensic animations, the principal point being that inherently clear presentations can be manipulated to confound and excessively prejudice parties in trials. Another criticism is that juries become transformed into pseudo-witnesses because of the "realness" of the technology. Another critique is related to the cost aspect of developing animation, which makes animations less appealing compared to other tools and presentation methods.

Many researchers have worked on empirical studies where the efficacy of visualizations has been investigated in the context of courtroom use, for example, animations (Schofield, 2009; Morell, 1998), computer simulations (Schofield, 2009), graphics (Denenberg, & Learned, 1994), video (Hahn, & Clayton, 1996; Kassin, & Garfield, 1991), photographs (Douglas, Lyon & Ogloff, 1997), and other images (Tait, 2007; Golan, 2008). These studies affirm that visualization tools have a much higher influence than solely the additional support for verbal arguments. Furthermore, representing arguments and evidence with visualizations helps the jury to comprehend the larger picture of the case without losing vital details, while conversely understanding the centrality of those details as crucial points of the attorney's full case argument. Next, visualizations function to gather the legal case story that allow jurors to assess the case on a surface level or more attentively if visualizations contain contradictory points to the jury`s value system about the case (Fiedler, 2003). Thus to some extent, visualizations serve as a visual description of the case without additional verbal

explanation. Finally, while attorneys use visualization as an instrument of persuasion, it also marks evidence and arguments as comprehensible and memorable.

The challenge is that the visual features of demonstrative evidence are extremely heterogeneous, with the effectiveness of each type possessing different influential weight, technological complexity, and different levels of impact depending on the place they are introduced in the legal process. On the other hand, while the types of visualizations as demonstrative evidence are not uniform, most litigators think of and understand visualizations homogeneously only as instruments of persuasion in a case of deliberation (Kantor, 1998; Solomon, 2002; Morse, 2009). Also, concerns are beginning to be articulated that the use of modern, computer-generated visualization technology can distort perceptions, memories, attitudes, and decision-making in the court (Girvan, 2001; Spiesel et al., 2005; Bailenson et al., 2006; Schofield, 2007). Furthermore, not all applications of technology have equal transformative effects in court proceedings both regarding the mode of the presentation as well as how judges and juries perceive that mode (Sainato, 2009).

3. EXPLORATORY RESEARCH

3.1. Exploratory Research

Exploratory, explanatory, and descriptive describe three approaches to social science research. Exploratory research aims to explore a specific subject matter about which there is limited knowledge (Babbie, 2015). Focus groups, case study analysis, experience surveys, and in-depth interviews are the most effective techniques of an exploratory approach to start a research project when there is a general idea of the research or a gap of knowledge is identified, but the knowledge about the area does not suffice for the design of data collection in order to define the subjects, the methodology, and to develop a hypothesis. Exploratory research primarily gives some indication of the "what, why, how, and when." Although exploratory research does not give a final result, it is flexible and can be employed in various research areas of psychology, social work, marketing, and business.

To gain further insight into the topic and to advance knowledge about the underlying process in forensic engineering and dispute resolution, this study begins with an exploratory research using face-to-face interviews with forensic engineers and construction law attorneys.

The General Interview Guide Approach was adopted in this research. This approach is more structured compared to the informal, conversational interview, but allows some flexibility in its composition (Gall, Gall, & Borg, 2003). In the interviews conducted in this research, identical questions are asked from the participants of each category including forensic engineers and construction law attorneys. However, depending on the clarity of the answers and the experience of the interviewee, there is a bit of variation in follow-up questions. During the interviews, it happens that the participants require more clarification or they

prefer to answer questions in different orders. The interviews are started with questions that are easy to answer by respondents and then proceed to more difficult or sensitive topics (Gill, Stewart, Treasure & Chadwick, 2008).

All participants were willing to openly and honestly share information or "their story." Also, all interviews were conducted with participants in a comfortable environment based on their preference so that they did not feel restricted or uncomfortable to share their knowledge (Turner, 2010).

The process of developing these qualitative interviews includes following steps:

1. Preparation for the interview through studying the literature, training videos, or learning from other researchers with similar experience and pre-interview exercise.
2. Constructing the effective questionnaire.

According to McNamara (2009), to create an effective questionnaire, the following suggestions were considered:

- The wording was open-ended so that respondents could choose their terms when answering questions, and there was not any leading questions or yes/no questions in the interview. Also, the rules described below were followed in the preparation process of the questionnaires:
- Questions were as neutral as possible.
- Questions were asked one at a time.
- Questions were worded clearly as possible.
- Questions were mainly about how and what.

The interview questionnaire was finalized and prepared by consulting with a lawyer and a forensic engineer. Also, two exercise interviews were performed to assure the outcome is aligned with the expectations and the questions are unambiguous and comprehensible.

As mentioned earlier the respondents in this qualitative research were forensic engineers and construction attorneys. Forensic engineers were selected from the experts familiar with Building Information Modeling (BIM).

The following objectives were sought from the interviews:

1. To realize the flow of information between the lawyers and forensic engineers.
2. To understand how forensic engineers communicate their finding with lawyers, clients, and the jury.
3. To identify challenges in information transferring and communication between parties involved in construction claims or disputes.

3.2. Lawyers' Questionnaire

Attorneys and forensic engineers have different approaches, responsibilities, and needs in claims and dispute resolution processes. Therefore, the interview questions were adjusted for each group accordingly.

Forensic engineers are largely experienced engineers who help lawyers find facts and analyze the failure mechanism that led to a claim. In other words, forensic engineers help attorneys who are not as knowledgeable in engineering in order to validate the case and design the lawyers' argument strategy.

Also, follow up questions were asked during the interview according to the information provided by the interviewees.

Interview questions used for data collection from lawyers include:

- How many years have you been licensed?
- How much of your practice consists of handling construction matters?
- Can you give me some examples of the client base you have handled over the years?
- What construction companies have you worked with during your career?
- What are the most common types of matters your clients ask you to handle?
- What types of construction law matters do you prefer to handle?
- What type of construction law issues are the most challenging?
- What factors contribute to the challenge of the cases you have described?
- How does a forensic engineer go about his investigation?
- What information do you expect to get from a forensic engineer?
- How do you explain to a forensic engineer what information you need to assist in your cases?
- Why do you need the information?
- How do you get this information? (In what formats)
- How do you determine what to use and what not to use in presenting your case?
- What technology are you using in your communication with the ultimate fact finders?
- What tools have you used in the past to assist in visualizing problems to be solved?
- What tools do you presently use to assist in visualizing problems to be solved?
- What do you know about Building Information Modeling (BIM)?
- How could you use BIM in your practice?
- What are the functional characteristics of a model for your objective (what do you expect from a model?)

- In what types of construction cases do you think BIM might be of assistance?
- What are the obstacles to using BIM in your field?

3.3. Forensic Engineers' Questionnaire

Interview questions used for data collection from forensic engineers include:

- How many years have you been licensed?
- How much of your practice consists of handling forensic cases?
- Can you give me some examples of projects you have handled over the years?
- What are the most common types of forensic matters you have handled so far?
- What portion of your forensic cases/claims go to courtrooms to be resolved?
- What types of the cases are the most challenging?
- What factors contribute to the challenges of the cases you have described?
- How does a forensic engineer go about his investigation? What activities do they do from the beginning to the end?
- How do attorneys explain to a forensic engineer what information they need to assist in their cases?
- Why do they need the information?
- How do you deliver this information? (In what formats)
- How do you determine what to use and what not to use in presenting the cases?
- What technology are you using in your communication with the ultimate fact-finders and attorneys?
- What tools have you used in the past to assist in visualizing the problems to be solved?
- What tools do you presently use to assist in visualizing the problems to be solved?

- What do you know about Building Information Modeling?
- How could you use BIM in your practice?
- What are the functional characteristics of a model for your objective?
- In what types of construction cases do you think BIM might be of assistance?
- What are the obstacles to using BIM in your field?

3.4. Respondents' Information

In this study, eight forensic engineers and four construction law attorneys were interviewed. Two interviews were performed over the phone and the rest were face-to-face interviews. In face-to-face interviews, a voice recorder was used to record their voice; for the phone interviews "TapeACall" application for iOS smartphones was utilized. Since the research involved human subjects, before starting the process, the Institutional Review Board (IRB) approval at Texas A&M University was received on January 6, 2015, identified as IRB2016-0338D. This letter of approval is attached in the Appendix.

After the interview, the transcripts of the records were prepared and were decoded.

Respondents' experience in this exploratory research included façade problems, waterproofing, cost and damage disputes, scheduling disputes, foundation and building systems, labor inefficiency, injury, material quality problems, and payment disputes.

Among the respondents, one had six years of engineering experience and the rest had the minimum of 20 years of practicing as a lawyer or engineer in the construction industry. Professionals participated in this study had been working for different clients from international general contractors to regional subcontractors, suppliers, and for owners such as small private developers, highway administrations, and power plant owners. They also

were engaged in different types of projects such as bridges highways, roads, residential, and commercial buildings in the U.S. The outcome of the interviews is summarized in following paragraphs.

3.5. Investigation Process

After receiving the case from an attorney, forensic engineers usually take the following steps:

- Understanding the problem
- Developing the possible failure scenarios
- Data collection

  To realize the failure mechanism, forensic engineers need to look at the facts objectively and gather the data. Data acquisition is a significant challenge in the investigation process. The process begins with the most available data that relates to the project or to the area of the specific concerns with which the forensic engineers would be dealing. The steps in data collection process are as follows:

  - Review of any documents available and related to the original design, such as contract documents, drawings, material data sheets, specification, change orders, progress reports, and meeting minutes.
  - Interview to find information about operating and maintaining the project.
  - Visual inspection of the property or reviewing others' observation reports to investigate the possible causes. When the investigators are not able to visit the project or property in person, they have to rely on available videos or photographs taken by other experts. Mining the information from the others'

visual observation documents can be challenging because there is a chance the observers have a different approach or the visual documents are not clear enough for the investigation purposes.

  - An invasive investigation of the building is done to make sure the as-built drawings are correct.
  - Testing if necessary. Testing could be material testing or performance testing.

- Performing computer simulation and some additional analysis to scientifically comprehend and formulate the failure causes.
- Verbally communicating the findings with attorneys
- Repair recommendations
- Repair cost estimating
- Writing the report

  Depending on the investigation outcome, attorneys decide if writing a report is necessary or not.
- Expert witness testimony or presentation of findings

Data collection is the critical factor in the success of a forensic investigation process. Not seeing the information and missing some data, even if they do not change the result, might be detrimental to the credibility of the analysis. The uncertainty embedded in the process adds to the challenges of the data gathering because the mass of data processing is performed without knowing whether the data will merge. Fig. 2 presents an overview of the forensic investigation process in the construction industry.

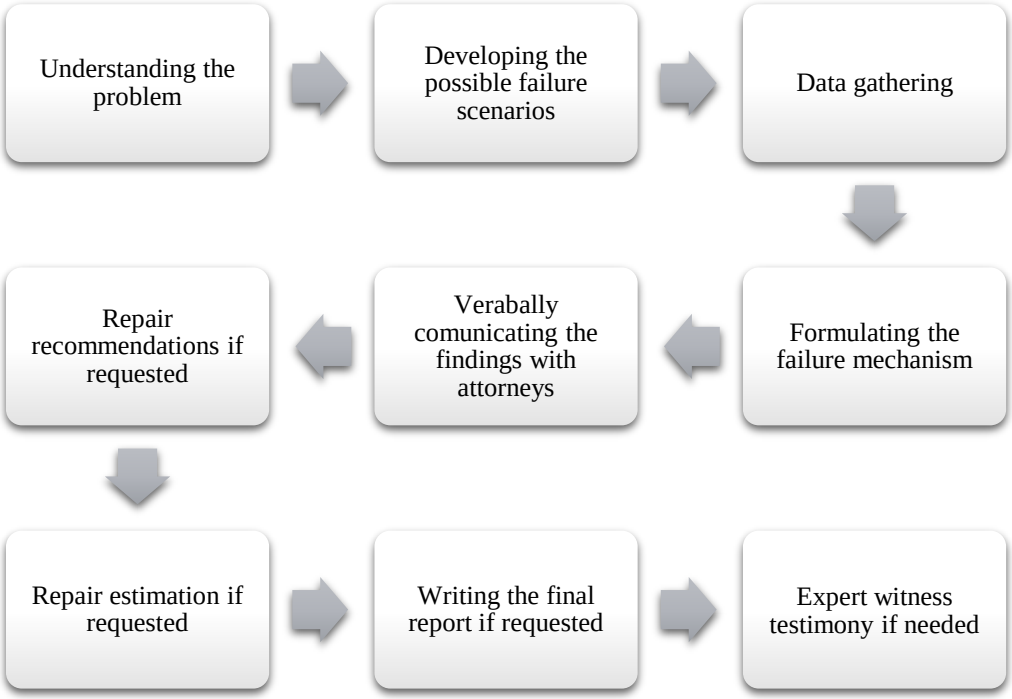

Figure 2. Forensic investigation process in construction disputes

3.6. Flow of Information

Attorneys initiate the communication with forensic engineers by sending the citation and the case report and telling them verbally what specific information they need as the lawyers. Communications between attorneys and forensic engineers are mainly face-to-face or over the phone. Forensic engineers are hired by lawyers to provide them with truthful information regarding what happened, what caused the situation, who caused the situations, who could fix it, how the problem can be resolved, and what is the cost of repairs.

In disputes, people must say what they believe and their opinion with enough support. Evidence and information help people involved in a dispute, including a jury, to believe the information and trust the source. Forensic engineers help attorneys formulate their arguments and validate their cases with facts and evidence or to refute the opposition case.

At the end of the investigation, forensic engineers initially discuss their findings verbally. Depending on the findings, attorneys may say if they need a written report. They also may not want any information against them to be recorded in the written format. The report could be the final deliverable in investigation process for a forensic engineer unless the attorneys asked the forensic engineers to do a deposition and testify before the jury, which is not always the case.

3.7. Communication Tools

During the investigation process, forensic engineers have to communicate with different people involved in the dispute, including experts or non-experts. Depending on the audience and some established procedures and the case, communication channels and presentation technology may vary. The written report supplemented with illustrations is the most common deliverable of the investigation process performed by forensic engineers. Inside a courtroom, expert witnesses mostly combine narration with visual displays such as videos, photographs, graphs and flowcharts, animations, and 3D models. PowerPoint is a popular platform for presentation of the information.

3.8. Advantages of Using BIM

Based on the experts' opinion, using BIM in the dispute resolution and forensic investigation process can be beneficial in the following aspects:

1. Integrating (or coordinating) the different disciplines of the investigation team.
2. Real assessment of the situation and doing exploratory work by forensic engineers.

3. Understanding the interaction between the elements, especially when the building (structure) is not accessible for a visual inspection or the items of interest are covered up.
4. Presenting the case before the jury in a vivid fashion compared to videos or photographs.
5. Reducing the mistakes during the investigation.
6. Explaining relationships between different failures in buildings caused by an accident.

3.9. Disadvantages of Using BIM

Based on the conducted interviews, the challenges of using BIM inside courtrooms from the subject matter experts' perspective would be as follows:

- Three-dimensional modeling is expensive and takes time: creating a 3D model is costly and time-consuming. Clients primarily do not expect to pay for BIM, unless a large amount of money is involved in the case or/and the case is extremely complicated.

- Building Information Modeling is very new for forensic engineers: BIM was mainly introduced for design and engineering of new projects and is not therefore for forensic investigations. BIM is not worth spending money and time when you can accomplish the work using conventional tools, and also is beneficial for few cases that are very complicated.+

- Building Information Modeling is a complicated tool: BIM is difficult to understand not only for expert witnesses who need to use it in a court setting, but for jurors who are not construction experts, especially if unfamiliar with modern technology and 3D modeling.

- Reliability issue: using BIM might be extremely risky. For jurors, three-dimensional models might look beautiful but not necessarily true.

- Lack of experimental supports: the complexity of BIM might negatively affect a jury's verdict against a party that uses it. Since this effect is not tested, experts are reluctant to use BIM models in courtrooms.

- In litigation, having experience is more important than being familiar with advanced technology: many people who are expert witnesses at present are not familiar with BIM and are reluctant to use the technology. Typically forensic engineers who are selected by attorneys and judges have many years of experience, and the newer generation does not know how to use BIM properly.

- Lack of information for creating a model for existing buildings: creating a BIM model for existing buildings is very challenging. Many of these buildings do not have the design or as-built drawings. Thus, it is not possible to make an accurate and reliable model and pull information out of the model with the accuracy level that people are expected to provide in litigation.

- Manipulating the model: BIM models have the potential to prejudice the outcome of the cases and twist the real story behind an incident if not used properly.

3.10. Forensic Engineers' Challenges

In addition to the data collection process, communicating the findings, especially non-expert clients or juries involved in a dispute, is the most critical issue for forensic engineers. Also, disputes involving injuries and fatalities, and the cases in which numerous factors can contribute to the problem such as delay cases or fire incidents, are the most challenging projects for them.

Although the outcome of this phase of the study did not directly contribute to achieving the research objective, it was beneficial in better understanding the topic and assisted in case study development and test material preparation as further described in Chapters IV and V.

4. FORENSIC INFORMATION MODELING

4.1. Case Study Development

On the advice from expert participants in the interviews, a fire incident in a pump station building was chosen for the case study. Incidents involving a property loss are the best cases to be displayed to the jury via computer animation (Denenberg & Learned, 1995). Furthermore, fire incidents are a challenging forensic matter in which the connections between the damages in different parts of the structure are difficult to comprehend, especially by lay people. The reason for selecting a pump station was that as an industrial building it has all disciplines (structural, architectural, mechanical, and electrical), but does not have complicated modeling and, therefore, expertly suffices for the purpose of this research.

After consulting with experts and due to the difficulties in finding an actual case study, a fictitious dispute according to their previous experience was created, and the data required for building the FIM were collected or developed. The dispute story that was the basis for creating the model is described in the following section.

4.2. Claim Story

In October 2016, the Department of Water Management hired a contractor to renovate the basement of the pump station building. The pump station is a two-story building including a ground floor and a basement. The ground floor is divided into a pump room and an office area. The basement of the office area (where the contractor was working) was used as the storage to keep tools, materials, and equipment needed for occasional maintenances. Two

rotary pumps and electrical motors were under operation in the pump room at the time of the project. Also, the inlet and outlet water main pipes passed through the basement of the pump area. Based on the contract, the contractor was expected to renew the storage room of the pump station building (including replacement of shelves, replacement of tiles, and painting the walls) in the specified times as presented in Fig. 3.

During the construction work, the basement of the office area (storage room) caught fire when welders were working inside the storage. Although the contractor's workforce had reported the fire instantly, it took 70 minutes for firefighters to extinguish the fire completely. Because of the fire, the basement was damaged and needed fundamental maintenance (Fig. 4). Also, two steel columns inside the storage room were buckled during the fire incident as can be seen in Fig. 5.

After extinguishing the fire, the pump station operating manager reports some issues outside of the construction area. He notices that the pump shaft was broken at the coupling which leads him to shut down both pumps shortly. He also reports misalignments and breakage in the piping system in the pipe room (Fig. 6).

This incident results in a dispute between the insurer of the pump station, FP Insurance Group, and the contractor, Texas Builders Construction.

GENERAL SERVICE AGREEMENT

THIS GENERAL SERVICE AGREEMENT (the "Agreement") dated this 24th day of September, 2016

BETWEEN:

City of Bryan of 1201 Southh Wood Drive, Bryan, Texas, 77843
(the "Client")

- AND -

Texas builders, Ltd of 1101 S Austin Ave, College Station, Texas, 77840
(the "Contractor").

BACKGROUND:

A. The Client is of the opinion that the Contractor has the necessary qualifications, experience and abilities to provide services to the Client.

B. The Contractor is agreeable to providing such services to the Client on the terms and conditions set out in this Agreement.

IN CONSIDERATION OF the matters described above and of the mutual benefits and obligations set forth in this Agreement, the receipt and sufficiency of which consideration is hereby acknowledged, the Client and the Contractor (individually the "Party" and collectively the "Parties" to this Agreement) agree as follows:

Services Provided

1. The Client hereby agrees to engage the Contractor to provide the Client with the following services (the "Services"):
   - Renovating the storage room in Pump Station including the replacement of the existing shelves, replacing the existing tiles, doors and painting the walls according to the plans and drawings.

2. The Services will also include any other tasks which the Parties may agree on. The Contractor hereby agrees to provide such Services to the Client.

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Figure 3. Agreement between the client and the contractor

Figure 4. Storage room after the fire incident

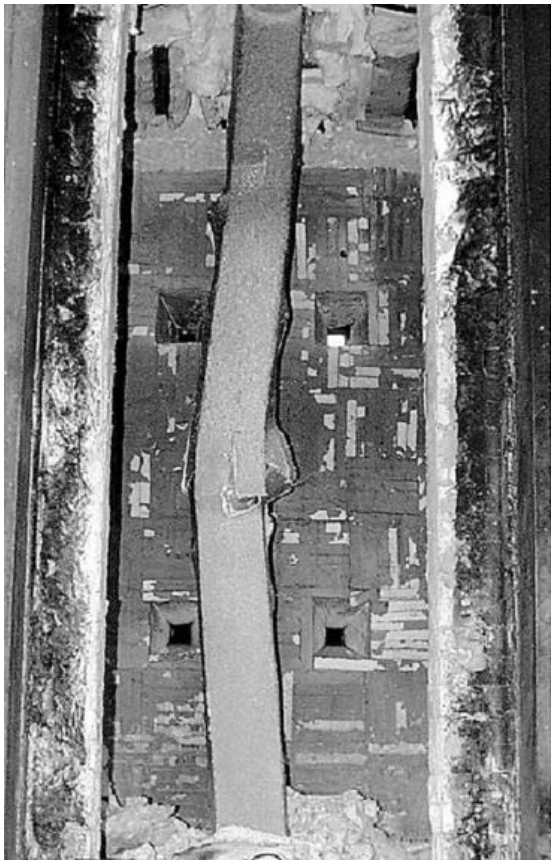


Figure 5. Buckled columns inside the storage room

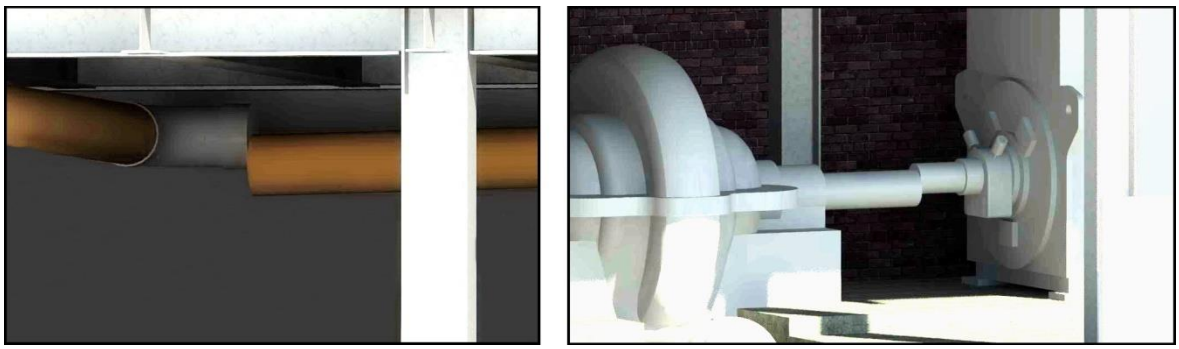


Figure 6. Pipe damage and pump shaft breakage outside the storage room

FP Insurance Group holds the contractor responsible for the fire and liable for all compensations including rebuilding the storage, replacing all its contents, repairing the pump shafts, and fixing the piping system, referring to an article in the contract which states: "contractor is liable for all damages during the work."

After negotiating the issue through holding a few meetings between parties, including the owner and the contractor, the contractor accepts being faulty in the fire incident and also agrees to repair the storage area and replace its contents, but rejects being liable for other damages outside the storage room where the fire occurred.

FP Insurance and Texas Builders fail to settle the dispute and go into a litigation process to resolve this issue. After an unsuccessful mediation and arbitration process, this case ends up in court, where jurors are in charge of decision making on the dispute.

As described above, FP Insurance Group as the plaintiff claims all damages, inside and outside of the construction area, were caused by the incident and therefore the contractor has to fix them. However, Texas Builders Construction as the defendant blames the client for damages outside of the construction area and rejects its liability for those damages.

Hypothetically, this fictitious claim will be presented in a trial in four different conditions. Each condition will make one treatment in this experimental research in which expert

witnesses representing the defendant or the plaintiff are required to present their evidence using FIM or PowerPoint.

4.3. Forensic Information Modeling

The process of creating a Forensic Information Model for this case includes the following steps:

1. Data gathering and organizing the documents
2. Making a 3D model in Revit
3. Performing the analysis and investigations to formulate the failure mechanism
4. Including the investigation results into the BIM model
5. Using the model as a storytelling tool to explain the failure mechanism in the plaintiff's case and the defendant's crossing argument.

Creating any information model begins with collecting the information that the model has to include or transmit. Since this case is not real, the documents required to support the case were mostly developed according to the knowledge acquired from the interviews with experts. Also, the adequacy of this information was approved by experts prior to the final experiment (Fig. 7 and Fig. 8).

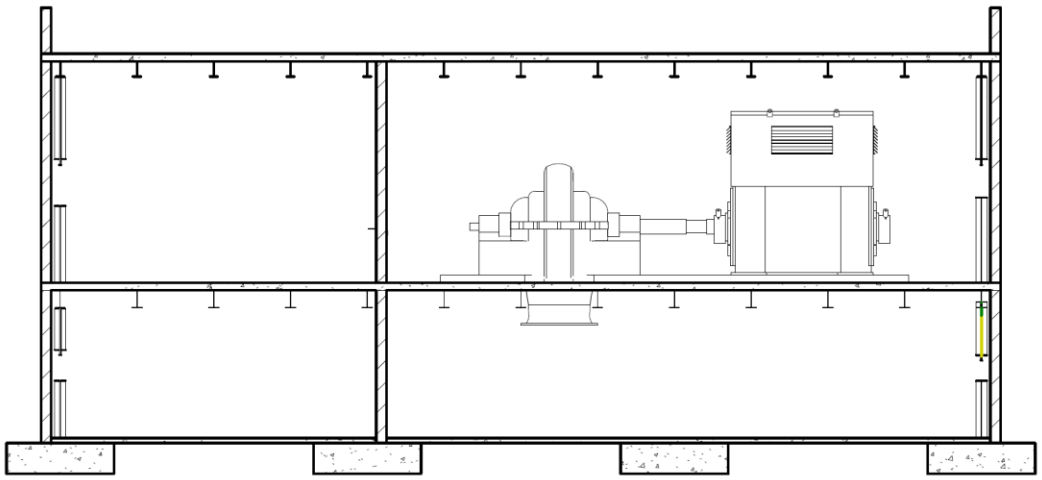


Figure 7. Sample of pump station as-built drawing - motor and building section

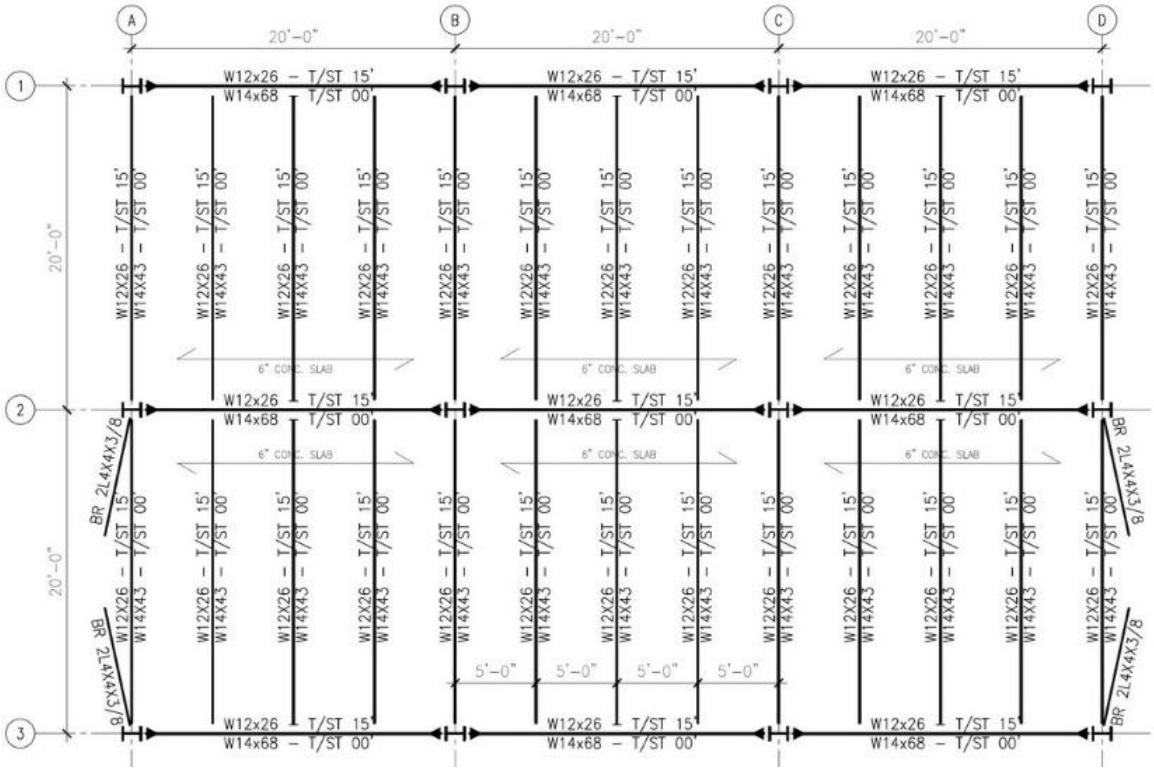


Figure 8. Sample of pump station as-built drawing - structural plan

In the second step, a 3D model of the building was created using Revit application. The required data for this purpose included geometric data, structural systems, facilities, and materials used in structural and nonstructural components. These data can be collected

through the site visit, from design drawings, as-built drawings, and technical specifications. Based on the assumptions, all required information for making the 3D model are available in this case. However, for real cases acquiring these data and building the BIM model of a collapsed structure can be very challenging because not only all buildings are not necessarily built in accordance with design drawings, but also many of them, especially the old ones, do not comply with codes and standards. There are other methods and techniques for making the 3D model of these cases, such as photogrammetry and laser scanning.

Figure 9. Isometric view of pump station in Revit

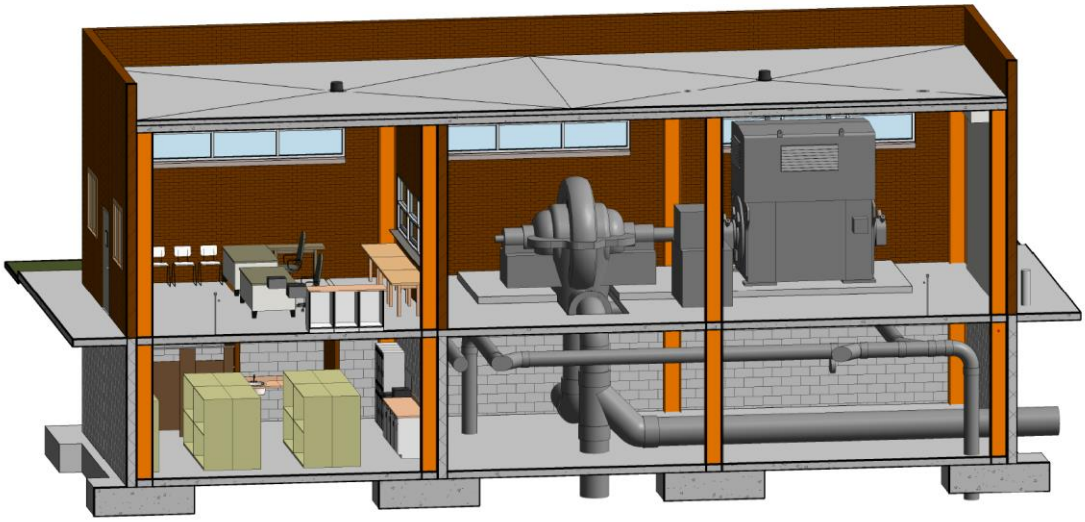


Figure 10. 3D section of pump station in Revit

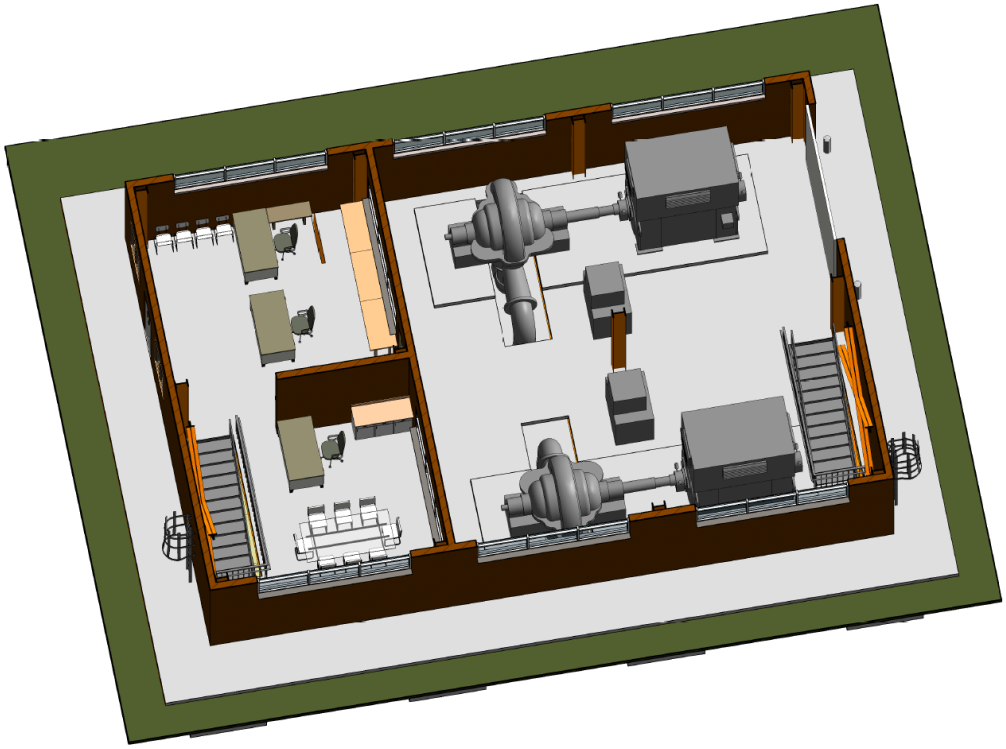


Figure 11. Isometric view of ground level in Revit (office area and pump room)

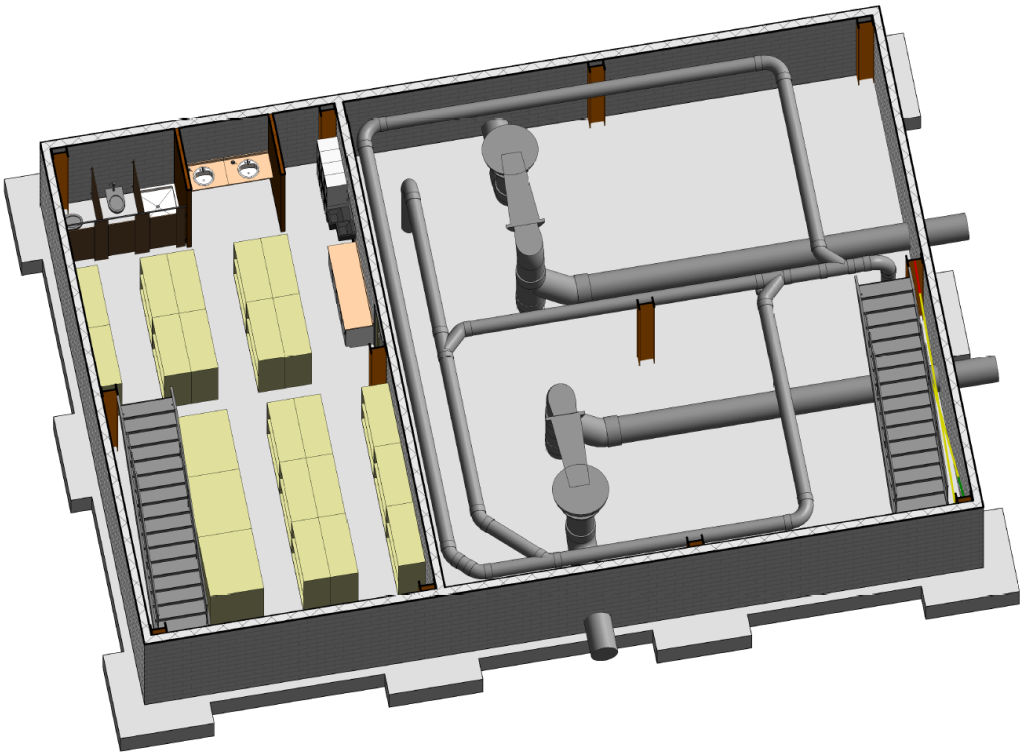


Figure 12. Isometric view of basement including storage and piping room in Revit

In addition to visualizing the case, the FIM has to include forensic investigation results such as drawings, contracts, analysis, reports, technical data sheets, specifications, and standards. For this purpose, the collected or produced information were attached to the members in the model. In Revit, all documents were linked to the structural elements by defining the extra parameters. The associated documents to the model were popped up by clicking the elements in the model.

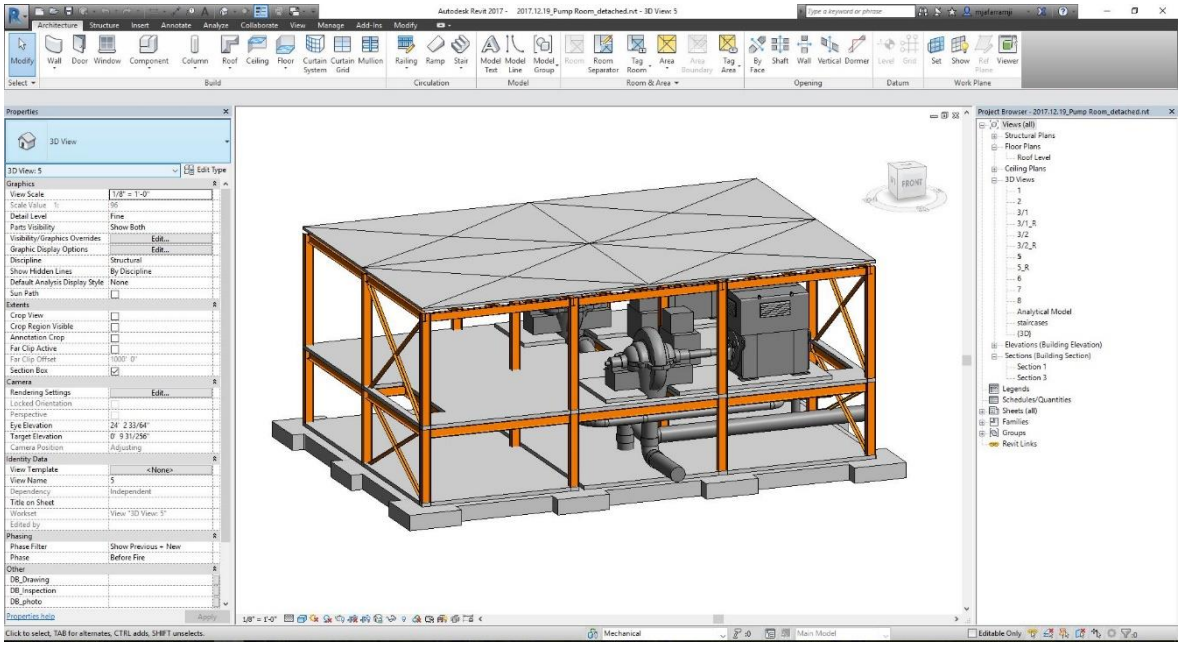


Figure 13. View of Revit model that has been used as FIM

Also, using Revit made the phasing possible and facilitated presenting pre- and post-incident conditions of the building. The phasing was very beneficial in the storytelling using FIM and enhanced understanding the damages caused by the incident. In the developed model, by phasing, all damaged or demolished items were highlighted during the presentation. As shown in Fig.14, all damaged elements have been highlighted in red in the post-incident phase.

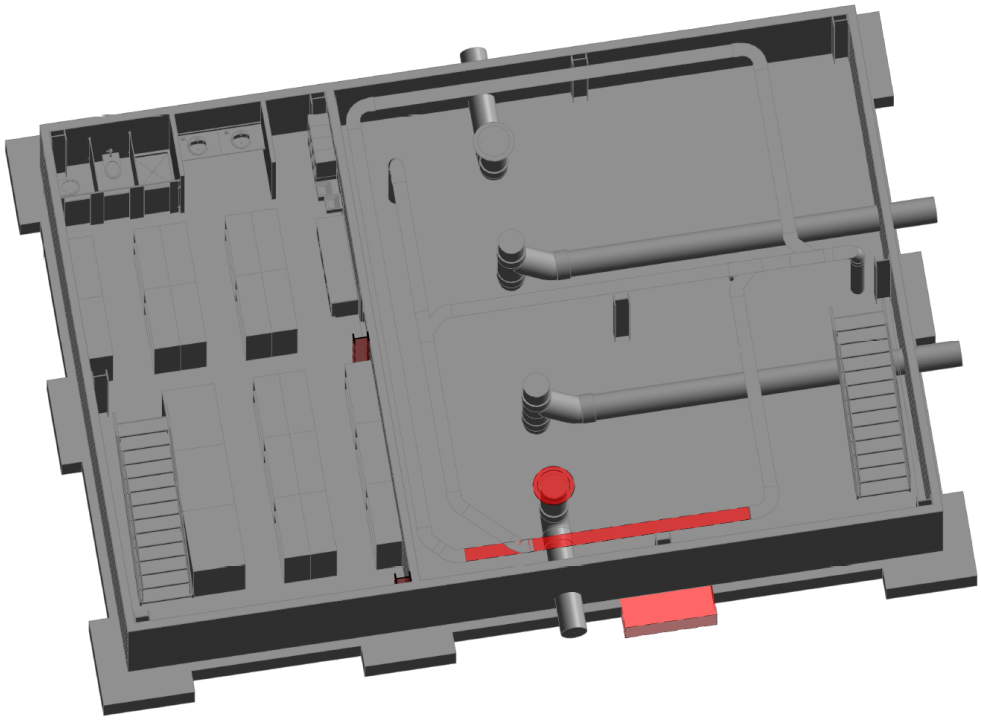


Figure 14. Damaged items highlighted in red, after incident phase of FIM model

In general, the plaintiff and the defendant create and use their model to back up their specific arguments and to present their story in the trial. Therefore, two forensic information models were created for the argumentative sides. In this study, both parties used the same BIM model as the platform to build their FIM. The FIM created and used by FP Insurance Group as the plaintiff and the Texas Builders Construction as the defendant are described in further details in sections 4.3.1 and 4.3.2.

4.3.1. Plaintiff's FIM

The FP Insurance Group argues that the damages to the pump shaft located on the ground floor and to the pipe in the pipe room were all caused by the incident. To support this claim, the investigation team performed structural Finite Element Analysis for pre-incident and post-incident conditions of the building using RISA software to investigate the failure

mechanism and to prove the correlation between the damages outside the storage and the incident inside the storage room. For this purpose, the structural members were exported directly to RISA software from Revit.

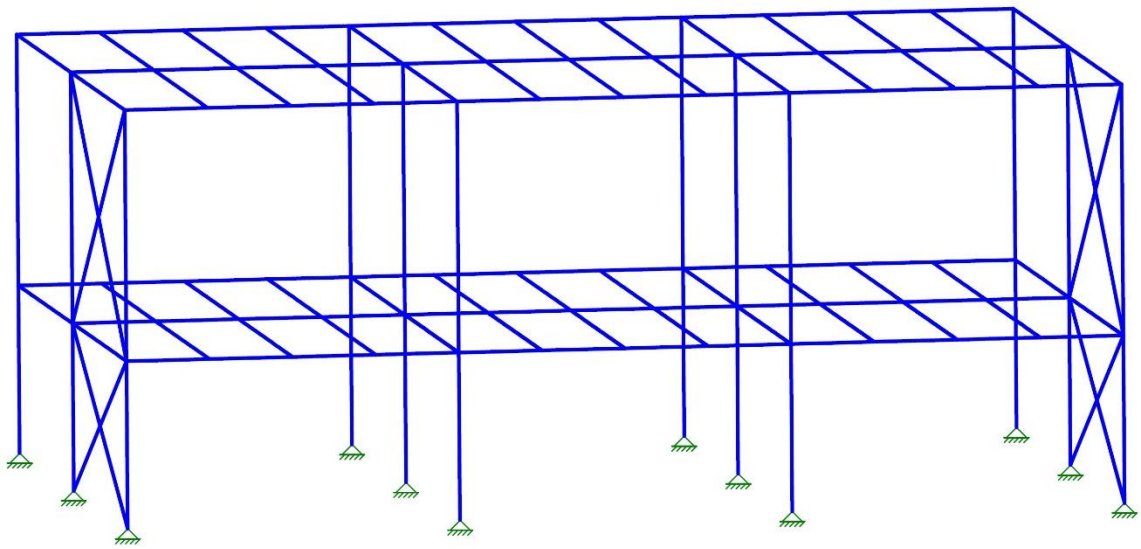


Figure 15. Pump room 3D finite element model in RISA-3D

To assess the strength of the structural elements under pre- and post-incident conditions (column loads, foundation loads, deflection of floors, etc.), the structural and nonstructural loads were applied to the elements. These loads included water pumps, motors, exterior and interior walls, framing and slabs, equipment pads, roofing, and actual operational live loads. One example of applied loads is shown in Fig. 16. These loads were calculated using components data sheets.

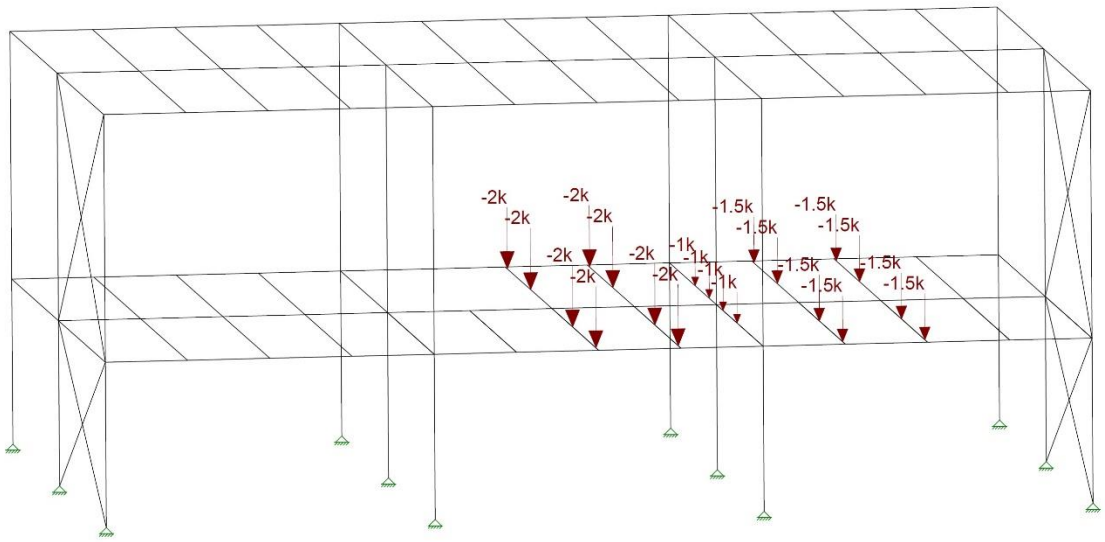


Figure 16. Applied mechanical equipment loads on building frames in RISA-3D

In the next step, the structural system of the pump station was analyzed and force distribution and deflections were calculated using Risa in the pre-incident condition. An example of the analysis result (moment diagram) is shown in Fig. 17.

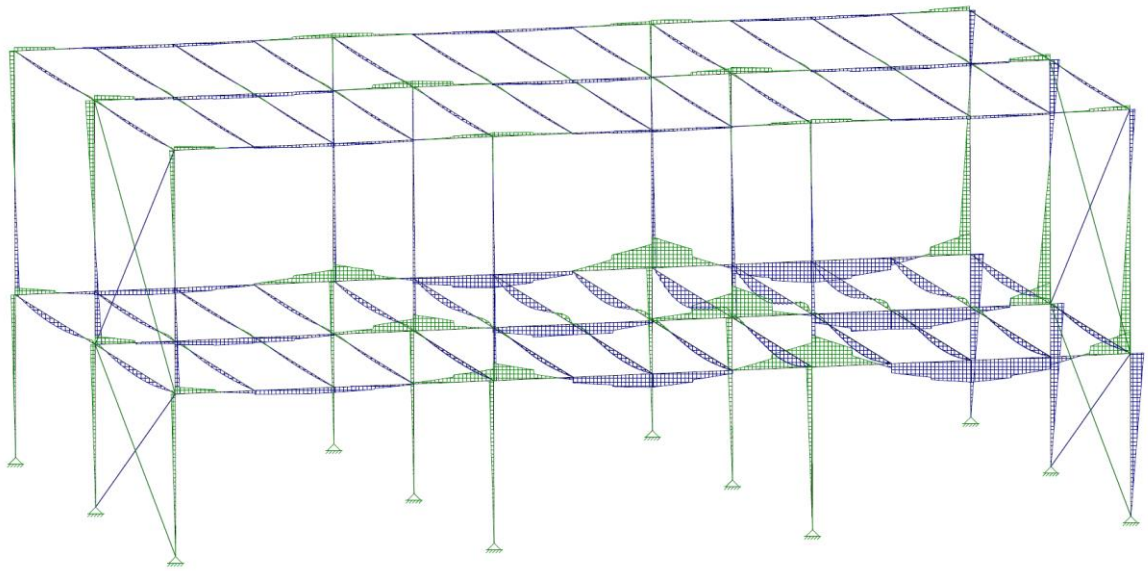


Figure 17. Analysis result (moment diagram) in the structural model

To check whether the structural system had adequate strength to resist all existing loads, the demand/capacity ratios for all beams and columns were calculated. As can be seen in Fig. 18, all demand/capacity ratios are less than one (<1), indicating that all structural elements met the minimum requirement determined by the AISC (American Institute of Steel Construction) standard. Therefore, the structural members were strong enough to resist the loads before the incident.

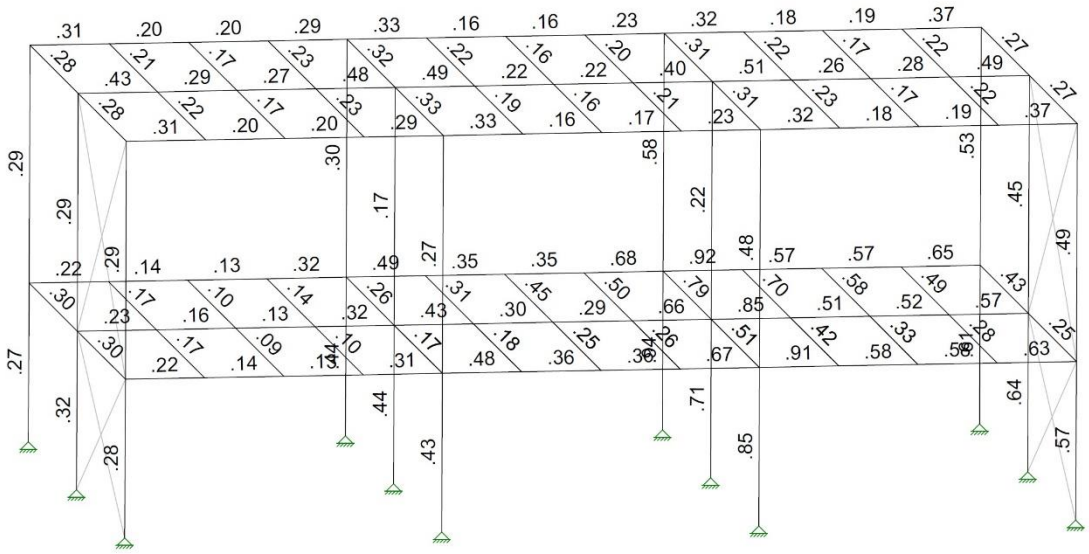


Figure 18. Design check ratio of columns and beams according to AISC

Next, the column loads, footing forces, and beam deflections (especially under the pumps on the ground level) were calculated in pre-incident condition to compare with the analysis result after the fire.

The model then was modified to present the changes in the structural system of the pump station caused by the fire incident. Under this new condition and considering the buckling of two columns in the storage room, the axial loads, footing forces, and floor deflections were calculated again and were compared with the analysis results before the incident.

Fig. 19 shows the ground level deflection before and after the incidents. As shown, the unbalanced deflection after the fire is significantly higher than pre-incident condition (0.1” before incident vs. 2.0" after the incident).

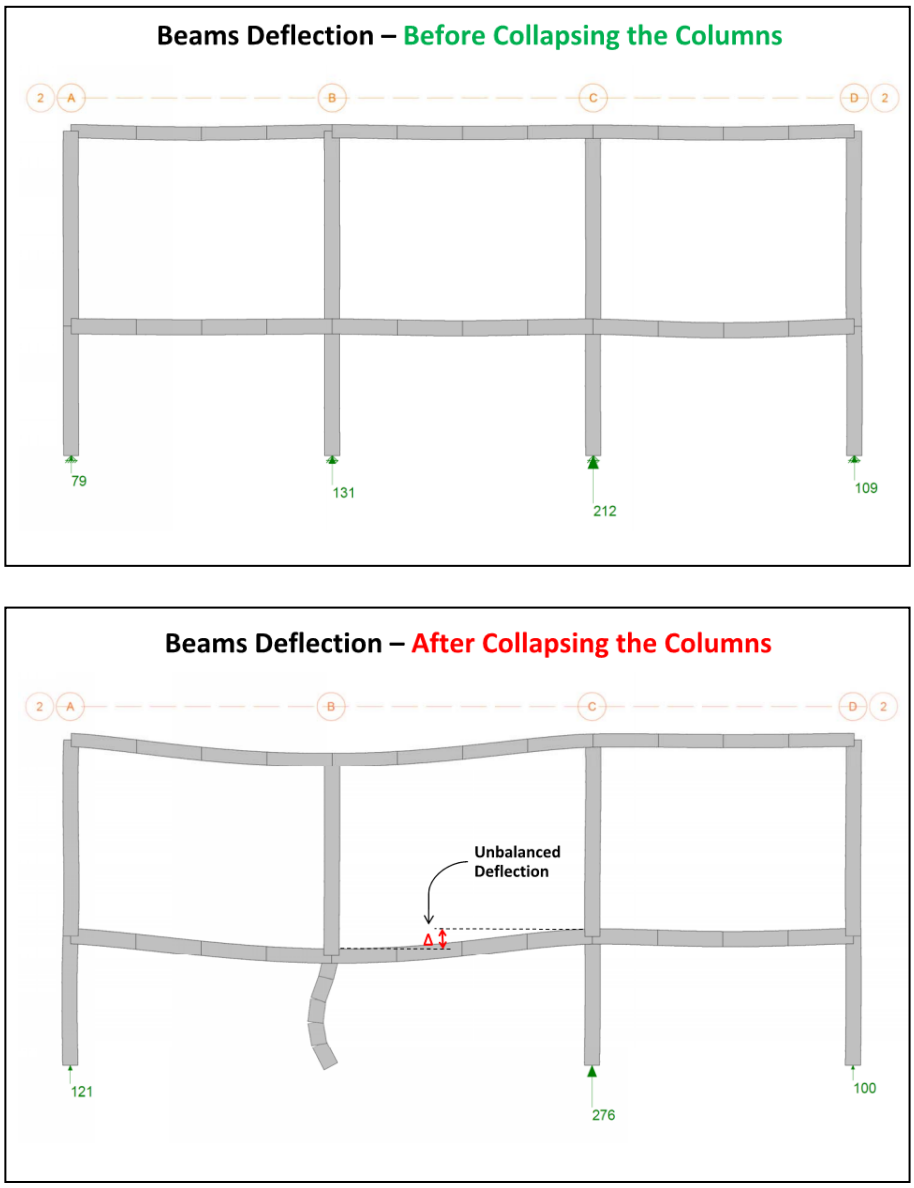


Figure 19. Ground level beam deflections before and after the fire incident

This unbalanced deflection occurred exactly under the pumps. Based on the pump specification (Fig. 20), the maximum allowable deflection under the pump shaft is 0.25”, which is much smaller than beam deflection after the incident.

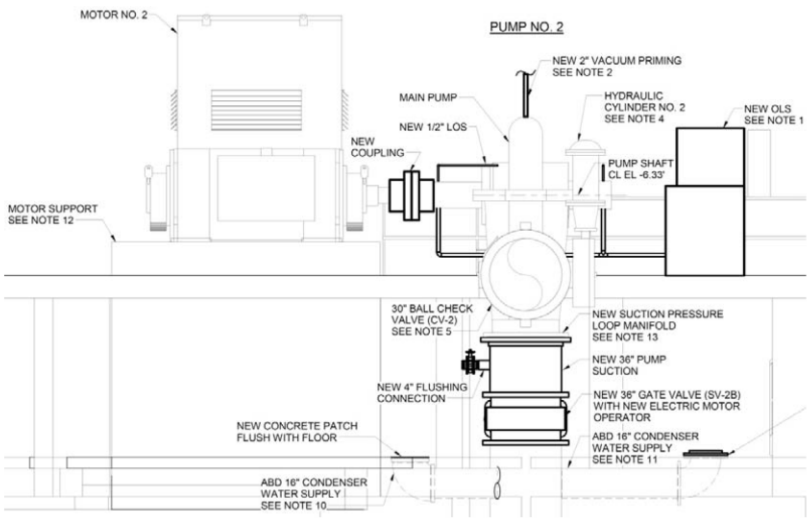
This analysis proved that the pump shaft breakage was the consequence of the fire although the pump was located outside the storage on the ground level inside the pump room.

CENTRIFUGAL PUMP AND MOTOR SPECIFICATION

HD PUMP

CENTRIFUGAL PUMP - MOTOR SECTION:

The pump-motor alignment and connection is shown as below:



PUMP CHARACTERISTICS:

The Pumps characteristics are summarized in the table:

Manufacturer	HD1	HD2
Hp	2800	3000
RPM	514	450
Rotational frequency (Hz)	8.57	7.50
Weight (Lb)	8000	7500
Base to shaft axis distance (in)	24.58	34.6
Imbalance force (lb)	3.14	5.02
Max Allowable Deflection on Shaft	0.25 inch	0.25 inch

The motors velocity at the shaft does not exceed 2 mm/s.

VERTICAL AND HORIZONTAL VIBRATIONS DATA:

The greatest imbalance force acting on the lightest motor and base combination and using an estimated foundation stiffness of 1.8 x 10^6 lb/in. This estimated stiffness is based on *Vibrations of Soils and Foundations,* Richart, Woods, and Hall, Prentice-Hall, 1970, p 350, and on a soil shear modulus of 5,000 lb/in^2. The greatest vertical natural frequency would be of the order of 10 Hz, implying the possibility of a resonance with the motor rotational frequencies.

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Figure 20. Pump and motor data sheet

In the next step, the soil pressures under the footings were analyzed. Based on the geotechnical report, as can be seen in Fig.21, the allowable soil pressure is equal to 4500 pound per square foot.

Geotechnical Report Summary:

- General:
  - Existing pavement is 2”-3” asphalt over 9”-13”.
  - Miscellaneous urban fill from elevations +14 to +18.
  - Brown and gray, stiff to very stiff clay soils at elevations +5 to +10.
  - Soft to stiff clay down to -28.5 to -33.5 , bedrock at -43 to -50.

- Estimated water table elevation is +4.0 to +10.0.
  - Water found in only two borings, at 11’ below grade and 75’ below grade.
  - Per report, water table estimated using local hydrogeological data and depth of soil color changes.
  - No piezometer data included, unsure if piezometer tests are being performed.

- Recommended foundation system: Spread Footings
  - Recommended net allowable soil bearing pressure: 4,500 psf.
  - Elevation of bearing material ranges from +15.0 to +18.0.
  - Borings B-3 and B-6, located between the parking lot and coal storage building, list a surface elevation of +32.0 which require depths of 14’ to 16’ to reach bearing material elevation. There will be excavation in this area for the new buildings. The T/Slab-on-Grade is +21’-7” for new building.
  - Maximum settlement of footings estimated at approximately ¾”, with maximum differential settlement estimated as half of total settlement.

- Slabs-on-Grade; fill materials appear generally suitable for support of floor slabs, some risk due to undocumented urban fill materials. Some remediation may be required.
  - Minimum 6” granular base recommended for slabs.

Soil Parameters

Parameter	
Unit weight (pcf)	120
Active Earth Pressure Coefficient (Ka)	0.36
Active Pressure (psf/ft of depth)	43
Passive Earth Pressure Coefficient (Kp)	2.76
Passive Pressure (psf/ft of depth)	330
“At-Rest” Coefficient of Lateral Earth Pressure (Ko)	0.5
“At-Rest” Equivalent Fluid Pressure (psf/ft of depth)	65
Coefficient of Sliding	0.35

Figure 21. Geotechnical report of the pump station building

By dividing the footing loads by the footing areas, the soil pressures under the footings were calculated. As shown in Fig. 22, the maximum soil pressure before the incident was 4300 psf (pound per square foot), which is within the allowable range.

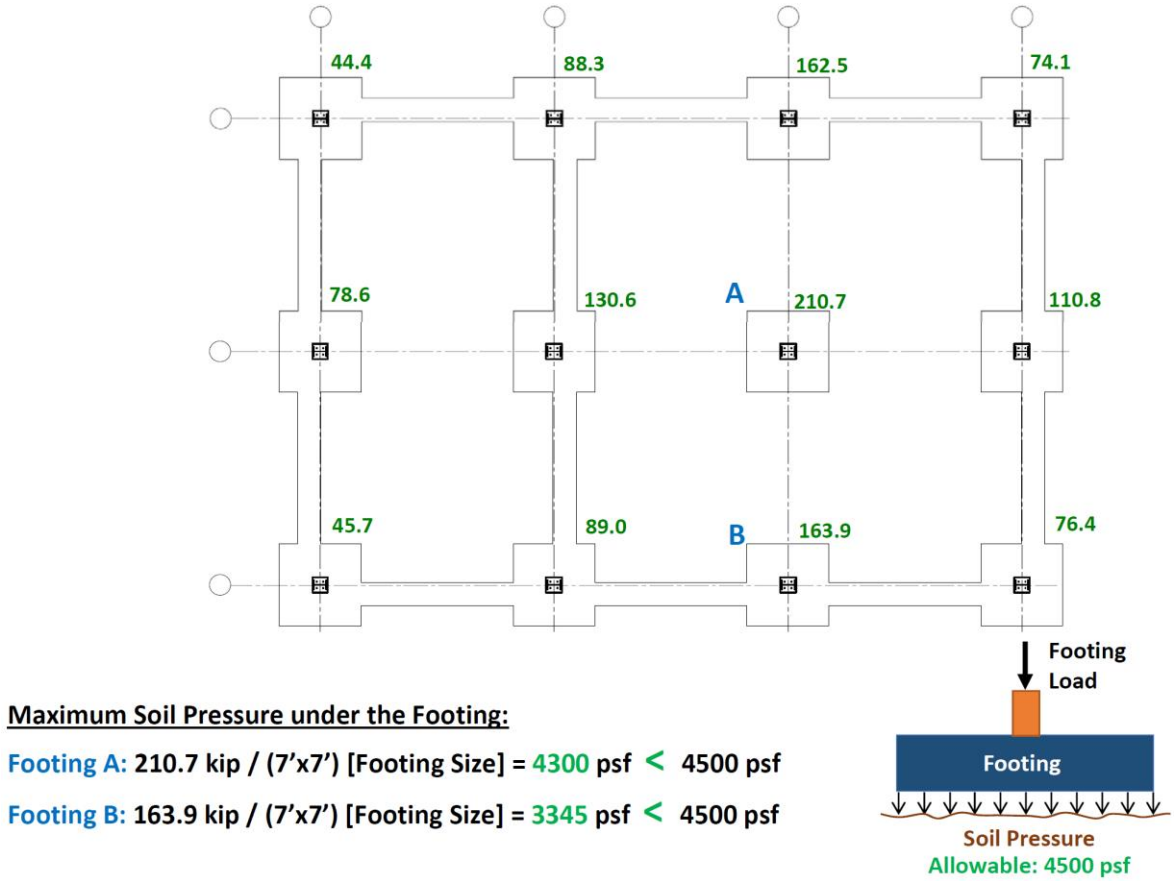


Figure 22. Soil pressure under the footings before the incident

The axial forces and the soil pressures were calculated after the incident as well. As shown in Fig. 23, the pressure on soil under footing "A" reached 5600 psf, which is higher than the allowable pressure according to the geotechnical report. This excess pressure under the footings explains the unexpected settlement under the footings "A" and "B" and proved the relationship between the pipe breakage in the pipe room and the fire incident.

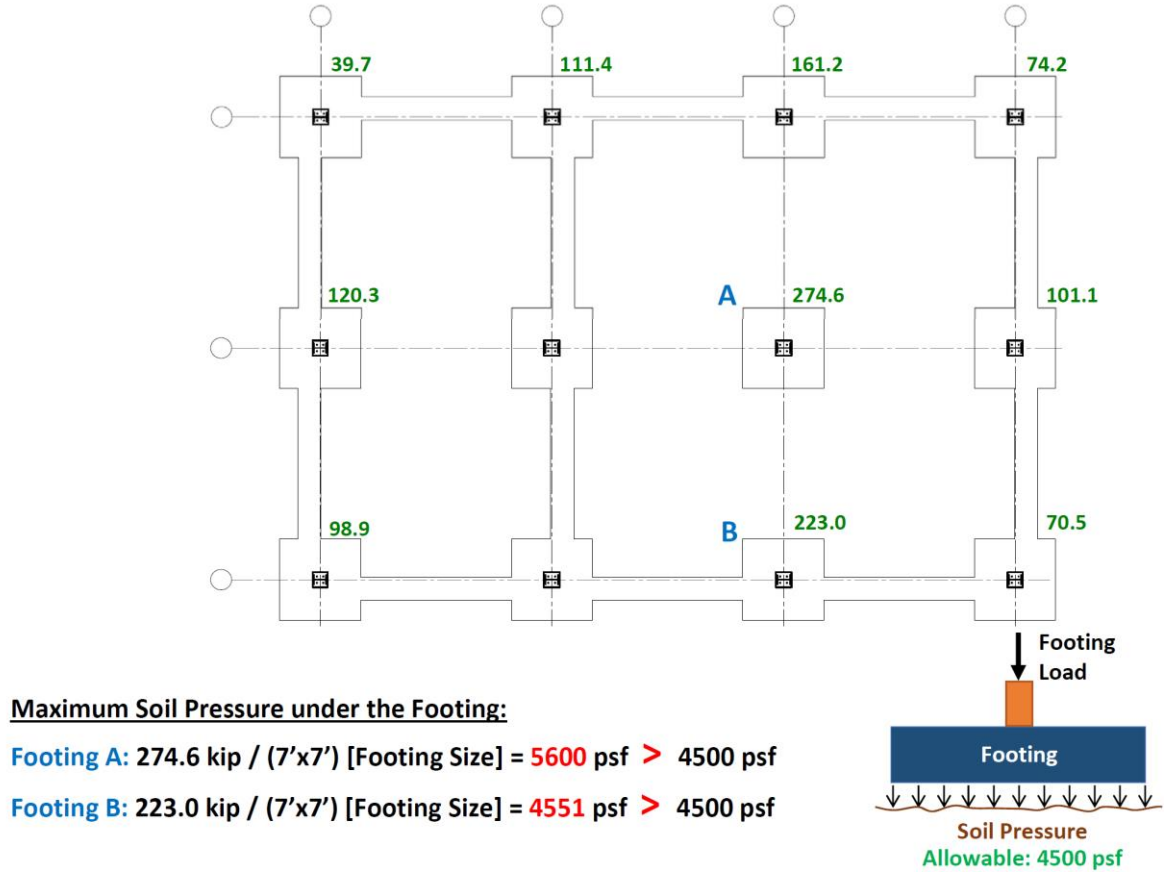


Figure 23. Soil pressure under the footings after the incident

After understanding the failure mechanism, all information and supporting documents were incorporated into the FIM. This model is utilized by the plaintiff as the storytelling tool to communicate the technical findings and causal relationships between the events with non-technical fact finders in this study.

4.3.2. Defendant's FIM

Texas Builders Construction as the defendant also created a Forensic Information Model to support its argument in the pump station fire case. The following items are the defendant's arguments in response to FP Insurance's claim. All documents required to support these

arguments were collected and incorporated to the model to be utilized during the hypothetical trials (treatment in this research).

- Plaintiff's analysis indicated that the failure occurred in the buildings were all rooted in the fire incident caused by the contractor in the basement. However, according to the standards, the minimum period of fire resistance for columns of industrial buildings is 90 minutes, implying that the columns inside the storage were expected to resist at least 90 minutes during the fire before buckling (Fig. 24). Whereas, based on the incident report, the fire extinguished in 70 minutes, indicating that the fire protection of the columns did not comply with the standards out of the contractor's control and liability.
- When the fire happened, in spite of all the efforts, the fire extinguishing process was slowed due to the accessibility issue to the storage room from the outside because the storage room was located on the basement level and the furniture in the office area on the ground floor blocked firefighters' way to the incident area. The office area was the only access to the storage room from the outside, as can be seen in Fig. 25.
- For all hot work permit required areas, the contractor needs to get a "Hot Work Permit" from the clients before starting the welding. According to NFPA 51B, issuance of the hot work permit indicates the hot work area is free of any combustible materials. Instead, at the time of the incident the client had left containers of flammable liquids on the shelves inside the storage room. Defendant argues that the existence of the flammable liquids intensified the fire and led to other damages. The hot work permit issued by the client is presented in Fig. 26.

Table A2 **Minimum periods of fire resistance**

Purpose group of building	Minimum periods of fire resistance (minutes) in a:					
	Basement storey [5] including floor over		Ground or upper storey			
	Depth (m) of a lowest basement		Height (m) of top floor above ground, in a building or separated part of a building			
	More than 10	Not more than 10	Not more than 5	Not more than 18	Not more than 30	More than 30
1. Residential:						
a. Block of flats						
– not sprinklered	90	60	30*	60**†	90**	Not permitted
– sprinklered	90	60	30*	60**†	90**	120**
b. Institutional	90	60	30*	60	90	120#
c. Other residential	90	60	30*	60	90	120#
2. Office:						
– not sprinklered	90	60	30*	60	90	Not permitted
– sprinklered [2]	60	60	30*	30*	60	120#
3. Shop and commercial:						
– not sprinklered	90	60	60	60	90	Not permitted
– sprinklered [2]	60	60	30*	60	60	120#
4. Assembly and recreation:						
– not sprinklered	90	60	60	60	90	Not permitted
– sprinklered [2]	60	60	30*	60	60	120#
5. Industrial:						
– not sprinklered	120	90	60	90	120	Not permitted
– sprinklered [2]	90	60	30*	60	90	120#
6. Storage and other non-residential:						
a. any building or part not described elsewhere:						
– not sprinklered	120	90	60	90	120	Not permitted
– sprinklered [2]	90	60	30*	60	90	120#
b. car park for light vehicles:						
i. open sided car park [3]	Not applicable	Not applicable	15*+	15*+ [4]	15*+ [4]	60
ii. any other car park	90	60	30*	60	90	120#

Single storey buildings are subject to the periods under the heading "not more than 5". If they have basements, the basement storeys are subject to the period appropriate to their depth.

$ The floor over a basement (or if there is more than 1 basement, the floor over the topmost basement) should meet the provisions for the ground and upper storeys if that period is higher.

* Increased to a minimum of 60 minutes for compartment walls separating buildings.

** Reduced to 30 minutes for any floor within a flat with more than one storey, but not if the floor contributes to the support of the building.

\# Reduced to 90 minutes for elements not forming part of the structural frame.

\+ Increased to 30 minutes for elements protecting the means of escape.

† Refer to paragraph 7.9 regarding the acceptability of 30 minutes in flat conversions.

Notes:

1. Refer to Table A1 for the specific provisions of test.
2. "Sprinklered" means that the building is fitted throughout with an automatic sprinkler system in accordance with paragraph 0.16.
3. The car park should comply with the relevant provisions in the guidance on requirement B3, Section 11.
4. For the purposes of meeting the Building Regulations, the following types of steel elements are deemed to have satisfied the minimum period of fire resistance of 15 minutes when tested to the European test method;:

   i) Beams supporting concrete floors maximum Hp/A=230m-1 operating under full design load.

   ii) Free standing columns, maximum Hp/A=180m-1 operating under full design load.

   iii) Wind bracing and struts, maximum Hp/A~210m-1 operating under full design load.

   Guidance is also available in BS 5950 Structural use of steelwork in building. Part 8 Code of practice for fire resistant design.

Figure 24. Minimum period of fire resistance for different types of buildings

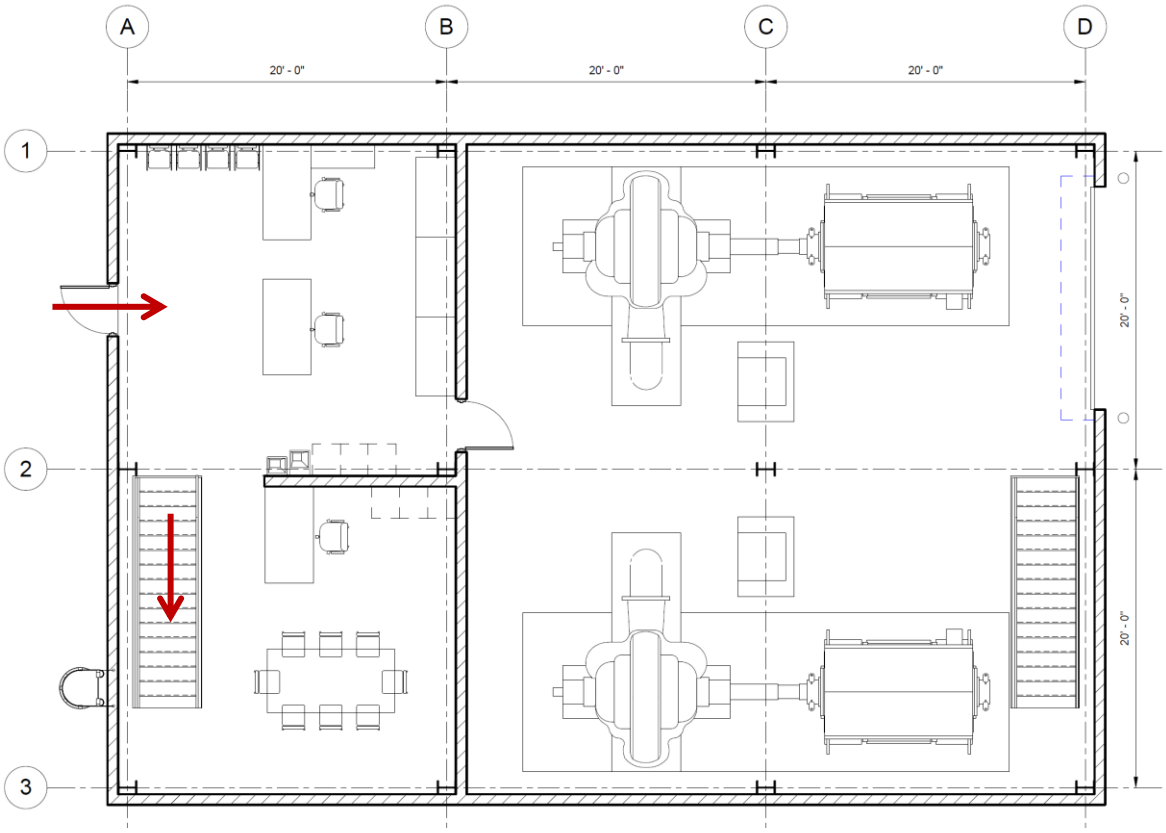


Figure 25. Access to the storage room from the office area

Likewise, after finalizing the argument and preparing the supporting documents such as standards, standards, permits, specifications, and drawings, they were incorporated into the FIM created by the defendant to be utilized in the trials (treatments).

No. 2016 - W1306 **HOT WORK PERMIT**

Company (Location/ Site name): Texas Builders Company / Pump Station Employee/ Contractor: —

Work location (Level, area, building, room): Pump Station Building - Storage Room

☑ Blowtorch Cutting / Welding ☑ Grinding ☐ Brazing ☐ Shrinking/Hot-bonding ☐ Roof Work ☐

Work Order ..... to be carried out by: .....

Beginning of Work (Date): Oct. 16, 2016 (Time): Full day Permit expiry (Time): Nov. 16, 2016 Actual end: .....

Maximum Validity: 1 Shift to a maximum of 10 hours. Permit can be renewed/extended: Yes ☑ No ☐

Emergency Number 814 - 011 - 0000 Nearest phone/push button alarm 814 - 011 - 0001

Measures to be taken prior to beginning work

Topic	Action	Required	Completed
Work area and within 50 feet / 15 m	Define the hazardous area, cordon off the area (radius at least 50 ft.[15 m], secure steel grating floors below)	☑	☐
	Safety instructions by the supervisor	☑	☐
	Remove any combustible substances (gases, liquids, solids)	☑	☐
	Cover with non-combustible panels, mats. Wet down area if possible	☑	☐
	Wash/clean pipes/containers/appliances/floor racks	☑	☐
	Inspect safety of work equipment	☑	☐
Provision of extinguishing agents	☑ CO_2 ☐ Dry powder ☐ Foam ☐ Water extinguisher ☐ Wall hydrant, pressurized hose in work area ☐ Inergen / FM 200 / Novec 1230	☑ ☐	☐ ☐
Plant Technology	If fire detection or suppression systems are shut down, inform/coordinate with fire depatment, specify alternative measures	☑	☐
Gas detection	LEL: - % CO: - % O_2: - % H_2S: - %	☐	☐

Measures to be taken during work

Topic	Action	Required	Completed
Fire watch	Continuous inspection of the hazardous area (also during work breaks)	☑	☐
	Instructed and trained fire watch	☑	☐
Interruption	Person who carries out the work must secure the work equipment (close valves on gas cylinders, isolate electrical equipment)	☑	☐
Continuous Gas Detection recorded each 15 min.	LEL: ..... % CO: ..... % O_2: ..... % H_2S: ..... %	☐	☐

Measures to be taken after completion of work

Topic	Action	Required	Completed
Work Area	Remove entire work equipment from area	☑	☐
	Remove all covers with due care and attention	☑	☐
Fire alarm system	Reconnected automatic fire detection & suppression systems	☑	☐
	Inform fire department	☑	☐
Supervision of the Work area	Inspection for a minimum of 30 minutes after completion of the work (fire extinguishers at the workplace)	☑	☐
	Check every ½ hour and for an additional 3 ½ hours (fire extinguishers at the work place)	☑	☐
	Mobile fire alarm system	☑	☐
Completion (after the supervision)	Remove barricade	☑	☐
	Remove fire extinguishers and take them back to their correct location	☑	☐
	Record any incident, if applicable	☑	☐

Release of work

Parties Involved	Action	Name (in print)	Date / time	Signature
Supervisor	Above listed measures are appropriate to cover any hazards that might occur	Adam Smith	Oct 15, 2016	Adam
Executing contractor	Work can only be started once all required fire protection measures have been implemented and the fire watch is present	Mike Brown	Oct 15, 2016	Mar
	Knowledge of the listed measures			
Fire watch	Has taken note of the listed measures	Jeff clark	10/15/16	[illegible]

Transfer of workplace following completion of work

Parties Involved	Action	Name (in print)	Date / time	Signature
Executing contractor	Execution of the listed measures			
Fire watch	Execution of the listed measures			
Supervisor/Area manager	Execution of the listed measures			

Figure 26. Hot work permit issued by the client before the construction

5. TEST MATERIAL PREPARATION

To prepare the test materials, the following activities were performed in this research:

- Four presentations were produced for the argumentative sides (Plaintiff's PowerPoint, Plaintiff's FIM, Defendant's PowerPoint, Defendant's FIM).
- An introductory video was created.
- Four questionnaires were prepared.
- A web-based platform for the experiment was developed.

5.1. Presentations

According to the claim scenario, as explained in Chapter IV, and to fulfill the requirements of the experiment design, a PowerPoint-based presentation was created for each argumentative side. The PowerPoint slides contained the same supporting documents as included in the Forensic Information Model as described in the previous chapter. Then four narration scripts were developed for the arguments made by FP Insurance Group as the plaintiff and Texas Builders Construction as the defendant for each presentation method with the same narrative structure for PowerPoint-based and FIM-based presentations of the argumentative sides. The narrative structure is about two things, the content of a story and the form used to tell the story. In the PowerPoint-based method, the building systems and facilities were presented using 2D CAD drawings, whereas in the FIM-based presentation the argument was presented using the three-dimensional model of the building and facilities in an interactive manner. Supporting documents as described in Chapter IV were

incorporated into the BIM model when using FIM and were presented on the white slides when using PowerPoint without any extra textual information.

After preparing the materials (FIMs, PowerPoint slides, and narration scripts), four presentations were videotaped.

Since the presenter's gender and the presentation style affect the result according to the research conducted by Hann and Clayton (1996), all four videos were narrated by the same male narrator. Additionally, to eliminate the impact of the durations of the presentation on participants' free recall, all four presentations had equal lengths (eight and half minutes).

To control the learning effect bias, the ordering of the presentations by the argumentative sides changed during the test. In other words, in each treatment half of the participants started the test by watching the defendant's presentation and the other half began with the plaintiff's presentation, which resulted in eight different test conditions.

Furthermore, to facilitate following the arguments by the participants in the test according as to whether they start with the plaintiff or the defendant, the presenter repeated the highlights of the other side's argument in the closing part of the presentations. Also, a brief introductory video was prepared to provide a big picture of the claim scenario to the participants. The script of the introductory video, the PowerPoint-based, and FIM-based presentations for both sides are documented in the following sections.

5.2. The Scripts of the Introductory Video

"In Oct 2016 the Department of Water Management hired the Texas Builders Construction as the contractor to do a renovation project at the pump station. During the project, a fire

incident occurred in the pump station, when the hot work operators were working inside the building.

Caused by the fire, the damages to the building and equipment were severe, and the client shut down the pump station.

The client held the contractor responsible for the fire and liable for all damages and asked for compensation for all damages to the building whereas the Texas Builders Construction as the contractor declined its full liability for all damages.

These two sides could not resolve the dispute through negotiation, mediation, and arbitration. So the case went to the courtroom where jurors are going to make judgment for the case.

Today you are invited here to play mock jurors for this case.

In this experiment, you are going to watch the Texas Builders' argument as the defendant, and FP Insurance Group's argument as the plaintiff which is the insurer of the pump station.

You may listen to the defendant's arguments first or begin with the plaintiff's presentation.

Following the presentations, you will be requested to answer questions about what you have watched and what you remember from the presentations.

In the end, you will be asked to render the verdict and answer the questions regarding the persuasiveness of the presentations.

Your participation in this experiment and contribution to the resolution of this dispute is highly appreciated."

5.3. The Script of Plaintiff's FIM-Based Presentation

"I am representing the FP Insurance Group to present its argument in the pump station fire case. Texas Builders Construction was hired by the Water Management Department to renovate the storage room in the basement of the pump station building, as you see here (using the model).

While working inside, shown here on the left side of the screen (referring to the model), the welders caused a fire that resulted in damages to and inside the storage room. Highlighted here, these two columns, this one and this one in the corner (referring to the model), were buckled due to the duration and temperature of the fire. Looking at the resulting images shown, you can only begin to understand the extent of the damages. However, the severity of the damages as can be seen here (referring to the model) were not limited to just the storage room and columns. Upon inspection to the pump station, after the fire was suppressed, the operating manager noticed this pipe here and the pump shaft on the ground floor was incurred damages as well. By running a post-incident structural analysis, using the finite element analysis software, we are now capable of having a deeper understanding of the succession of events, and the cause and effect relationship of the fire, in regards to the damages inside of the pump station building. Specifically, by running the software, we can see the failure mechanism and the casual relationship between the fire inside the storage room and damages to the equipment in another part of the building.

Before moving to the analysis result, I need to explain the structural system of the building because it is important to understand the analysis. As you can see here in the model, the pump station is a two-story building with a basement and the ground floor. This building has

steel beams and steel columns with concrete roof and floors. Also, the pump station building has individual footings under the columns and strip footings under the walls.

To investigate the causes of the pump shaft failure, we have compared the deflection modes before and after the incident using the finite element model. As you can see here (referring to the relevant document incorporated to the model), this is the deflection of the beams under the damaged pump.

Before the incidental buckling of the beams, this one in the middle and this one, (in the model) we notice small and negligible deflections in beams, particularly under the pump shaft. However, when these two columns buckled under this new condition (referring to the model), we have a significant unbalanced deflection in this beam amounting to a total of 2 inches according to the analysis result.

Now let's take a look at the specifications regarding the allowable deflections under the pump to see how this large deflection would affect the pump shaft (referring to the model).

Here we have the pump manufacturer's catalog (referring to the relevant document incorporated to the model). According to this catalog, the maximum allowable deflection on the shaft is 0.25 in, which is smaller than the unbalanced deflection caused by the buckling of these two columns (referring to the model). So, we can deduct that our post-incident analysis proved that the pump shaft breakage on the ground floor is the result of the fire in the storage room, which was caused by the unbalanced deflection under the pump, exceeding its designed tolerance.

Another damaged area resulting from the fire occurred outside the storage area, in addition to the pump shaft breaking on the ground floor was the damage of this pipe located in the

pipe room, next to the basement of the storage room. I have highlighted all the damages on the basement in red (referring to the model).

As you can see here (referring to the model), this pipe was tied to this column, so we thought, and therefore this damage may have been caused by the settlement of the footing under the wall. Investigating these two columns buckling and not performing in bearing the loads from the building, we analyzed the changes of the footing loads in the building after the fire, ultimately determining the cause of the failing mechanism.

Footing loads are the portion of the building loads which are transmitted into the soil from the connected structure above ground, through the footing. To analyze the footing loads we used the finite element analysis software, as we did for the building deflection mode.

Here you can see the analysis result for the building before the incident (referring to the model). Under this condition, column A and column B have the higher loads in the building. Under column "A" we have 210.7-kilo pound-force, and under column" B" we have 163.9-kilo pound-force as the footing loads (referring to the model).

If we divide these values by the dimension of the footing, which is the same for all individual footings, we get 4300 pounds per sq. foot under Column A and 3345 pounds per sq. foot under column B. As calculated, the pressure on soil both are less than 4500 pounds per sq. foot before the fire, which is the allowable pressure on this specific soil, according to the geotechnical report for this location (referring to the model).

So according to the analysis, we can deduct that the settlement of the footing from this building before the fire incident was very unlikely, particularly under column A.

When these two columns buckled as the direct result of the fire incident (using model while narrating), according to the analysis result, we get 5600 pounds per sq. foot as the pressure

on soil under column A and 4551 pounds per sq. foot as the pressure on soil under column B, both higher than 4500 pounds per sq. foot, which is the recommended soil bearing pressure according to our geotechnical report.

When the footing load becomes greater than the allowable soil bearing pressure, occurring in this case, consequently we expect footing settlement under Columns A and B, leading to the pipe breakage in the pipe room, because as I mentioned previously the pipe was tied to the column B. Therefore according to our analysis we deduct that the pipe breakage was the indirect consequence of the fire incident inside the storage.

Demonstrated in our investigation, and unilaterally understood by most, the plaintiff, FP Insurance Group, believes that the defendant, Texas Builders Construction, is liable for all damages inside and outside the storage room. This includes the buckling of these two columns inside the room, the pipe breakage in the pipe room next to the storage room, and the pump shaft breakage in the pump room on the ground floor. The plaintiff seeks fiduciary equitable compensation amounting to the cost of the repairs.

The Texas Builders Construction declined its responsibility for damages outside the storage room, claiming that the accessibility issue of the building to the storage room slowed down the firefighting process and the existence of the flammable materials added to the intensity of the fire which was out of contractor's control. This defendant also claims that if columns resisted the fire according to the standard, the damages outside the storage would not have occurred. However, this claim is not acceptable because of our contractual agreement succinctly stating the contractor is liable for all damages to the building during the work, with no exception."

5.4. The Script of Plaintiff's PowerPoint-Based Narration

"I am representing the FP Insurance Group to present its argument in the pump station fire case.

Texas Builders Construction was hired by the Water Management Department to renovate the storage room in the basement of the pump station building as you see in this plan.

While welders were working inside the room, which is here on the left-hand side of the plan, they caused a fire resulting in damages to the room and its contents.

These two columns which are shown using the red dash lined circles were also buckled as a direct result of the fire (referring to the CAD drawing on the slides).

In this picture, you can see what happened to the columns caused by the fire incident inside the storage room. But unfortunately, damages in the pump station building were not limited just to the mentioned damages inside the storage room. After the incident, the operating manager noticed this pipe, as you can see in this picture, and also this pump shaft on the ground floor, as you see here (referring to the CAD drawings on the slides), were also broken.

To realize the failure mechanism and the casual relationship between the fire inside the storage room and damages to the equipment in the other parts of the building, we have run the post-incident structural analysis using the finite element analysis software.

Before moving to the analysis result, I need to explain the structural system of the building because it is very important in understanding the analysis. As you can see here in this section (the CAD drawings on the slides), the pump station is a two-story building including the basement and the ground floor. This building has steel beams and steel columns with

concrete roof and floors. Also, pump station building has individual footings under the columns and strip footings under the walls.

To investigate the causes of the pump shaft failure, we had compared the deflection modes before and after the incident that we got from the finite element model. This is the deflection of the beams under the damaged pump, as you can see here (on the slides).

Before the incident, when these beams had not buckled, this one in the middle and the model, we have small and negligible deflections in beams in particular under the pump shaft, but when these two columns buckled (referring to the CAD drawings on the slides) under this new condition, we have a significant unbalanced deflection in this beam, which is two inches according to the analysis result.

Now let's take a look at the specifications regarding the allowable deflections under the pump regarding the allowable deflection to see how this large deflection would affect the pump shaft (on the slides). Here we have the pump manufacturer's catalog. According to this catalog, the maximum allowable deflection on the shaft is 0.25 in, which is smaller than the unbalanced deflection caused by the buckling of these two columns. So, we can deduct that our post-incident analysis proved that the pump shaft break on the ground floor is the result of the fire in the storage room. This was caused by the unbalanced deflection under the pump, exceeding its designed tolerance.

Another damaged area resulting from the fire occurred outside the storage area in addition to the pump shaft breaking on the ground floor as you see here (referring to the CAD drawings on the slides) was the damage of this pipe located in the pipe room, next to the basement of the storage room.

As you can see here (referring to the CAD drawings on the slides), this pipe was tied to this column, so we thought, and therefore this damage may have been the caused by the settlement of the footing under the wall. To investigate the failing mechanism we analyzed the changes of the footing loads in the building after the fire when these two columns buckled and did not perform in bearing the loads from the building (referring to the CAD drawings on the slides).

Footing loads are the portion of the building loads which are transmitted into the soil from the connected structure through the footing. To analyze the footing loads we used the finite element analysis software as we did for the building deflection mode.

In this slide, you see the analysis result before the incident. Under this condition, column A and column B have the higher loads in the building. Under column "A" we have 210.7-kilo pound-force, and under column" B" we have 163.9-kilo pound-force as the footing loads (referring to the CAD drawings on the slides).

If we divide these values by the dimension of the footing, which is the same for all individual footings, we get 4300 pounds per sq. foot under Column A and 3345 pounds per sq. foot under column B as the pressure on soil both less than 4500 pounds per sq. foot, which is the allowable pressure on this specific soil, according to the geotechnical report for this location. According to the analysis, we can deduct that the settlement of the footing from this building, in particular under column A and before the fire incident was very unlikely.

When these two columns buckled as the direct result from the fire incident, according to the analysis result, we get 5600 pounds per sq. foot as the pressure on soil under column A and 4551 pounds per sq. foot as the pressure on soil under column B, both higher than 4500 pounds per sq. foot, which is the recommended soil bearing pressure according to the

geotechnical report. When the footing load becomes higher than the allowable soil bearing pressure as happened in this case, consequently we expect footing settlement under Columns A and B leading to the pipe breakage in the pipe room which was leaned to the column B. Overall according to our investigation in which I demonstrated, the plaintiff, FP Insurance Group, believes that the defendant, Texas Builders Construction, is liable for all damages inside and outside the storage room including the buckling of these two columns inside the room, the pipe breakage in the pipe room next to the storage room, and the pump shaft breakage in the pump room on the ground floor and have to compensate all these damages. The Texas Builders Construction declined its responsibility for damages outside the storage room, claiming that the accessibility issue of the building to the storage room slowed down the firefighting process and the existence of the flammable materials added to the intensity of the fire which was out of contractor's control. This defendant also claims that if columns resisted the fire according to the standard, the damages outside the storage would not have occurred. However, this claim is not acceptable because of our contractual agreement succinctly stating the contractor is liable for all damages to the building during the work, with no exception."

5.5. The Script of Defendant's FIM-Based Narration

"The Texas Builders Construction was hired by the Water Management Department to renovate the storage room in the basement of the pump station building. According to the contract between the Water Management Department and the Texas Builders Construction, this project included: replacement of the existing shelves, tiles, doors, and painting the walls, according to the plans and drawings.

When the hot work operators were working in the storage room, a fire incident occurred and resulted in damages inside the storage room including the buckling of these two columns (referring to the model). After the fire, other damages to the equipment inside the pump station, in other rooms, were also observed and led to a disagreement between the FP Insurance Group, which was the insurer of the pump station and the Texas Builders Construction.

The FP Insurance Group holds the contractor not only liable for buckling of these two columns inside the storage but also for the pump shaft breakage on the ground floor, the pipe breakage in the pipe room (next to the storage room on the basement level) and also the settlement of these two footings as you can see in this model (referring to the model).

Today I am representing the Texas Builders Construction, which is the defendant in this case to present its defense and to respond to FP Insurance's claims as the plaintiff.

To help you better understand our arguments, let me give you a quick introduction to the pump station building. The pump station building is a two-story building including the basement and the ground floor. This green plane represents the ground level (referring to the model). In the basement we have two separate areas this one, the storage room the place where the fire incident occurred, this one is the pipe room, and on the ground floor we have the office area and next to the office area we have the pump room in where two pumps were operating at the time of the incident (referring to the model).

The fire incident occurred inside the storage room on the basement as I mentioned before. According to "NFPA 51B" which is the standard for fire prevention during welding cutting and other hot work, the storage room is a permit required area, so our hot work operators or our welders had to receive the hot work permit before starting the welding. Here is the hot

work permit the contractor received from the client before the starting the hot work operation inside the storage room (referring to the permit included in the model). The issuance of the permit indicated that the area is ready and safe for the welding which is a hot work operation because according to the standard the client had to make the storage free and clear from any kinds of combustible materials.

However, unexpectedly, when the welders started working, they noticed these shelves that you see in the model have not left the room yet, and these four shelves that I am highlighting this one and also this one (referring to the model) were still full of contents as you see here in the picture. This is the picture which was taken before the contractor started working. When the fire started, the welders realized that despite the standard obligations among the materials stored in these shelves, there were some containers of the flammable liquids, which added to the intensity of the fire. If there were not these containers, the welders might be able to extinguish the fire and prevent further damages (referring to the model).

In addition to the existence of the flammable liquids inside the storage room, the other issue out of contractors' control, which delayed the firefighting process, was the accessibility issue to the building from the outside. Let's take a look at the building using the model. As you see here, the pump station building has two entrances from outside environment to the building (referring to the model).

The first one is here, and the next one as you see in the model is this one on this side of the building (referring to the model). As you see in the model, the storage room and the pipe room can be accessed through these two staircases which connect the office area on the ground floor and the pump room on ground floor.

At the time of the incident, the firefighters had to use this door to make their way to the storage room through the office area (referring to the model). Since the building was under operation in the time of the incident, as you see in the model, the office area was full of furniture and consequently slowed down the firefighting process and led to more damages to the building.

Eventually, in spite of all drawbacks in the firefighting process, the fire was extinguished in 70 mins, and by exposure to the fire for this duration, these two steel columns in the storage room were buckled, unfortunately (referring to the model). The FP Insurance Group claims that the Texas Builders Construction is also liable for all damages outside the storage room in addition to the inside because they are the consequences of buckling of these two columns (referring to the model). So we have investigated the compliance of these two columns with the fire resistance standard. As you see according to the standard, the minimum period of fire resistance in the nation- sprinkled basement of the industrial buildings is 90 minutes when the depth of the basement is not more than 10 meters, which is the case here (referring to the standard tied to the columns). Whereas the columns in the storage room were buckled in less than 70 min as I explained before, indicating that the columns did not have enough fire protection and did not comply with the relevant standard.

To summarize the presentation, the Texas Builders Construction as the contractor in the renovation project of the pump station, and as the defendant, in this case, does not accept its liability for damages outside the storage room including the pump shaft breakage, the pipe breakage, and the footing settlements. The client had not removed the shelves from the storage room, a condition specified in the contract, but also issued the notice to proceed for welding, while the containers with the combustible materials were in the shelves, which is

against the obligation of the standard for fire prevention during welding cutting and other hot work, therefore added to the intensity of the fire. Further, the accessibility for the firefighters to the incident area took longer than expected and led to more damages. In spite of these two issues, still, the contractor accepts the responsibility to compensate for damages inside the storage room, but not outside the room even though the FP Insurance claims they were caused by the buckling of the columns inside the storage. Because as I explained during the presentation, these columns did not resist the fire as much as they were prescribed in the standard indicating that they did not meet the standard requirement. Even accepting that the damages outside the building were the consequences of the buckling of the columns inside the storage, if they met the standard requirements and resisted the fire, the other damages in another part of the building would never be occurred."

5.6. The Script of Defendant's PowerPoint-Based Narration

"The Texas Builders Construction was hired by the Water Management Department to renovate the storage room in the basement of the pump station building. According to the contract between the Water Management Department and the Texas Builders Construction, this project included: replacement of the existing shelves, tiles, doors, and painting the walls, according to the plans and drawings.

When the hot work operators were working in the storage room, a fire incident occurred resulting in damages inside the storage room including the buckling of these two columns that is shown with the red dashed rectangular line (referring to the CAD drawings on the slides). But after the fire, other damages to the equipment inside the pump station in other

rooms were also observed and led to a disagreement between the FP Insurance Group, the insurer of the pump station, and the Texas Builders Construction.

The FP Insurance Group holds the contractor liable for buckling of these two columns inside the storage room and the pump shaft breakage on the ground floor (referring to the CAD drawings on the slides). Additionally, the FP Insurance Group also holds the contractor liable for the pipe breakage in the pipe room, next to the storage room in the basement, and the settlement of these two footings as you can see in the footing plan (referring to the CAD drawings on the slides).

Today, I am representing the Texas Builders Construction, which is the defendant in this case to present its defense and to respond to FP Insurance's claim as the plaintiff.

To help you better understand our arguments let me give you a quick introduction to the pump station building. The pump station building is a two-story building including the basement and the ground floor. This thick black line represents the ground level (referring to the CAD drawings on the slides).

In the basement, we have two separate areas: this one, the storage room, the place where the fire incident occurred, and this one, the pipe room. On the ground floor, we have the office area and the pump room, where the two pumps were operating at the time of the incident (referring to the CAD drawings on the slides).

The fire incident occurred inside the storage room in the basement. According to "NFPA 51B," which is the standard for fire prevention during welding cutting and other hot work, the storage room is a permit-required area, so our hot work operators and our welders had to receive a hot work permit before beginning their work. In this slide, you see the hot work permit that the contractor received from the client before starting the hot work operation

inside the storage room. The issuance of the permit indicated that the area is ready and safe for the welding according to the standard the client had to make the storage free and clear from any kinds of combustible materials.

However, unexpectedly when the welders started working, these shelves shown with black dash lines had not been removed, and these four shelves inside the red dash lined rectangular were still full of contents (referring to the CAD drawings on the slides) as you see here in the picture. This is the picture which was taken by the contractor before performing the work. When the fire started, the welders realized that despite the standard obligations among the materials stored in these shelves (referring to the CAD drawings on the slides), there were some containers of the flammable liquids stored, which added to the intensity of the fire. If there were not these containers (referring to the CAD drawings on the slides), the welders might have been able to extinguish the fire and prevent further damages.

Also, accessibility issues to the building delayed the firefighting process. As you see in this slide, the pump station building has two entrances from the outside environment to the building. One is here on the west side of the building, and the next one is on the east side, and the storage room and the pipe room can be accessed through these two staircases (referring to the CAD drawings on the slides). This one connects the office area on the ground floor to the storage room, and the other from pump room on ground floor to pipe room in the basement. At the time of the incident the building was under operation, and as you see in this section, the office area was full of furniture, consequently slowing down the firefighting process leading to more damages to the building (referring to the CAD drawings on the slides).

Eventually, in spite of all drawbacks in the firefighting process, the fire was extinguished in 70 minutes, but the exposure to the fire for this duration, these two steel columns in the storage room, which are shown with red rectangular dashed lines were buckled, unfortunately (referring to the CAD drawings on the slides). The FP Insurance Group claims that the Texas Builders Construction is also liable for all damages outside the storage room in addition to the inside because of the buckling of these two columns. We have investigated the compliance of these two columns with fire resistance standard. As you see in this slide, according to the standard, the minimum period of fire resistance in the not sprinkled basement of the industrial buildings is 90 minutes when the depth of the basement is not more than 10 meters, which is the case here. Whereas the columns in the storage were buckled in less than 70 minutes as I explained before indicating that the columns did not have enough fire protection and did not comply with the relevant standard.

To summarize the presentation, the Texas Builders Construction as the contractor in the renovation project of the pump station does not accept its liability for damages outside the storage room including the pump shaft breakage, the pipe breakage, and the footing settlements. The client had not removed the shelves from the storage room, a condition specified in the contract, but also issued the notice to proceed for welding, while the containers with the combustible materials were in the shelves, which is against the obligation of the standard for fire prevention during welding cutting and other hot work, therefore adding to the intensity of the fire.

Further, the accessibility for the firefighters to the incident area took longer than expected and led to more damages. In spite of these two issues, still, the contractor accepts the responsibility to compensate for damages inside the storage room, but not outside the room

even though the FP Insurance claims they were caused by the buckling of the columns inside the storage. Because as I explained during the presentation, these columns did not resist the fire as much as they were prescribed in the standard (referring to the CAD drawings on the slides) indicating that they did not meet the standard requirements. Even accepting that the damages outside the building were the consequences of the buckling of the columns inside the storage, if they met the standard and resisted the fire, the other damages in another part of the building would never have occurred."

5.7. Questionnaires

In this experimental study, participants were required to fill out four questionnaires in total. An exercise question was also provided after the introductory video to prepare the participants for the test and reduce the learning effect bias in the experiment as mentioned earlier. The questionnaires are listed below:

1. Demographic information questionnaire
2. Plaintiff's free recall questionnaire (12 questions)
3. Defendant's free recall questionnaire (12 questions)
4. Persuasion effect questionnaire

As can be seen in the following sections, free recall questions were asked from the explicitly mentioned concepts in the arguments.

5.7.1. Plaintiff's Free Recall Questionnaire

1. What was the structural system of the building?
    a) Concrete columns and steel beams

b) Steel columns and concrete beams

c) Concrete columns and concrete beams

d) Steel columns and steel beams

e) None of above

2. The pump station has ____ footings under the columns and___ footings under the walls.

a) Individual, Individual

b) Individual, Strip

c) Strip, Strip

d) Strip, Individual

e) None of above

3. The unbalanced deflection under the pump after the fire was about:

a) 2"

b) 2.5"

c) 1.5"

d) 0.5"

e) 0.25"

4. The maximum allowable unbalanced deflection under the pump is:

a) 0.5 " according to the analysis

b) 0.25 " according to the analysis

c) 0.5" according to the manufacturer's catalog

d) 0.25" according to the manufacturer's catalog

e) None of above

5. What damages did occur inside the storage room?

a) Footing settlement

b) Unbalanced deflection under the pump

c) Buckling of columns

d) Pump shaft breakage

e) All of above

6. Why did the plaintiff analyze the building deflection?

a) To prove that the deflection caused damage to the pump

b) To prove that the deflection caused damage to the pipe

c) To prove that the footing settlement was caused by the pump breakage

d) To prove that the result analysis is accurate

e) None of above

7. Why did the plaintiff analyze the building footing loads?

a) To realize why the fire happened

b) To prove that the footing settlement was caused by the pump breakage

c) To prove that the footing settlement was caused by the pipe breakage

d) To prove that the pipe breakage was caused by the footing settlement

e) None of above

8. What is the allowable soil bearing pressure according to the geotechnical report?

a) 4500 lb/sf

b) 3500 lb/sf

c) 5600 lb/sf

d) 3345 lb/sf

e) None of above

9. According to the analysis, before the incident, column "A" and column "B" had higher footing loads in the building.

a) True

b) False

c) Was not discussed

10. Which statement is true?

a) The damaged pipe was leaned to the column inside the pipe room.

b) The fire incident occurred because the welders were smoking inside the storage.

c) The storage room was located on the ground floor next to the pipe room.

d) The footing loads have to exceed the soil bearing pressure to prevent the footing settlement.

e) All of above

11. The FP Insurance claims that the Texas Builders is liable for all damages inside and outside the storage room because they all were the direct or indirect consequences of the fire.

a) True

b) False

c) Was not discussed

12. The FP Insurance rejects the Texas Builders' claims by referring to the contractual agreement which states "the contractor is liable for all damages to the building during the work, with no exception."

a) True

b) False

c) Was not discussed

5.7.2. Defendant's Free Recall Questionnaire

1. What was the easiest access to the storage room from the outside?

   a) There was no access to the storage room from the outside.

   b) By the staircase connecting the office area to the storage room.

   c) By the windows.

   d) By the staircase connecting the pump room to the storage.

   e) Was not discussed

2. What was the prerequisite for the issuance of the hot work permit?

   a) There was no prerequisite.

   b) The location must be free of any combustibles (flammable-materials).

   c) The location should be detached from the building.

   d) Safety equipment must be available in the hot work area.

   e) Was not discussed

3. According to the presentation, ____ was in charge of removing the combustibles (flammable materials) before the project.

   a) The contractor

   b) The client

   c) The pump operation technician

   d) FP Insurance Group

   e) Was not discussed

4. In the storage room, the existence of the flammable materials was one of the main reasons for the fire intensity.

a) True

b) False

c) Was not discussed

5. The fire completely was extinguished after___ minutes.

a) 30

b) 50

c) 70

d) 90

e) 120

6. Based on the building code, what is the minimum required fire resistance before the failure of structural elements in the basement of the non-sprinkled industrial buildings, when the basement depth is less than 10 m?

a) 20 minutes

b) 45 minutes

c) 60 minutes

d) 90 m minutes

e) 120 minutes

7. Why did the hot work operators (welders) need to get the hot work permit to start the work?

a) Because it was obligated by FP Insurance Group.

b) Because it is what the Texas Builders always does according to its organizational regulation.

c) To comply with NFPA 51B: Standard for Fire Prevention During Welding, Cutting and Other Hot Work.

d) All of above

e) It was not mentioned.

8. The steel columns of the pump station building did not meet the code requirements for the fire resistance.

a) True

b) False

c) Was not discussed

9. What caused the fire extinguishing process to slow down?

a) The storage was occupied by the combustible materials.

b) The welders delayed in reporting the incident.

c) The firefighters did not arrive promptly.

d) The storage room had the accessibility issue.

e) Was not discussed

10. What was the location of the pipe room in the building?

a) On the ground floor next to the office area

b) On the basement next to the office area

c) On the basement next to the storage room

d) Outside the building

11. How many accesses does the pump station building have from the outside?

a) One

b) Two

c) Three

d) Four

e) Was not discussed

12. According to Texas Builders' claim, what added to the intensity of the fire?

a) Lumbers in the storage room

b) Curtains

c) Shelves

d) Flammable materials

e) None

5.7.3. Persuasion Effect Questionnaire

1. How easy was it to understand the plaintiff's presentation?

- Very difficult
- Difficult
- Neutral
- Easy
- Very easy

2. How easy was it to understand the defendant's presentation?

- Very difficult
- Difficult
- Neutral

- Easy
- Very easy

3. As a juror, who has to win the case? In other words, which argumentative side do you support in this case?
   - The plaintiff (FP Insurance Group)
   - The defendant (Texas Builders Construction)
4. On a scale of 1 to 5, how confident are you about your decision? (Your answer to the previous question)

   (Not confident at all) 1 2 3 4 5 (Extremely confident)

5. Self-report the importance of the following items in your verdict about who you believe has to win the case.

	Not important at all	Of little importance	Of average importance	Very important	Absolutely essential
The argument					
The presentation tool					

6. How easy were you able to visualize the sequence of the following events in your mind? In other words, how easy were you able to create the mental image of the sequence of the following events?

	Very difficult	Difficult	Neutral	Easy	Very easy
Footing Settlement					
Firefighters' access to storage room					
Plaintiff's story (overall)					
Defendant's story (overall)					

5.8. Web-based Experiment

After being finalized, all test materials were uploaded to Survey Gizmo, which is an advanced surveying website. All videos including the four presentations and the introductory video on the YouTube website were linked to the Survey Gizmo. To participate in the experiment, all participants signed into the website and based on their Experiment ID were randomly assigned to one of eight experimental conditions automatically. The overview of the online experiment is illustrated in Fig. 27. Presentations and the online experiment can be found in following URLs:

- Video 1: The introduction to the case: https://www.youtube.com/watch?v=5Lasve4taGg
- Video 2: Plaintiff's PowerPoint-based presentation: https://www.youtube.com/watch?v=NcAdD72IDTI&t=63s
- Video 3: Plaintiff's FIM-based presentation: https://www.youtube.com/watch?v=1al6rt4nUec
- Video 4: Defendant's PowerPoint-based presentation: https://www.youtube.com/watch?v=gzS4JjYnBxc
- Video 5: Defendant's FIM-based presentation: https://www.youtube.com/watch?v=FC_xsTQR9Hc&t=390s
- Experiment: http://www.surveygizmo.com/s3/4179027/Investigating-the-effectiveness-of-BIM-based-storytelling-models-in-jurors-decision-making-in-the-construction-dispute-resolution-process

5.9. Pilot Testing

The material presented in the above sections are the final versions of the presentations and the questionnaires. Prior to preparing the final versions of the material, the pilot testing was performed to ensure the questions were clear for the participants, the arguments made sense

and seemed real, and the narrations were understandable for undergrad students. In the pilot testing process, 24 Texas A&M students from different majors participated. Six participants including three males and three females were randomly assigned to each treatment, and collected data were analyzed to exercise the analysis method and to make sure that the experiment and the questionnaires were aligned with the research objectives. According to the outcome of the pilot testing, the final sample size was determined, the arguments were revised, the final version of the FIM-based and the PowerPoint presentations were prepared for both argumentative sides, and the questionnaires were finalized. To ensure that the fictitious case looks like an actual case, the videos were reviewed several times by two experts who were among the participants in the face-to-face interviews.

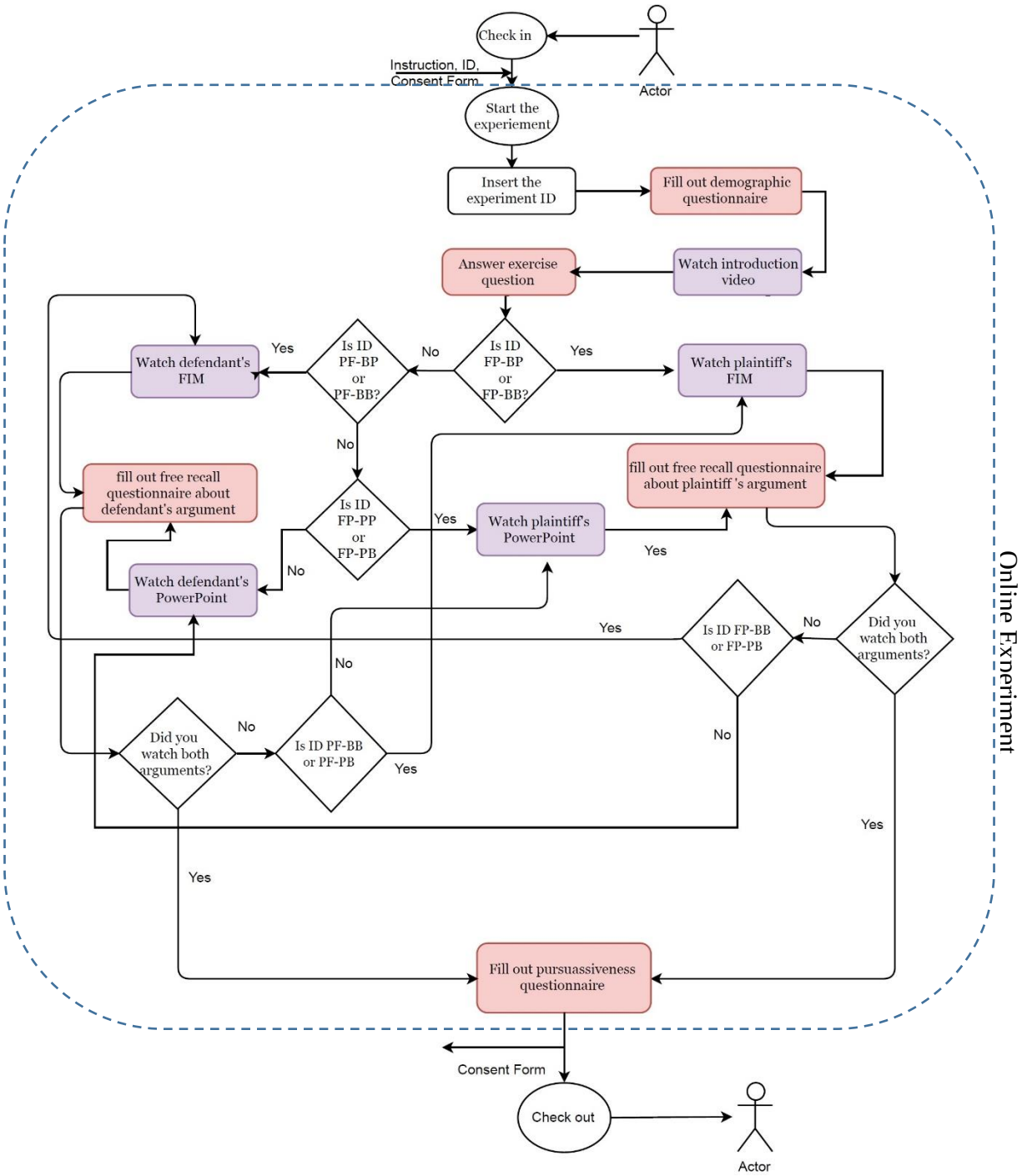


Figure 27. The experiment flow chart

6. EXPERIMENT AND DATA ANALYSIS

6.1. Sample

According to U.S. Code, Title 28, Part V, CH 121, all U.S. citizens shall have the opportunity to be considered for service on grand and petit juries in the district courts of the United States and shall have an obligation to serve as jurors when summoned for that purpose.

To be legally qualified for jury service, an individual must:

- Be a United States citizen
- Be at least 18 years of age
- Reside primarily in the judicial district for one year
- Be adequately proficient in English to satisfactorily complete the juror qualification form
- Have no disqualifying mental or physical condition
- Not currently be subject to felony charges punishable by imprisonment for more than one year, and
- Never have been convicted of a felony (unless civil rights have been legally restored).

Accordingly, for this research 120 graduate or undergraduate U.S. citizen students of Texas A&M (jury-eligible) from all colleges were considered as the sample. Thirty students were randomly assigned to each treatment including:

1. Treatment#1: Plaintiff/PowerPoint vs. Defendant/PowerPoint
2. Treatment#2: Plaintiff/PowerPoint vs. Defendant/ BIM
3. Treatment# 3: Plaintiff/BIM vs. Defendant/PowerPoint
4. Treatment#4: Plaintiff/BIM vs. Defendant/BIM

To recruit participants for the research, Texas A&M bulk email service was used. Five bulk emails during four weeks were sent out to all Texas A&M students on the College Station campus. Overall, 385 students were signed up for the test, and 157 of the respondents participated in the experiment in 10 sessions from February 6, 2018, to March 3, 2018. This experiment had the financial incentive for the participants in the form of "Lucky Draw." The participants in the experiment were qualified for the Lucky Draw, which included one Visa card of $100, two Visa cards of $50, and 15 gift cards of $10 to Starbucks as mentioned in the approved consent form by Institutional Review Board (IRB) at Texas A&M University. The IRB approval letter is attached in the Appendix. This study required almost 40 minutes of participant's time.

6.2. Experiment Logistics

To prepare a fair condition for all participants, the virtual open access labs in Blocker Building, West Campus Library, Student Computer Centers, and Horticulture Department in the east and west campus of Texas A&M University were booked for the test sessions. From the 10 sessions, four were executed at 3:30 to 5:30 p.m. and seven from 10:30 a.m. to 12:30 p.m. All students used lab computers and their own headphones, as can be seen in Fig.28 and Fig. 29.

All participants checked in before the test to be instructed verbally. They also received an instruction sheet to review before the test in addition to two copies of the consent form, one to keep and one to sign and return in compliance with the IRB rules. Additionally, an Experiment ID was given to each participant to assign them to one of eight different test conditions. The ID included two different parts separated by a dashed line. Each part

consisted of two letters: the first two letters represented the argumentative sides, FT or TF in which “T” stands for Texas Builders Construction, the defendant, and “F” for FP Insurance Group, the plaintiff in this construction claim. The next two letters represented the presentation device; BP, PP, PB or BB in which B stands for the BIM-based presentation and P stands for PowerPoint Based Presentation. First letters of the second part of the experiments referred to the first argumentative side in the first section of the ID, for example “FT-PB” indicates that FP Insurance Group is the first presenter and will use PowerPoint and Texas Builders Construction is the second presenter and would use the BIM-based presentation device.

All participants in this study were required to follow the rules listed below:

- They were not allowed to eat or drink during the test.
- They were not allowed to check their cellphone.
- They were requested to watch each video once without going back or forward.
- They had to answer all question.
- They were not allowed to use the subtitle.
- They were not allowed to take a break during the test.

Figure 28. An experiment setting in Student Computer Center Open Access Lab

Figure 29. An experiment setting in Student Computer Center Open Access Lab

6.3. Demographic Information of the experiment

6.3.1. Gender

As shown in Fig. 30, the participants in the experiment were formed of 53 males and 67 females. Fig. 31 depicts the number of participants from each gender in the treatments.

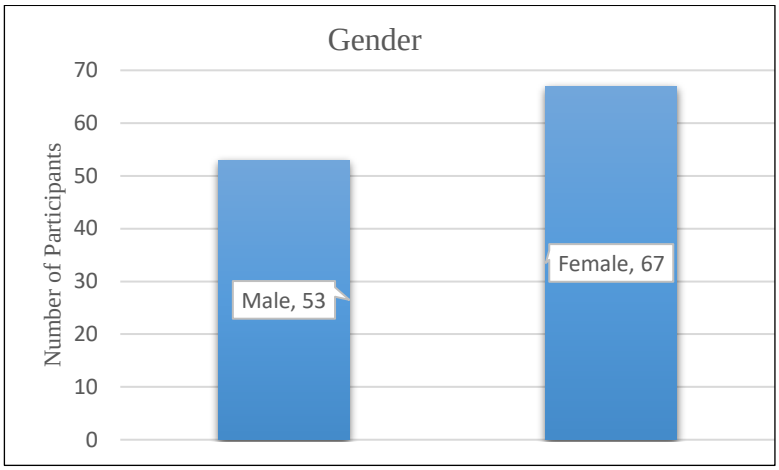


Figure 30. Male and female participants in the experiment

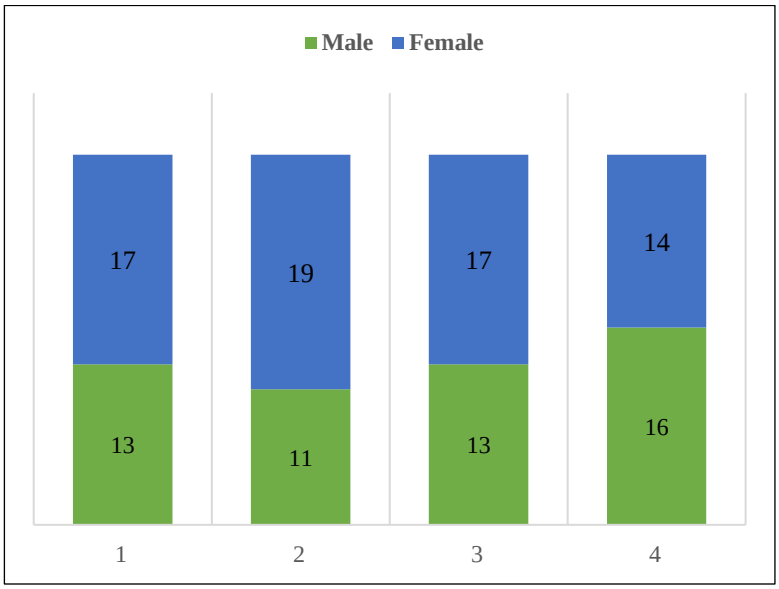


Figure 31. Gender per treatment

6.3.2. Age

Besides U.S. citizenship, the other criteria for being on a jury duty is being 18 or older, so all students participated in the experiment were 18 or above. Fig. 32 presents the distribution of the participants' age groups.

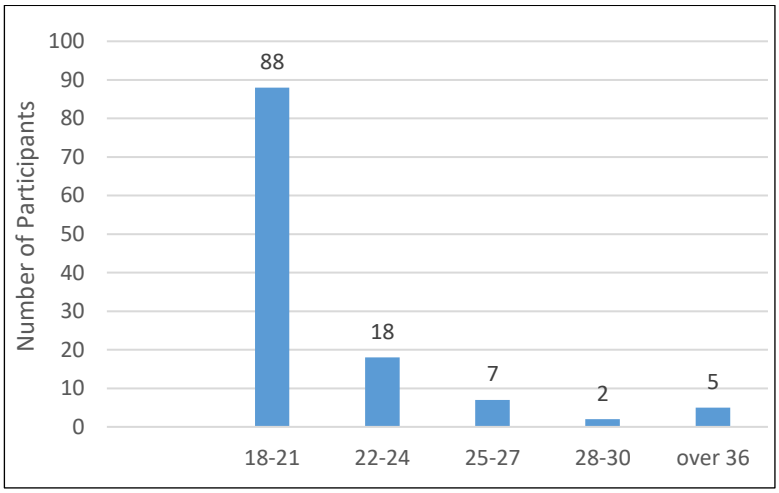


Figure 32. Age group of participants in the experiment

As can be seen in Fig. 32, 106 participants out of 120 are between 18 and 24 and the average age of the participants is 21.5.

6.3.3. Majors

Participants in the experiment were from different majors and schools including Communication, Economics, Finance, Computer Engineering, Computer Science, Biomedical Engineering, Biology, Animal Science, Nuclear Engineering, Mathematics, Physics, Urban & Regional Planning, Biochemistry, Sociology, Construction Science, Entomology, Politic Science, Architecture, Physiology, Law, and Civil Engineering.

Additionally, among all participants, nine had completed an associate degree, six bachelor's, one doctorate, ten high school, nine master's degree, one professional degree, and eighty-

four had some college educational experience. Also, none of the participants had been involved in jury duty prior to the experiment.

6.4. Free Recall

To test the impact of using FIM on participants' (mock jurors) free recall compared to the PowerPoint-based presentation, the participants were asked to answer 12 multiple choice and true/false questions immediately after each presentation. The questions were explicitly discussed in the presentations. The free recall questions are available in Chapter V (see pages 76-83).

Based on the ANOVA analysis, as shown in Fig. 34 and Fig. 35, FIM did not improve participants' working memory compared to PowerPoint, neither in defendant's case nor plaintiff's in 95% confidence interval (α=0.05). Means and standard deviation of the mistakes (wrong answers) are presented in Table 1 and the total number of the incorrect answers are shown in Fig. 33.

Table 1. Means and standard deviation of mistakes (M (SD))

	Plaintiff		**Defendant**	
	FIM	PPT*	FIM	PPT*
Mistakes	3.97 (2.52)	4.28 (1.95)	3.10 (1.32)	3.27(1.64)

* PowerPoint

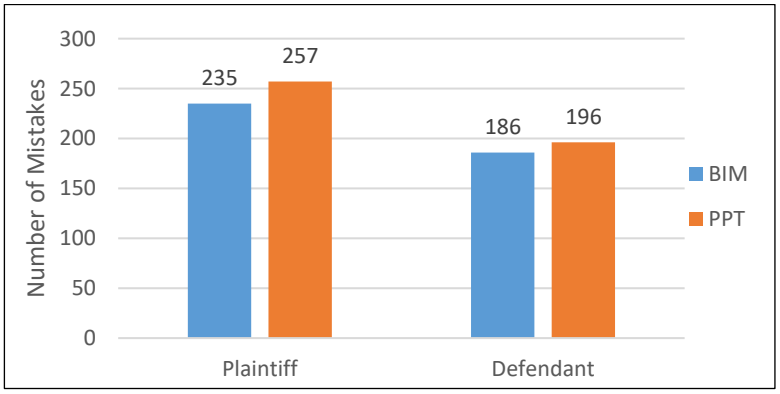


Figure 33. Mistakes made by participants in each condition

However, regardless of the presentation device and according to the ANOVA analysis that is presented in Fig. 36, participants had significantly better performance in remembering the defendant's argument (M=8.20), compared to the plaintiff (M=8.37), F (1, 118) =14.17, p=0.0003.

Oneway Anova

Summary of Fit

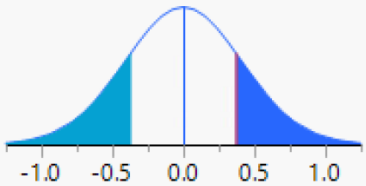
Rsquare	0.006691
Adj Rsquare	-0.00173
Root Mean Square Error	2.252619
Mean of Response	4.1
Observations (or Sum Wgts)	120

t Test

PPT-BIM

Assuming equal variances

Difference	0.3667	t Ratio	0.891547
Std Err Dif	0.4113	DF	118
Upper CL Dif	1.1811	Prob > |t|	0.3745
Lower CL Dif	-0.4478	Prob > t	0.1872
Confidence	0.95	Prob < t	0.8128



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	4.03333	4.03333	0.7949	0.3745
Error	118	598.76667	5.07429		
C. Total	119	602.80000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	3.91667	0.29081	3.3408	4.4926
PPT	60	4.28333	0.29081	3.7074	4.8592

Std Error uses a pooled estimate of error variance

Figure 34. Comparison of means of free recall from plaintiff's story- BIM vs PPT

Oneway Anova

Summary of Fit

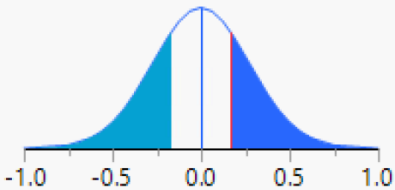
Rsquare	0.003157
Adj Rsquare	-0.00529
Root Mean Square Error	1.4933
Mean of Response	3.183333
Observations (or Sum Wgts)	120

t Test

PPT-BIM

Assuming equal variances

Difference	0.16667	t Ratio	0.611311
Std Err Dif	0.27264	DF	118
Upper CL Dif	0.70656	Prob > |t|	0.5422
Lower CL Dif	-0.37323	Prob > t	0.2711
Confidence	0.95	Prob < t	0.7289



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	0.83333	0.83333	0.3737	0.5422
Error	118	263.13333	2.22994		
C. Total	119	263.96667			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	3.10000	0.19278	2.7182	3.4818
PPT	60	3.26667	0.19278	2.8849	3.6484

Std Error uses a pooled estimate of error variance

Figure 35. Comparison of means of free recall from defendant's story- BIM vs. PPT

Summary of Fit

RSquare	0.107228
RSquare Adj	0.099662
Root Mean Square Error	2.667337
Mean of Response	7.283333
Observations (or Sum Wgts)	120

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	100.83333	100.833	14.1726
Error	118	839.53333	7.115	Prob > F
C. Total	119	940.36667		0.0003*

Figure 36. Comparison of means of free recall from plaintiff's story vs. defendant

6.5. Comprehension

6.5.1. Plaintiff BIM vs. Plaintiff PowerPoint

To investigate whether manipulation of the presentation device would affect the participants' comprehension (sub-hypothesis 2), the participants were asked to self-report the ease of understanding of each arguments on the five-point Likert scale.

Fig. 37 presents the distribution of the scores for ease of understanding based on the participants' self-report for FP Insurance Group's different presentation methods. The higher score represents the better understanding (5= very easy, 1=very difficult). According to the analysis results, the understanding of the plaintiff's argument significantly increased when it used FIM (M=3.32) compared to PowerPoint slides (M=2.88), as can be seen in Fig. 38, F (1,118) =4.284, p=.041.

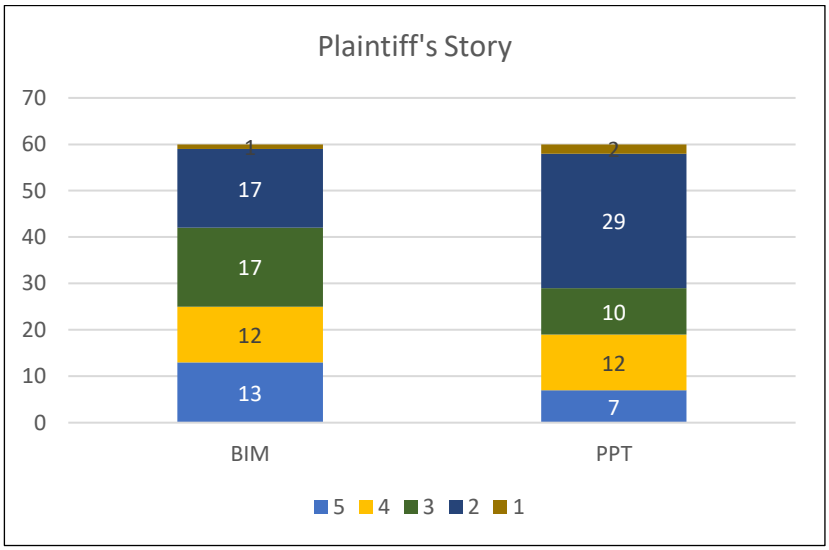


Figure 37. Comprehending the plaintiff's story-distribution of scales

Oneway Anova

Summary of Fit

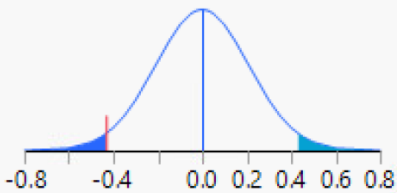
Rsquare	0.035033
Adj Rsquare	0.026855
Root Mean Square Error	1.146722
Mean of Response	3.1
Observations (or Sum Wgts)	120

t Test

PowerPoint-BIM

Assuming equal variances

Difference	-0.43333	t Ratio	-2.06978
Std Err Dif	0.20936	DF	118
Upper CL Dif	-0.01874	Prob > |t|	0.0407*
Lower CL Dif	-0.84793	Prob > t	0.9797
Confidence	0.95	Prob < t	0.0203*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	5.63333	5.63333	4.2840	0.0407*
Error	118	155.16667	1.31497		
C. Total	119	160.80000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	3.31667	0.14804	3.0235	3.6098
PowerPoint	60	2.88333	0.14804	2.5902	3.1765

Std Error uses a pooled estimate of error variance

Figure 38. ANOVA analysis - comprehending the plaintiff's story (FIM vs PPT)

6.5.2. Defendant BIM vs. Defendant PowerPoint

Likewise, to investigate the impact of different presentation tools on participants' comprehension of the defendant's presentation, participants were asked to self-report their understanding of each presentation on the five-point Likert scale. Fig. 39 presents the distribution of the scores according to the participants report for different tools that the Texas Builders Construction as the defendant used to present its argument. According to the analysis, as shown in Fig. 40, unlike the plaintiff' case, using FIM did not assist participants to have better comprehension of the defendant's argument compared to PowerPoint.

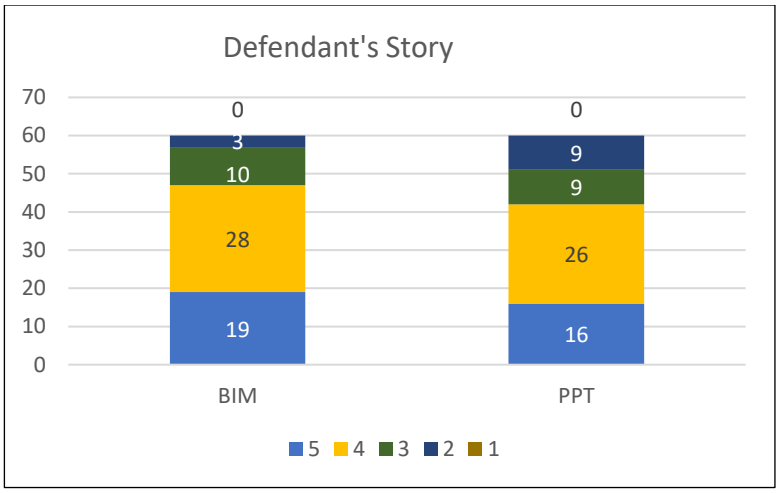


Figure 39. Comprehending the defendant's story- distribution of scales

Oneway Anova

Summary of Fit

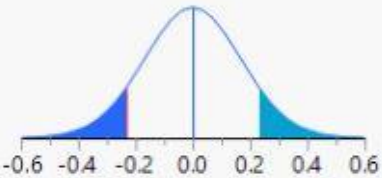
Rsquare	0.016097
Adj Rsquare	0.007759
Root Mean Square Error	0.919807
Mean of Response	3.933333
Observations (or Sum Wgts)	120

t Test

PowerPoint-BIM

Assuming equal variances

Difference	-0.23333	t Ratio	-1.38944
Std Err Dif	0.16793	DF	118
Upper CL Dif	0.09922	Prob > |t|	0.1673
Lower CL Dif	-0.56589	Prob > t	0.9163
Confidence	0.95	Prob < t	0.0837



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	1.63333	1.63333	1.9306	0.1673
Error	118	99.83333	0.84605		
C. Total	119	101.46667			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	4.05000	0.11875	3.8148	4.2852
PowerPoint	60	3.81667	0.11875	3.5815	4.0518

Std Error uses a pooled estimate of error variance

Figure 40. ANOVA analysis – Comprehending the defendant's story (FIM vs PPT)

6.5.3. Defendant vs. Plaintiff

According to the statistical analysis, regardless of the presentation tool, participants reported that they had significantly better understanding of the defendants' story (M=3.93) than the plaintiff's (Mean=3.06) in 95% confidence interval, F (1, 238) =43.034, p<.0001, as can be seen in Fig. 42. In Fig. 41 the distribution of the scales is also presented.

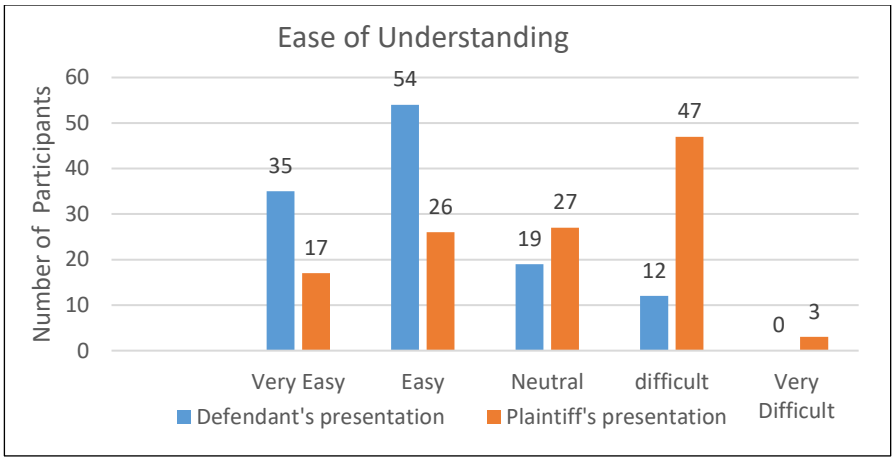


Figure 41. Participants' comprehending of the each side-distribution of scales

Summary of Fit

RSquare	0.153127
RSquare Adj	0.149569
Root Mean Square Error	1.033185
Mean of Response	3.495833
Observations (or Sum Wgts)	240

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	45.93750	45.9375	43.0339
Error	238	254.05833	1.0675	Prob > F
C. Total	239	299.99583		<.0001*

Figure 42. ANOVA analysis of participants' comprehending - plaintiff vs. defendant

Means and standard deviations of the scales in each treatment are presented in Table 2 for further understanding the analysis.

Table 2. Means and standard deviations of the ease of understanding (M (SD))

	Pl. PPT		Pl. FIM		Def. PPT		Def. FIM	
	Def. PPT	Def. FIM	Def. PPT	Def. FIM	Pl. PPT	Pl. FIM	Pl. PPT	Pl. FIM
Comprehension of Plaintiff	2.73 (1.048)	3.00 (.999)	3.50 (1.163)	3.03 (1.217)				
Comprehension of Defendant					3.90 (.995)	3.73 (1.015)	4.27 (.828)	3.83 (.791)

6.6. Measure of Agreement (Supporting Verdict)

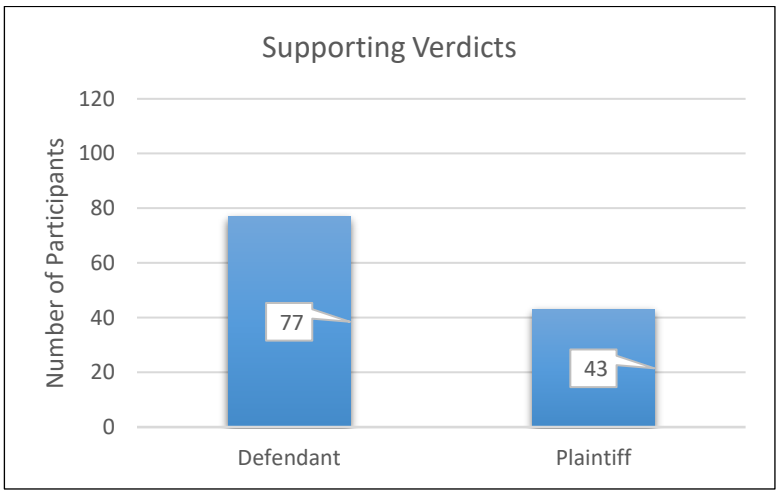


Figure 43. Distribution of supporting verdicts

To compare the persuasiveness effect of the presentation tools (sub-hypothesis 3), participants deliberated their verdict in favor of a party and self-reported their confidence in their judgment. As shown in Fig.43, 63% of the participants (77/120) rendered their verdict in favor of the defendants and 37% of the participants (43/120) supported the plaintiff in this fictitious trial. In other words, the outcome of the trial was skewed in favor of the defendant (63% vs 37%). In Fig. 44, the examination of the verdicts by condition in favor of the plaintiff is shown.

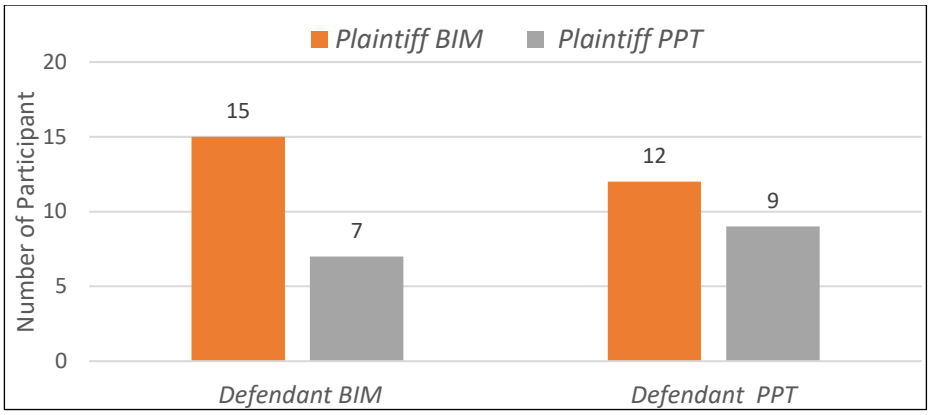
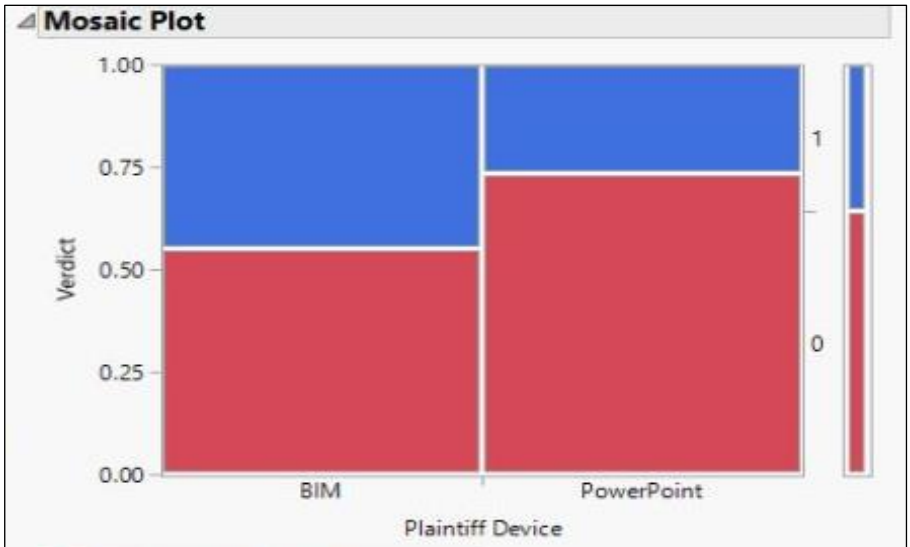


Figure 44. Verdicts in favor of the plaintiff in each condition

Regardless of the presentation device of the opposing side, the plaintiff gets 16 supporting verdicts when using PowerPoint versus 27 votes when using FIM. In the other words, using FIM leads to 68 percent growth in supporting verdicts for the plaintiff. According to the independence analysis as shown in Fig. 45, FIM has a significant impact on persuading the participants to support the FP Insurance in the case in 95% confidence interval (α=0.05), $\chi 2$ (1) =4.422, p=.035. Specifically, when defendant is using FIM, the plaintiff FIM increases the proportion of the supporting verdicts for the plaintiff from 23% (7/30) to 50% (15/30) of the total verdicts, $\chi 2$ (1) =4.674, p=.031.

A similar analysis was performed to investigate the effectiveness of FIM in the supporting verdicts that the Texas Builders Construction received from the participants in the experiment. The number of supporting verdicts for the defendant in each condition is shown in Fig. 46.

According to the independence analysis as shown in Fig. 47, the defendant's FIM does not make any significant difference in proportion of the supporting verdicts $\chi 2(1)$=.036, p=.849 when the confidence level is 95%.



Contingency Table

Plaintiff Device	Verdict	0	1	Total
	Count			
	Total %			
	Col %			
	Row %			
BIM		33	27	60
		27.50	22.50	50.00
		42.86	62.79	
		55.00	45.00	
PowerPoint		44	16	60
		36.67	13.33	50.00
		57.14	37.21	
		73.33	26.67	
Total		77	43	120
		64.17	35.83	

Tests

N	DF	-LogLike	RSquare (U)
120	1	2.2111476	0.0282

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	4.422	0.0355*
Pearson	4.385	0.0362*

Figure 45. Independence analysis for the verdicts supporting the plaintiff

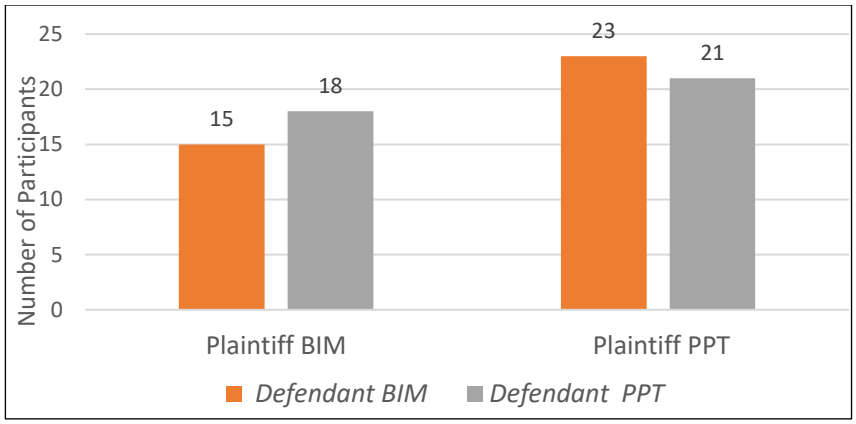
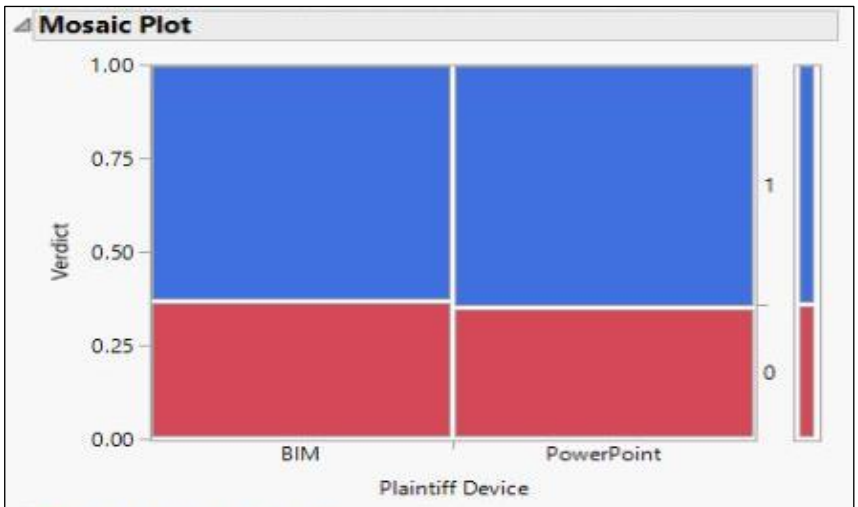


Figure 46. Verdicts in favor of the defendant in each condition



Contingency Table

Plaintiff Device	Verdict 0	Verdict 1	Total
Count			
Total %			
Col %			
Row %			
BIM	22	38	60
	18.33	31.67	50.00
	51.16	49.35	
	36.67	63.33	
PowerPoint	21	39	60
	17.50	32.50	50.00
	48.84	50.65	
	35.00	65.00	
Total	43	77	120
	35.83	64.17	

Tests

N	DF	-LogLike	RSquare (U)
120	1	0.01812264	0.0002

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	0.036	0.8490
Pearson	0.036	0.8490

Figure 47. Independence analysis for the verdicts supporting the defendant

6.7. Comparison of Confidence

To test the influence of different presentation methods on the participants' confidence in their supporting verdicts (sub-hypothesis 4), the participants were requested to report their confidence on the five-point Likert scale.

The higher score implies the higher level of confidence (1= not confident al all, 5= very confident). The distributions of the reported scores by the presentation tools are shown in Fig. 48 and Fig. 49.

The analysis results indicated that using FIM did not have any significant impact on participants' confidence when they supported plaintiff compared to PowerPoint presentation.

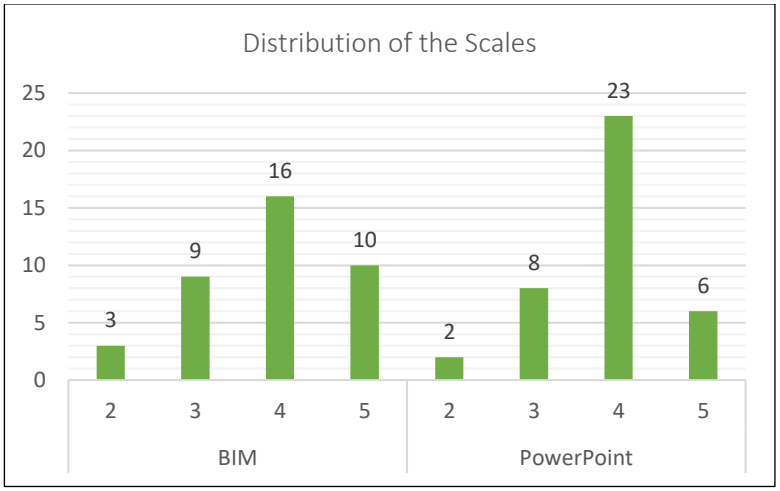


Figure 48. Participants' confidence scales in supporting the defendant

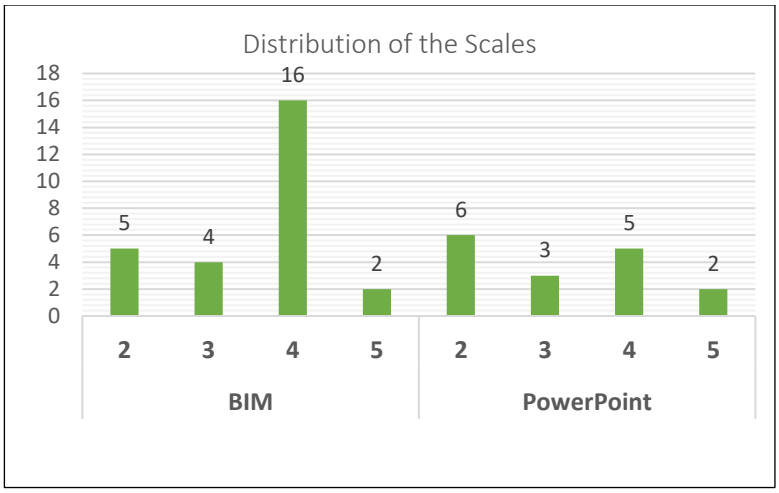


Figure 49. Participants' confidence scales in supporting the plaintiff

Also, the manipulation of the presentation device did not have any impact on the participants' confidence in their verdicts for the defendant either. The analysis results are presented in Fig. 50 and Fig. 51. Means and standard deviations of the confidence levels reported by the participants in each condition are presented in Table 3 in further detail.

Table 3. Means and standard deviations of confidence in the supporting verdicts

	Plaintiff_ FIM		Plaintiff _PPT	
	Defendant FIM	Defendant PPT	Defendant FIM	Defendant PPT
Plaintiff	3.60 (.91)	3.40 (.90)	3.28 (1.11)	3.11 (1.17)
Defendant	4.07 (.87)	3.72 (.89)	3.74(.91)	3.95 (.59)

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
BIM	27	3.55556	0.89156	0.17158	3.2029	3.9082
PPT	16	3.00000	1.03280	0.25820	2.4497	3.5503

t Test

PPT-BIM

Assuming unequal variances

Difference	-0.5556	t Ratio	-1.79206
Std Err Dif	0.3100	DF	28.02054
Upper CL Dif	0.0795	Prob > |t|	0.0839
Lower CL Dif	-1.1906	Prob > t	0.9580
Confidence	0.95	Prob < t	0.0420*

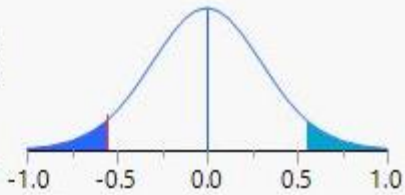


Figure 50. T test comparison of participant's confidence in supporting the plaintiff

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
BIM	38	3.86842	0.905570	0.14690	3.5708	4.1661
PPT	39	3.84615	0.744752	0.11926	3.6047	4.0876

t Test

PPT-BIM

Assuming unequal variances

Difference	-0.02227	t Ratio	-0.11768
Std Err Dif	0.18922	DF	71.57103
Upper CL Dif	0.35497	Prob > |t|	0.9066
Lower CL Dif	-0.39950	Prob > t	0.5467
Confidence	0.95	Prob < t	0.4533

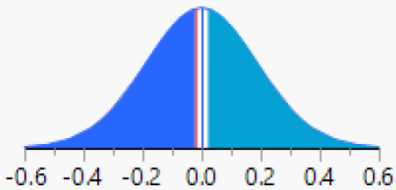


Figure 51. T test comparison of participant's confidence in supporting the defendant

Although different presentation devices did not affect the confidence level, according to the analysis, the participants were significantly more confident in supporting the defendant (M=3.86), F (1,118) =5.260, p=.024, compared to the plaintiff (M=3.49) regardless of the presentation tools. The result analysis are shown in Fig. 52 and Fig. 53.

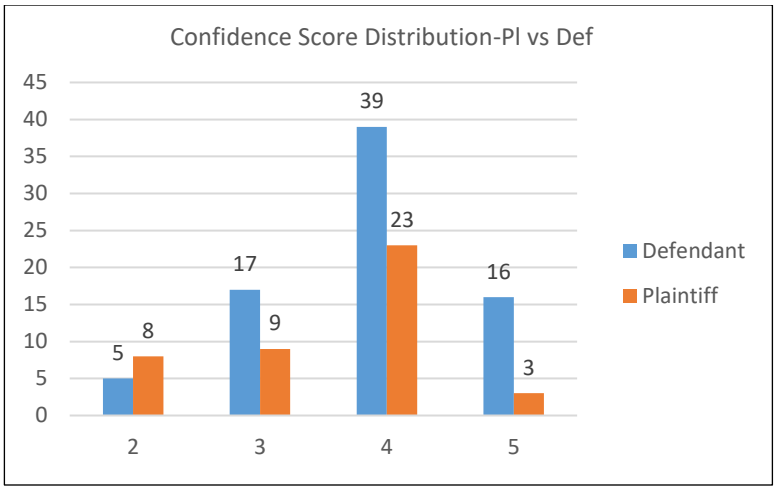


Figure 52. Confidence score distribution, defendant vs. plaintiff

Oneway Anova

Summary of Fit

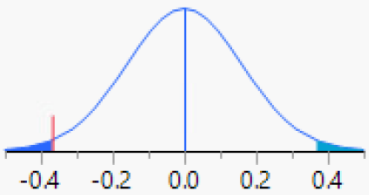
Rsquare	0.042675
Adj Rsquare	0.034563
Root Mean Square Error	0.844588
Mean of Response	3.725
Observations (or Sum Wgts)	120

t Test

Plaintiff-Defendant

Assuming equal variances

Difference	-0.36877	t Ratio	-2.29351
Std Err Dif	0.16079	DF	118
Upper CL Dif	-0.05037	Prob > |t|	0.0236*
Lower CL Dif	-0.68718	Prob > t	0.9882
Confidence	0.95	Prob < t	0.0118*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Argu. Side	1	3.752243	3.75224	5.2602	0.0236*
Error	118	84.172757	0.71333		
C. Total	119	87.925000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Defendant	77	3.85714	0.09625	3.6665	4.0477
Plaintiff	43	3.48837	0.12880	3.2333	3.7434

Std Error uses a pooled estimate of error variance

Figure 53. ANOVA analysis of participant's confidence in supporting the sides

6.8. Ease of Visualization

According to the vividness studies, ease of visualizing implies better perception leading to persuasion as mentioned in sub-hypothesis 5. To test this sub-hypothesis, participants were requested to rate how easy they found the following items to visualize on a five-point scale, with low scores indicating the item was difficult to visualize and high scores indicating the item was easy to visualize:

- The sequence of events in plaintiff's story
- The sequence of events in defendant's story
- Footings settlement as a specific event in the plaintiff's argument
- Firefighters' access to the storage room as a specific event in the defendant's argument

According to the analysis result, using FIM significantly facilitated visualizing the plaintiff's case for participants (M=3.58) compared to the PowerPoint presentation (M=3.05) in 95 percent confidence interval, F (1,118) =5.943, p=.0163. However, the analysis failed to prove that FIM made it easier for the participants to visualize the footings settlement. Distribution of the scales reported by the participants and the analysis results are presented in Fig. 54 to Fig. 57.

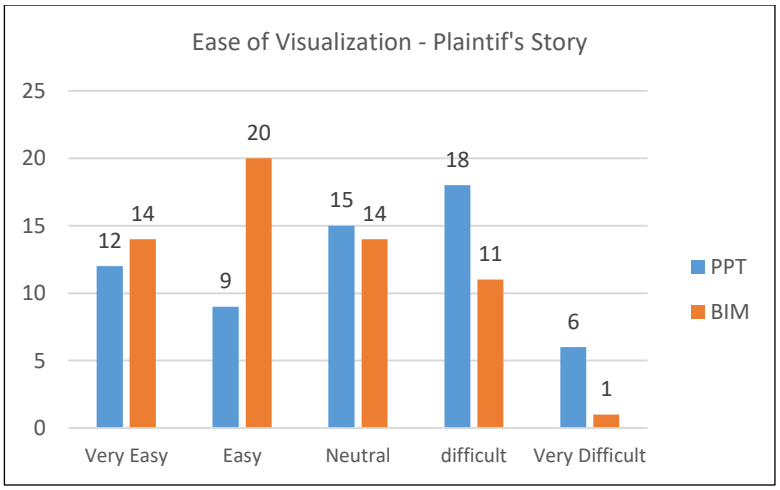


Figure 54. Ease of visualizing the plaintiff's story-distribution of scales

Oneway Anova

Summary of Fit

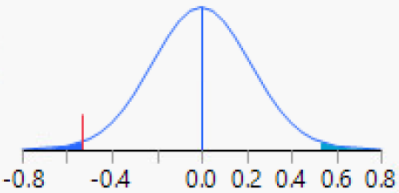
Rsquare	0.047949
Adj Rsquare	0.039881
Root Mean Square Error	1.19828
Mean of Response	3.316667
Observations (or Sum Wgts)	120

t Test

PowerPoint-BIM

Assuming equal variances

Difference	-0.53333	t Ratio	-2.43782
Std Err Dif	0.21878	DF	118
Upper CL Dif	-0.10010	Prob > |t|	0.0163*
Lower CL Dif	-0.96657	Prob > t	0.9919
Confidence	0.95	Prob < t	0.0081*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	8.53333	8.53333	5.9429	0.0163*
Error	118	169.43333	1.43588		
C. Total	119	177.96667			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	3.58333	0.15470	3.2770	3.8897
PowerPoint	60	3.05000	0.15470	2.7437	3.3563

Std Error uses a pooled estimate of error variance

Figure 55. Ease of visualizing the plaintiff's story-ANOVA analysis

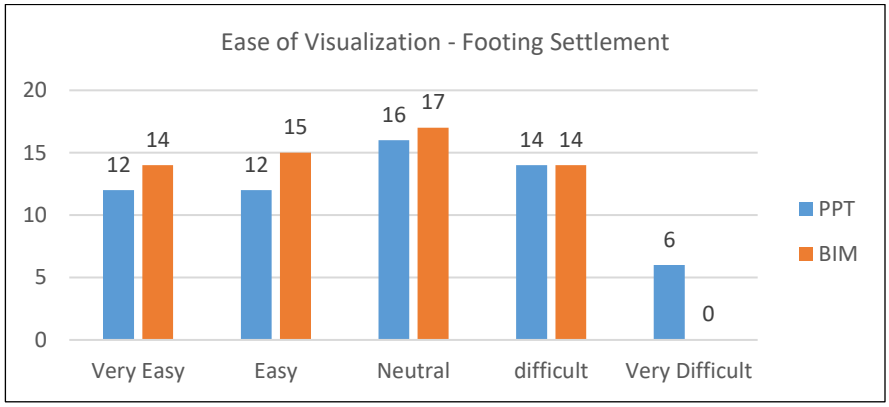


Figure 56. Ease of visualizing the footings settlement-distribution of scales

Oneway Anova

Summary of Fit

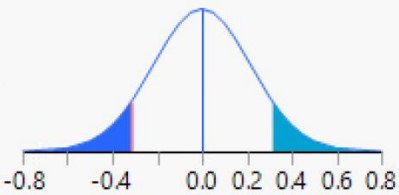
Rsquare	0.017662
Adj Rsquare	0.009337
Root Mean Square Error	1.190772
Mean of Response	3.325
Observations (or Sum Wgts)	120

t Test

PowerPoint-BIM

Assuming equal variances

Difference	-0.31667	t Ratio	-1.45658
Std Err Dif	0.21740	DF	118
Upper CL Dif	0.11385	Prob > |t|	0.1479
Lower CL Dif	-0.74719	Prob > t	0.9261
Confidence	0.95	Prob < t	0.0739



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	3.00833	3.00833	2.1216	0.1479
Error	118	167.31667	1.41794		
C. Total	119	170.32500			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	3.48333	0.15373	3.1789	3.7878
PowerPoint	60	3.16667	0.15373	2.8622	3.4711

Std Error uses a pooled estimate of error variance

Figure 57. Ease of visualizing the footings settlement-ANOVA analysis

Unlike the plaintiff's case, the analysis result did not indicate any significant improvement in ease of visualizing the defendant's story and the firefighter's access to the storage room as an important event in Texas Builders' argument. The distribution of the scales reported by the participants and the analysis results are shown in Fig. 58 to Fig. 61. Additionally, comparing the reported scales for ease of visualizing the defendant's story with the plaintiff indicated that the participants were more comfortable with visualizing the defendant's story, F (1, 238) =27.00, p<.0001. The analysis results can be seen in Fig. 62 and Fig. 63.

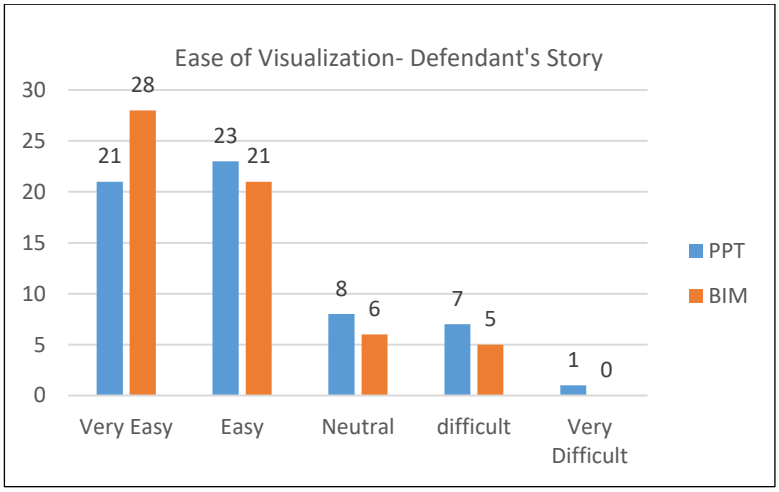


Figure 58. Ease of visualizing the defendant's story-distribution of scale

Oneway Anova

Summary of Fit

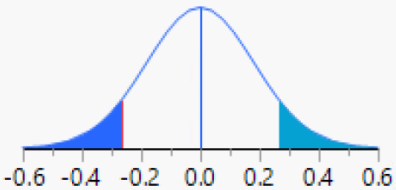
Rsquare	0.017857
Adj Rsquare	0.009534
Root Mean Square Error	0.997171
Mean of Response	4.066667
Observations (or Sum Wgts)	120

t Test

PowerPoint-BIM

Assuming equal variances

Difference	-0.26667	t Ratio	-1.46474
Std Err Dif	0.18206	DF	118
Upper CL Dif	0.09386	Prob > |t|	0.1457
Lower CL Dif	-0.62719	Prob > t	0.9272
Confidence	0.95	Prob < t	0.0728



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device 2	1	2.13333	2.13333	2.1455	0.1457
Error	118	117.33333	0.99435		
C. Total	119	119.46667			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	4.20000	0.12873	3.9451	4.4549
PowerPoint	60	3.93333	0.12873	3.6784	4.1883

Std Error uses a pooled estimate of error variance

Figure 59. Ease of visualizing the defendant's story- ANOVA analysis

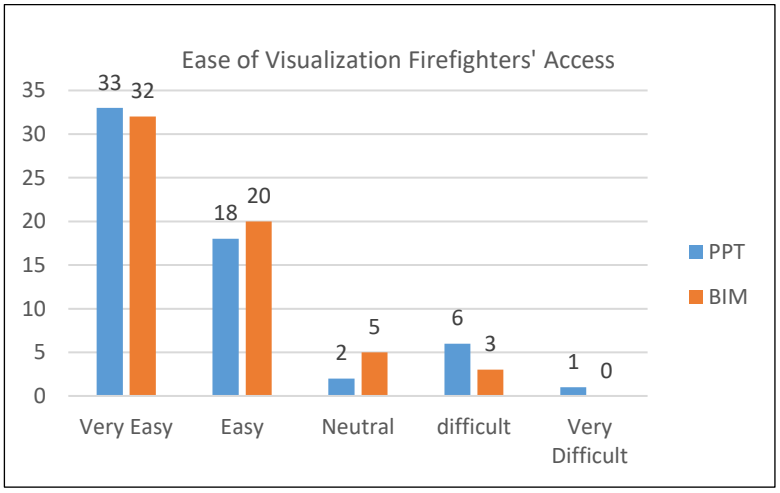


Figure 60. Ease of visualizing the firefighter's access to storage-distribution of scale

Oneway Anova

Summary of Fit

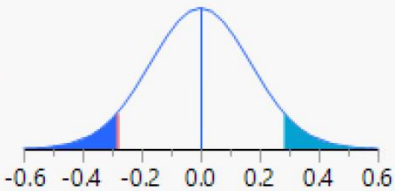
Rsquare	0.022808
Adj Rsquare	0.014527
Root Mean Square Error	0.935112
Mean of Response	4.308333
Observations (or Sum Wgts)	120

t Test

PowerPoint-BIM

Assuming equal variances

Difference	-0.28333	t Ratio	-1.65957
Std Err Dif	0.17073	DF	118
Upper CL Dif	0.05475	Prob > |t|	0.0997
Lower CL Dif	-0.62142	Prob > t	0.9502
Confidence	0.95	Prob < t	0.0498*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Device	1	2.40833	2.40833	2.7542	0.0997
Error	118	103.18333	0.87444		
C. Total	119	105.59167			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
BIM	60	4.45000	0.12072	4.2109	4.6891
PowerPoint	60	4.16667	0.12072	3.9276	4.4057

Std Error uses a pooled estimate of error variance

Figure 61. Ease of visualizing the firefighters' access to storage-ANOVA analysis

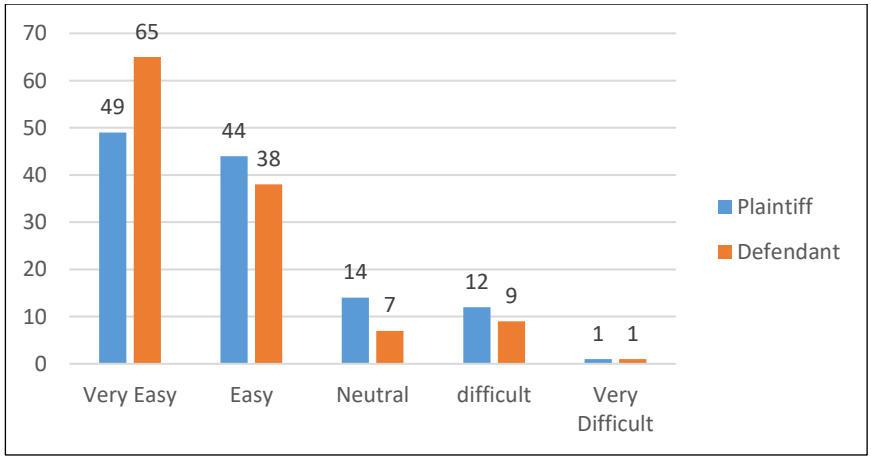


Figure 62. Ease of visualizing the plaintiff's and the defendant's story

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Argu. Side	1	33.75000	33.7500	27.0061	<.0001*
Error	238	297.43333	1.2497		
C. Total	239	331.18333			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Defendant	120	4.06667	0.10205	3.8656	4.2677
Paintiff	120	3.31667	0.10205	3.1156	3.5177

Std Error uses a pooled estimate of error variance

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Defendant	120	4.06667	1.00196	0.09147	3.8856	4.2478
Paintiff	120	3.31667	1.22291	0.11164	3.0956	3.5377

Figure 63. Visualizing the defendant and the plaintiff's story-ANOVA analysis

6.9. Importance of the Testifying Items

As a post-presentation question, the participants were asked to report the importance of the presentation device and the argument in their judgment making on the five-point Likert scale from not important at all (equals 1) to absolutely essential (equals 5). According to the analysis results and considering the different experimental conditions, the importance of the argument (M=4.53) was significantly higher than the importance of the presentation tools (M=3.87), F (1, 238) =38.926, p<.0001, that the argumentative sides used to support their narrations. Consolidation of the data can be seen in Fig. 64 and the analysis result is presented in Fig. 65. Means and standard deviations of these items by treatment are presented in Table 4.

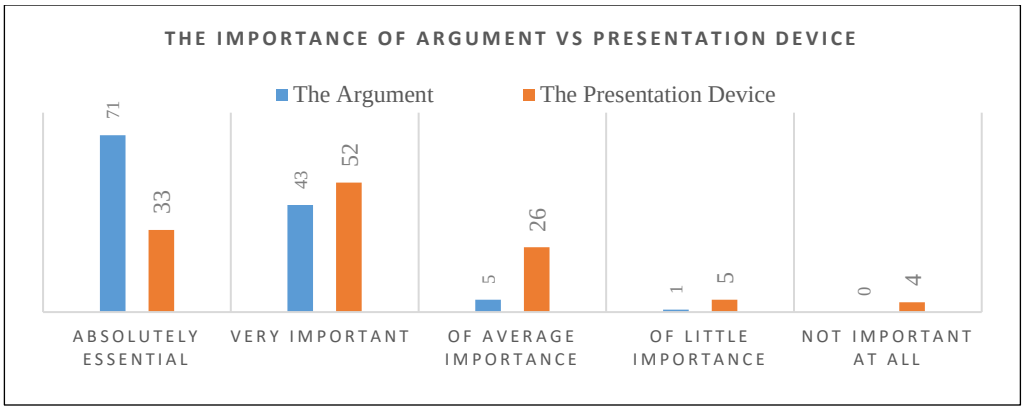


Figure 64. The importance of argument vs presentation device

Oneway Anova

Summary of Fit

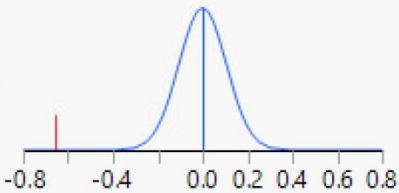
Rsquare	0.140566
Adj Rsquare	0.136955
Root Mean Square Error	0.817332
Mean of Response	4.204167
Observations (or Sum Wgts)	240

t Test

Presentation Tool-Argument

Assuming equal variances

Difference	-0.65833	t Ratio	-6.23911
Std Err Dif	0.10552	DF	238
Upper CL Dif	-0.45047	Prob > |t|	<.0001*
Lower CL Dif	-0.86620	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001*



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Item	1	26.00417	26.0042	38.9265	<.0001*
Error	238	158.99167	0.6680		
C. Total	239	184.99583			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Argument	120	4.53333	0.07461	4.3863	4.6803
Presentation Tool	120	3.87500	0.07461	3.7280	4.0220

Std Error uses a pooled estimate of error variance

Figure 65. ANOVA analysis of importance of testifying items

Table 4. Means and standard deviations of the importance of testifying items

	Plaintiff _FIM		Plaintiff _PPT	
	Defendant _FIM	Defendant _ PPT	Defendant _FIM	Defendant _ PPT
Argument	4.5 (.568)	4.5 (.682)	4.5 (.630)	4.57 (.626)
Presentation Device	3.9(.884)	3.77 (.858)	4.1 (.803)	3.83 (1.085)

6.10. Summary of the Analysis

The analysis results did not show a significant improvement in subjects' memory of the arguments when the presenters used FIM versus PowerPoint neither for the plaintiff nor the defendant. However, according to the analysis results, participants had better performance in remembering the defendant's case regardless of their presentation device compared to the plaintiff's story.

The participants self-reported their understanding of the arguments on a five-point Likert scale (1=very difficult, 5= very easy). According to the analysis results, when the plaintiff used FIM to present its argument, the level of comprehension reported by the participants was significantly higher. However, using FIM did not have any significant impact on the subjects' comprehension of defendant's story. Also, according to the statistical analysis, the participants had a better understanding of the defendants' argument regardless of the presentation device compared to the plaintiff.

To measure the agreement, participants rendered their verdict in favor of an argumentative side. In total, 37% of the participants supported the plaintiff, and 63% supported the defendant. According to the analysis results, using FIM significantly increased the proportion of the plaintiff's votes compared to the PowerPoint presentation. However, using

FIM did not have any significant impact on increasing the proportion of supporting verdicts for the defendant.

To evaluate the level of confidence in the supporting verdicts, the participants reported their confidence using the five-point Likert scale. According to the analysis, there is no significant difference between the participants' average confidence for those who watched FIM-based presentation or PowerPoint. Since this fictitious trial was skewed in favor of the defendant, the size of the sample for testing the sub-hypothesis 4 does not seem specifically enough for the plaintiff case.

To examine the vividness of FIM, the participants were required to self-report the ease of visualization of the arguments presented by each argumentative side and one specific event in each story. According to the analysis results, visualizing the plaintiff's argument was significantly easier. However, using FIM did not increase the importance of the access issue and footing settlement in participants' judgment compared to PowerPoint (Pennington & Hastie, 1998).

In the defendants' case, FIM did not enhance visualizing the defendant's case compared to PowerPoint.

To examine the importance of the testifying elements in mock jurors' decision making, participants were asked to rate the importance of arguments and the presentation tool in their judgment using the five-point Likert scale. According to the analysis results, arguments were more important than the presentation tools in all conditions whether the presentation tools were different or the same. Excluding the sub-hypothesis 4, the outcome of the analysis is summarized in Table 5.

Table 5. Summary of the analysis

Sub-hypothesis	**Defendant**	**Plaintiff**
Sub-H_1	F= 0.378 P=0.54, α= 0.05 H_1 was not supported	F=0.795 P=0.37, α= 0.05 H_1 was not supported
Sub-H_2	F= 1.931 P=0.167, α= 0.05 H_2 was not supported	F= 4.284 P=0.041, α= 0.05 H_2 supported
Sub-H_3	χ^2= 0.036 P=0.849,α= 0.05 H_3 was not supported	χ^2= 4.422 P=0.035, α= 0.05 H_3 supported
Sub-H_4	t= -0.118 P=0.907,α= 0.05 H_4 was not supported	t= -1.792 P=0.083,α= 0.05 H_4 was not supported
Sub-H_5	F= 2.145 P=0.148, α= 0.05 H_5 was not supported	F= 5.943 P=0.016, α= 0.05 H_5 supported

7. CONCLUSION

7.1. Conclusion

Reported by the participants in this experimental study, they had a better comprehension of the defendant's story and were more comfortable with visualizing the defendant's case regardless of the presentation tools. They voted for the defendant and were more confident in their verdicts for the defendant, which aligns with the story model theory of jurors' decision making. The impact of BIM-based storytelling model or Forensic Information Model, however, is not the same for different parties according to the results. In other words, when it comes to the impact of FIM as opposed to the PowerPoint-based presentation, according to the analysis, using FIM does not make a significant difference for a defendant, whereas it helps the plaintiff to communicate their argument vividly and understandably with the mock jurors compared to the PowerPoint-base presentation.

As can be seen in Table 5 (see page 118), three sub-hypotheses out of five were supported in the plaintiff's case. The supported sub-hypotheses included sub-hypothesis 2 (impact of using FIM on participants' comprehension), sub-hypothesis 3 (impact of using FIM on participants' agreement) and sub-hypothesis 5 (impact of using FIM on participants 'ability to visualize the arguments), whereas in the defendant's case none of the sub-hypotheses were proved.

Perhaps the causes of these conflicted outcomes are rooted in the difference between the defendant's and the plaintiff's arguments. The contents of the defendant's argument were mostly nontechnical and non-engineering, whereas the plaintiff's arguments were more focused on communicating the engineering concepts and chain of causalities between

various failures inside the pump station. As mentioned above, the participants who were mostly undergraduate students reported a better understanding of the defendant's case according to the analysis and their comments, but had difficulty in digesting the engineering analysis explained in plaintiff's story. Therefore, it seems that BIM-based storytelling presentation was not more effective than the PowerPoint-based presentation in communicating the concepts close to peoples' experience and background even though it was dynamic and included three-dimensional representations of the building's geometry and facilities. On the other hand, using Forensic Information Modeling to communicate technical concepts with nontechnical people who did not have any knowledge about the concepts was effective and helped the argumentative side (plaintiff) to look more persuasive before the mock jurors. The experiment conducted by Dunn et al. (2006) had a similar outcome when the researchers investigated the persuasiveness of computer animation compared to diagrams in a car accident and a plane crash. According to Dunn et al. (2006), computer animation in the plane crash was persuasive for jurors, but in the car accident, the animation did not affect the verdicts. They used the word "familiarity" to explain this phenomenon.

Although FIM (BIM-based storytelling model) did not enhance the persuasiveness of the defendant's argument in comparison with using CAD drawings on PowerPoint slides, according to the analysis outcome it also did not impose a bad cognitive load on working memory of the participants. The modern presentation tools have the potential to negatively affect the learning process due to the bad cognitive load caused by their complexity for audiences.

7.2. Limitations

The age of the participants was not normally distributed in this study, and they were all college students familiar with computer games. The age difference and people's familiarity with computer games and 3D applications can affect the results in more realistic situations due to the jurors' different attention span and their different backgrounds.

The other variables that may change the outcome of an actual trial and that were not investigated in this research include presenters' characteristics such as gender and narration style and the length of the presentations. These factors were considered as the fixed factors in this experiment. However, they play a critical role in real cases.

In this experimental research, FIM was compared with PowerPoint in which the CAD drawings were used for presenting the building geometry and facilities in a fire incident. Any variations in these elements may result in different outcomes. Therefore, the result of this study cannot be generalized for other formats of information provided. Also, using different BIM applications to create an FIM may lead to different outcomes.

This study tested the participant's free recall immediately after the presentation. Performance of the working memory might be different at the longer intervals.

Using the five-point Liker scale instead of the seven-point range was a possible shortcoming in this study in capturing the differences between the tools.

7.3. Future Studies

Delay claims are one of the most complex yet common issues in construction projects. Using four-dimensional presentations of the project schedule in a commercial or residential building to communicate the chain of causalities behind the delay versus using the Gantt

chart can be an exciting research topic. Gantt charts are convenient and common tools in project scheduling and presentation of the work sequence in construction projects.

One of the significant concerns and barriers to adopting the new technologies in litigation is their potential to prejudice the trials. Investigating the impact of Forensic Information Models (FIMs) twisting the facts can be another research topic.

In addition to the vividness of FIMs, they are interactive three-dimensional models that allow the forensic engineers to extract and use the required information inside the courtrooms in real-time fashion. This capability of FIM was not tested in this case and can be the topic for a future study.

Visual displays are utilized by lawyers not only for their cognitive impact on jurors but because they can affect the presenter's credibility. Since the presenter was identical in all presentations, the effect of using FIM on the presenters' credibility was not assessed in this research and can be investigated in another study.

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APPENDIX

DIVISION OF RESEARCH

TEXAS A&M UNIVERSITY

DATE: June 23, 2016

MEMORANDUM

TO: Stuart D Anderson
TEES - College Of Engineering - Civil Engineering

FROM: Dr. James Fluckey
Chair, TAMU IRB

SUBJECT: Expedited Approval – Initial Application

Study Number:	IRB2016-0338D
Title:	The Impact of BIM based visualization on Jurors' decision-making process involved in construction disputes
Date of Determination:	
Approval Date:	06/23/2016
Continuing Review Due:	05/15/2017
Expiration Date:	06/15/2017
Documents Reviewed and Approved:	Only IRB-stamped approved versions of study materials (e.g., consent forms, recruitment materials, and questionnaires) can be distributed to human participants. Please log into iRIS to download the stamped, approved version of all study materials. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB liaison assigned to your area.

Document of Consent: Written consent in accordance with 45 CF 46.116/ 21 CFR 50.27

Comments:

- This IRB study application has been reviewed and approved by the IRB. Research may begin on the approval date stated above.
- Research is to be conducted according to the study application approved by the IRB prior to implementation.
- Any future correspondence should include the IRB study number and the study title.

Investigators assume the following responsibilities:

1. **Continuing Review:** The study must be renewed by the expiration date in order to continue with the research. A Continuing Review application along with required documents must be submitted by the continuing review deadline. Failure to do so may result in processing delays, study expiration, and/or loss of funding.
2. **Completion Report:** Upon completion of the research study (including data collection and analysis), a Completion Report must be submitted to the IRB.
3. **Unanticipated Problems and Adverse Events:** Unanticipated problems and adverse events must be reported to the IRB immediately.
4. **Reports of Potential Non-compliance:** Potential non-compliance, including deviations from protocol

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Figure A-1. IRB approval of interviews

DIVISION OF RESEARCH

TEXAS A&M UNIVERSITY

Submission Approval DATE: February 28, 2017

MEMORANDUM

TO: Stuart D Anderson
TEES - College Of Engineering - Civil Engineering

FROM: Human Research Protection Program
Institutional Review Board

SUBJECT: Exempt Determination REF: 047971

Study Number: IRB2016-0880M

Title: INVESTIGATING THE IMPACT OF BIM-BASED FORENSIC STORYTELLING MODELS ON JUROR'S DECISION MAKING IN CONSTRUCTION DISPUTE RESOLUTION PROCESS

Determination Date: 02/28/2017

Continuation Due: 02/15/2022

Expiration Date: 02/15/2022

Documents Reviewed: Only IRB-stamped approved versions of study materials (e.g., consent forms, recruitment materials, and questionnaires) can be distributed to human participants. Please log into iRIS to download the stamped, approved version of all study materials. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB liaison assigned to your area.

Submission Components			
Study Document			
Title	Version Number	Version Date	Outcome
Questionnaire	Version 1.1	02/05/2017	Approved
Questionnaire	Version 1.0	02/05/2017	Void
Recruiting Email-Zohreh Soltani	Version 1.2	02/05/2017	Approved
Recruitment Email	Version 1.0	02/05/2017	Void
Study Consent Form			
Title	Version Number	Version Date	Outcome
Consent form	Version 1.7	12/09/2016	Approved
Consent form	Version 1.5	12/09/2016	Void
Consent form	Version 1.4	12/09/2016	Void
Consent form	Version 1.3	12/09/2016	Void
Consent form	Version 1.2	12/09/2016	Void
Consent form	Version 1.0	12/09/2016	Void

Comments:

- This IRB study application was determined to be not greater than

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Figure A-2. IRB approval of the experiment