INVESTIGATING 3D GEOVISUALIZATION FOR FIRE INCIDENT COMMAND

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INVESTIGATING 3D GEOVISUALIZATION FOR FIRE INCIDENT COMMAND

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ABSTRACT

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Geovisualization is a multidisciplinary field that develops domain-specific geospatial technologies for data exploration, analysis, and content communication. Nowadays, these novel geovisualizations are implemented for decision-making in emergency situations. The objective of this research is to develop and test the usefulness and usability of a three-dimensional desktop-based building model for fire related incident command processes. The development of the three-dimensional model incorporates theories of cartographic representation design and a structured user-centered design approach, i.e. requirements analysis, prototype design and usability testing. This research collects existing incident response practices by emergency responders, utilizes modern visualization techniques and compares the effectiveness, efficiency, and satisfaction of a three-dimensional geovisualization to a two-dimensional digital map.

CHAPTER 1

STATEMENT OF RESEARCH PROBLEM

1.1 Problem Investigation

In emergency response situations, time is a critical factor experienced by fire fighters. Due to time constraints, the utilization of special tools, techniques and training methods by fire fighters will satisfy the public with critical services. Specifically, a Geographic Information System (GIS) is a tool that can be used by fire fighters to optimize emergency services (Johnson and Price 2006). A GIS can provide a variety of theories, methods and tools to fire fighters during emergency response management in a *geovisualization* environment for the visual exploration, analysis, synthesis and presentation of geospatial data (Kraak 2003). Some of which include effectively locating fire stations around service areas, reducing response times en route to a fire activity, and visualizing spatial and tabular information about features at an incident, such as fire hydrants.

Unfortunately, fire fighters generally lack accessibility to geospatial technologies such as interactive mapping applications, which could provide timely and accurate information. The lack of geospatial technologies in fire departments is often caused by insufficient budgets for modern equipment, software, and skilled personnel.

Subsequently, most fire fighters lack the knowledge required to use these geospatial technologies (Baker and Kuhlman 2007).

At the federal level, the needs of emergency responders are being discussed across different public safety organizations in order to meet the needs of communities and provide effective public safety. The National Institute of Standards and Technology (NIST) from the Technology Administration in the U.S. Department of Commerce conducted a workshop on May 3, 2004. The workshop identified the various stages of a building emergency and what essential information would be needed during each stage of the incident command process (Jones et al. 2005). Similarly, at the local level, government fire and rescue departments rely on the combination of incident-gained experience with the use of on-hand materials, such as maps and documents, to communicate both spatial and descriptive characteristics of an incident area, such as a building, to emergency responders (Baker and Kuhlman 2007).

The ultimate goal of this research is to test the usefulness and usability of a 3D model for fire related emergency response management. The objectives of this research include (a) identifying domain-specific requirements for the visualization of content in a geospatial tool, (b) identifying how the requirements could be integrated into useful and usable 3D geovisualizations, and (c) determine if a 3D model provides more effective wayfinding guidance for fire fighters than a 2D model. Effective, efficient and satisfactory geovisualization will be measured qualitatively and quantitatively from the results of a field-based usability test comparing 2D PDF maps and a 3D model of a high-rise building. The usability testing methods of data collection include time-stamps, participant questionnaire, semi-interview, and evaluator observations. The values recorded will provide the information necessary to analyze and assess the overall usability of a 3D model for fire incident command.

1.2 Motivation

A good example of a fire department that understands the potential a GIS may bring to emergency responders is San Marcos Fire and Rescue (SMFR) in San Marcos, TX. SMFR provides emergency response services to the local municipality and responds to all type of fires, including fires on commercial and residential properties, as well as fires at the local university, Texas State University–San Marcos (Texas State). SMFR presently collects data on buildings throughout the city, referred to as pre plan surveys, which help facilitate the emergency response process. SMFR records the pre plan surveys along with building maps, either building footprints or hand-created documents in Microsoft Word. The paper maps display as much information as possible, which can include locations of stairs, elevators, floor plans, fire department connections, and room amenities.

SMFR utilizes a set of standardized map symbols and icons for ease of use. However, there are two major problems when using these maps, (a) the maps are either stored on a computer housed in a local fire station or in a large binder that is cumbersome to use and locate, therefore often not readily available at the site of an incident, and (b) the maps only provide a 2D representation of each floor of a high-rise building, which may limit a users cognitive ability to understand and perceive such a building as a whole entity. Some buildings, such as those found at Texas State, contain floor plans that vary by level, include mixed uses, and may have hazardous materials on site. Availability of time during incident command response, computer hardware and software, and technological skills are limitations of SMFR resources (Baker and Kuhlman 2007). These limitations are variables which are considered during the design and implementation of the 3D geovisualization.

The development of a usable and useful 3D geovisualization for fire incident command requires a careful balance of the needs of emergency responders and the functionality of the geospatial information being conveyed. Therefore, to effectively investigate and answer the research questions discussed in Chapter 3, it is necessary that an applicable real-world case study be performed to describe the domain and situational use of 3D geovisualizations for fire-related incidents. This research collaborated with SMFR, which represented the domain for this research, as well as participants in usability testing. The goal of this research is to develop and investigate geospatial information technology that (a) provides quick and easy access to high-rise building information at the scene of a fire, (b) functions on existing hardware within the domain, (c) is interoperable with other applications SMFR currently applies or might use in the future, and (d) is easy to use by fire fighters.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a general review of spatial cognition and relative terms, orientation and wayfinding concepts, geovisualization, cartographic principles, user-centered design methods, user-interface design issues, and usability testing methods. These components are reviewed as related to the scope of this research.

2.1 Spatial Cognition

Spatial cognition is a subfield of Cognitive Science, which is the study of cognitive processes such as problem solving, language, and reasoning. Many disciplines, such as sociology, psychology, and geography research the various cognitive processes (Freska 2004, Smelser and Baltes 2001). Therefore, cognitive principals have various definitions based on the fundamental theories they are applied to. Spatial cognition is concerned both with the ways humans think about real or abstract space and with the ways spatial structures can be exploited for reasoning, and time is an implicit factor during all cognitive processes (Freska 2004).

Cognitive mapping is a process by which individuals acquire, code, store, recall, and decode information about relative locations and the spatial environment (Downs and Stea 1973). There are two types of spatial knowledge: declarative knowledge and procedural knowledge. Declarative knowledge is the storage of pieces of information about places, lines, and areas. Procedural knowledge refers to the rules for linking pieces of information into a hierarchal order in the spatial domain (Golledge 1992). The process of cognitive mapping is subjective to an individual's spatial thinking and reasoning about declarative and procedural knowledge.

The term cognitive map refers to how humans, animals, or machines represent spatial models of the environment (Tolman 1948). The cognitive map is different than a cartographic map in the brain because it consists of separate discrete pieces of information partially linked or associated frequently to represent hierarchies, such as a location inside a larger region (Smelser and Baltes 2001). Humans construct spatial knowledge of an environment by integrating information about landmarks, routes and survey. Landmarks are objects at fixed locations, routes are fixed sequences of locations identified when traveling along a route, and survey knowledge combines experiences from different sequences of routes into a single model (Werner et al. 1997).

Understanding how humans form cognitive maps in a 3D virtual environment is important to the design of a 3D geovisualization application. Humans form cognitive maps in three ways, (a) through an individual's sensory modalities, (b) from symbolic representations such as maps, and (c) from ideas about the environment based on previous experiences with similar locations (Briggs 1973). There are two cognitive factors that stimulate cognitive mapping and allow humans to store and recall information: control process and characteristics of the memorial system. Control processes operate in cognitive mapping based on an individual's prior knowledge of maps. Individuals are able to first assess task demands before studying a map and finally decide when to end the map learning process (Kulhavy and Stock 1996).

2.2 Orientation and Wayfinding

Orientation is an individual's awareness of surrounding space, and *wayfinding* is the task individuals complete to navigate through surrounding space from a start point to an endpoint (Hunt and Waller 1999). The ease in which spatial orientation and wayfinding can be accomplished is affected by understanding psychological, information-processing, operation conceptualizations, and physical-setting variables in an environment (Gärling et al. 1986). Hunt and Waller (1999) describe the three ways of using maps for wayfinding, (a) maps as guides to exploration, (b) maps as substitutes for exploration, and (c) maps as the basis for directions.

This research is interested in identifying methods that effectively communicate geospatial knowledge in order to provide map-based directions for a wayfinding task. Due to the limited human senses that a fire fighter can rely on, such as loss of sight, feel, and smell, it is imperative that incident commanders can effectively and efficiently communicate spatial knowledge of an incident scene. Therefore in this study, the user of the proposed 3D geovisualization model will give directions to fire fighters during the execution of a wayfinding scenario. Incident commanders will deliver task-based directions to fire fighters by means of both a 2D PDF and 3D model. Usability testing will provide measurements for effective wayfinding.

2.3 Cartographic Representations

Digital representations have been evolving from the combination of cartographic theory elements and digital production methods (Hardisty, MacEachren, and Takatsuka 2001). Bertin (1967) identified the foundation for cartographic principles into seven visual variables: size, value, texture, color/hue, orientation, shape, and position. Under the influence of technical, conceptual and user-oriented developments, Blok (2000) presents a framework for dynamic visualization variables based on the adaptation and extension of Bertin's original framework. It is suggested that new techniques and applications, such as 3D and animated mapping, can be developed based on the continuously adapted and extended visual variables.

Hardisty, MacEachren, and Takatsuka (2001) categorize visual variables for the creation of 3D animated maps. First, they identify tactual properties of a 3D model, which includes shape, size, location and orientation of objects. Next, they identify purely visual properties of elements of a 3D model, which include color, visual texture, reflectance and transparency. The combination of visual variables in interactive cartography provides several ways to visualize and interact with complex data, such as data used to develop 3D models. (Huber et al. 2007). Humans can successfully navigate through space and communicate geographic information based on their cognitive skills. The cartographic representation of map projections, generalizations, feature labeling, and map design all influence a human's perception of cartographic representations (Skupin 2000). This research will subsequently test the usability of the cartographic visualization techniques including generalizations, feature labeling, and map design implemented in the development of the 3D model of the Evans Liberal Arts building at Texas State.

Cartographic generalizations provide visual interpretations of spatial information. Ferry et al. (2002) explains that cartographers manipulate the way information is displayed by using twelve 'operators' of cartographic domain-specific knowledge. The concept of these operators can be further applied to the generalization of the level of detail (LOD) in a 3D model. Cartographic generalizations are useful in both traditional cartography and 3D models in their ability to reduce visual complexity of representations. The research by Ferry et al (2002) states that traditional cartographic generalization operators can be transitionally used in virtual reality environments.

As this research is concerned with the design and implementation of 3D models, it is not necessarily considered traditional cartography. Similarly, this research is not concerned with the development of a fully functional virtual reality environment. Therefore, the research is a combination of traditional cartographic techniques utilized in a digitally modern cartographic form. Table 1 outlines cartographic generalization operators and their descriptions for use in traditional and virtual reality environments. The following six cartographic generalization operators will be used in the development of the 3D model: simplification, aggregation, exaggeration, enhancement, classification, and symbolization. The effectiveness and efficiency of these generalizations will be analyzed quantitatively and qualitatively during usability testing.

Table 1. Cartographic Generalization Operators (modified from Ferry et al. 2002)

Operator	Name	Description
OP1	Simplification	Reduce the number of vertices employed to represent the element, preserving the original appearance.
OP2	Smoothing	Displace the vertices used in the representation, in order to eliminate small disturbances and to capture the overall shape.
OP3	Aggregation	Join nearby elements.
OP4	Amalgamation	Join nearly contiguous and similar areas, by eliminating boarders between them.
OP5	Merging	Join two or more parallel lines that are close to each other into a single line.
OP6	Collapse	Reduce the dimension of the representation of an object.
OP7	Refinement	Discard unimportant elements, which are close to important ones.

Table 1-Continued. Cartographic Generalization Operators (modified from Ferry et al. 2002)

Operator	Name	Description
OP8	Exaggeration	Increase the dimensions of elements considered important for the map.
OP9	Enhancement	Increase the dimensions of symbols presents in the map.
OP10	Displacement	Shift the position of a feature, in order to make it distinct to other ones.
OP11	Classification	Group objects that share identical or similar characteristics into categories.
OP12	Symbolization	Change objects (or categories) for symbols.

Feature labeling is another problematic factor in 2D and 3D information visualization. Three issues related to the representation of 2D labeling are graphic complexity, choice of label positions, and choice of label terms. Graphic complexity refers to the display of text labels for symbols (Skupin 2000). In many cases, labels are larger than the symbols they represent. Generalizing labels and limiting the number of labels placed may reduce graphic complexity. Generalizing and optimizing label positions using a label hierarchy will also reduce the clustering conflict of neighboring labels. Finally, using acronyms or abbreviations to label features can reduce visual clustering in a representation (Skupin 2000). Spatial and non-spatial data must be represented within the 3D model developed for this research. Examples of spatial data that will be labeled include a fire alarm control panel, fire pump, and room numbers. An example of non-spatial data is the SMFR pre plan survey (see appendix A). The pre plan survey contains data such as building contact information and estimated fire flow needed to put out a fire.

Communication approaches to the input and output of visual information in a geovisualization model are a function of the map designer. The creation of visual hierarchies to display thematic information by way of cartographic principles will ensure achievement in map interpretation (Dent 1972). Visual hierarchies will organize information displayed with visual variables. Examples of visual hierarchies include size of symbols, saturation or transparency of color, and typology of feature labeling. The use and implementation of visual hierarchies and visual variables will determine the successfulness of the 3D geovisualization model.

2.4 Geovisualization

In recent years, *geovisualization* has allowed users to explore and present dynamic geospatial data in highly interactive virtual environments enabling users to explore data to generate hypotheses, develop solutions, and construct knowledge (Kraak 2002). Exploratory techniques of geovisualization systems depend on the characteristics of data and goals of analysis. Domain-specific geovisualization applications analyze spatio-temporal data from the types of data they are applicable to and the exploratory task they can support (Andrienko, Andrienko, and Gatalsky 2003). As these systems become more prevalent, common methods and procedures of system design, development, and use are being established.

A conceptual level of user-centered 3D geovisualization is introduced by Nielsen (2004) which connects geospatial information stored as 3D objects with the end user of a system into four categories: representation, rendering, interface, and interaction. This process allows for the representation of objects in 3D geovisualization to closely reflect objects in the real world. The representation can be multimodal by providing visual, aural, or haptic sensory input or be multidimensional by providing spatio-temporal changes or attribute layer information (Nielsen 2004). The process of development of 3D geovisualization is based on the relationship between technology and user-centered issues. Developers focus on the relationship between positivistic and phenomenological 3D geovisualization resulting in useful systems users can interact with (Nielsen 2004).

In review, geovisualization is the integration of geospatial information with highly interactive technology which provides end users with methods and tools to explore data. A structured approach to developing a user-centered 3D geovisualization should focus on the needs of the user and requirements of the technology used. This research will implement a well-planned user-centered design process for the development of a 3D geovisualization model designed to facilitate the communication process during incident command. The effectiveness and efficiency of 3D geovisualization will be measured by performing usability testing in a field-based environment.

2.5 User-Centered Design

This research is interested in how humans interpret geospatial concepts being represented in a 3D geovisualization model. This requires the planning and execution of a manageable user-centered design process for activities throughout the life cycle of interactive computer-based systems (Bevan 2001). User-centered design (UCD) is a methodology based on the approach of human-centered design and is used to guide information system design while focusing on understanding the needs and requirements of users.

UCD is critical to the success of interactive systems. Benefits can include increased productivity, enhanced quality of work, reductions in support and training costs, and improved user satisfaction (Maguire and Bevan 2002). Bevan (2001) summarized the comprehensive range of national ergonomic standards that have been developed by the International Organization for Standardization (ISO) and the

International Electrotechnical Commission (IEC) over the past 15 years. These standards define the general principles of UCD and good practices in user interface design (Bevan 2001). In review, there are three international standards that closely reflect the research being proposed: ISO 13407, ISO DTR 16982, and ISO/IEC 14598. These standards refer to the human-centered development processes, which are integral to user-centered design. These three standards outline the information system design that will be utilized during the phases of this research: user-centered design framework, usability methods, and usability testing (see table 2).

Table 2. International Standards for Human-Centered Design (Bevan 2001)

Standard (year developed)	Summary
ISO 13407: Human-centered design processes for interactive systems (1999)	Provides guidance on human-centered design activities throughout the life cycle of interactive computer-based systems.
ISO DTR 16982: Usability methods supporting human-centered design (2001)	Outlines different usability methods available to support user-centered design.
ISO/IEC 14598: Information technology – Evaluation of software products (1998-2000)	Multi-part standard specifying the processes used to evaluate software products.

The approaches to user-centered design have been investigated in order to identify and define appropriate methods and common challenges to determine a cost-benefit analysis (Bevan 2001, Bevan 2003, Maguire 2002, Vredenburg et al. 2002). ISO 13407 provides a framework for applying user-centered design but does not identify the appropriate methods to be used (Bevan 2003). ISO 13407 identifies four activities that form an iterative framework process for the human-centered design process: specify the context of use, specify requirements, create design solutions, and evaluate design. This cycle can be seen in figure 1 below.

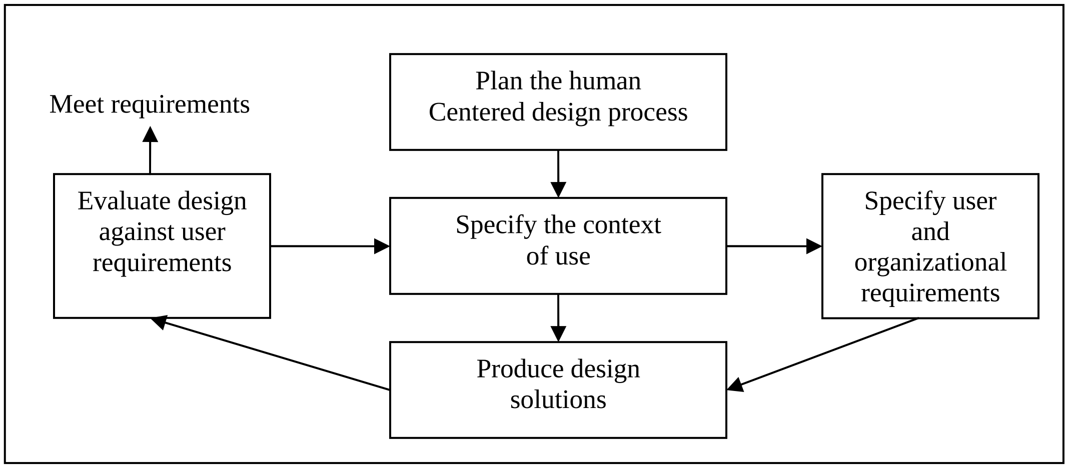


Figure 1. Human-Centered Design Process (ISO 13407).

Generally, this research will follow a structured approach to plan the user-centered design process. Context of use is determined to be fire incident command processes for high-rise building fires. User requirements are defined during stakeholder meetings and user card sorting techniques. Card sorting is a technique that is easy to conduct, enables the developer to understand how users group items, identifies items likely to be difficult to categorize, and identifies terminology likely to be misunderstood. Traditional card sorting is conducted with a participant categorizing items listed on individual cards. Participants are then asked to group items in a way that makes sense to them (Gaffney 2000). Design solutions are iteratively tested with key stakeholders before usability testing is performed

2.6 User-Interface Design

Successful user-interface design can be equated to the usability and usefulness of a geovisualization system. Usability is defined as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction of a specified context of use.” (Bevan 2001). Usefulness is defined as “the appropriateness of a tool’s functionality and relates to whether the tool meets the needs and requirements of users when carrying out tasks….” (Koua, MacEachren, and Kraak 2006). Digital user-interface systems have been improved over recent years through technological advancements. Unfortunately, many existing geovisualization systems are poorly structured making map use a passive and difficult process (Wang et al 2001). Therefore, user-interface design issues related to a user-centered geovisualization system should be investigated to avoid choosing an incorrect software platform for this research.

The issues associated with the integration of scientific visualization and geographic representation methods outlined by Howard and MacEachren (1996) present a structured approach to geovisualization interface design. Howard and MacEachren offer three levels of analysis, displayed in table 3, based on the synthesis of interface design perspectives by Marr (1982), Foley et al., (1990) and Lindholm and Sarjakoski (1994): *conceptual, operational, implementation.* Howard and MacEachren suggest that these levels of analysis emphasize the goals of using a system, rather than the details of implementing a system on a specific hardware/software configuration.

When implemented properly, these levels of analysis assist in successfully developing user-interface design for geovisualization. Overall, this research outlines the development of the 3D geovisualization model by understanding conceptual design issues, operational functionality, and implementation strategies of a user-centered geovisualization system.

Table 3. Levels of Analysis for Geovisualization Interface Design (Howard and MacEachren 1996)

Level of Analysis	Issues
Conceptual	Those associated with a system as a connection to information. • What need is met by the system? • How is this goal reached? • What should be the result of working with the system?

Table 3-Continued. Levels of Analysis for Geovisualization Interface Design (Howard and MacEachren 1996)

Levels of Analysis	Issues
Conceptual	• Who is the system designed for?
Operation	Delineating the appropriate operations to match conceptual level goals. Decisions should be independent of the hardware/software environment.
Implementation	Anything the user will have to see and decipher in order to interact with the system. Issues include methods of display, data storage and retrieval, choice of hardware/software platform, optimization of program routines.

2.7 Usability Testing

The field of human-computer interaction has been researching and evaluating methods testing usability of systems for many years. Choosing appropriate methods for iterative design is based on criteria in previous research such as efficiency, simplicity, timing, and cost (Olson and Moran 1998). Usability testing is a collection of methods used to explore a product's functionality in accordance with predefined criteria. "It is therefore concerned with establishing whether people can use a product to complete their tasks with ease and at the same time help them complete their jobs more effectively." (Tobón 2002).

Usability testing methodology should follow a general framework based on initial goals outlined for a study. Zhang and Adipat (2005) outline a generic framework, shown in figure 2, for a mobile application that researchers should consider when designing a usability test. They base their research on two methodologies: laboratory testing and field testing. The framework is also broken-down into four phases: testing method, tools used, selecting what to measure, and data collection approaches. Efficient design of a usability test will ultimately determine the effectiveness of the overall study.

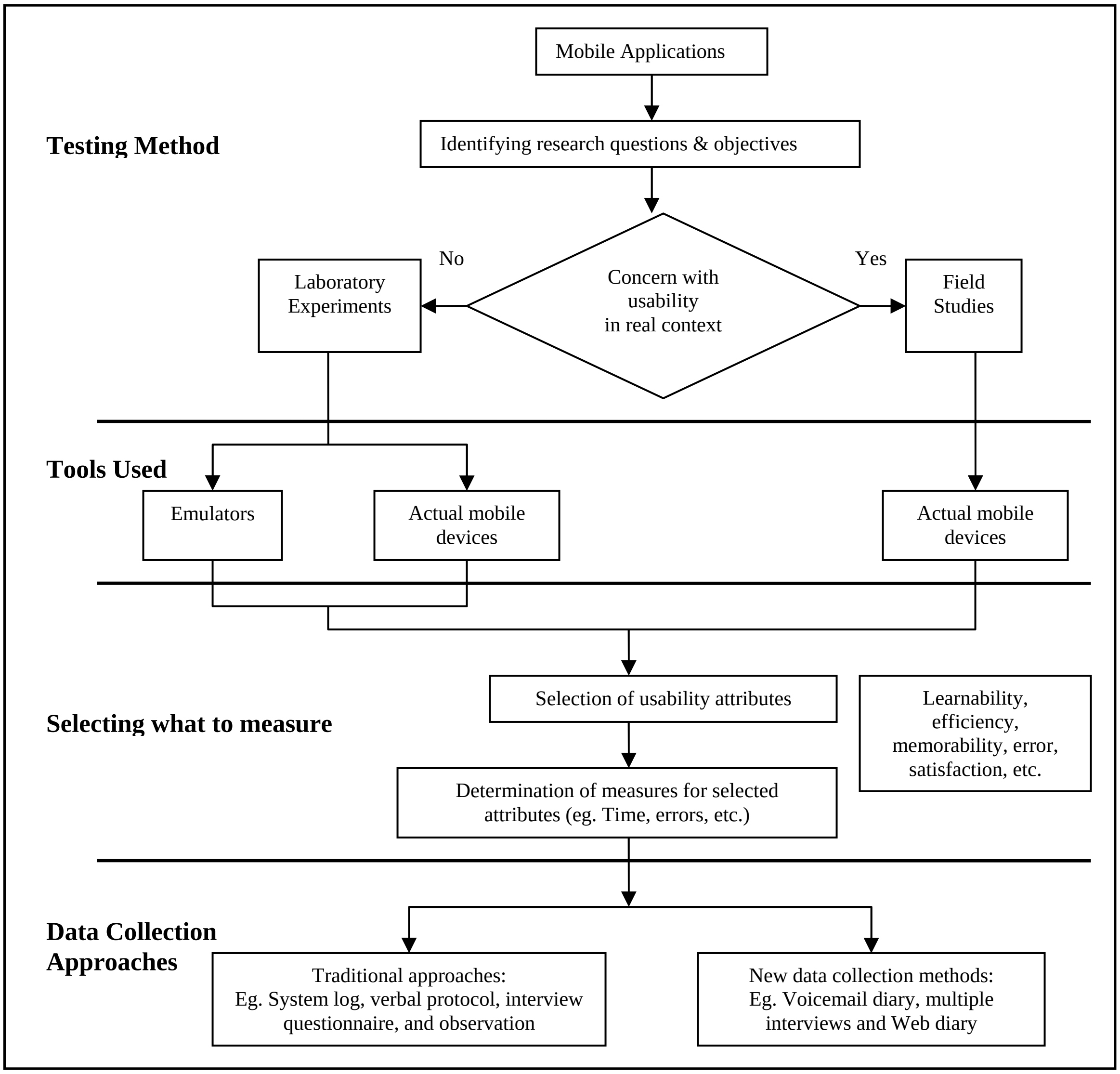


Figure 2. Usability Testing Framework. Based on a framework for usability testing of mobile applications by Zhang & Adipat (2005).

In a comparative study to establish environmental variables in usability tests, Kaikkonen et al. (2005) concluded that there are no significant differences between laboratory and field usability tests when usability testing is designed on domain-specific scenarios. The research claimed that participants are more comfortable in field environments even though the overall length of testing is longer. Participants felt at ease in real-world settings to complete real-world tasks. However, even though the overall time to conduct usability testing in the field is longer than in a lab, the time to complete a task in the field was not significantly longer. Field testing timing is longer due to set up and recording methods. Kaikkonen et al. (2005) also noted was that pilot testing is critical for field-based testing, if time permits, to remove any malicious tasks involved in a field experiment.

There are arguably three prominent usability evaluation methods available for professionals: cognitive walkthrough, heuristic evaluation, and think-aloud study. The three methods differ in their approach to usability evaluations but share a common goal of determining usability of a product (Hertzum and Jacobsen 2001). However, these three evaluation methods are generally applicable to laboratory testing. Evaluation methods that involve participants which represent the domain rather than the experts which develop the tools being tested are usually referred to as field-based tests. Classic methods of evaluation such as research surveys and comment cards can be applied to field-based testing; however there are some inherent disadvantages. Unfortunately, the main disadvantages to field-based testing are problems including funding, timing, and proper selection task-based context (Hertzum and Jacobsen 2001).

Heuristic evaluation involves using experts to evaluate an interface based on a predefined set of principles or heuristics (Nielsen 1992). Implementation is generally easy and does not require prototypes or real users. The number of participants recommended varies between three to five experts, depending on the types of heuristics being evaluated and experience of experts involved (Po et al. 2004).

Cognitive walkthrough identifies usability problems through cognitive procedure-based simulated tasks executed in a lab. It is used in early stages of product design and focuses on the usability attribute learnability. It attempts to identify aspects of a system that users will find the greatest difficulty (Sears and Hess 1999). Participants are asked to answer questions related to the usability of a product: "*Will the correct action be made sufficiently evident to the user? Will the user connect the correct action's description with what he or she is trying to do? Will the user interpret the system's response to the chosen action correctly?*" (Blackmon et al. 2001).

Pluralistic walkthrough is cognitive walkthrough using group meetings and scenarios to discuss each qualitative element of an interface. It allows for an inspection of usability problems using a paper prototype of an interface. Participants are asked to walkthrough tasks and write detailed actions they wish to take. Pluralistic walkthrough evaluates the usability attributes effectiveness and satisfaction (Bias 1994).

Think-aloud study involves users continuously thinking out loud while they interact with a system and is vital to usability evaluation (Nielsen 1994). This makes it easy for the evaluator to identify what aspects of a system are problematic. A small number of users and evaluators can participate using this method in order to collect a sufficient amount of performance information. Unfortunately, participants may find it distracting to constantly think out loud during testing. They may become uncomfortable and thus lose focus on the task (Kaikkonen et al. 2005).

Test methods involving users representing the domain ensure essential usability characteristics exist in a prototype. Formal evaluation of usability parameters in field-based experiments can be difficult and time consuming. They require careful consideration of task-based scenarios in a real-world environment and data collection methods to record qualitative and quantitative information. However, despite the hindrances, field-based testing provides more valid results for real-world tasks (Nivala 2005).

Data collection techniques are imposed to successfully record vital information related to usability. User reactions can be measured by usability indicators collected with questionnaires and comments from interviews (Koua, MacEachren, and Kraak 2006). Recorded methods include video/voice recording and data logging. This research will record information during usability testing to be used for both quantitative and qualitative analysis, see Chapter 4. The collection techniques will include a user questionnaire and semi-structured interview session at the conclusion of all executed task-based scenarios. Advantages of using the semi-structured interview include its ability to probe a deeper level of detail than a questionnaire while obtaining an individual's subjective reactions and opinions about the material in question (Pula and Smith 2004). Participants will be video recorded while they represent incident commanders delivering task-based instructions and while they represent fire fighters as they receive and follow instructions from the incident commander.

In review of the literature review on usability evaluation methods, there are many techniques that can be applied to usability testing. Predefined sets of criteria ultimately determine which methods should be used for appropriate research. Therefore, as this research is concerned with the usefulness and usability of 3D geovisualization in a real-world environment, field-based usability testing will be performed. Quantitative and qualitative data will be collected to measure the efficiency, effectiveness and user-satisfaction of the 3D geovisualization model.

CHAPTER 3

RESEARCH METHODS AND DESIGN

This chapter combines knowledge gained from the literature review and meetings with key stakeholders to outline a methodology for creating and testing the usability and usefulness of a 3D geovisualization model for fire fighters during the incident command process. The methodology includes the implementation of a structured user-centered design process, iterative 3D model development, and usability testing.

The goals of the research questions are to investigate the needs of fire fighters at high-rise building fires in conjunction with a 3D geovisualization model offering timely and accurate geospatial information. The 3D geovisualization model will be compared against the present use of 2D building footprints utilized by San Marcos Fire and Rescue. SMFR represents the domain in this research and participants in a field-based case study. The objective of this research is to successfully answer the following questions:

1. What are the domain-specific requirements for the visualization of content in a geospatial tool displaying high-rise building information for fire fighters?
2. How could domain-specific requirements be integrated in useful and usable 3D geovisualizations?
3. Does a 3D geospatial tool assist in providing more effective wayfinding guidance for fire fighters through a high-rise building than a 2D geospatial tool?

The research methodology began with planning a user-centered design process, which followed a framework outlined by ISO 13407 (Bevan 2001). The development and usability testing of the 3D model provided evaluation criteria for the overall usability of the geovisualization system. The scope of the study included the Evans Liberal Arts (ELA) building and adjacent areas of the Texas State University–San Marcos (Texas State) campus. This research will provide a qualitative and quantitative assessment of the effectiveness, efficiency, and satisfaction of usability testing that are identified in the Results and Discussion chapters that follow.

3.1 Planning the User Centered Design Process

In order to reduce the failure risk of the 3D model, it was important to carefully plan and manage the user centered design process (Maguire 2001). The initial step in the planning phase was to meet with stakeholders relevant to the development of the 3D model and identify user and task requirements. The initial phase was initiated during a relatively informal meeting held on August 28, 2007 from 4:00 pm to 5:30 pm in San Marcos, TX with Chief Mike Baker and Lieutenant Karl Kuhlman of SMFR. The meeting was conducted using a question and answer format to discuss the general research objectives.

The knowledge gained from the initial stakeholder meeting included needing the software to be easy to use, be relatively inexpensive to purchase, and be easily implemented on laptop hardware that the department presently has. Key functionality in the software environment representing the 3D model must include the following: tools to orient point-of-view, organized layers of vital information, and simple graphical user interface. Information gained during the stakeholder meeting was used to choose a software platform that would best implement the needs of the end-user, see table 4.

Table 4. User and Interface Requirements

Question	Answer
Who are the intended users and what are their tasks?	•Fire incident commanders •Make strategic decisions
What are the overall objectives for the system being developed?	•Provide incident commanders a tool that contains vital information related to the incident.
What are the technical and environmental challenges?	•Technical limitations include access to laptops and proper training on technical applications. Also, the software needs to be inexpensive. •Environmental limitations include weather conditions, such as heat, humidity, and rain.
What key functionality is needed to support a users needs in a 3D environment?	•Orientation of point-of-view •Layers of vital information, such as: • Floor plans • Fire hydrants • Fire alarm control panel •Simple user interaction
What are the display requirements?	•Easy to use and readily accessible •The display should not be overloaded with contextual information.

Based on the information provided during the initial stakeholder meeting, the software platform chosen to develop and test the usability and usefulness of a 3D geovisualization model for fire-related incident command processes was Google SketchUp. Google offers free software, SketchUp, which covers all key functionally required by the stakeholder: orientation of view point, layers of information, and simple user interaction. The software maintains accuracy and scale in a location-based environment, it is simple to integrate custom data and allows for intricate details of vital information, such as the examples previously listed, to be visible. SketchUp tools include the ability to change orientation/rotate, zoom, and pan buttons, as well as layer functionality. There are other software platforms that could have been used to develop 3D models for fire-related incident command. Examples of these include Adobe Flash, ESRI 3D Analyst, and AutoCAD. These tools were not chosen because of the time necessary to create custom animation and user interaction tools, limited 3D representation capabilities and complicated graphical user interface for novice users, and cost, respectively. Once the software for the model platform was identified, the next phase of the user-centered design process was to understand context of use and user requirements.

3.2.1 Understanding Context of Use and User Requirements

Before 3D modeling could take place, it was important to fully understand the context of use and user requirements. This information was obtained during a requirement meeting, held on September 13, 2007 from 5:00 pm to 7:00 pm, with Chief Mike Baker and Lieutenant Karl Kuhlman in San Marcos, TX. The meeting was digitally recorded using a voice recorder. The results of the requirement meeting provided substantial understanding of how the 3D geospatial information should be modeled within SketchUp. This study was able to better understand how to balance the user requirements with the fundamental development of the 3D model from the information gathered during the requirement meeting. Overall, the following information was collected and used to develop the 3D Evans Liberal Arts building at Texas State (Baker and Kuhlman 2007):

1. Members of SMFR has basic map reading skills for 2D maps. Fire fighters are taught how to read maps during their first year of service.
2. Incident commanders (IC) will give directions to a fire fighter to complete a task-based scenario from both a 2D PDF map and the 3D model.

a. IC's create strategic objectives from scene assessments:

    i. What is the problem? (Example: Fire in room 312 is causing extreme smoke conditions across third floor.)

    ii. Where is it now? (Example: Smoke is heavy on the third floor.)

    iii. Where is it going to be in the next 5-10 minutes? (Example: Smoke will continue to spread across the third floor.)

    iv. How long are we going to be here? (Example: Three hours.)

    v. What all is involved? (Example: Fire, smoke, human life, property)

    vi. It is important to know what is at the scene ahead of time so that the IC can make decisions on way to scene of incident.

b. IC's strategic objectives are prioritized based in the following order:

    i. Life safety

        1. Fire Fighters

        2. Potential victims

    ii. Incident stabilization (Example: Put out fire and save lives)

    iii. Property conservation

3. Building floor plans should contain information related to the following types of incident, which are universal to emergency response management:

    a. Fire response

    b. Medical response

    c. Haz-Mat response

    d. Rescue scenario

4. Vital information will be displayed in the 3D model based on a hierarchical organization for level of importance identified during domain-knowledge elicitation.

3.2.2 Data Collection

Data to be used in the 3D model was gathered three ways. First, floor plans of ELA were provided by Texas State in two formats: computer aided design (CAD) and portable document format (PDF). Texas State also provided CAD data displaying the location of fire hydrants, water lines, and streets. Second, fire-related spatial information was identified during a walk-through assessment of Evans Liberal Arts (ELA) on December 19, 2006 with SMFR and Texas State representatives. Finally, information related to the four incident types, and defined by a report based on a workshop conducted on May 3, 2004 from the National Institute of Standards and Technology (NIST) in the U.S. Department of Commerce, was hierarchically organized by a SMFR representative. The data collected from each method was combined during the development of the 3D model in SketchUp.

During the initial data collection process Lieutenant Kuhlman of SMFR and James Frye of the Texas State department of Risk Assessment participated in a walk-through assessment of ELA to identify features that should be included in the 3D model were marked on a paper copy of the PDF floor plans. Features included stand pipes, sprinkler stand pipes, fire department connections, fire alarm control panel, fire pump, mechanical shut-off, and elevator shafts.

The second data collection method identified vital information needed to be grouped by layer in SketchUp for the different types of incidents including fire response, medical response, haz-mat response, and rescue scenario. Lieutenant Karl Kuhlman, who was identified as the appropriate representative for this task by Chief Baker, elicited this information. It is important that many individuals have the ability to represent incident commanders at the scene of an incident because not all individuals respond to each incident (Baker and Kuhlman 2007). On September 13, 2007, Lieutenant Kuhlman was provided the NIST report. The NIST report resulted from a workshop set up to identify the various stages of a building emergency and what essential information would be needed during each stage to both assist emergency responders and determine how it should be conveyed (Jones et al. 2005). The workshop included emergency responder professionals from across the United States. The combination of the NIST report and the needs of SMFR provided a structured set of information to be included in the 3D model.

A modern method of card sorting was used to structure fire-related information into organized data. Lieutenant Kuhlman organized the NIST information into the four different types of incidents based on what SMFR requires by incident command using Microsoft Excel. The four different types of incidents were then broken down into two scenarios: information needed while responding to an incident, see table 5, and information needed at the scene of the incident, see table 6. The majority of information needed by incident commanders while en route to a fire, haz-mat, or rescue incident was the same. There was little information identified that would be needed en route for a medical response. Likewise, the majority of information needed by incident commanders while at the scene of a fire or haz-mat incident was the same. There was also little information necessary at the scene of either a medical or rescue incident.

Information was collected from the PDF and CAD drawings provided by Texas State as well as fire-related information collected during the walk-through assessment. The majority of information needed en route and at the scene was combined into one layer, “fire-response,” in the 3D model. This was done in order to identify the information available for ELA needed by incident commanders while en route and on scene of an incident. It was concluded there was not enough data available for ELA to divide the information into each of the four the incident types. Some information was required to exist in separate layers due to their spatial relationship with other features and SketchUp functionality, see section 3.2.3.

The two methods of data collection used during the domain-knowledge elicitation process, walk-through assessment and card sorting, provided the information necessary to begin the modeling process of ELA in SketchUp. All data collected during this phase of the user-centered design process were used to create a 3D model of ELA.

Table 5. Incident Command Information: En Route to an Incident

Responding	Fire	Medical	HazMat	Rescue
Any access issues	x	x	x	x
Building Condition	x		x	x
Building Construction	x			x
Building Occupancy	x		x	x
Building Style	x		x	x
Building Type	x		x	x
Estimated fire flow information	x			
Exposures	x		x	
Hazardous Materials	x		x	x
Knox Box Information	x	x	x	x
Location of entrances and exits	x	x	x	x
Location of FDC's	x		x	
Location of Fire Hydrants	x		x	
Location of Stairwells	x		x	x
Location of Standpipes	x		x	x

Table 5-Continued. Incident Command Information: En Route to an Incident

Responding	Fire	Medical	HazMat	Rescue
Roof Construction/Access	x			x
Room Number		x		

Table 6. Incident Command Information: At the Scene of an Incident

On Scene	Fire	Medical	HazMat	Rescue
Areas	x		x	
Building Generator	x		x	
Building Owner/Representative Info	x		x	
Building System Controls	x		x	
Elevator Locations	x	x	x	
Location of FACP	x			
Room Numbers	x		x	
Utilities Information	x		x	
Utility Shutoff Locations	x		x	
Vertical Openings	x			

3.2.3 3D Model Design and Implementation

The development of the 3D model began on September 14, 2007, and incorporated information collected during the domain-knowledge elicitation process. The modeling process included four components of a visual and graphical hierarchy:

1. Representations of elemental aspects of ELA.
    a. Examples include building features such as walls, staircases, windows, etc.
2. Representations of fire-related information.
    a. Examples include: fire hydrants, standpipes, fire department connectors, etc.
3. Feature labeling.

   a. Examples include: room numbers, fire department connectors, elevator, etc.

4. Layer organization.
   a. Examples include building features: first floor, second floor, fire response, etc.

The 3D model of ELA went through three iterations until SMFR stakeholder's needs were satisfied. The stakeholders reviewed the 3D model on October 5, 2007. At this time, the stakeholders reported erroneous aspects of the 3D model in SketchUp. The following changes were made as a result of this process:

1. Modify the symbol used for standpipes outside and inside the building.
   a. Standpipes outside should have two available hose connections.
   b. Standpipes inside should have one available hose connection.
2. Display the SMFR pre plan survey as an image of the actual document rather than displaying the information found on the pre plan survey in a 2D text callout.
3. Display the Texas State water lines in the "fire-response" layer.
4. Create a callout feature label for the fire department connectors and fire alarm control panel.
5. Create 3D feature label for the fire alarm control panel.

Initial creation of each floor plan was based on the PDF drawings made available from Texas State. The PDF drawings were much easier to work with in the SketchUp environment than the CAD data. It was easier to integrate the PDF drawings in SketchUp because the image represented a single element when added to the model. Moreover, all text elements and staircases were easy to identify on the PDF drawings. On the other hand, when CAD drawings are added to SketchUp, the entities created in the AutoCAD environment were split into their own layers. For example, when the first floor CAD drawings of ELA were added to SketchUp, 64 layers, 48 blocks, 2 arcs, 42 ellipses, 95 inserts, 1534 lines, and 40 2D poly-lines are inserted. Also, all AutoCAD text entities were ignored. This made it very difficult to manipulate and visualize the information stored in each layer.

Due to the location of ELA along the slope of a hill, it is comprised of a basement, mezzanine, first, second, and third floor. The mezzanine level was grouped with the first floor to reduce visual complexity of the model. The floor plan layers for the basement, first, second, and third floor can be seen in figure 3. Figure 4 displays all floors.

Colors were chosen for the interior floors and walls to represent the actual colors of the building. More importantly, however, the colors were set with transparency to allow for visual depth across the floor. The floor transparency was set at 95% and the wall transparency was 90%. Transparency of the walls allowed room numbers and stairs to be seen from multiple viewpoints. Figure 5 shows a viewpoint from the south east corner of the first floor where stairs and room numbers can be seen through the walls. The organization of all non-floor plan layers in the 3D model was based on SketchUp functionality and SMFR needs. These layers include fire-response, textual information, and representative information.

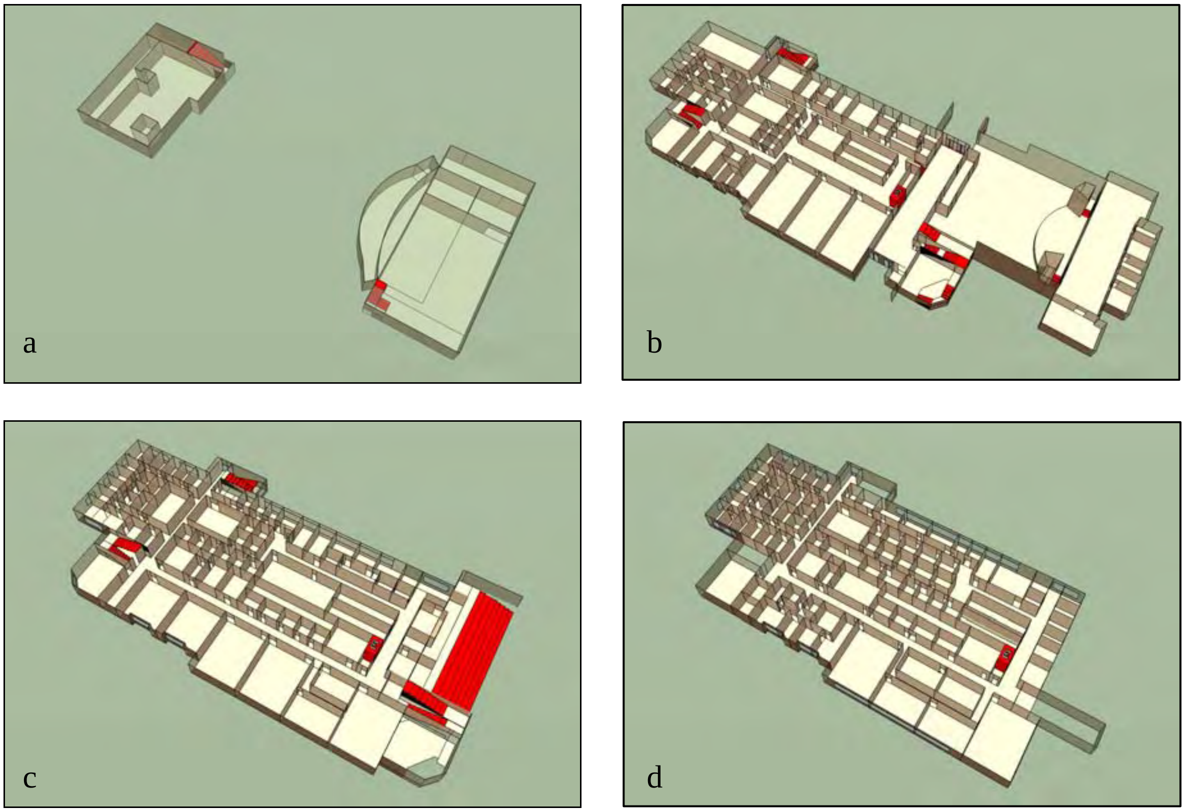


Figure 3. SketchUp: Evans Liberal Arts Building Floor Plans. a, basement; b, first floor; c, second floor; d, third floor. Note: The basement layer has a shaded mask as it is underground from the viewpoint of the user.

Figure 4. SketchUp: Evans Liberal Arts Building.

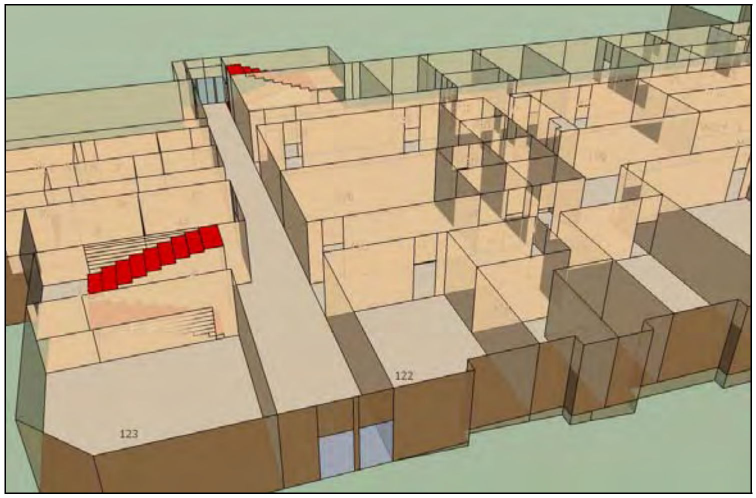


Figure 5. SketchUp: Color Transparency.

The placement and integration of text labels proved to be problematic in terms of graphic complexity and label positions in both 2D and 3D form (Skupin 2000). 2D text in SketchUp is feature linked and can either exist as a simple text box or as a callout to a feature. In SketchUp, a callout is a label displayed at the endpoint of an arrow pointing to a specific area or feature. The callout label orients itself with the viewpoint of the user. For example, as a user rotates the 3D model, the label will always read left-to-right. In both cases, the typography of the text can be modified but the color cannot. 3D text can only be placed as a text box; however it can have typography modified within 3D form. There are two issues to take into consideration when placing 2D text in SketchUp: (a) text labels are readable relative to scale and viewpoint, and (b) text labels are always visible no matter where it exists in 3D space. When placing 3D text, it was important to consider height, width, color, and angular placement (Hardisty, MacEachren, and Takatsuka 2001).

A visual hierarchy of feature labels was created based on the importance of the feature it was linked to and the dimension of the text, see figure 6. There were two cases where 2D text was placed in the 3D model. Room numbers were placed in the center of each room as simple 2D text boxes. The choice of text type for room numbers was made by how easily visible they were within the 3D model. This allowed for greater visualization of the room number from any 360° viewpoint. 2D callouts were placed on vital fire-related data identified by SMFR, including the fire alarm control panel, fire department connections, main electrical power source, outdoor standpipes, and outdoor sprinkler locations.

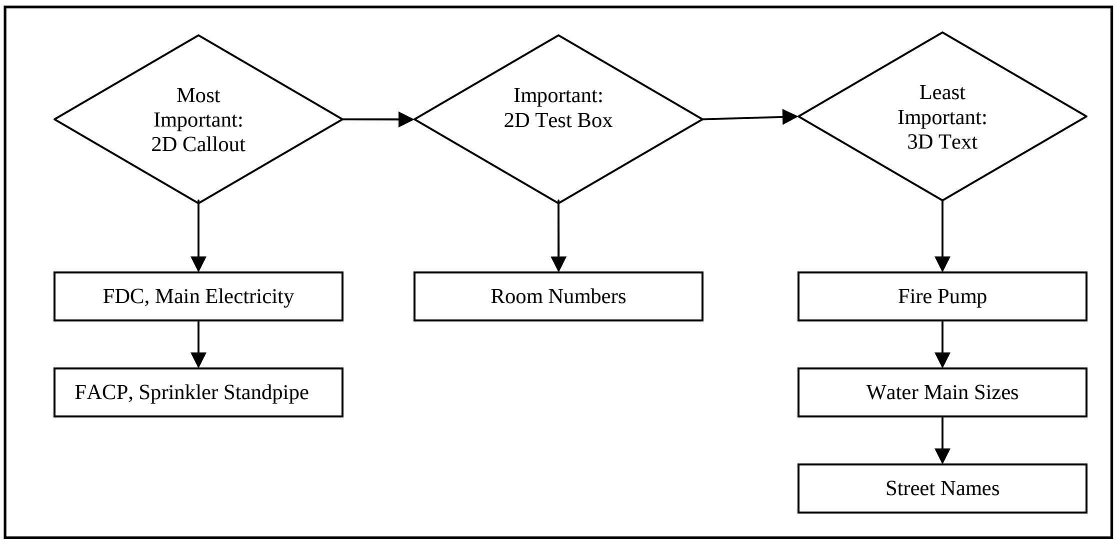


Figure 6. Visual Hierarchy: Feature Labeling in SketchUp.

3D text was used for water main sizes, an acronym of the fire alarm control panel, the location of the fire pump, and street names. The water main lines in the 3D model were generalized to a single 2D line to reduce level of detail bottlenecking. Unfortunately, 2D line representations in SketchUp always display with the color black. Therefore, in order to display the water main information as part of the fire response layer, the labels were made to be 3D and colored red. The label for the fire pump in ELA was 3D for two reasons. First, text callouts for more important information already existed in a similar location. Therefore, if a text callout for the fire pump was added, the labels would have been cluttered (Skupin 2000). Also, the fire pump was located in a large room of ELA which could accommodate the 3D text size. Street names were also labeled with 3D text. This decision was made so that the labels could be easily visible with an aerial photo in the background. The choice of height and size of all 3D labels was made so that the labels were visible from any 360° viewpoint.

Based on the knowledge gained during domain-knowledge elicitation, information necessary for incident command needed to be a prominent feature in the 3D model. The information was grouped in two ways: all fire-related data that could coexist in one layer and fire-related data existing in parts of other layers. The first group contained fire department connections, standpipes, sprinklers, fire hydrants, water lines and sizes, fire pump, and fire alarm control panel (see figure 7). The second group included stairs, elevators, and the SMFR pre plan survey.

As part of the second group, stairs and elevators could not exist in a single fire-related layer because of the need to have them visible with each floor. Stairs and elevators were created in the floor layer they belonged to. The use of the color red tied these layers together to represent fire-related data. The red was fully saturated and visible throughout the entire model. All features were created in the proper location; however fire hydrants were exaggerated in size to be visually apparent throughout the model (Ferry et al. 2002). Figure 7 displays the first floor and fire response layers from the southwest corner of the building.

The pre plan survey that SMFR presently uses to collect building information was required to be represented in the 3D model. The representation of the pre plan survey was shown to SMFR in two ways: a) either to have all information from the pre plan survey to exist as text beside the model or b) as an inserted image in the model. SMFR decided to have the pre plan survey as an inserted image because personnel are already accustomed to it.

The remaining layers available in the model included a 2D aerial photo, north arrow, roof, and streets with street names. These layers represent reference layers for an end-user to orient point-of-view with the building. An overview of the entire model within the SketchUp application can be seen in figure 8. Overall, the 3D model was created based on knowledge gained during the user-centered design process and functionality required by both SMFR and SketchUp.

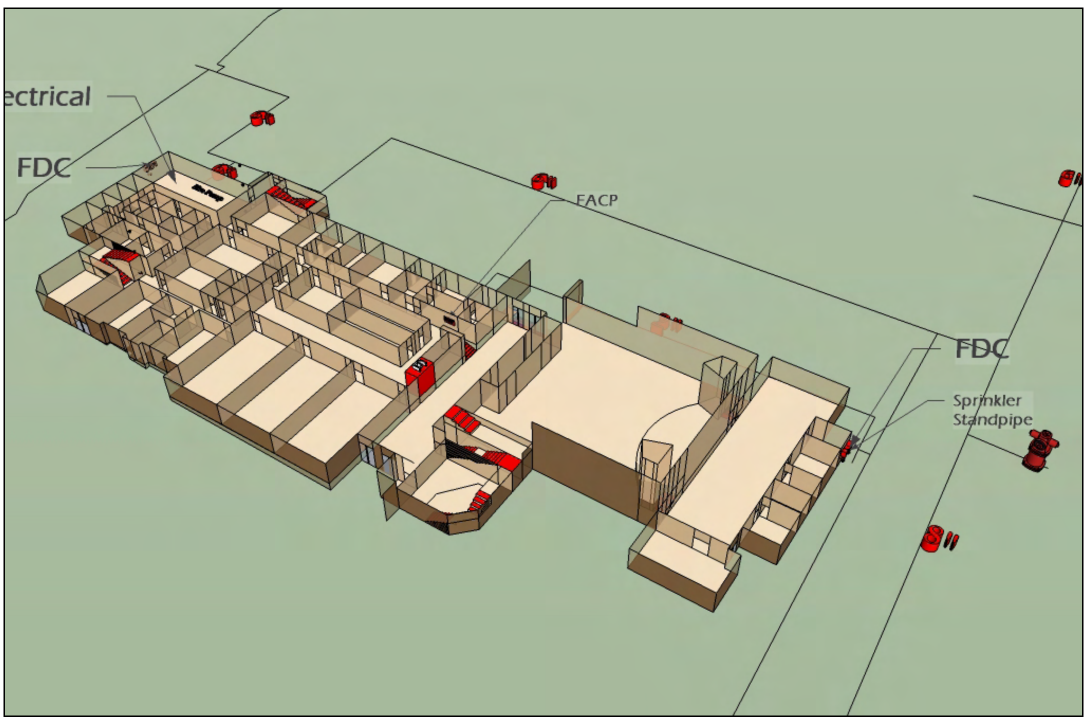


Figure 7. SketchUp: Fire Response.

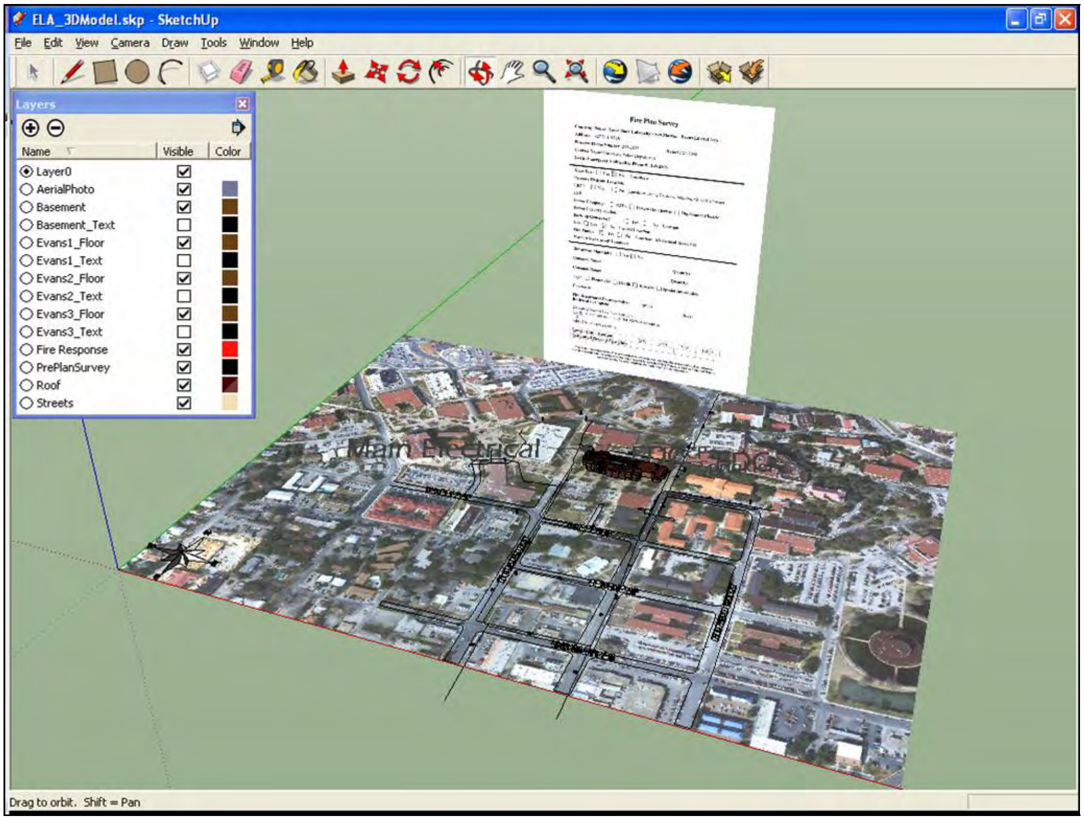


Figure 8. SketchUp: 3D Model.

3.2.3 Usability Testing

Usability evaluation methods were chosen based on the literature review and the requirements of this research. The approach to usability testing was based on the framework outlined by Zhang and Adipat (2005), see figure 9. Usability testing was broken down into 3 phases: participant training, execution of task-based scenario, and conclusion. Usability testing occurred on October 8, 2007 from 4:00 pm – 7:00 pm and October 11, 2007 from 5:00 pm – 7:30 pm in the Evans Liberal Arts building at Texas State.

The selected testing method for this research was field-based. There was a strong concern for usability in real-world fire-related incident scenarios. The 3D SketchUp model and 2D PDF maps were loaded onto a laptop to be used during testing. A mouse with a scroll wheel was attached to the laptop. SketchUp has enabled functionality with a mouse scroll wheel to zoom in and out of the interface display. The usability attributes selected to measure were efficiency, effectiveness, and satisfaction. These usability attributes were measured in number of questions asked by a user, time to complete a task, and number of frustrations, respectively. Traditional data collection methods were chosen to limit the invasiveness of the evaluation process on a user. These methods included video recording, questionnaire, and semi-structured interview.

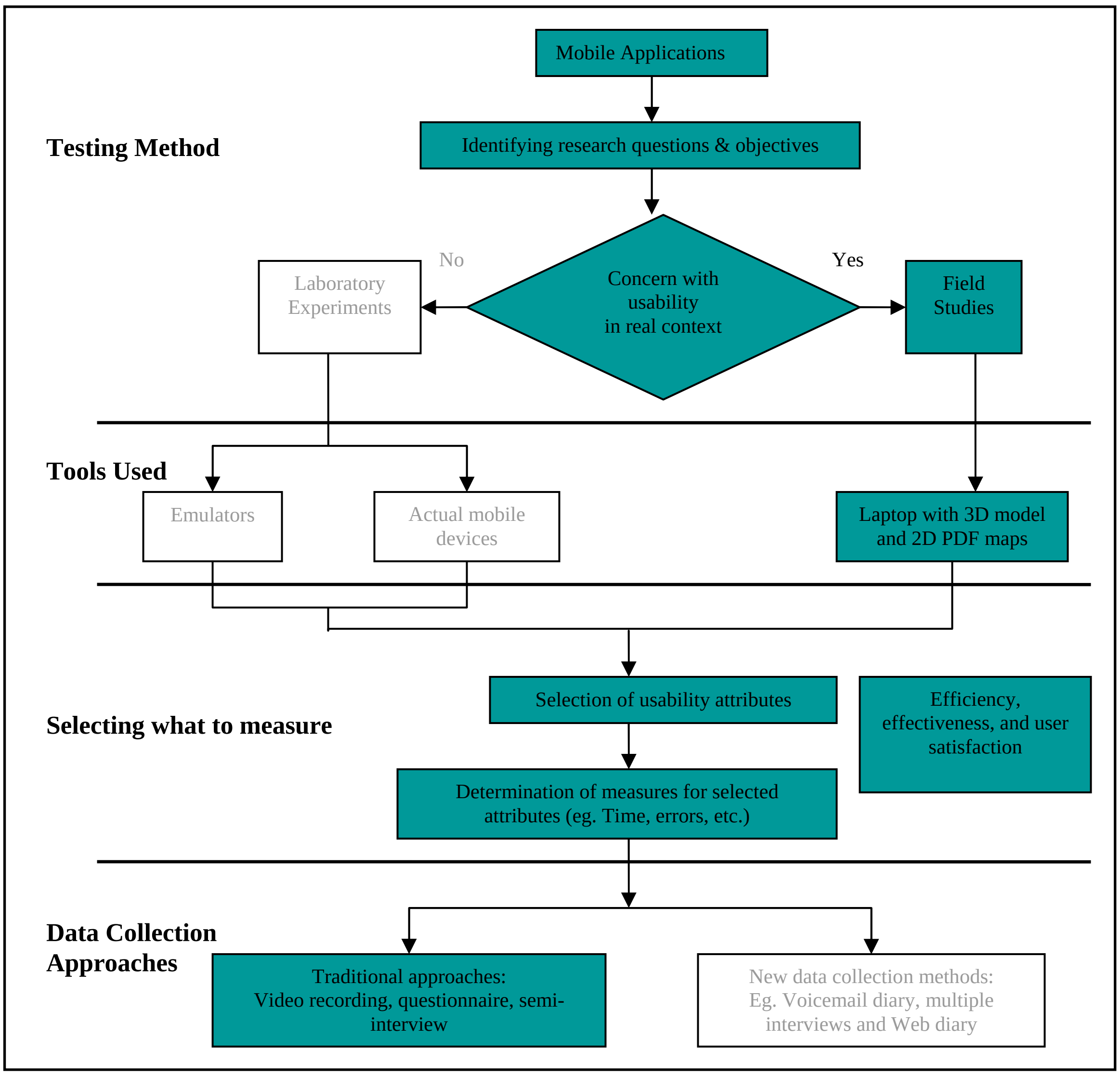


Figure 9. Usability Testing Framework: Research Approach. Based on a framework for usability testing of mobile applications by Zhang & Adipat (2005).

On the first day of usability testing, participants from SMFR were introduced to SketchUp and briefed on the goals of this research. Training participants on SketchUp included an overview presentation which explained the graphical user interface. A sample model was used to explain how information is stored in various layers, how to turn on and off layers, and how to use the tools within the graphical user interface, such as rotate, pan, and zoom. The sample model was extremely basic so that the 3D model of ELA would be unfamiliar to the test participants. Participants were then allowed hands-on time to work with SketchUp and the sample model until they felt they were comfortable. The overall training time including overview presentation and individual hands-on training was 30 minutes.

The second phase of usability testing was the execution of the task-based scenario. The task-based scenario was repeated a total of sixteen times, eight for each of the 2D PDF maps and 3D ELA model. The task-based scenario was developed before the commencement of usability testing. Chief Baker and Lieutenant Kuhlman collaborated with the representatives of this research to outline the steps for each task objective in the scenario. These steps can be seen in figure 9.

At the beginning of the scenario, a participant acting as an incident commander would either use the 2D PDF maps or 3D ELA model to give directions a participant acting as a fire fighter. The incident commander first instructed the fire fighter to the fire alarm control panel (FACP) by communicating over a radio. Once at the FACP, Lieutenant Kuhlman, who was reading a predefined scenario script that an alarm signaling in room 217a and 360, instructed the fire fighter and the conditions of the third floor were smoky. The fire fighter then reported these conditions back to the incident commander. The incident commander then directed the fire fighter to find room 217a. Once the fire fighter successfully found room 217a, they reported that everything was okay in the room. The incident commander would then direct the fire fighter to room 360. When the fire fighter successfully navigated to room 360, they found a professor trapped in the room. The fire fighter reported to the incident responder that they found the professor. After all was cleared from room 360, the incident commander would direct the fire fighter and the professor out of the building. Participants randomized the execution of the task-based scenario in an attempt to reduce the development of a cognitive map of the Evans Liberal Arts building. The incident commander and fire fighter were both video recorded throughout the entire usability training process. This process can be seen in figure 9.

Finally, the usability testing concluded with a semi-structured interview and questionnaire with all participants. Participants were asked to fill-out a questionnaire and answer a few short-answer questions to measure the usability of the 3D ELA model. During this time, participants also discussed their subjective reactions towards the satisfaction of the 3D model with the evaluator.

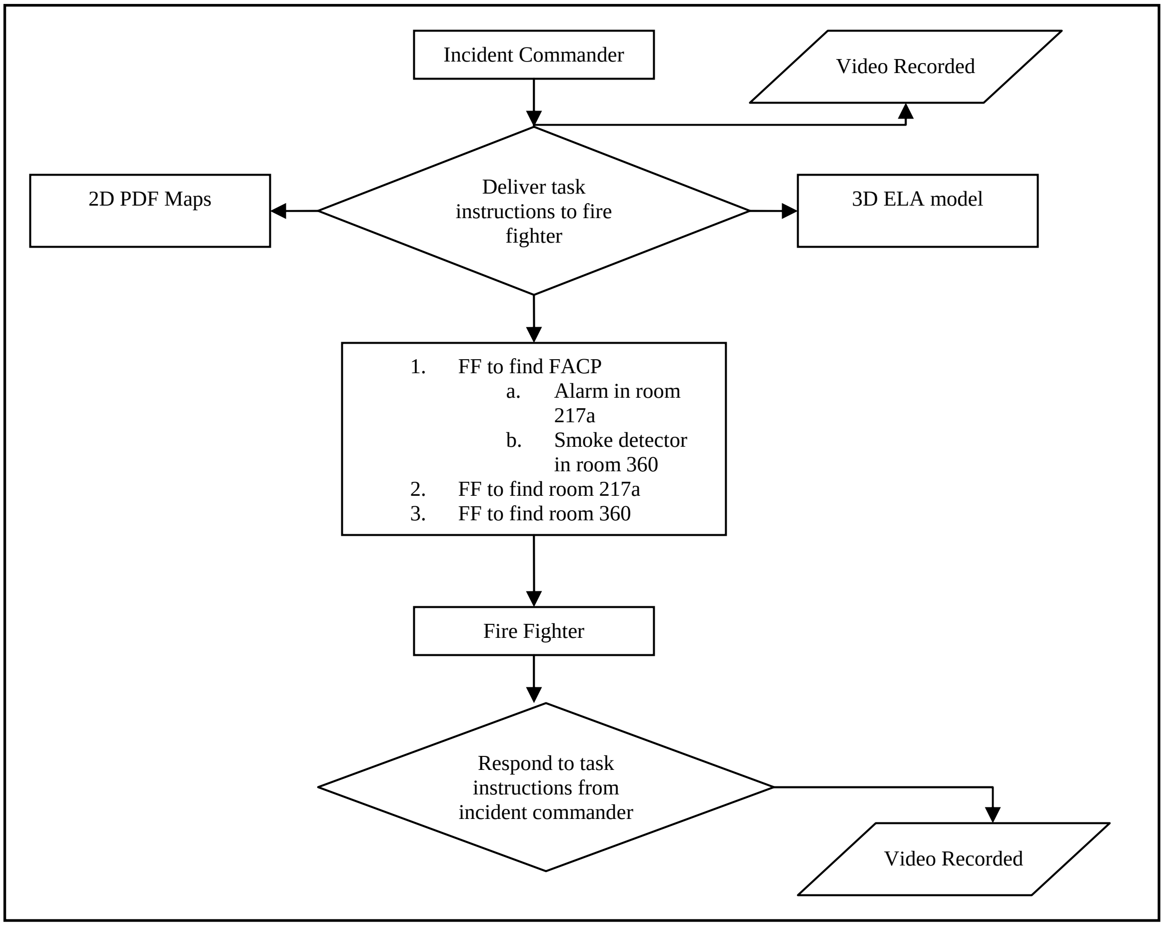


Figure 10. Structured Task-Based Scenario. This scenario was repeated 8 times for the 2D PDF maps and 8 times for the 3D ELA map.

CHAPTER 4

RESULTS

This chapter describes an overview of the usability testing based on methodology provided in the previous chapter. This research sought to study the efficiency, effectiveness, and satisfaction of a 3D geovisualization model using comparative qualitative and quantitative analysis techniques. Problems discovered during the execution of a task-based scenario with domain specific representatives will be presented. Chapter 5 includes a discussion about the solutions to help mitigate the issues in future research.

4.1 Implementation of Domain-Specific Requirements

The development of the structured user-centered design process revealed domain-specific requirements necessary for successful geovisualization of fire-related information during an incident command process. These domain-specific requirements were integrated into a 3D model developed in SketchUp. The integration techniques used were based on knowledge gained in previous chapters. Limited by this research's scope of study, domain-specific requirements were grouped into a single active "fire-response" layer in SketchUp, unless it was easier to display the information in other layers. For example, stairs were identified as information needed by incident commanders en route to an incident. However, stairs also needed to be displayed as a part of the floor plan.

Therefore, stairs were kept in the floor layer they spatially belonged to, however were identified with the color red to tie them to the features colored red in the "fire-response" layer.

Out of the four categories of incident response, the majority of data for the ELA building at Texas State fell under "fire-response", little to no data existed for "medical-response", "haz-mat response", or "rescue-response". The aggregation of vital data into fewer layers reduced the overall complexity of SketchUp layer functionality. Table 7 lists the domain-specific content for ELA by each layer.

Table 7. SketchUp Layers: Domain-Specific Content

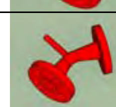
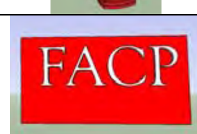
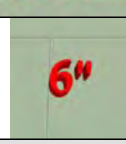
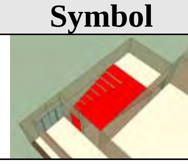
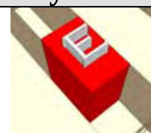
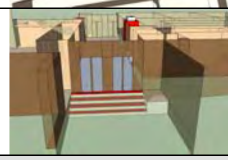
LAYER: FIRE RESPONSE		
Feature	**Symbol**	**Label**
Fire department connector		2D text callout and 3D text; bold, abbreviated in all caps; 3D text in red
Standpipes		2D text callout; bold, full name description in lower case
Sprinkler standpipes		2D text callout; bold, full name description in lower case
Fire hydrants		Not labeled
Fire alarm control panel		2D text callout, abbreviated in all caps; 3D text in white
Fire pump		3D text ; full description red in red
Water main lines		3D text ; full description red in red
LAYER: FLOOR PLANS		
Feature	**Symbol**	**Label**
Stairwells		Not labeled

Table 7-Continued. SketchUp Layers: Domain-Specific Content

Feature	Symbol	Label
Elevator		3D text ; full description red in white
Rooms		2D text box
Entrances and Exits		Not labeled
LAYER: PRE PLAN SURVEY		
Feature	**Symbol**	**Label**
SMFR pre plan survey for ELA	Jpeg image of actual document (see Appendix A)	Not labeled

4.2 Execution of Task-Based Scenario

The effectiveness of the methodology implemented to integrate domain-specific requirements in the 3D model was tested on October 8, 2007, and October 11, 2007. The total number of participants was twenty two persons, including sixteen participants from SMFR, one study facilitator from SMFR, two risk assessment representatives from Texas State, two people to video record tasks, and one conductor of the usability test. All seventeen participants from SMFR were males between the ages of 22 to 50.

Usability testing commenced with a briefing of the research objectives and a presentation on the graphical user interface of SketchUp in a room on the first floor of ELA. SketchUp training needed to occur in a place where all participants could have access to a computer and see a projected image during the training presentation. Participants were directed to the training room from an entrance to the building opposite than the entrance for the task-based scenario. This was done in to reduce spatial learning by fire fighters of ELA.

Once SketchUp training was complete, participants executed the task-based scenario in teams of two. Unfortunately, due to time constrictions posed on this research, a pilot test was not conducted before initial usability testing. A problem was discovered during the execution of the task-based scenario by the first two teams which could have been avoided if a pilot test had been conducted. This problem was identified in the task objective involving a fire fighter rescuing a professor from room 360 in heavy smoke conditions. In order to simulate the visual imparity caused by smoke, fire fighter representatives wore a sock to cover their eyes. Blindfolding the fire fighters caused the total time to complete a task to increase while not benefiting in the usability evaluation of the 3D model. Blindfolding tested communication skills but not the usability of the 3D model.

After the completion of the task-based scenario by the first two teams, the task-based scenario was modified. Incident commanders were still informed of heavy smoke conditions on the third floor however fire fighters did not need to simulate the conditions. This modification still allowed incident commanders to make strategic objectives from scene assessments while reducing the complexity of orientation and wayfinding by a fire fighter. Quantitative analysis will remove the first two tasks to evaluate efficient geovisualization. However, to evaluate effective geovisualization and overall user satisfaction, all tests will be included for qualitative analysis.

At the conclusion of the usability test, participants were asked to fill out a questionnaire and discuss questions posed in a semi-structured interview. According to the responses by participants on the questionnaire and during the semi-structured interview, the participants were satisfied with the overall usability of the 3D model. Generally, participants felt that using a 3D model was a challenging yet exciting task. The variability of challenges was most readily noted by the level of computer skills a user already maintained before usability testing. Users who had moderate to advanced computer skills felt much more comfortable when using the 3D model. Nevertheless, the users with limited computer skills were able to sufficiently acquire the knowledge necessary to successfully complete the task.

4.3 2D vs. 3D Comparisons

The analysis of comparative features for task-based scenarios using 2D and 3D representations attempts to answer the question of whether 3D geovisualization is appropriate for use by fire fighters. The goal of this research was not to test the usability of a specific software application, rather the usability of geovisualization for an incident command process. These abilities were evaluated based on timing, observed characteristics of end-users, and participant responses on a questionnaire and during a semi-structured interview.

4.3.1 Efficient Geovisualization

Time stamps were recorded during each of the following task objectives to efficiently measure geovisualization. The time stamps were recorded as follows: Start time, time when fire fighter reached room 217a, time when fire fighter reached room 360, and time when fire fighter exited the building (see tables 8 and 9). The initial two test runs during usability testing are omitted for analysis due to the modification of the task, as mentioned above in section 4.2. The total times to complete each task objective were statistically compared using an unpaired two-sample assuming equal variances *t*-test based on a 95% confidence interval to compare the mean times of different task execution times. A *t*-test for independent variables was chosen to analyze the different task execution times of randomly selected individuals from the same population at different times (Caprette 1996). The statistical results can be seen in table 10. Box plots were used to represent the variability of response times for each task objective using the PDF maps and 3D model in SketchUp (see figures 10, 11, 12, 13). Box plots are a useful way of identifying variability when comparing distributions (Lane 2003).

Table 8. Task Completion Times: 2D PDF Maps

Incident Commander	Fire Fighter	Start Time	Start to 217a	Start to 360	217a to 360	Total Time
P3	P4	18:20	05:00	08:00	03:00	12:00
P5	P6	18:55	04:00	10:00	06:00	13:00
P4	P7	17:10	03:00	07:00	04:00	10:00
P7	P8	17:23	03:00	08:00	05:00	11:00
P8	P3	17:54	05:00	07:00	02:00	10:00
P2	P9	18:08	02:00	05:00	03:00	07:00
P9	P10	18:31	04:00	07:00	03:00	14:00
		Average	**03:43**	**07:26**	**03:43**	**11:00**

Table 9. Task Completion Times: 3D Geovisualization Model

Incident Commander	Fire Fighter	Start Time	Start to 217a	Start to 360	217a to 360	Total Time
P2	P3	17:56	09:00	17:00	08:00	20:00
P4	P5	18:38	03:00	07:00	04:00	11:00
P6	P7	17:39	08:00	09:00	01:00	11:00
P9	P2	18:20	02:00	05:00	03:00	07:00
P3	P2	18:52	02:00	05:00	03:00	07:00
P11	P12	19:05	03:00	07:00	04:00	10:00
P12	P1	19:17	04:00	09:00	05:00	13:00
		Average	**04:26**	**08:26**	**04:00**	**11:17**

Table 10. Task Completion Times: Unpaired Equal Variance *t*-Test

				95 % confidence interval of differences					
Task Objective	**Map**	**M**	**SD**	**Conf.**	**Lower**	**Upper**	***t***	**df**	**p-value**
Start to Room 217a	2D	03:43	01:07	00:49	02:53	04:32			
	3D	04:26	02:53	02:08	02:18	06:34	-0.61	6	0.55
Start to Room 360	2D	07:26	01:31	01:07	06:19	08:33			
	3D	08:26	04:07	03:03	05:23	11:29	-0.60	6	0.56
217a to room 360	2D	03:43	01:23	01:01	02:42	04:44			
	3D	04:00	02:10	01:36	02:24	05:36	-0.29	6	0.77
Start to Finish	2D	11:00	02:19	01:43	09:17	12:43			
	3D	11:17	04:25	03:17	08:01	14:34	-0.15	6	0.88

The first task objective recorded was the time the fire fighter reached room 217a. The average time to reach room 217a using PDF maps was 03:43 minutes compared to 04:26 minutes using the 3D model. There was greater variability in task times with users of the 3D model (PDF: SD = 01:07; 3D: SD = 02:53). Overall, the time to complete the first task objective while using the 3D model was not significantly different than when using the PDF maps ($p = 0.55$).

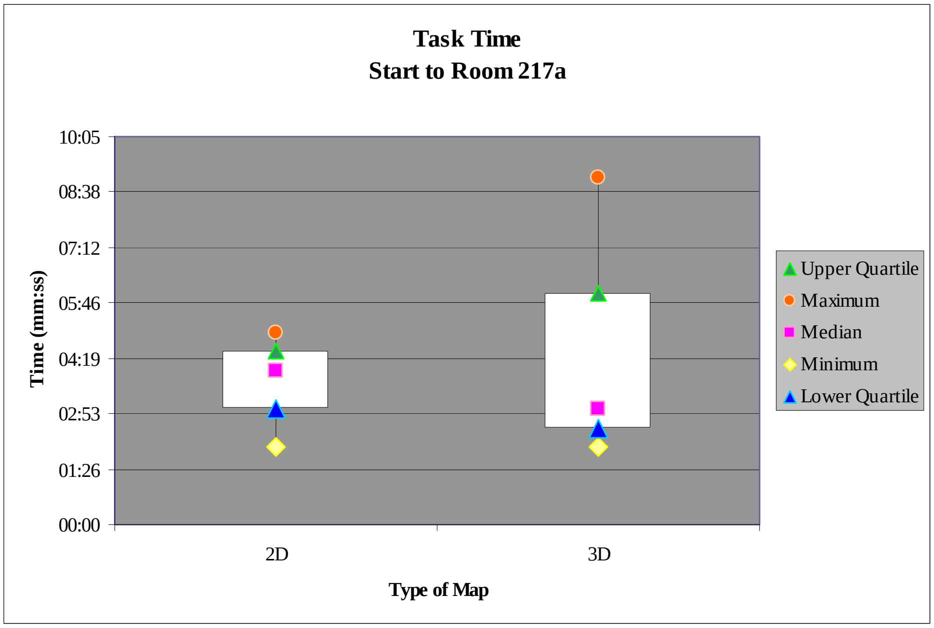


Figure 11. Task Completion Time: Start to Room 217a. The time to complete the task using the 3D model was not significantly different than when using the PDF maps (p = 0.55).

The second task objective recorded was the time from the start of the task to the time the fire fighter reached room 360. The average time from the start of the test to room 360 using PDF maps was 07:26 minutes compared to 08:26 minutes using the 3D model. There were extreme differences in variability of task times with users of the 3D model (PDF: SD = 01:31; 3D: SD = 04:07). Out of all measures of task objective time comparisons, this task objective contained the greatest variability. Overall, the time to complete the second task objective while using the 3D model was not significantly different than when using the PDF maps (p = 0.56)

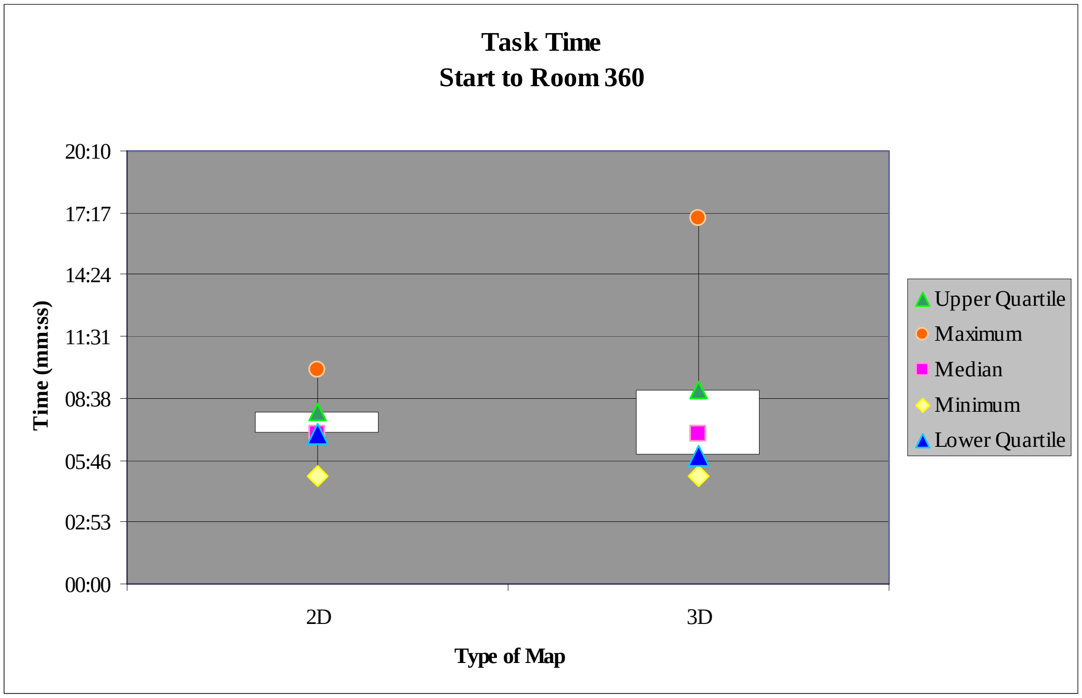


Figure 12. Task Completion Time: Start to Room 360. The time to complete the task using the 3D model was not significantly different than when using the PDF maps (p = 0.56).

The third objective recorded was the amount of time required to respond to room 360 from room 217a. The average time from room 217a to room 360 using PDF maps was 03:43 minutes compared to 04:00 minutes using the 3D model. There was greater variability in task times with users of the 3D model (PDF: SD = 01:23; 3D: SD = 02:10). Overall, the time to complete the third task objective while using the 3D model was not significantly different than when using the PDF maps (p = 0.77) (see figure 12).

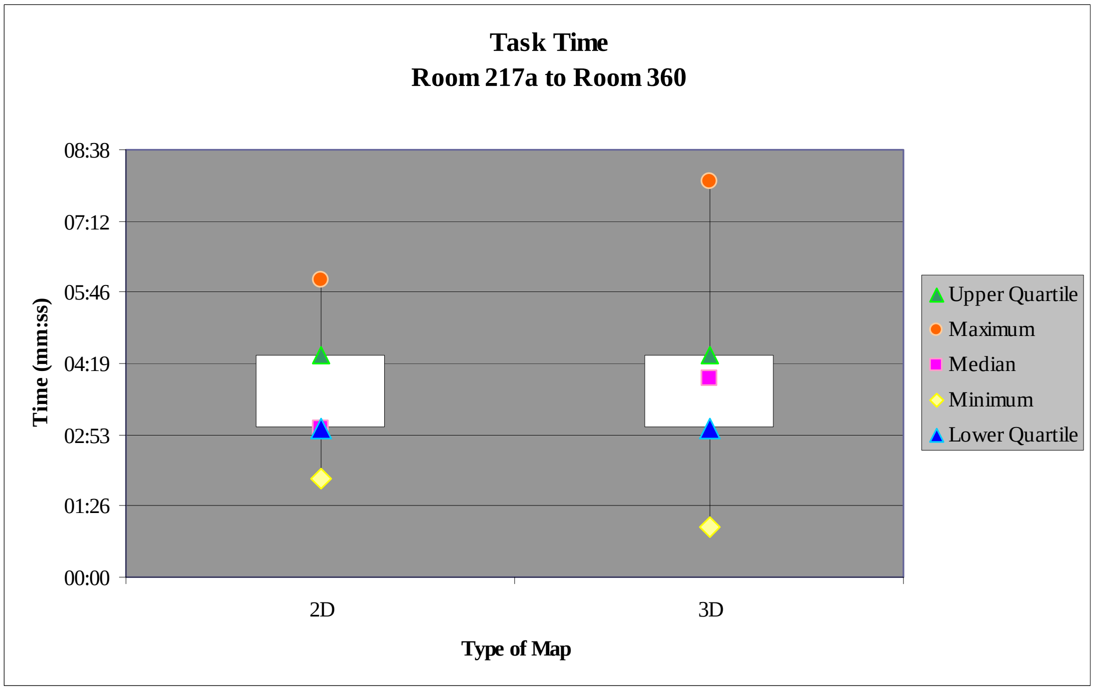


Figure 13. Task Completion Time: Room 217a to Room 360. The time to complete the task using the 3D model was not significantly different than when using the PDF maps (p = 0.77).

The final time recorded was when the fire fighter existed the ELA building. The average time from the start to finish of the test using PDF maps was 11:00 minutes compared to 11:17 minutes using the 3D model. There was greater variability in task times with users of the 3D model (PDF: SD = 02:19; 3D: SD = 04:25). Overall, the time to complete all task objectives while using the 3D model was not significantly different than when using the PDF maps (p = 0.88).

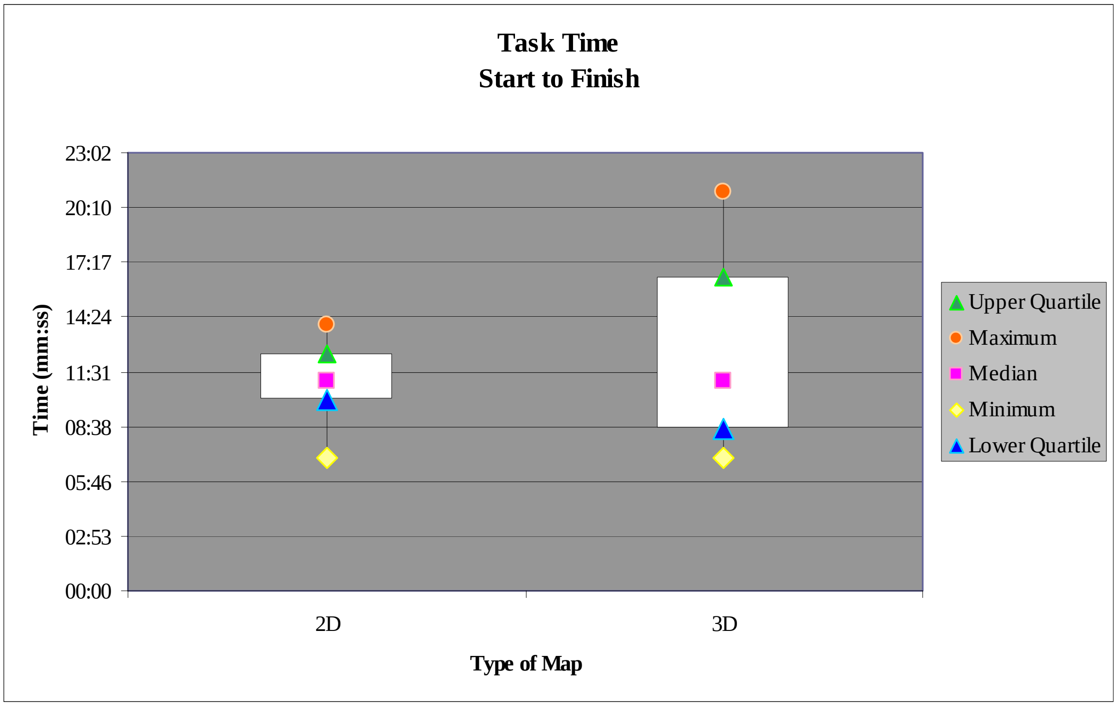


Figure 14. Task Completion Time: Start to Finish. The time to complete the task using the 3D model was not significantly different than when using the PDF maps (p = 0.88).

There is no statistical evidence from this research to support the hypothesis that a 3D geovisualization can provide more efficient wayfinding for a high-rise building fire than a 2D PDF based on a small sample size (*n* = 7). However, this does not necessarily eliminate the need for efficient and effective geovisualizations in fire-related incident command processes. Qualitative analysis in the section below will investigate the effectiveness and desire for 3D geovisualizations in fire-related incident command.

Basic trends indicated by the box plots reveal that the minimum times recorded for each task execution with both the 2D PDF maps and 3D model are relatively similar. This may indicate there is a minimum amount of time required to complete a specific task objective. However, there is greater variability in range of times for the 3D model than the 2D PDF maps. This could signify a variation in cartographic map reading skills by participants or insufficient usability training for 3D geovisualization.

4.3.2 Effective Geovisualization

Effective geovisualization was qualitatively measured through observations of participants by the usability testing evaluator. Users were monitored throughout the usability testing process to record observed ease of use with the PDF maps and the 3D geospatial tool. Observations were ranked into three levels of difficulty: easy, medium, and difficult. Ease of use was calculated by observing the total number of users that felt a feature or task was easy to identify. All sixteen tasks were observed for ease of use because all incident commander representatives delivered the same task-based instructions to fire fighter representatives. The recorded observations of end-users for both map types were:

- Visibility of stairwells
- Ability to turn on and off layers
- Visibility of room numbers
- Visibility of interior room doors
- Visibility of mezzanine level
- Visibility room 217a

The total effectiveness of features was calculated by add the number of participants that felt a feature was easy to use with half of the number of users that felt a feature was medium. Therefore, the total did not include participants which felt a feature was difficult. As an example, to visualize the half-level to room 217a within the 3D model, 4 users felt it was easy, 2 users felt it was medium, and 1 user felt it was difficult.

The total ease of use was calculated by adding the 4 users that felt it was easy with half of the 2 users that felt it was medium; the overall total was 5. Overall, visualizing stairwells and the ability to turn on and off layers was easy for both the 2D PDF maps and the 3D model. It was easier to visualize room numbers and doors in the 2D PDF maps. It was easier to visualize the mezzanine level and room 217a in the 3D model. These results are displayed in figure 14.

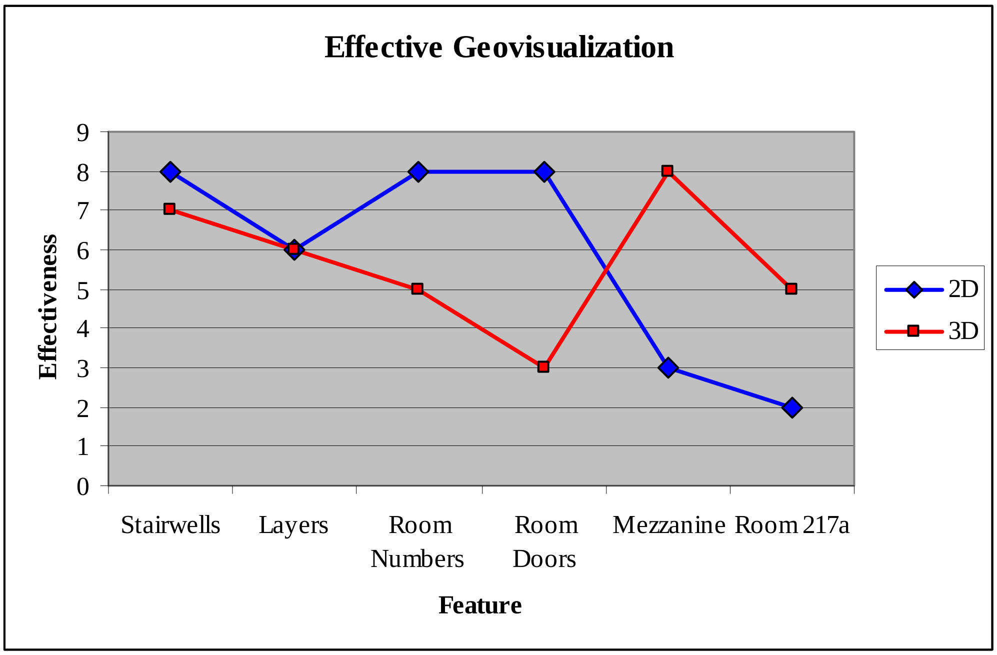


Figure 15. Effective Geovisualization. The effectiveness of feature geovisualization in both the 2D PDF maps and 3D geospatial tool are measured by ease of use observed during usability testing. Ease of use was ranked on level of difficulty (easy, medium, and difficult).

The effectiveness of fire-related data was only tested for ease of use when displayed in the 3D model. Texas State does not apply domain-specific information in the 2D PDF building floor plans, such as fire-related data needed for incident command. The case study for this research was to compare the present use of maps by SMFR with the development of a 3D geovisualization process through usability testing. Therefore, fire-related information was not created and applied to the 2D PDF maps. Overall, four out of eight users found the “fire-response” layer easy to use; two users found the level of difficulty medium and two users found the level of difficulty hard.

4.3.3 User-Satisfaction of Geovisualization

The final means to qualitatively measure the overall satisfaction of participants was a questionnaire filled out at the end of the usability testing phase (see Appendix B). Participants answered questions based on a scale of one to five, strongly agree to strongly disagree respectively.

Usability of SketchUp

It is important to note the overall satisfaction of users with the software platform chosen for the 3D geovisualization model. It was not a research objective to test usability of different 3D software platforms. However, the usability of the software chosen to develop and implement the geovisualization process may provide some insight to the overall user satisfaction by participants. In general, most participants agreed that they were comfortable using the graphical user interface of SketchUp. However, some participants felt that increased training on the graphical user interface would have increased the user satisfaction. Most participants either strongly agreed or agreed that they were comfortable and trained sufficiently in SketchUp (see figure 16).

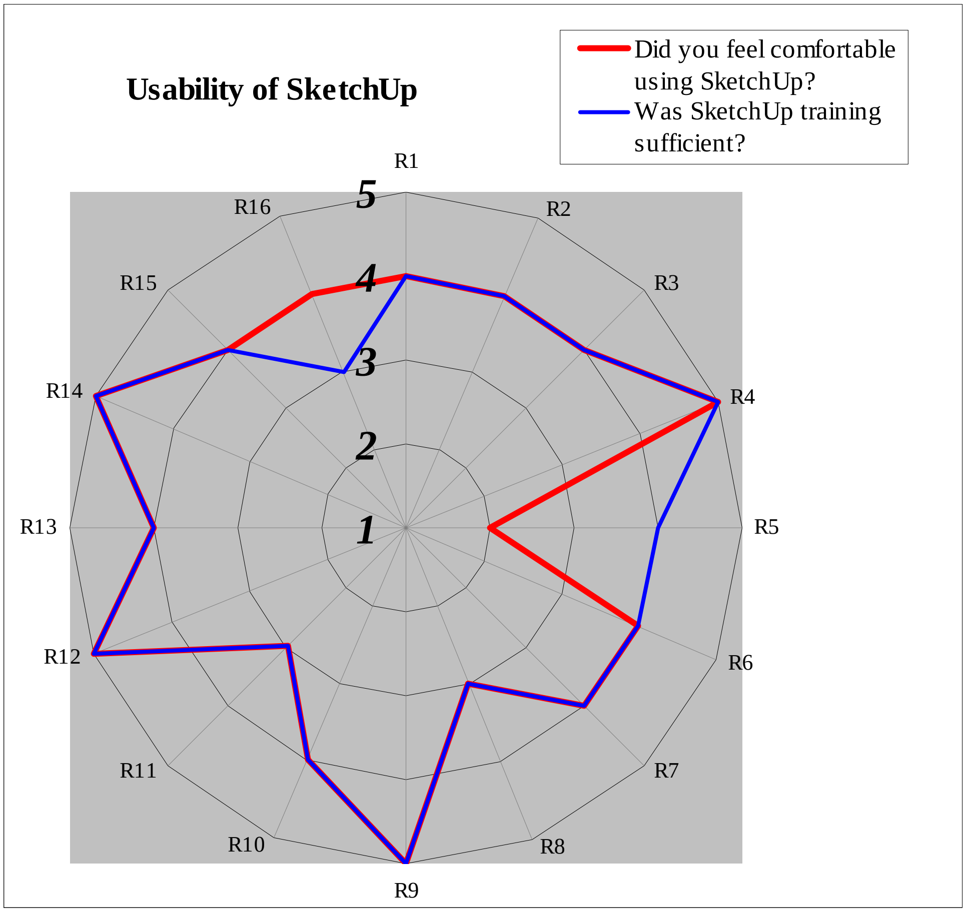


Figure 16. Questionnaire Response: Usability of SketchUp. Questions were answered based on a scale of 1-5; strongly disagree to strongly agree, respectively.

Using Maps to Familiarize with ELA

Participants were asked whether they were able to familiarize themselves with the ELA building at Texas State using both the 2D PDF maps and the 3D geospatial tool. Overall, participants strongly agreed or agreed that they were able to become familiar with ELA using 3D geovisualization and 2D PDF maps. There was one user who disagreed that 2D PDF maps worked better than the 3D geospatial tool (see figure 17).

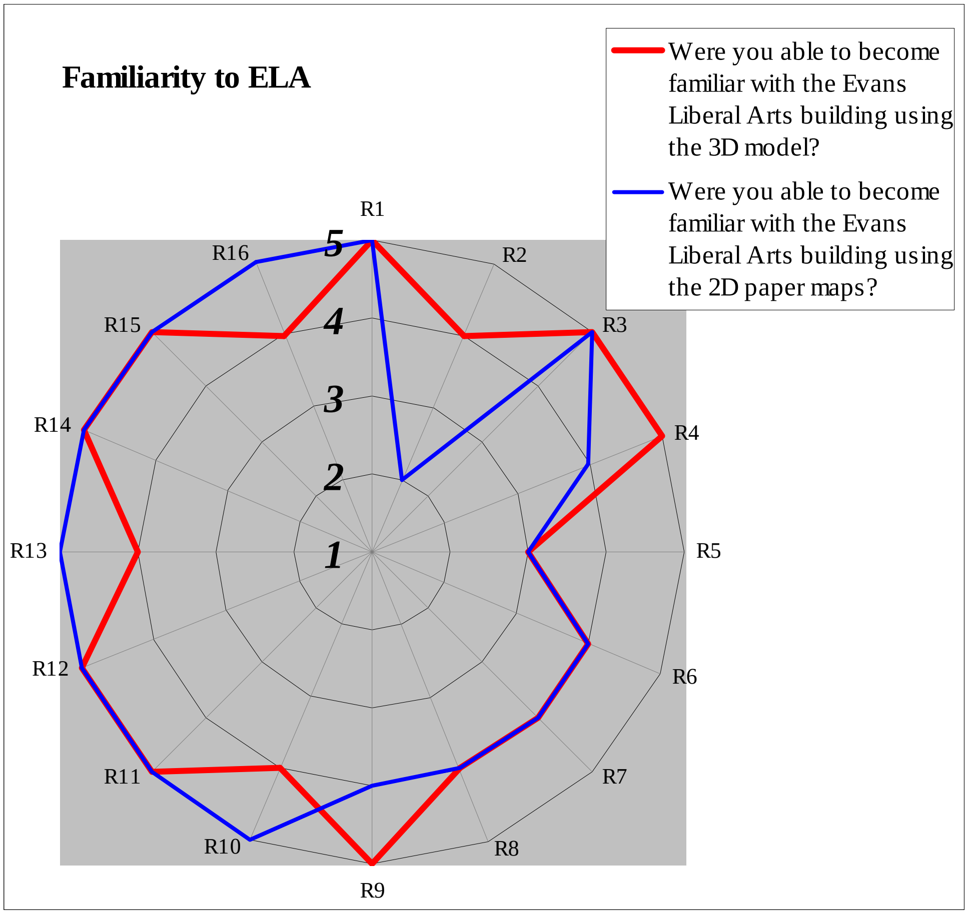


Figure 17. Questionnaire Response: Familiarity to Evans Liberal Arts Building. Questions were answered based on a scale of 1-5; strongly agree to strongly disagree, respectively.

SketchUp Layers

When comparing questionnaire responses concerning SketchUp layer functionality, most participants strongly agreed or agreed that the organization of layers in the 3D geospatial tool was helpful and that they could easily decide what layers to turn on and off (see figure 18).

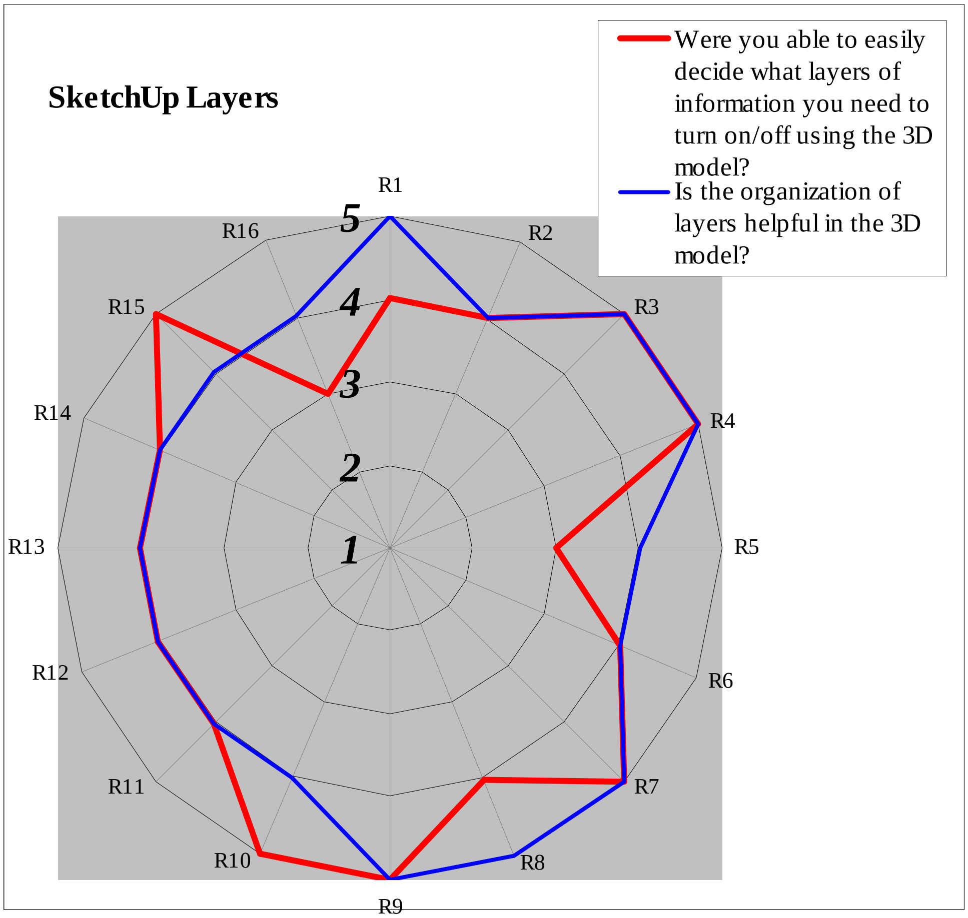


Figure 18. Questionnaire Response: SketchUp Layers. Questions were answered based on a scale of 1-5; strongly disagree to strongly agree, respectively.

Identification of Fire-Related Data

Three questions were related to the identification of fire-related data in the 3D geospatial tool. All users either strongly agreed or agreed that fire-related data were easy to identify. There was a variable response range between strongly agree, agree, and neutrality when asked whether transparently of building features assisted in the ease of identification. However, most participants strongly agreed or agreed that coloring all fire-related data red assisted in identifying the critical features (see figure 19).

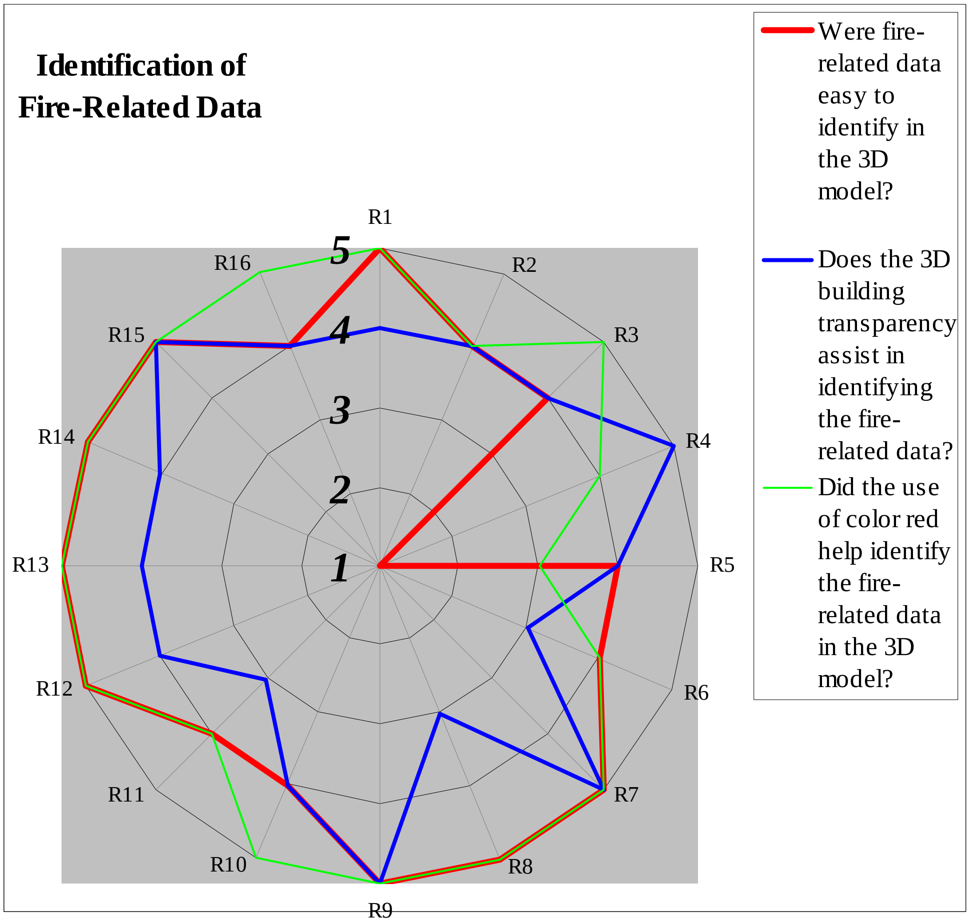


Figure 19. Questionnaire Response: Identification of Fire-Related Data. Questions were answered based on a scale of 1-5; strongly disagree to strongly agree, respectively.

Feature-Labeling

Three questions were related to feature labeling within the 3D geospatial tool, both for 2D and 3D text. Most participants either strongly agreed or agreed that they were pleased with the use of 3D text. Similarly, the participants were relatively more pleased with the use of 2D text, such as when used for room numbers. Overall, however, most users disagreed that they would prefer the use of 2D text over 3D text (see figure 20).

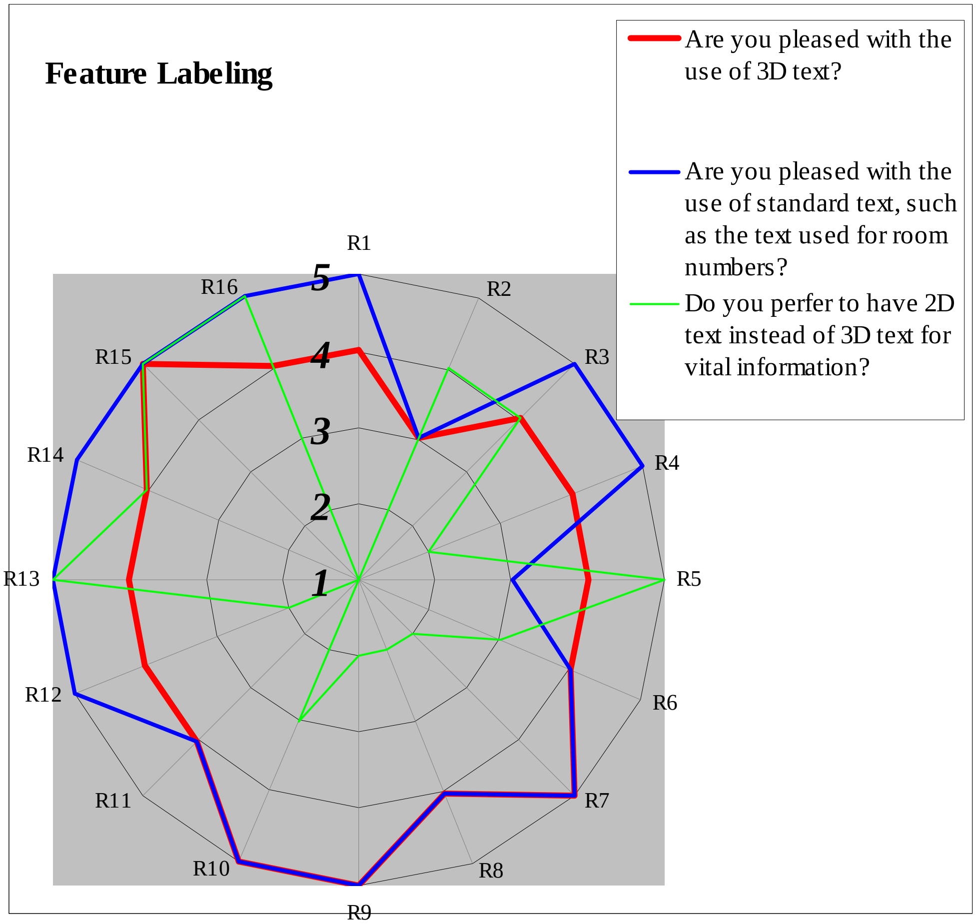


Figure 20. Questionnaire Response: Feature Labeling. Questions were answered based on a scale of 1-5; strongly disagree to strongly agree, respectively.

Delivery of Task Instructions

Three questions were relevant to the delivery of task instructions from a user representing an incident commander. Participants felt they either strongly agreed or agreed that task instructions were easy to deliver from both the 2D PDF maps and the 3D geospatial tool. However, the majority of the participants felt they preferred to deliver task instructions while using the 3D geospatial tool. It should also be noted that there was one user who strongly disagreed and one user who disagreed that they would prefer to deliver task instructions from the 3D geospatial tool (see figure 21).

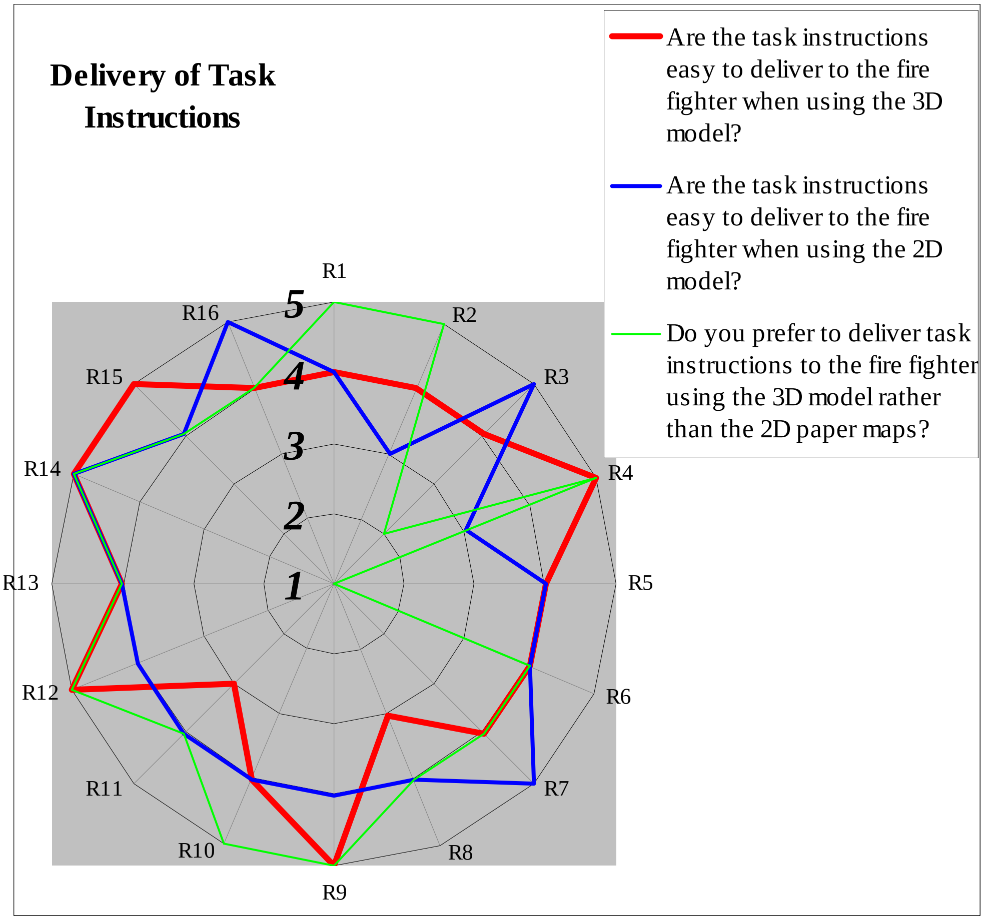


Figure 21. Questionnaire Response: Delivery of Task Instructions. Questions were answered based on a scale of 1-5; strongly disagree to strongly agree, respectively.

2D vs. 3D Overall Mapping

There were three questions that evaluated participants overall feeling towards the research objectives. When comparing 2D mapping to 3D mapping, there was a wide range of responses by participants. When asked whether they preferred 3D mapping over 2D mapping, the spectrum covered the entire response availability range. Likewise, the most participants felt the same way when asked if they would prefer a combination of two and 3D mapping. However, there was an overwhelming notion that 3D mapping has a future in fire-related incident command (see figure 22).

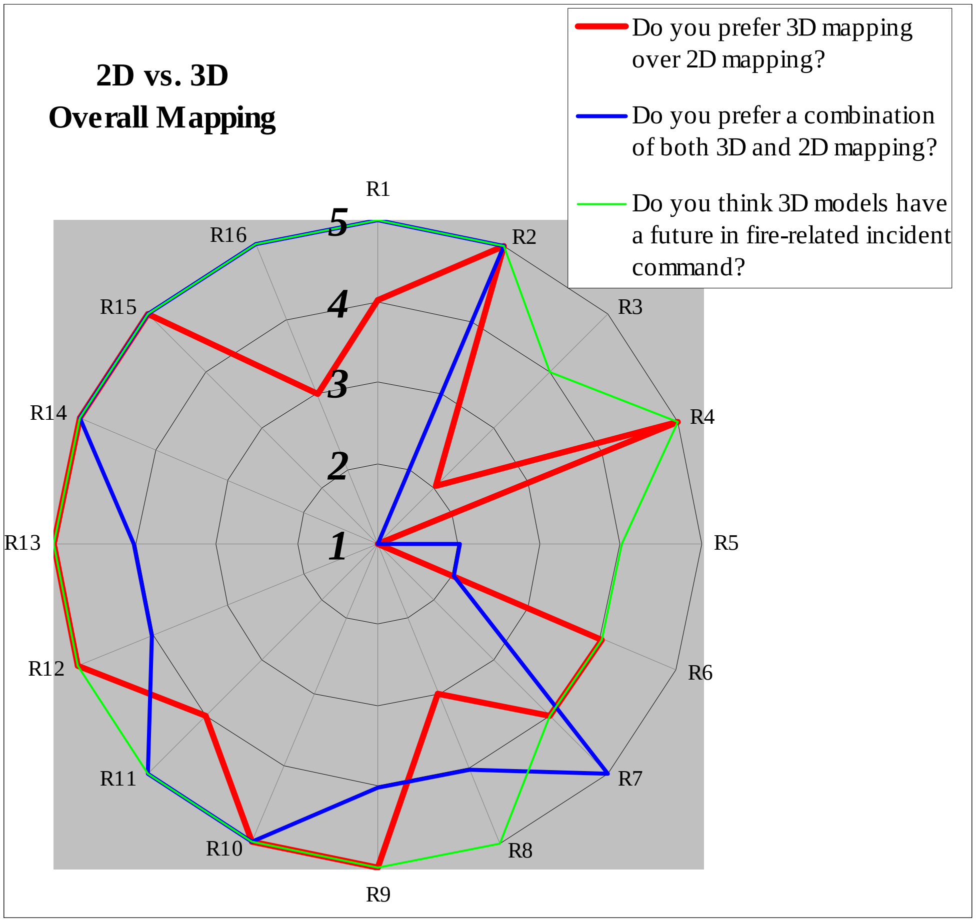


Figure 22. Questionnaire Response: 2D vs. 3D Mapping. Questions were answered based on a scale of 1-5; strongly disagree to strongly agree, respectively.

In review of the qualitative analysis performed on the questionnaire filled out by all participants after usability testing, a general trend can be noted: *The general attitude towards characteristics of 3D geovisualizations is positive*. Most participants agreed that the cartographic features implemented in the 3D geovisualization process were useful and usable. Most importantly, the majority of participants strongly suggested that there is a future for 3D geospatial tools in fire-related incident command processes.

CHAPTER 5

DISCUSSION

This chapter provides a review of the quantitative and qualitative results analyzed in relation to the usability of 3D geovisualizations in fire-related incident command processes. This analysis will ultimately conclude whether the research objectives outlined in Chapter 3 were successfully examined in this study. Solutions to the problems discovered in Chapter 4 will also be identified to mitigate any issues that were experienced during this research. Areas of possible future research will be presented in Chapter 6.

As stated in Chapter 3, the domain-specific requirements necessary for geovisualization of vital information during fire-related incident command processes were identified successfully. By combining domain-specific knowledge from multiple sources, a complete list of vital building information was compiled that can be implemented by various fire response teams. The context of use for these requirements provided a solid foundation which enabled the creation of a visual hierarchy for cartographic representations of fire-related data.

This study utilized SketchUp to build a 3D model which incorporated the domain-specific requirements identified during Stakeholder meetings and modern card sorting techniques. They were implemented three ways: 1) Traditional Cartographic Principals, 2) Dynamic Visualization Variables and 3) Cartographic Generalization Operators. The success of the implementation varied based on the technique used.

Based on the results from observed characteristics of users acting as incident commanders, certain representations were problematic for geovisualization in the 3D model including room numbers and doors. In response to the questionnaire, the majority of participants felt they were comfortable with the use of 2D standard text, such as the text used for room numbers. However, they preferred the use of 3D text. This preference was contradicted during observations in usability testing. There were two features, room numbers and room doors, which were not effectively visualized in the 3D geospatial tool. During usability testing observations, it was apparent that participants who found these features difficult to interpret and communicate also did not sufficiently utilize the graphical user interface of SketchUp. The visibility of room numbers and interior doorway openings changed as the 3D model was rotated and the point-of-view was modified (e.g. rotate, zoom, and pan). Unfortunately, it seemed that some users were timid when manipulating the 3D model of ELA. Reasons for the discomfort may have included insufficient training, weak cartographic representations, or limited computer skills.

A secondary issue for room numbers was the placement of 2D text boxes in separate layers. This problem was two-fold; it was a problem of naming convention and visibility. An example of this naming convention is “Evans1_Text.” By using a more descriptive naming convention directly in the layer name, for example "Evans1stFloor_RmNums," the user's comprehension of the layer content may have improved. A list of how the layers were named in the SketchUp model and how they would be recommended for further testing can be seen in figure 23. The detailed naming convention would still require keywords to reduce the size of the table of contents box, which reduces allocated screen space. Any 2D text placed in the model is visible when the layer it belongs to is activated. Therefore, it was necessary for room numbers to exist in separate layers due to SketchUp functionality.

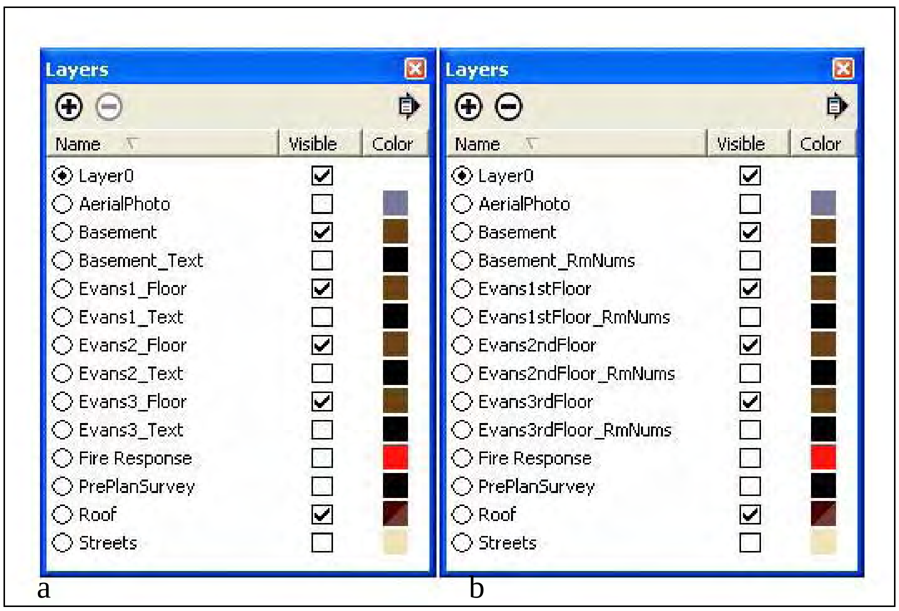


Figure 23. SketchUp: Layer Window. a, organization of layers used during usability testing; b, proposed organization of layers for improving user satisfaction of geovisualization model.

The final research objective focused on whether the use of 3D models provided more effective wayfinding than a 2D PDF map. The execution of the field-based usability testing illustrated that overall 3D models did not signifigantly enhance wayfinding. However, there are a few aspects of the test that would be recommended for modification for future research. In review, a pilot test would have been beneficial to discover erroneous scenarios outlined in the methodology, including SketchUp training and blindfolding the fire fighters when they reached the third floor of the Evans Liberal Arts building. The majority of responses on the questionnaire implied that SketchUp training was sufficient and the organizations of layers were easy to use. However, in review of the problems mentioned above concerning the visual ability to recognize room numbers and doors and the questionnaire responses regarding SketchUp layers, more extensive training could have improved the ability to manipulate the graphical user interface. A pilot test would have identified the fact that blindfolding participants did not assist in the overall analysis of effective or efficient geovisualization.

Out of the task objective times recorded, the greatest variability between the 2D maps and the 3D model was observed when fire fighters were instructed to find room 360. During usability testing, it was observed that participants were challenged to find the most optimal route to room 360 from room 217a, which are on opposite sides of the building. Incident commanders needed to first decide which route they wanted the fire fighters to navigate. Then, they needed to count the room doors and identify room numbers at identifying stopping places. It seemed that the difficulty in visualizing room numbers and room doors within the 3D model caused the task times to be greater than those of the 2D PDF maps. Overall, a different method to display these features and increased SketchUp training could have improved these findings.

Statistically analyzing timing of task objectives proved that the use of 3D geovisualizations is not significantly different than 2D PDF maps. However, there was sufficient qualitative evidence to support the idea that users are highly interested in using

3D models for fire-related incident command processes. Training was minimal to reduce experience-based learning of SketchUp before the commencement of usability testing. In return, increased training with the software application could have improved usability of the 3D model without affecting experienced-gained knowledge before commencement of the test.

Possible future research may discover advanced techniques and methods to further develop geovisualization with the use of 3D animations. Improving unsatisfactory features such as layer organization, display of room numbers and doors, and increased training, would impact the results of future analysis.

CHAPTER 6

CONCLUSION

This study investigated the applicability of 3D geovisualization in fire-related incident command processes by comparing the execution of task-based scenarios with the use of 2D PDF maps. Geovisualization is an emerging field which offers many benefits to emergency response management. It allows users to explore geospatial data to develop solutions and construct knowledge in highly interactive and dynamic environments. As technologies improve with advancing research, the methods used in geovisualizations may save lives and property during emergency response.

This research successfully identified the critical components required within a domain-specific 3D model for incident command processes that relate to fires at high-rise buildings. The support of users participating in the field-based case study encourages future research to improve the methods and designs implemented in this research. Potential challenging and informative research should expand on the knowledge gained from this study.

1. **Determine usability and usefulness of collaborative geovisualization in a large-scale model.**

This research focused on testing the usability and usefulness of a single building in a 3D model. Investigating 3D geovisualization for a shared-task performance on both a group and individual level could reveal usability and usefulness implications advancing user-centered design methodologies. Similarly, it would be interesting to investigate the use of 3D geovisualization models for other emergency responders such as police and paramedics. Integrating numerous data elements into the geospatial display could further facilitate problem solutions and knowledge construction for incident commanders. The 3D model developed in this research did not implement real-time data such as fire hydrant pressures per square inch, water distribution measurement data, or local traffic conditions. Large-scale details integrated and implemented in 3D geovisualizations should be considered in future research.

As an expansion of this research, it would be informative to test the usability of a 3D model with the incorporation of all four incident call types: fire response, haz-mat response, medical response, and rescue response. The building site tested in this study did not contain enough features to support the use of individual layers of response per type in SketchUp. By determining a site location with the availability of data to support this, the usability of a 3D model can be tested comprehensively.

2. **Test the use and usability of 3D models for emergency response in advancing software and hardware.**

As technology advances, new or enhanced 3D software applications are being developed. Test results of the usability of 3D geovisualization in an inexpensive and easy to use geospatial application may vary depending on the software. By testing 3D geovisualization for emergency response on multiple software applications, research can more confidently answer the question of whether the objective is useful and usable.

Another aspect of importance is the medium in which geospatial data is represented. The geovisualization environment could include the use of an online application to deliver geospatial data. Including dynamic data in a highly interactive environment could also effectively deliver methods and tools to a diverse population of municipal personnel. Future research could include testing 3D geovisualization for emergency response on portable devices, such as mobile phones, personal digital assistants, or even optical lenses in a fire fighters mask.

3. **Develop methods to train emergency responders how to use and interpret geovisualization methods.**

The approach to training domain-specific users on 3D geovisualization methods is dependant on expert interpretation and presentation. An evaluation of general guidelines in a training framework would facilitate the use and usability of an application. Usability training conducted in this research was weak and was apparent in usability observations, therefore encouraging a formal need for adequate instruction of the methods and tools presented.

4. **Analyze effectiveness and efficiency of geovisualization methods for emergency responders.**

Investigating different measurement techniques of effectiveness and efficiency in 3D geovisualization could result in the discovery of usability improvements such as those applied in this research, as well as continued identification of advanced methodologies. An assessment of the quantitative and qualitative measurements may also provide informative data, which would result in continued expansion of this research.

Overall, this thesis demonstrates that 3D geovisualization models are of interest to fire fighters and emergency responders because it provides problem-solving tools in an attractive digital environment. The integration of scientific and information visualization, exploratory cartography, data analysis, and a GIS to provide theory, methods, and tools to explore and communicate geospatial data create a synthesized approach to *geovisualization* (Kraak 2003). As time is a critical factor in emergency response management, GIS tools and the geovisualization environment stimulate the interpretation of geospatial patterns and relationships than can impact and optimize public service. Advancing technologies in the domain of 3D geovisualization will continuously improve the use and usability of geospatial visualization methodologies.

APPENDIX A: SMFR PRE PLAN SURVEY

Fire Plan Survey

Company Name: Texas State University - San Marcos - Evans Liberal Arts

Address: 627 N. LBJ Dr.

Business Phone Number: 245-2805 **Date:**12/21/2006

Contact Name: University Police Department

24-Hr. Emergency Notification Phone #: 245-2805

Knox Box: ☐ **Yes** ☒ **No** **Location:**

Primary Hydrant Location:

FDC? ☒ **Yes** ☐ **No** **Location:** Along 2 sides of building: Quad & Flowers Hall

Power Company: ☐ **SMEU** ☐ **Pedernales Electric** ☐ **Bluebonnet Electric**

Power Cut-off Location:

Back-up Generator? ☐ **Yes** ☐ **No** **Location:**

Gas: ☐ **Yes** ☒ **No** **Cut-off Location:**

Fire Pump: ☒ **Yes** ☐ **No** **Location: Mechanical Room 131**

Water Meter Cut-off Location:

Hazardous Materials? ☐ **Yes** ☒ **No**

Common Name: **Quantity:**

Common Name: **Quantity:**

Type: ☐ **Flammable** ☐ **Health** ☐ **Reactive** ☐ **Special Information**

Comments:

Fire Department Representative: (print)
Reviewed by Captain: **Date:**

Estimated Needed Fire Flow Formula:
$\frac{L \times W}{3}$ x # of stories = GPM for 100% involvement.
Add 25% for each exposure

Level of Involvement	25%	50%	75%	100%
Estimated Needed Fire Flow				

This is not a code inspection. This statement of review in no way alleviates the responsibility of the owner or tenant to comply with all ordinances and codes adopted by the City of San Marcos, as well as, State and Federal Laws and Codes. No code violations are "approved" by this department.

APPENDIX B: USABILITY TESTING QUESTIONS

User Questionnaire:

Male:
Female:
Age:

Please circle the number that best represents your answer on a scale of 1 to 5:

1: Strongly Disagree **2:** Disagree **3:** Not Applicable **4:** Agree **5:** Strongly Agree

1. Was the SketchUp training sufficient?

   1 2 3 4 5

2. Did you feel comfortable using SketchUp?

   1 2 3 4 5

3. Were you able to become familiar with the Evans Liberal Arts building using the 3D model?

   1 2 3 4 5

4. Were you able to become familiar with the Evans Liberal Arts building using the 2D paper maps?

   1 2 3 4 5

5. Were you able to easily decide what layers of information you need to turn on/off using the 3D model?

   1 2 3 4 5

6. Is the organization of layers helpful in the 3D model?

   1 2 3 4 5

7. The use of colors in the 3D model allowed me to become familiar with the building

   1 2 3 4 5

8. Were fire-related data easy to identify in the 3D model?

   1 2 3 4 5

9. Does the 3D building transparency assist in identifying the fire-related data?

   1 2 3 4 5

10. Did the use of the color red help identify the fire-related data in the 3D model?

    1 2 3 4 5

11. Is it helpful to have the fire plan survey for incident command processes?

    1 2 3 4 5

12. Is it helpful to have the fire plan survey bundled with the 3D model?

    1 2 3 4 5

13. Are you pleased with the use of 3D text?

    1 2 3 4 5

14. Are you pleased with the use of standard text, such as the text used for room numbers?

    1 2 3 4 5

15. Do you prefer to have 2D text instead of 3D text vital information?

    1 2 3 4 5

16. Are the task instructions easy to deliver to the fire fighter when using the 3D model? *(note: task refers to the routine the fire fighter was instructed to complete during the incident)*

    1 2 3 4 5

17. Are the task instructions easy to deliver to the fire fighter when using the 2D paper maps?

1 2 3 4 5

18. Do you prefer to deliver task instructions to the fire fighter using the 3D model rather than the 2D paper maps?

1 2 3 4 5

19. Do you prefer 3D mapping over 2D mapping?

1 2 3 4 5

20. Do you prefer a combination of both 3D and 2D mapping?

1 2 3 4 5

21. Do you think 3D models have a future in fire-related incident command?

1 2 3 4 5

Semi-Interview Questions

1. What are the deficiencies of the map, if any, including feature representation and availability of data?

2. What tool functions or data did you not like to use in this 3D application?

3. What tool functions or data would you have liked to use in this 3D application?

4. What other suggestions do you have that you feel could improve this 3D application?

5. What are your overall feelings towards the use of the 3D application versus the present use of 2D paper maps?

6. Do you have any questions or general observations that were not covered by the questionnaire?

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