2016-05-01

Implementation of BIM in the Municipal Plan Review Process

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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May 2016

ABSTRACT

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Obtaining a building permit is an important step for any construction project. Whether it is for a new construction or a remodel job, the process involves a plan review performed by building officials. The purpose of this research was to explore ways in which Building Information Modeling (BIM) could be used to aid code officials during the plan review process. The objectives of the study were to determine if the level of detail in BIM was complete enough to allow a plan review to be perform accurately, to identify the extent to which architects are comfortable with using their models for the plan review, and to identify barriers to implementation.

A case study was conducted where BIM was used to supplement the traditional 2D plans plan review process. Additionally, a survey was given to local architects to obtain their thoughts on using BIM in the plan review process.

The research found that BIM has the potential of helping code officials visualize the project, extract information from objects, and allow them to have a better understanding of unique building features relationship to other building elements. Challenges of using BIM in the plan review process identified by architects included: the accuracy of the model, the level of detail modeled, legal implications, and ability of reviewers to use BIM.

Keywords: plan review, code check, BIM, code official

ACKNOWLEDGEMENTS

I would like to express my humble gratitude to everyone involved in making this study a reality. A sincere thanks to my advisors Evan Bingham, Kevin Miller and Clifton Farnsworth for their mentoring and support. Thanks to George Williams for being a key player in the study. Special thanks to my wonderful husband and children, for their love, support and encouragement. Thank you to my mother for always inspiring me to achieve my goals even when they seemed hard to reach. Thanks to all of you.

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1. INTRODUCTION

1.1. Background

Ever since the creation and implementation of building codes, facilities can be safely accessed with the confidence they instill with the occupants that the buildings follow and are in conformance with, the laws and regulations established by the building code. Building codes address a building's quality, safety, accessibility, and energy performance.

The process for a building to obtain the different required permits involves a plan review performed by the city building officials. Plans go through several reviews in which officials ensure that the construction is in conformance with the current and applicable codes. This process is lengthy, and due to the nature of the codes, the requirements typically contain ambiguity leading to different interpretations. The current plan review process relies heavily on manual processes, the ability of the reviewer to interpret the 2D design, and extensive paperwork.

While code officials are working with 2D plans, other portions of the industry such as the design and construction teams are quickly moving to a 3D environment known as Building Information Modeling (BIM). With BIM technology, a virtual model of a building, is digitally constructed. When completed, the building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building. (Eastman, 2008).

With the wide use of BIM in the construction industry, the production and spread of information across all stakeholders in the building process is accelerated, thus making it potentially possible for code officials to use this information to perform the plan review.

1.2. Statement of the Problem

Building codes are large and complex requiring substantial understanding and knowledge by the users, they are ill-structured, may be inconsistent, redundant, and self-contradictory, and ultimately they depend upon interpretation by public officials that may differ from the interpretation by the building designer (Rosenman and Gero, 1985).

The manual checking of building designs for compliance is complex and prone to human error with significant cost implications. The errors in the plan view process may often stem from the reviewer working from 2D documents but applying a building code that has 3D considerations. The ability to apply 3D codes to 2D documents is tricky at best because the lack of information from which the code official has to work. To complicate the process, the information is typically scattered throughout the 2D architectural, structural, mechanical, plumbing, electrical and civil drawings. Often the information between drawings is incomplete and can be contradictory.

The current plan review process uses 2D documents which is often difficult for the reviewer to visualize the design intent of the project and to understand the spatial relationships that are required by the building code. This process is often an iterative process, meaning that the plans are reviewed with comments from the municipality's reviewer, the design team then incorporates the comments into the design, and then the plans are submitted again for review. The municipality then reviews the project again. The process continues until the municipality

approved the project. Many of the comments about the plans are due to conflicts between the design disciplines or from the lack of information contained in the 2D documents.

1.3. Background and Need

The number of code officials is expected to decrease dramatically due to retirement. Several studies have suggested that 50+ percent of the current code officials will retire during the next 10 years (Williams, 2015). These retirements will create a shortage of people to do the work as well as the loss of a knowledge base and skillset. The massive loss of people will most likely not be able to be replaced because most industries are facing the same retirement challenges, therefore the people that are hired will need to do more work in the same amount of time. The knowledge base loss will only be made up through educating the new hires. The skillset of being able to analyze the various information sources from the plans, work through the contradictions found from the various sources, and then being able to apply the 2D information to the 3D building code considerations will be difficult for the new hires, especially since they will be expected to do an increase of work at the same time.

1.4. Purpose of the Study

The development of BIM has created better and more efficient design tools with enhanced visualization methods for the design and construction teams. BIM has created an environment where the various building systems, (architecture, structure, MEP, etc) can be viewed together in 3D while at the same time provide data about the systems and components. Using the enhanced visualization tools instead of the traditional 2D documents, construction teams have become more efficient in the coordination process for the various building systems and reduced the number of building systems conflicting with each other in the field. The

increased visualization and coordination tools has decreased the time required to build projects and has reduced the amount of rework required on projects.

Researchers are working on automated compliance checking which would prove beneficial to designers, building certifiers, contractors, building code authorities, specification writers and facility owners and managers (Nawari, 2013). "Software products for 3D model compliance checking exists, but code-based rule-sets to govern the process are not yet well developed or tested. Nor is the creation of an automated code-checking workflow, and many of the intended users-code enforcement officials-have little exposure to any of it" (ENR, 2012). This research appears to still be years away from being developed to a point where it could be used in industry.

Even though BIM hasn't fully automated the design or other preconstruction process, it has provided greater assistance through visualization, data exchange and communication between the design team, contractor and trade contractors. However, BIM is not commonly used in the code-checking process during the plan review. This research examines if BIM could be utilized in the plan review process. It is anticipated that findings from this research will provide guidance to code officials on the most effective areas where BIM could be used for plan review. While BIM is not ready to completely automate the plan review process by municipalities, potentially, BIM could assist the code officials with its visualization and data features.

The purpose of this research was to evaluate the process of plan check reviews. Once this process was evaluated, the data could then be used to determine if incorporating BIM would be beneficial in aiding code officials to perform a more accurate, efficient plan review process.

Since the automated code-checking capabilities of BIM remains a research topic, the purpose of this study is not to advocate for full automation, but instead the purpose is to

determine how BIM can be used to aid in the current process and how it can help code officials be more effective in their work. Recognizing the benefits, as well as the disadvantages is key to establishing the successful implementation of this technology in the plan review process. Understanding the process using BIM allows for innovation, while also showing the broader application of BIM in the construction industry.

The process of compiling the data necessary for this research involved interviewing a code official and reviewing areas where BIM could be beneficial and also contacting a selected group of local architectural firms who are in charge of creating the 3D models of the buildings evaluate how these models are prepared and determined if these models contain the necessary information to be used in the plan review process.

1.5. Research Objectives

The objective of this research was to evaluate how Building Information Modeling (BIM) could be used in the plan review process. The research objectives were to:

1. Determine if it was possible to incorporate BIM in the plan review process, and provide a synthesis of the advantages, and challenges, of using BIM.
2. Determine if the level of detail in the current 3D models was complete enough to allow a plan review to be perform accurately.
3. Identify the extent to which design teams were comfortable with using their models for the plan review. If they are not, determine what needed to change in the design process.
4. Identify barriers to implementation.

To achieve these research objectives, this thesis is separated into the following: Chapter 2 provides a summary of current and relevant literature regarding the current plan review process,

and the potential applications of BIM in the review process. Chapter 3 discusses the research methods used for the research, and Chapter 4 contains a presentation and discussion of the results. Chapter 5 is a summary article of the research that was submitted to a conference, Chapter 6 provides conclusions, recommendations and suggested areas for further research.

1.6. Significance to the Field

The different municipal jurisdictions that perform the plan review process, could greatly benefit from this research. code officials could use BIM to standardize the process of plan review across the different offices and help remove ambiguities and contradicting design and code interpretations. This research could potentially be expanded and tested into other states or regions experiencing similar challenges.

Another important challenge the Code Professional Industry is facing, is the anticipated shortage of code officials that is expected in the near future. Understanding how BIM can be used in the code checking process could help the remaining code officials to be more efficient in their work.

1.7. Definitions

Plan Check: A municipality's process of reviewing and approving all drawings for constructions, and specifications for improvements to verify compliance with buildings zoning and fire codes.

Automated Plan Check: Efforts through the development of technology that the reviewing process can be done automatically.

Code Checking: the process of reviewing construction plans against current and applicable building codes.

Building Code: A set of minimum requirements for building design, construction and operation to protect public health, safety and the natural resources that sustain us.

Code Official: Also known as code professional, building official or building inspector who perform building plan examinations concerning construction or alterations of industrial, commercial, residential and public assembly structures to determine compliance with applicable codes, laws and regulations.

Building Permit: Gives legal permission to start construction of a building project in accordance with approved drawings and specifications.

Rule-based Checking: Piece of software that does not modify a building design, but rather evaluates it on the basis of configured building objects.

BIM: An accurate virtual model of a building. When completed, it contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building.

2. LITERATURE REVIEW

2.1 Introduction

The current plan review process relies heavily on building official's interpretation, is not necessarily consistent among jurisdictions, and is prone to errors (Nawari, 2013). Discovering how BIM tools could be used in the plan review process could make the existing process more effective and efficient.

The literature review addresses the history and evolution of building codes and their role in the modern construction process. It also addresses the current plan review, and permit process its challenges and the areas of improvement that can be evaluated. Finally, the third section addresses BIM's current applications in the construction field and the possible code checking capabilities of BIM.

There is extensive, existing research on the code-checking capabilities of BIM and the possibility of one day allowing BIM to automatically perform the plan review process. The intent of this specific research was not to advocate for a fully automation of the code checking process, but to evaluate the possible of use of BIM to assist in the current process.

2.2 The Role of Building Codes

Building codes have existed since the early years of civilization. These codes and regulations are enforced to protect the public, and are used to ensure structures are designed and constructed in a way that focus on safety, comfort, accessibility, and building performance

specifications (Martins, 2013). Building codes are intended to specify minimum design and construction standards to provide for safety of building occupants and the public (Clayton, 2013).

The earliest known building code of law—the Code of Hammurabi, king of the Babylonian Empire, written circa 2200 B.C.—assessed severe penalties, including death, if a building was not constructed safely (ICC, 2016). Although these regulations have changed drastically in the way they are created and implemented, they have always existed in an attempt to ensure the public safety. Most aspects of any building construction such as electrical wiring, heating, sanitary facilities, etc. represent a potential hazard to the building occupants and users.

Building codes do not prescribe how work should be done, but states, in general terms how the completed building must perform in its intended use; it contains functional requirements, and performance criteria that covers matters such as protection from fire, structural strength, moisture control, and durability (Building Performance, 2015).

2.3 History of Building Codes in the U.S.

The earliest record of an attempt to enforce building codes can be traced back to early America. George Washington and Thomas Jefferson encouraged the development of building regulations to provide for minimum standards that would ensure health and safety (ICC, 2016).

Following the building fires in the 1800's such as the great Chicago fire in 1871, insurance companies started requiring building codes for structures. In 1915 three regional model code groups were created: Code Officials and Code Administrators (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International Inc. (SBCCI). These groups were established as professional associations of code officials and

code enforcement personnel, (BOCA) operated primarily in the Northeast and Midwest, ICBO primarily in the West, and SBCCI primarily in the Southeast.

These organizations began developing model codes in response to the increasing difficulty for state and local governments to develop and maintain technically complex building codes, the recognized need for uniformity in building codes and code enforcement methods, and encouragement from industry and government (Listokin and Hattis, 2005).

Each of these organizations had its own separate set of model codes. None of the codes developed by these three independent organizations had any legal force to them, nor any jurisdiction to enforce their codes upon a specific geographic area. Essentially, the purpose of these groups was to develop codes and then encourage state and local governments to adopt them.

To address the non-uniformity of building code models across the United States, these three organizations merged their different code models in one set of uniform codes. The result was the formation of the International Code Council (ICC) founded in 1994. The ICC publishes building codes that promote safety and fire prevention. The result is a uniform building code used throughout the U.S. to construct residential and commercial buildings, including homes and schools.

The first draft of the International Building Code (IBC) was prepared in 1997 by five drafting subcommittees appointed by the ICC and consisting of representatives of BOCA, ICBO, and SBCCI. The intent was to draft a comprehensive set of regulations for building systems consistent with and inclusive of the scope of the existing model codes (IBC, 2006). The first edition of the International Building Code (2000) was the culmination of an effort initiated in 1997 by the ICC.

2.4 Traditional Plan Review

Building code inspections are performed by licensed or certified professionals. They are either employed within the jurisdiction of a city or county or by third-party inspectors from private companies.

Building officials perform conformance assessment against the applicable code and then issue building permits upon demonstration of compliance with all applicable requirements in that code. Unfortunately, this process is usually iterative and time consuming due to the complex nature of the codes and standards. The requirements expressed in the natural language versions typically contain ambiguities leading to different interpretations. Some requirements may be completely missed due to manual checking procedures based on text versions of codes and standards. Hence, what may be considered compliant by the designer may be considered noncompliant by the building officials. These problems cause delays in the permitting process and sometimes result in safety hazards. To address this issue, a great deal of research and development has been carried out on the creation and use of building codes via computer-based approaches (Omer, 2012).

Currently, design and construction documents submitted to the governing body for permitting are checked manually against a continuously changing and increasingly complex set of building codes. The complexity and changing nature of codes leads to delays in both the design and construction processes (Han et al. 1997).

Because of the limitations and challenges present in the plan review process, it is worth extending the field of research to determine how modern technological tools like those available in BIM could help in the plan review.

2.5 Permit Processing

A building permit is generally required when undertaking any type of construction. A building permit is considered the ultimate goal of any builder when submitting plans for approval. The 2012 International Residential Code Section R105.1 states,

> "Any owner or authorized agent who intends to construct, enlarge, alter, repair, move, demolish or change the occupancy of a structure, or to erect, install, enlarge, alter, repair, remove, convert or replace any electrical, gas, mechanical or plumbing system, the installation of which is regulated by this code, or to cause any such work to be done, shall first make application to the code official and obtain the required permit."

Review is required for all new construction, as well as additions and most alterations and repairs to existing structures including interior/exterior improvements. The process of obtaining a building permit is time consuming. It involves the interaction and review of several departments which each review an aspect of the building and it may be an iterative process.

In the city of Provo, Utah, the Community Development Department is the facilitator for all construction projects in the city. An application needs to be submitted before any type of construction is initiated. Plans then circulate for approval by the various city departments, which review it for compliance with the planning, zoning and building codes.

The planning and zoning divisions review the plans to determine if the use is appropriate for the zone, and if the project meets certain requirements such as parking, setbacks, and lot coverage. The building division reviews the plans to make sure that they meet the requirements of the adopted building codes, then inspect the project at various stages of construction to ensure the safety of the structure.

The permit cost is based on the cost (valuation) of the construction. A table found in the 1997 UBC is used to assess the permit fees. The permit cost is mainly used to cover the cost of the inspections. A plan check fee of 65 percent of the building permit fee is charged to cover the

cost of reviewing a plan before the permit is issued. A state fee of 1 percent of the building permit fee is charged and sent to the state for training of inspectors and contractors. Other city departments assess fees based on various factors of each project (Provo City, 2016).

2.6 Effect of Mass Retirement of Building Inspectors in the Review Process

To be effective, codes must have both a robust development process and an enforcement infrastructure. America's code administration and enforcement professionals serve as the backbone of such a code development and enforcement process. However, there is a growing concern among code developers and the building industry at large that demographic shifts in the makeup of the code-related workforce will challenge the current building regulatory system (ICC, 2014).

To validate these concerns, a survey conducted by the International Code Council (ICC) and the National Institute of Building Sciences from March to May 2014 noted that the current workforce of building inspectors is aging, and more than 80 percent of the existing code professional workforce is planning on retiring in the next 15 years, with more than 30 percent in the next five years (ICC, 2014).

Only about 15 percent of the respondents are under 45 years old, with only about three percent under 35. The retirement of multiple members in such a department over a short timeframe would result in a significant loss of institutional memory and capacity.

This mass retirement will affect the availability of building inspectors since the rate of retirement exceeds the rate of new inspectors entering the workforce. These building inspectors work at the local level as jurisdiction employees. With less building inspectors available the need to require these services from third-party providers will increase substantially.

This research, among its other primary objectives, intends to shed some light into finding possible solutions to address this issue. Potentially discovering ways to utilize technology to improve the productivity of the code professional industry.

2.7 Building Information Modeling (BIM)

Building Information modeling (BIM), "a modeling technology and associated set of processes to produce, communicate and analyze building models", has been changing the capital project delivery (CPD) processes significantly. BIM provides a common way to store information that is created by different stakeholders in a data-rich, parametric, and digital representation. It also provides semantically rich information for building elements that can be accessed automatically by software applications (Borrmann and Rank, 2010).

With BIM technology, an accurate virtual model of a building, known as a building information model, is digitally constructed. When completed, the building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building (Eastman, 2008).

A building information model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories, and project schedule. The model can be used to demonstrate the entire building cycle (Bazjanac, 2006). As a result, quantities, and shared properties of materials can be easily extracted. Scopes of work can be easily isolated and defined (Azhar, 2011).

BIM is both a technology and a process. The technology component of BIM helps project stakeholders to visualize what is to be built in a simulated environment to identify any potential design, construction or operational issues. The process component enables close collaboration and encourages integration of the roles of all stakeholders on a project (Azhar, 2012).

The principal difference between BIM technology and conventional 3D CAD is that the latter describes a building by independent 3D views such as plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 3D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns.

A building information model carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of "smart objects". For example, an air conditioning unit within a BIM would also contain data about the supplier, operation and maintenance procedures, flow rates and clearance requirements (Azhar and Richter, 2009; CRC Construction Innovation, 2007).

2.8 Current BIM Applications

Building Information Modeling can potentially affect every aspect of a business enterprise. Therefore, BIM implementation is best viewed as an integral part of every business process, rather than an isolated endeavor related only to a few specific tasks or projects. The different BIM applications are to be used over the life span of a building (Smith, and Tardif, 2009).

2.8.1 BIM and Project Programming

It is important to note that during the conceptual design stage of a building, important decisions such as the building's functions, general appearance, and cost, need to be determined. Using BIM in such a crucial stage where these decisions will likely affect not only the entire

construction process, but the life of the building, presents numerable benefits. Architects and designers can take advantage of BIM in all three facets of project design. Table 2-1 provides a summary of the different used of BIM during each design stage (Azhar, 2012).

Table 2-1: BIM in Project Design

Schematic	Detailed Design	Construction Detailing
• Options Analysis (to compare multiple design options) • Photo Montage (to integrate photo realistic images of project with its existing conditions)	• 3D exterior and interior models • Walk-through and fly-through animations • Building performance analyses (e.g. energy modeling) • Structural analysis and design	• 4D phasing and scheduling • Building systems analysis (e.g. clash detections) • Shop or fabrication drawings

Decisions are often made in the programming phase of a project that have enormous downstream implications—for aesthetics, cost, energy consumption, and the ultimate suitability of a building for its intended purpose—on the basis of inaccurate, incomplete, or unreliable information (Tardiff, 2007). Initiating BIM at this phase creates additional substantial potential for efficiencies.

The use of BIM on projects allows for information to be pushed upstream in the design development to include planning and programming. This added detail allows planners, designers and builders to better coordinate details and information amongst the multiple parties involved in the process (Klotz and Horman, 2006).

2.8.2 BIM and Project Design

The BIM Forum in its 2013 Level of Development Specification, defined the "Level of Development (LOD) as a reference that enables practitioners in the architecture engineering and construction (AEC) industry to specify and articulate with a high level of clarity the content and reliability of BIM [elements] at various stages in the design and construction process."
It describes the steps through which a BIM element can logically progress from the lowest level of conceptual approximation to the highest level of representational precision.

A BIM contains detailed information depending on the LOD level, the higher the level, the more detail and accurate the model will be. Figure 2-1 the different LOD possible and provides a description of what level of information is included in each (DDC, 2012)

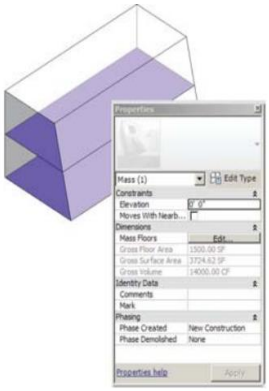
LOD 100 Models include elements such as Masses and are used for preliminary studies, such as Conceptual Design and Overall Project Phasing Analysis based on their location and orientation. **Quantities based on overall area and overall volume**.	 Image shows the building elements as Masses and its associated Area and Volume.

Figure 2-1: Model Level of Development 100

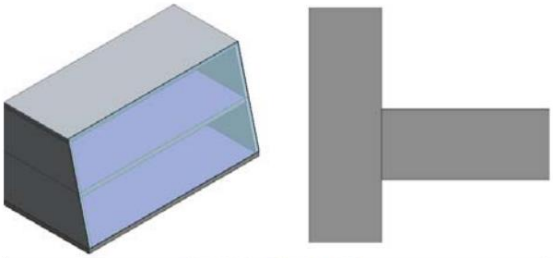
LOD 200 Models include elements in which Masses have been replaced with Generic Components. Analysis based on overall systems can be performed. **Quantities based on specific elements.**	 Wall Schedule (LoD-2) Family | Type | Width | Length | Area | Volume Basic Wall | Generic - 8" | 0' - 8" | 39' - 0" | 656 SF | 437.51 CF Basic Wall | Generic - 12" | 1' - 0" | 39' - 4" | 759 SF | 759.22 CF Image shows the different building elements as Generic Components. The major characteristics of components are their thickness and width allowing quick take-offs.

Figure 2-2: Model Level of Development 200

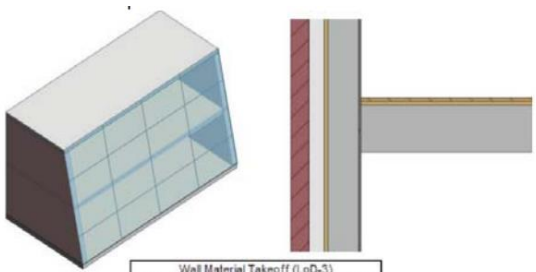
LOD 300 Models included elements in which Generic Components have been replaced with fully defined **Assemblies**. Analysis based on Specific Systems can be performed. **Quantities based on Materials**. Al LOD 300 the models can be leveraged for the generations of traditional Construction Documents and Shop Drawings. The model can be used for analysis such as: energy Performance, Clash Detection and Cost.	 Wall Material Takeoff (LoD-3) Material: Name | Material: Volume Gypsum Wall Board | 58.66 CF Masonry - Brick | 425.26 CF Metal - Stud Layer | 703.87 CF Misc. Air Layers - Air Space | 351.94 CF Wood - Sheathing - plywood | 87.98 CF Image above shows the different Building Elements as fully defined Assemblies, where the different components have well-defined characteristics.

Figure 2-3: Model Level of Development 300

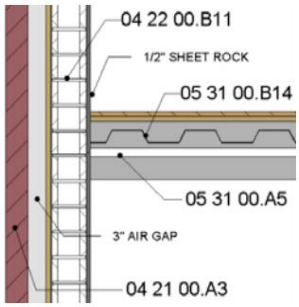
LOD 400 Models include elements that are accurate in terms of size, shape, location, quantity and orientation with complete fabrication, assembly, and detailing information. At this Level, the model may also have information such as text, dimensions, notes, 2D details, etc. At LOD 400 the model is a **representation of the proposed elements**.	 Image shows a detail where 2D information has been placed on top of the 3D model on a Section View.

Figure 2-4: Model Level of Development 400

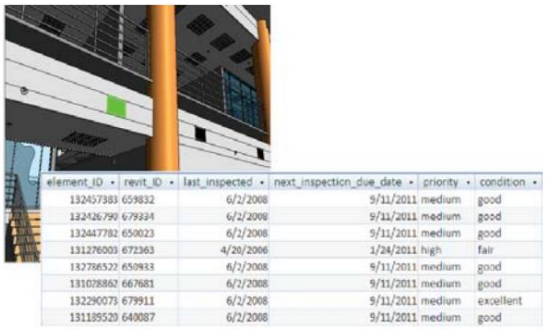
LOD 500 Models include elements modeled as constructed. Elements are created to accurate size, shape, location and orientation. Non geometric or physical attributes are included as parameters to the geometric shape. At this level, model is similar to LOD 400 with the exception that elements are as constructed. At LOD 500, the model is capable of being **utilized for operations and maintenance.**	

Figure 2-5: Model Level of Development 500

2.8.3 BIM in the Pre-Construction Phase

Some of the applications of BIM during the pre-construction phase can be summarized as the following:

2.8.3.1 Estimating

Traditionally, the cost estimates of a building are usually done by importing the architect's 2D drawings into a cost estimating software, or by doing manual takeoffs to the drawings. These methods introduce the potential for human error and inaccuracies that may be in the original drawings. By using a BIM instead of drawings, the takeoffs, counts, and measurements can be generated directly from the underlying model. Therefore, the information is always consistent with the design. And when a change is made in the design – a smaller window size, for example – the change automatically updates all related construction documentation and schedules, as well as all the takeoffs, counts, and measurements that are used by the estimator (Autodesk, 2007).

Cost-estimating process has always relied on the inputs from the design process, and this remains unchanged. The difference in BIM is that the method and organization of the inputs by designers have an impact beyond the design process. All inputs are rich with information and available for other stakeholders, as such the coordination of information at all points in a BIM is important. The estimator's ability to complete an accurate estimate using BIM is a challenge at this time. A major obstacle is the lack of a standard that establishes how a BIM is created so that it contains valid and reliable information to meet the needs of all stakeholders across the lifecycle of a facility (Construction Advisor Today, 2009).

2.8.3.2 Site Coordination

Using 3D or 4D site coordination models allows contractors to plan for site logistics more effectively, develop traffic layouts, as well as identifying potential hazards at the jobsite (Azhar, 2012).

2.8.3.3 Clash Detection

Traditionally, to analyze that the different building systems do not interfere with each other according to the design, a time and effort was required because of the 2D nature of the plans. Many times, this was not performed because it was too difficult to do from the 2D plans. This resulted in many of the system clashes being discovered as the systems were installed. These clash created delays, change orders and forced the stakeholders to make rushed decisions that could eventually have a negative impact on the overall result of the project. BIM enables potential problems to be detected prior to construction (Chowdhury, 2016).

2.8.3.4 Project Visualization

Building simulation allows the owner to visualize how the project will be built through the construction process. This step has great benefits since it has the potential to save time, cost, and rework.

2.8.4 BIM in the Construction Phase

During this phase of construction, the project team is expected to continually update the BIM model to ensure it reflects all changes, and the most up-to-date information. The availability of smartphones, and tablets technology has allowed contractors and subcontractors to be able to use BIM at the jobsite, and be able to extract information directly from the model. Some of the notable BIM apps include BIMX®, Bentley Navigator®, Buzzsaw®, etc. Recently the Autodesk® has started a Cloud-based service, The Autodesk 360©, which allows users to share BIM in a web environment and perform various tasks in the field such as walk-throughs, clash detection and preparing digital RFIs (Rubenstone, 2012).

2.8.5 BIM in the Post-Construction Phase

One of the benefits of BIM is the ability to communicate to facility managers important information about a building such as its systems and components. Facility managers can easily access this information by simply clicking an object in the model and obtain information such as name, location, model number, warranty information and maintenance manuals.

Research suggests that 85 percent of the lifecycle cost of a facility occurs after construction is completed and approximately $10 billion are annually lost in the U.S. alone due to inadequate information access and interoperability issues during operations and maintenance phases (Azhar, 2012).

2.9 Code Checking Capabilities of BIM

Automated code-checking or standards analysis and compliance has been an active area of research since the 1960s. Automated code-checking gained additional relevance as a research topic in the 90's. With the widespread adoption of CAD tools by industry professionals, the emergence of BIM technologies as a paradigm shift and the development of the IFC standard file format, and inspired by the constraint checking of designs in mechanical engineering, researchers began to investigate the possibility of automating the validation of building designs according to the enforced legislation (Martins, 2013).

Object-oriented and parametric modeling provides a way to automate code-checking procedures in building designs, as it is possible to associate parametric rulings to the elements that compose the virtual model, allowing the computerization of otherwise manual procedures.

If the building objects in the design are represented simply by geometric entities, such as lines or shapes, they will not be recognized as such by code-checking routines. Users will be

required to provide the parameter value input manually. BIM applications address this issue by enforcing object-oriented modeling, which covers some of the modeling requirements for code-checking purposes. It is debatable whether manual parameter value input will ever cease to be necessary, however, BIM tools already represent a big advance compared to the traditional approach by enabling automated checking of geometrical and spatial constraints (Martins and Monteiro, 2013).

Research conducted at the University of Porto in Portugal studied an original method and a software application for the automated code-checking of a building's water network systems. This study reinforced the belief that although truly comprehensive automated code-checking is not expected soon, it is still possible to use BIM-based applications for compliance tests in some domains (Martins and Monteiro, 2013).

2.10 Automated Code-Checking Initiatives

Several international initiatives on the automation of code-checking procedures are currently being undertaken, including the SMARTCodes and CORENET projects. The development of a fully automated procedure is an important goal of the BIM community that should not, however, be achieved in the short term (Martins and Abrantes 2010).

2.10.1 SMARTcodes

Smart or intelligent code is referred to as a computable digital format of the building codes that allow automated rule and regulation checking without modifying a building design (Nawari 2013). Smart Codes employ rule-based systems to a proposed design, and give results in format such as "PASS", "FAIL" or "WARNING", or 'UNKNOWN'' for conditions where the

required information is incomplete or missing (Nawari, 2012). SMARTcodes, if implemented, could reduce the time needed to review construction documents, issue building permits, and approve buildings for occupancy by 50 percent (Smith and Tardiff, 2009). The primary requirement in application of SmartCodes is that object-based building models (BIM) must have the necessary information to allow for complete code checking. BIM objects being created normally have a family, type and properties. For example, an object that represents a structural column possesses type and properties such as steel, wood or concrete, and sizes etc. Thus the requirements of a building model adequate for code conformance checking are stricter than normal drafting requirements (Nawari, 2012).

The real challenge is then the need to move toward an object-based software environment that provides the building industry professionals who create and use that information with a familiar, easy-to-use interface (Smith and Tardiff, 2009).

2.10.2 CORENET

CORENET stands for Construction and Real State Network. It was a major IT initiative where Singapore code officials started considering code checking on 2D drawings back in 1995, nevertheless, it was proven too ambitious to be true, since most architects and designers were not aware of the possibilities of drawing based 2D technologies. In its next development, it switched and started the CORENET System working with IFC (Industry Foundation Classes) building models in 1998 (Khemlani, 2005). Although the initial approach did not prove to be successful it served as a platform for the subsequent code-checking project, e-Plan check which was launched in September 2000. e-PlanCheck currently covers code-checking for specific aspects of Architecture and Building services and will eventually be expanded to include Structure and External works (GIS related) as well.

The key technologies for e-PlanCheck implementation are the IFC model, and an independent platform called FORNAX. The IFC model allows for the exchange of model-based data across all the applications, but the IFC model alone was not sufficient for the code-checking application to be successful, this was because the IFC only represents the basic building information that can be modeled by a BIM application during the design stage. Basic building objects and their properties provide limited and static information for code compliance checking, and would make implementation too tedious and prohibiting. This is the reason why FORNAX was developed. FORNAX takes the basic building information model from the IFC and adds to it higher level semantics that are relevant to code-checking requirements. This is done by encapsulating building components into a set of FORNAX objects, each of which defines relevant attributes and behaviors. These objects are designed to be extendable for customization to handle the variance of requirements of building codes around the world, giving the FORNAX platform the ability to handle the code checking requirements for other countries as well (Khemlani, 2005).

The current abilities of CORENET are limited to specific aspects of architecture and Building Services. Further research is being undertaken to broaden the scope of the code-checking to other aspects of building design. Singapore's initiative has caused spread in other countries such as Norway, Japan, Australia, and the United States.

2.11 Benefits and Challenges of Using BIM in Code Checking

Some of the immediate benefits of code-check automation are: a quicker design review process, designers will avoid the preparation of lengthy documents that are usually necessary for the plan review (the model itself will suffice), and the entity responsible for performing the

design review will benefit from a shorter, simpler, less human resource intensive process. All computer generated verdicts can be changed manually so that non-compliances that are considered non-critical or that can be solved at a later date can be waved (Martins and Abrantes, 2010).

Architects and engineers creating BIM to be used for code-conformance checking must prepare them so that the models provide the level of detail needed in well-defined, agreed-on schema (Nawari, 2012). In general, for a BIM implementation strategy to succeed, it must be accompanied by a corresponding cultural transformation strategy. Cultural transformation is a greater challenge to the industry than any technological transformation resulting from BIM. It will require that building industry partners regard one another differently than they do today, as true collaborators with a mutual interest in a successful outcome (Smith and Tardif 2009, 35).

2D models printed on paper allow architects and designers to compare details from different consultants. Using the model instead of 2D drawings represents a challenge since it becomes impossible for designers, contractors, clients to interoperate unless the formats of the model are identical.

2.12 Current State of BIM and Plan Checking

BIM software, e.g. Autodesk Revit Architecture, have been found to be a suitable CAD platform for developing an automated building design system because they provide both geometric and non-geometric information that can be quickly extracted for evaluating the building code compliance as well as other building performance aspects (Nguyen, 2011).

It can be said that BIM faces the same issues as other aspiring standard formats before they are accepted as such: a cooperation problem. Although all users can expect benefits from adopting BIM, since many of these benefits derive from interoperability issues, they are limited

by the rest of the users' adoption rate. The initial direct and indirect costs are considerable and may hinder BIM adoption while models such as the IFC do not achieve the status of an official standard representation format. It is therefore essential to grant early BIM adopters clear, immediate advantages in order to address this cooperation problem (Martins and Abrantes, 2010).

Software products for 3D model compliance checking exists, but code-based rule-sets to govern the process are not yet well developed or tested. Nor is the creation of an automated code-checking workflow, and many of the intended users--code enforcement officials--have little exposure to any of it (ENR, 2011).

2.13 Summary

The plan review process has remained mostly unchanged despite the continual technological advances. Codes typically contain ambiguities leading to different interpretations, resulting in a process that is error prone and time consuming. BIM has been implemented across many stages of the building construction process and it has proven to present significant advantages since it helps identify any potential design, construction or operational issues, and enables close collaboration and encourages integration of the roles of all stakeholders on a project.

Automated code-checking or standards analysis and compliance has been an active area of research since the 1960s. However, many of the initiatives that advocate a fully automated code checking review are still under research.

BIM has the potential of helping building inspectors visualize the project, and allows them to extract the information they might need to check for compliance, resulting in a faster,

more effective review. Despite the benefits, other challenges such as interoperability issues, and training hinder immediate implementation as well.

Since a massive retirement of building inspectors is expected in the near future implementing BIM in the plan review process may help create efficiencies to compensate for the shortage of inspectors.

3. METHODOLOGY

3.1 Introduction

This research explores if Building Information Modeling (BIM) could help in the plan review process. The primary research objectives were to:

1. Determine if it was possible to incorporate BIM in the plan review process, and provide a synthesis of the advantages, and challenges, of using BIM.
2. Determine if the level of detail in the current 3D models was complete enough to allow a plan review to be perform accurately.
3. Identify the extent to which design teams were comfortable with using their models for the plan review. If they are not, determine what needed to change in the design process.
4. Identify barriers to implementation of BIM in the municipal plan review process.

Of particular interest is how BIM could be used in the plan review process. It is also important to understand whether there are changes that could be made in the plan review process to take advantage of benefits from using BIM.

In an attempt to address the above research objectives, the method deemed to be more effective for the data collection employed a qualitative approach. Qualitative research is generally exploratory with variables that are unknown and there is a lack of theory base. Given the exploratory nature of this study a qualitative research methodology was determined to be the

best suited for the data collection and analysis. Where quantitative research is mainly concerned with the testing of hypotheses and statistical generalizations (Jackson, 2008). Qualitative research does not usually employ statistical procedures or other means of quantification, focusing instead on understanding the nature of the research problem rather than on the quantity of observed characteristics (Strauss and Corbin, 1994).

3.2 Setting

The research performed for this study took place in the State of Utah. This location was suitable for various reasons including: proximity to the researcher, familiarity with the local industry, as well as the access to feedback from local industry professionals. This research was conducted through Brigham Young University located in Provo, Utah.

Two separate methodologies were used for this project. The first one was a case study conducted by an expert building inspector, where the 3D model of a building along with the 2D plans, were used to perform the plan review. The purpose of this case study was to assess how helpful BIM could be in the plan review process. The second methodology of the research consisted in a survey of local architecture firms. The survey focused on the architect's views of supplementing 2D documents with BIM for the city plan review and understanding the perception of these architects regarding using BIM in the plan review process.

3.3 Subjects & Participants

The idea behind qualitative research is to purposefully select participants, sites (or documents or visual material) that will best help understand the problem and the research question (Creswell, 2014).

For the case study portion of the study the subject expert was a Utah registered building inspector, licensed by the Division of Occupational and Professional Licensing (DOPL). He is a Master Code Professional, Certified Building Official, Combination Inspector and a Plans Examiner. The inspector was invited to conduct the experiment and run a plan review using a 3D model. The setting also included the researcher, and a BYU professor, who specializes in BIM technology.

For the survey portion of the study the subject and participants consisted of local architects who develop 3D models and who submit building plans to local municipalities for plan review. These professionals are not involved directly in the review process, however, they are responsible for submitting the plans to the municipalities and are key to understand the potential usage of 3D models in the process, based on the completeness and accuracy of these models.

In order to effectively address the research objectives of this study these two populations of industry professionals were considered. The licensed architects and designers were necessary in order to understand what is currently being done in preparation for a plan review, determine if it is possible to consider using 3D models as part of the submitting documents to the municipalities, evaluate the level of accuracy and detail of the 3D models as well as to determine if these models have the necessary information for a plan review to be conducted. Understanding the accuracy of information and the completeness of the 3D model at the moment of plan review is helpful in assessing the possibility of performing a plan review aided by a BIM model.

3.4 Measurement Instruments

3.4.1 Case Study

To study the possibility of including BIM in the plan review process, a case study approach was selected. A case study is "an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident and it relies on multiple sources of evidence" (Yin, 1994).

Case studies are intended … "To provide a level of detail and understanding, similar to the ethnographer Clifford Geertz's (1973) notion of 'thick description', that allows for the thorough analysis of the complex and particularistic nature of distinct phenomena" (Willis, 2014).

The researcher acknowledges that case studies are not representative of the entire target population but emphasizes that the goal was not to generalize but to understand. The code official selected to conduct this case study was chosen because of his expertise and reputation in the industry.

The licensed code official was invited to evaluate how BIM could help supplement traditional 2D documents plan review. The code official and the researcher sat down and performed a code analysis on several projects. During this process, the code official reviewed the 2D plans using the traditional methods of plan review. As the code official had questions about the special relationships between code items and the project, the code official was then led through the project in 3D using BIM to better understand the spatial relationships in the project. The code official provided feedback on how BIM was useful in this process and also what questions were not answered with either the 2D or BIM documents.

The code official reviewed the plans and model of a fast food restaurant. The code official had been licensed in Utah since 2005.

3.4.2. The Survey

To collect input on the concept of using BIM in the plan review process, a survey was administered to architectural firms in Utah. The survey asked specific questions and also allowed for follow-up questions and clarifications by the respondents.

Survey participants consisted of licensed architects or BIM managers. From their responses, the research team had a better understanding of their perceptions regarding supplementing 2D plan reviews with BIM.

Survey respondents involved in the survey were from a variety of backgrounds, and included both men and women. The number of years of the participants practicing as licensed architects varied from 1 to 43 years.

3.4.2.1 The Survey Instrument

The survey as a method of in-depth interviewing in this research study serves as a complimentary component to a multi-method approach. The mode of the selected in-depth interviewing method consists of an electronic survey, followed-up with face-to-face and telephone interviewing for clarifications and additional input if necessary.

The questions in the survey were pilot-tested to ensure that the appropriate questions were asked, and the research objectives met. This would allow an accurate representation of the constructs of interest, and ensure the usefulness of the data (Roller, 2015).

The survey questions were developed in order to gather the following data:

1. Content and accuracy of 3D models
2. Scopes of work modeled in the 3D model
3. Level of Development in the 3D model
4. Advantages of using 3D models instead of 2D
3. Disadvantages of using 3D models instead of 2D
4. Advantages of using 3D models to supplement the 2D
5. Disadvantages of using 3D models to supplement the 2D
6. Number of years as licensed architects
7. Number of years using BIM

The complete survey can be found in Appendix A.

3.5 Summary

To effectively address the research objectives, two populations of industry professionals were considered. The code official was used to understand the current plan review process and also to understand where BIM could potentially improve the current plan review process. The licensed architects' surveys were used to understand what is currently being done in preparation for a plan review. They were also used to understand the level of information contained in BIM, and discover any reservations architects may have about using BIM in the plan review process.

4. FINDINGS

4.1 Research Overview

This chapter serves as a compilation of the results of the Single Case Study Method conducted performing a case study complemented with semi-structured interviews. The Case study was conducted from January through March of 2016. The case study involved using the 3D model of a commercial building in a setting that replicated a plan review performed by a building inspector.

The semi-structured interviews were conducted among local architectural firms as discussed in Chapter 3. The researcher surveyed ten architects from firms in Utah. Interviews were conducted over the phone, and online via Qualtrics, and their content was analyzed and categorized for this research.

4.2 Case Study Results

A case study was considered the best approach for the study. The case study portion of this work took place on the BYU campus. The setting included the researcher, a BYU professor, who specializes in BIM technology, and the building inspector. The case study was done on a computer, using dual monitors. The software used included: Bluebeam to view the 2D plans, and Navisworks to navigate the 3D model. The 3D model used for this study was a single-story commercial building in Tucson, AZ modeled in 2014 by an architectural firm located in Utah.

The building inspector used the 2012 International Building Code as the code reference to conduct the plan review. A total of three sessions were conducted for the case study. All sessions were recorded, and their content was analyzed and categorized for this research.

During all three sessions of the case study the most up-to-date software for 2D drawings was used, thus demonstrating the best possible scenario electronically to do the plan review. Since it is very likely that not all reviewers are using this software, it is an even greater reason to believe that the potential of bettering the process will be even more than what was discovered during the study.

4.2.1. Session One

The first session was conducted on January 29th, 2016. The purpose of the session was to use BIM as the primary source of data for the review, and determine if it was possible to be done with the information provided in the 3D model. Upon the conclusion of the session it was determined that BIM alone is not sufficient to perform the review, rather than replacing the 2D documents the BIM modeled was more helpful as a supplement tool. Below are the encounters and finding. The session lasted approximately 45 minutes, after it was finished it was determined that:

1. Without a code analysis sheet the review would be virtually impossible. Although the model is very useful it does not adequately communicate the designer's approach to code compliance. The following assumptions had to be made, which may or may not be accurate, and resulted in time delays prior to being able to get started:
    - Occupancy Group- Assumed to be "B-Business", no indication of accessory uses, or mixed uses.

- Construction Type- It was determined that the building is of non-combustible construction, narrowing the possible construction types to I-A, I-B, II-A, II-B, in general; however, the other construction types III-A, III-B, and V-A or V-B, could still be used by the design team.
- There did not appear to be any sprinkler piping or heads in the model, leading one to believe that the building will not be sprinkled. As sprinklers are often a deferred item, this assumption may or may not be correct.
- Items such as the number of stories and overall building height were not provided, but were fairly easily determined.
- Actual floor area information was rather easily obtained within the model, but required more effort than normally necessary to find.
- Due to the nature of the building, an area increase due to frontage was not necessary. However, in the case that one was needed in order to demonstrate code compliance, the model would be of no use without the entire site being modeled.
- The fire ratings of various elements of the building such as exterior walls, structural frame, etc., was not found in the model. Some aspects could be assumed, but detailed assembly types with UL listings etc., did not exist.
- Exiting was rather unclear without an exiting plan. Some occupant load information was found in the supporting 2D drawings, however, the presentation of the information was less clear than standard 2D plan submittal practices, requiring more effort on the part of the reviewer.
- Location of exits was easy to determine.

2. Door swings were clear, however, door hardware required some effort in order to determine hardware groups, and then refer back to 2D drawings or spec sheets. In standard 2D plans, some of this would be more readily available.

3. Fire and smoke ratings of doors was included in the BIM model, which was a surprise to the reviewer.

4. Supporting documentation standard to 2D plans was not easily available. For example:

    - Site plans were not included.
    - Exiting plans/code plans did not exist.
    - A list of deferred submittal items was not included.
    - Structural calculations, geotechnical reports, energy code compliance documents were not included.

5. Although not applicable to this project, there was not a breakdown of potentially hazardous materials, locations, or quantities, which is sometimes critical to a plan review.

    Evaluating atriums, openings between floors, etc. would be much easier with the model. This is one area of potential benefit/improvement over the standard 2D plans.

6. Hand and guard railings at stairs were included in the model, which was a surprise. However, there was some debate about whether the rails were generic inserts, or actual proposed railings. This is sometimes the case even with 2D drawings.

    Stairs included rather detailed information, such as rise and run, profile, etc. Navigating the stairs in the model provided added benefit, as potential conflicts, lack of landings, etc. was easily visible. The presentation of the information was less clear than with standard stair details and sections.

7. Exit signage appeared to be provided in some locations; but missing in others. This is a common error in 2D drawings as well, so it is not necessarily a major concern. Other issues included erroneously placed directional arrows on exit signs.

8. The benefit with using the BIM model was with determining true visibility of exit signage with respect to dropped ceilings, interfering walls, and partial height walls. Depending on the level of detail in the model, conflicts with furniture could also be detected.

9. A number of fire alarm devices were modeled. This was a surprise. As the fire review is often handled by the fire authority, the code official performing the plan review does not always see the fire alarm plans. In this instance, BIM would provide better information for the code reviewer.

10. From an accessibility standpoint, BIM appears to have depicted accessible components such as grab bars etc.; however, additional effort on the part of the reviewer would be required in order to determine code compliance, involving physically measuring clearances, grab bar sizes, heights, etc. Standard 2D drawings generally provide boilerplate details outlining many aspects of accessibility that may or may not be relevant to the project. BIM would help in identifying potential problems, as they would be visible in a more true-to-life prospective view, which could then be verified.

    The following elements were modeled:

    - Grab Bars
    - Benches
    - Toilets

- Urinals
- Sinks
- Partitions

What was not modeled, or clear in the BIM model:

- Shower and sink controls
- Shower heads
- Knee and toe clearances
- Toilet heights
- Flush valve locations
- Toilet seats (open front/closed front)
- Toilet paper dispenser
- Clear floor spaces
- Maneuvering clearances
- Signage

From this session it was determined that a second attempt at a review needed to be undertaken, with the help of a complete code analysis, and supporting documentation. The day's experiment resulted in the following findings from the reviewer:

The BIM model helps in gaining a quicker/more accurate understanding of the project/building enabling a more accurate review. A lot of time is spent simply reading the plans initially, in order to understand the project before you can really get going with the review (in 2D plan review).

At this point, with the current model, the BIM review concept appears more useful as an aid to the reviewer, or as a plan review tool, as opposed to a replacement for the traditional 2D approach.

Navigating the model is more complicated than originally thought, and would require a fair amount of familiarity by the reviewer in order to be effective. This would come over time, but would be met with resistance from the older generation that currently perform a large percentage of plan reviews.

The use of the BIM model to create 3D. pdf's needs to be looked into as a possible hybrid between the two methods. This allows the design team to hand select specific perspectives within the model as well.

With the current state of the models, the BIM plan review does not yet provide significant time saving, but does provide potential quality improvement potential.

The plan review process as a whole would need to be modified in order to accommodate a 3D BIM review. Using the established 2D methods, in a 3D world would be problematic. The transition to BIM reviews would have to go hand in hand with a complete overhaul of the current system.

It was discovered that architects have things such as ADA maneuvering clearances pre-loaded into their models, for example "door blocks". When they insert a door into the Revit model, a 2D image of the required clearances is included.

4.2.2 Session Two

The second session was conducted on February 25th, 2016. This session lasted approximately 75 minutes. After determining from the first session that the model alone was not

sufficient to perform the plan review, but rather could be used as a tool to supplement the 2D plans, both the 2D plans and the 3D models were used. Session two was started by replicating a typical plan review, using primarily the 2D plans. The purpose was to identify the areas where the 2D plans was not as effective, and where the model would be more helpful. Session two included the review of the architectural sheets of the model. Since the code official in a usual review does not focuses on structural drawings, little time was spent on it.

1. The reviewer started by looking at the Design Criteria section found on the first page of the set of plans. By reading this section the reviewer extracts important information such as square footage, building height, construction type, and occupant load. The code officials rely only on this sheet to get a general idea of the building.

2. One note about 2D plans is that they are not organized in a logical fashion for plan review. From the reviewer's experience, he has found that the reviewer needs to create their own outline that is works better for their plan review process. Since the design team is not laying out information at the specific order for them. They have found it is easier to follow their system rather than getting in the habit of following the plan.

3. For more conventional type of buildings, it is easier to have a mental picture of the type of building since it is very likely someone has been inside a similar building, where in more unique/complex buildings this is not the case. This is a situation where the 2D drawings are not as helpful, and a model would be beneficial.

4. The amount detail the design team takes to bookmark the plans has a huge impact on how easy the review goes, since it is often necessary to have to switch back and forth through different pages in the plan.

5. Often on the 2D plans, bits of detail are often left off the plans. One example to illustrate this is that the code requires flush levers on the toilet to be on the wide side as opposed to be tucked in the corner. A lot of times this is not drawn on the plans and the reviewer is left guessing or making a comment to the architect to make a note on the plans. It was determined that the model would remove the need of unnecessary comments from the reviewer since it would allow them to visually see what needs to be checked rather than relying on the notes which are often missing.

4.2.3 Session Three

The final session was a continuation of session 2, and was conducted on March 15th, 2016. This session focused on looking at the mechanical, electrical and plumbing plans of the buildings. This session lasted approximately 50 minutes.

Just like the previous session, the purpose of this session was to replicate a plan review just like the reviewer would do in his day-to-day work, and identify the areas where the 2D plans are not as effective, and where the model would or wouldn't be more helpful.

1. Some information such as the location of gas lines feeding through roof top units and where are they placed, isn't necessarily shown correctly on the 2D plans. A reviewer often has to question if these lines are elevated off the roof or right on the roof.
2. On the 2D plans it is often very confusing to see duct work coming down from a roof, since it can gets confusing to see what's above what, especially if the ductwork is overlapping. The more complex the plan the harder it is to identify.

3. A reviewer can get a pretty good idea of layout of ductwork on plan view from a 2D. However, it is harder to see interferences, changes in ceiling elevation, and truss chords that may be the way.
4. All regular ductwork is drawn on the 2D plans as black lines, and it is hard to see overlapping lines since they are the same color.

When talking about the challenges of using the 2D models the code official said the following in instances where it was necessary to reference several pages to gather the information:

> "You need to flip back and forward on 2D models to gather the information you need. Obviously in the model you can just click on the wall element and you can find out what type of wall it is, as well as the material"

During this session it was determined that the model was helpful in looking at:

- Outlet elevations
- Floor drains
- Hoods
- Required clearances around boxes/panels
- Cord drops for electrical kitchen equipment
- Dedicated spaces inside walls
- Indoor plumbing
- Parapet walls
- Fire hoses in the way of door jamb – issue easy to view
- Clearance zone for lights
- Roof drain locations
- Goosenecks

- Combining views
- Interferences
- Changes in ceiling elevation

Not so easy to see or might be missing:

- Air balance schedules
- Natural gas Pressure Release Valve (PRV) details

The day's experiment resulted in the following findings from the reviewer:

Mechanical sets of plans usually contain key notes with an extensive amount of information, if the code official was able to quickly visualize it in the 3D model rather than taking the time to read the fine print it could potentially be translated into time savings for the reviewer.

The fact that 2D plans contain an extensive list of notes which code officials rely on to obtain the necessary information might prevent architects from fully developing the 3D model. This might also be associated with protecting themselves from legal issues.

The primarily benefit of using BIM models to check the mechanical portion of the plans is the fact that while using 2D plans the inspector needs to constantly switch through the architectural and the mechanical plans in order to find a detail, and measure elevations; the model would allow the reviewer to look at several views at the same time.

Using a model would be beneficial in checking mechanical details. On the 2D plans there is often a disconnect between the architect's design and the mechanical detail. Mechanical sets of plans often include generic "boiler plate" details that might not accurately represent the final design intention. Because of this, architects have tried to cover their bases by adding notes to the

plans, but this often translates into an overwhelming amount of description left for the reviewer to read, and interpret.

Reviewers with less experience seem to be the ones that would benefit the most from being able to visualize things with the 3D models, since those reviewers with more experience are able to quickly interpret notes from just looking at the 2D plans. Since the focus should be geared towards the rising generations of building inspectors, and training is expected

Model could help identify potential problems long before they are built. What is the incentive for architects to up their models?

Using the models in the plan review process would help change the chain of communication between the designer and the reviewer.

Perhaps the area where BIM would add the least amount of value would for the plumbing section in the plans. Plumbing on 2D plans are typically drawn in only a few pages, versus the amount of time it would take a designer to model all the plumbing features in the model.

Upon the conclusion of the Case Study, the code official said the following after realizing the potential benefits of BIM in the plan review process:

> "I could start that plan review probably 40 minutes ahead if I just sat down with set of plans and started looking through, cause really until you reach that base level of I know what I am working with here, it is really hard to do the review. I mean you make random notes but it does not really all come together to get that feel. And just looking at this model in five to six minutes I already know the design intent" and if there was a major issue with the building anything that would be required substantial redesign I could identify it really quickly".

4.3 Survey Results

The results obtained from the survey accompanied in this thesis are included in appendix B. The conclusions drawn from each of the survey questions are discussed below.

4.3.1 When Using BIM on A Project, How Do the Documents for the City Plan Review Differ from the 3D Model?

The 3D model of a project typically differs from the 2D documents in the fact that construction details in BIM do not always reflect actual conditions. For example: some roof plans sloping issues are shown as model lines and are therefore not inaccurate. The BIM model will only show elements modeled correctly where shown on the 2D plans. The model will be incomplete in areas not being printed. It would take a long time to model everything perfectly.

4.3.2 What Factors are Keeping the BIM Models from More Closely Approximating the Level of Detail in the 2D Drawings?

Common factors that are keeping BIM models from approximating the level of detail of 2D drawings were determined as the following: time, deadlines, software limitation, file size, and limited knowledge of BIM. Architects feel like the biggest limitation is time since having the model contain every detail is not necessary, and time consuming. They expressed that it is easier, and faster to use standard 2D details than creating an exact replica of the project in 3D. Some respondents feel like the common practice in architectural firms is to model the major elements and then use drafting details to achieve the level of detail in 2D drawings.

According to the designers, any building element can potentially be modeled, but doing so will cause the file to become extremely large, and run slow. There are elements that are difficult to model accurately like: stairs cases, railings, or unique decorative design elements.

Some feel like code officials lack the knowledge of BIM, and taking the effort to have the model completely finished is not necessary.

4.3.3 When Documents Are Submitted for the City to Review, What Percent of the Time Are the Following Scopes Modeled, and to What Level of Development (LOD)?

When architects were asked about the Level of Development of the different sections in the model, it was apparent from their answers that the question was not understood correctly among the respondents. Some shown to not have a correct understand of what LOD's are. Only data from four of the ten respondents were considered to have more realistic, accurate information against what's typically being done by architectural firms.

The responses determined to have a more accurate understanding of the question are presented in table 4-1.

Table 4-1 LOD Survey Responses

Modeled Element	Respondents			
	#5	#6	#10	#11
Architectural - Metal Stud Framing	50	100	10	100
Architectural - Insulation	15	30	80	5
Architectural - Interior Finishes	70	100	60	5
Architectural - Furniture Plans	90	0	5	85
Architectural - Building Signage, room number, exists	50	10	100	5
Structural	50	80	100	100
Mechanical - Equipment	10	50	100	100
Mechanical - Piping Major (pipe not sloped)	0	10	100	100
Mechanical - Ductwork	0	50	100	100
Plumbing - Pipes (Waste/Vent)	0	10	100	20
Plumbing - Traps	0	50	75	5
Plumbing - Fixtures	0	50	100	100
Electrical - Emergency Lighting	50	10	100	100
Electrical - Exit Signage	0	10	100	100
Electrical - Panel Locations	50	10	100	100
Site Grading - Distances to Property lines	70	100	100	100
Site Grading - Accessible parking, routes and signage	100	100	100	85

Because of the poor understanding of the LOD's and the different ranges of the responses, the researcher decided not to make any interpretations of the data since it is not sufficient to make valid assumptions or conclusions from them.

4.3.4 Do You Know of Any Jurisdictions That ALLOW BIM Models to Be Submitted with Permit Applications/Plan Sets?

The answer to this questions was unanimous among all respondents. 100 percent of the respondents indicated that they do not know any jurisdiction that allows BIM models to be submitted with plan sets. This indicates that this is something that has not been implemented, jurisdictions lack the knowledge of the potential benefits of 3D models, and up to this point are comfortable with continuing to request 2D plan sets to perform the plan review.

4.3.5 Do You Feel Submitting a Revit Model or a Navisworks Type of Model Would Be Better for City Plan Review?

When architects were asked about the feelings with regards of submitting a Revit model as a better method for the plan review, the responses for this question were divided. Some of them feel like it would be helpful but they understand the limitations. 3D models could help code officials visualize the project better, and models could be used as supplemental information for them to get a quick understanding of the building, as well as help clarify unique features.

On the opposite side, respondents feel that the degree of BIM's usefulness in the review process is dependent on the plan reviewer's knowledge of the software, and interpretation of the model. The cities will have to make a major investment in personnel training, and hardware/software. Some feel that before BIM can be used, smaller improvements need to happen, like simplifying the process as well as becoming more up to date technologically.

Some architects fear that if they start submitting models to the city, the reviewers will start dictating how the models should be done, they also feel like providing the city with such information could present a liability issue. Respondents understand that the models they produce are not 100 percent complete and for now they don't believe it is worth the amount of effort required compared to the usage the model will receive.

4.3.5 Do You Feel Using a Model to SUPPLEMENT the Plans Submitted to the City for Review Would Be Beneficial for the Plan Reviewer? Yes/No

When survey respondents were asked whether they would feel comfortable or not submitting their plans to the city for plan review 60 percent of the respondents said it would be beneficial, while 40 percent of the respondents said no.

a) What Advantages Would This Create?

The respondents only see advantages of supplementing the plans submitted with the model, if the code official has the knowledge of the technology and software. Some see potential benefits for those new code officials entering the field who are more willing to bring the process up to date with the technology available. The foreseen advantages lie in the possibilities of using the model to help inspectors understand the scope of the building, and use it to check area, travel distances, clearances requirements etc.

b) What Challenges Would This Create?

According to the respondents some of the challenges of using the model to supplement the 2D drawings include: time, knowledge, and strict standardization of modelling practices to make the needed information available to the code official in a useful and efficient way. The fact that models are not all inclusive and are not 100 percent complete is seen as a potential problem, architects and designers feel submitting

these models would create a false expectation that they are. They fear that cities could start dictating workflow, and project process to get a BIM model a particular to way to make their review easier.

Standard architectural details would need to be created in 3D resulting in more time, and higher costs for the firm, each firm uses their own set of graphic and modelling standards which can vary a wide range. These could also represent a challenge to small architectural firms who often do not keep current with available BIM software resulting in added costs for the firm. Architects feel like in order for this application to be successful a comprehensive BIM standards and requirements would need to be developed and issued by the building plan reviewers.

4.3.6 Do You Feel That the BIM Models Could Be Used for Plan Review IN PLACE of 2D Plans? Yes/No

When survey respondents were asked whether they would feel comfortable or not submitting their plans to the city for plan review 50 percent of the respondents said it would be beneficial, while 50 percent of the respondents said no.

a) What Advantages Would This Create?

This question was intended to be answered in reference to the advantages of using BIM in place of 2D plans, but even though it was reworded differently, architects replied the same way, as the previous question.

b) What Challenges Would This Create?

This question was intended to be answered in reference to the challenges of using BIM in place of 2D plans, but even though it was reworded differently, architects replied the same way, as the previous question.

4.3.7 Would You Feel Comfortable Submitting Models to the City for Plan Review? Yes/No

In response to the question whether architects would feel comfortable or not with submitting their models to the city for plan review purposes architect's opinions were divided. 50 percent expressed feeling comfortable submitting their model to the city for plan review while the other 50 percent said they would not.

4.3.8 How Could Using BIM Affect the Turnaround Time for the Plan Review?

Most architects believe that BIM could affect the turnaround time for the plan review, as of right now BIM would slow the review process, but perhaps with time, and implementation it could increase the time significantly. Some feel that unless existing obstacles to efficient use of BIM by code officials are resolved, turnaround time will only become longer as reviewers wrestle with extracting the info they need from a plethora of non-standardized models.

On the positive side some architects believe that it has the potential to speed up the process after an implementation and training period. BIM could potentially affect the turnaround time since it would facilitate communication between designers and the reviewers and would eliminate the need to deliver and return plan sets to the governing authority. Some architects believe that of software or plugins could check the model for code violations, energy, or other components, and the code official then reviewed the list of results to rule out any errors it would increase the turnaround time significantly.

4.3.9 Are You a Licensed Architect?

90 percent of the respondents are currently licensed architects for the State of Utah, with the other 10 percent licensed in Idaho.

4.3.11 How Many Years Have You Been Licensed?

The architects involved in this survey have been licensed architects with years ranging from 1 to 43 years.

4.3.12. How Many Years Have You Used BIM?

The architects and designer's experience with BIM varies among the respondents from 3 to 12 years.

4.3.13 Approximately How Many Architects Are in Your Firm?

The respondents who completed this survey, work in firms where the number of architects and designers range from 1 to 40.

4.3.14 What Other Comments Do You Have Regarding BIM for Plan Review?

Additional comments regarding the topic of BIM for plan review could be categorized into two groups. On one side respondents are confident that sometime in the near future a more automated approach will become the norm, however, for this to happen a digital submission standards need to be developed, and code officials need to be training in drafting and BIM. On the other side is the concern of how could these 3D models be submitted to the cities, since files are extremely large in size and contain multiple links.

5 BENEFITS AND LIMITATIONS OF BIM IN THE MUNICIPAL PLAN REVIEW PROCESS

5.1 Abstract

Obtaining a building permit is an important step for any construction project. Whether it is for a new construction or a remodel job, the process involves a plan review performed by building officials. The purpose of this research was to explore ways in which Building Information Modeling (BIM) could be used to aid building officials during the plan review process. The objectives of the study were to determine if the level of detail in BIM was complete enough to allow a plan review to be perform accurately, to identify the extent to which architects are comfortable with using their models for the plan review, and to identify barriers to implementation.

A case study was conducted where BIM was used to supplement the traditional 2D plans plan review process. Additionally, a survey was given to local architects to obtain their thoughts on using BIM in the plan review process.

The research found that BIM has the potential of helping code officials visualize the project, extract information from objects, and allow them to have a better understanding of unique building features relationship to other building elements. Challenges of using BIM in the plan review process identified by architects included: the accuracy of the model, the level of detail modeled, legal implications, and ability of reviewers to use BIM.

5.1.2 Keywords

Building Information Modeling (BIM), plan review, building codes, code professional, code official, 3D model, Utah.

5.2 Introduction

After a building design is completed, the design documents must be submitted to the city to be checked for code compliance. Code officials are responsible for performing the plan review process. They ensure all different divisions of construction in a building are in conformance with the current and applicable codes. These codes are intended to specify minimum design and construction standards to provide for safety of building occupants and the public (Clayton, 2013). If documents are found to be in compliance with local codes, a building permit is issued.

In current industry practices, the plan review process is usually iterative and time consuming due to the complex nature of the codes and standards. The requirements expressed in the natural language versions typically contain ambiguities leading to different interpretations. Some requirements may be completely missed due to manual checking procedures based on text versions of codes and standards. Hence, what may be considered compliant by the architect may be considered noncompliant by the code official. These problems cause delays in the permitting process and sometimes result in safety hazards (Akin, 2012).

In an attempt to assist the code official, there are numerous initiatives interested in finding ways to make the code checking process more automated. A full automation of the code checking process is something that might be available in the future, and is currently an active research topic. Until automated code checking becomes a reality, this research focuses on the possibility of using BIM to assist in the review process.

BIM is both a technology and a process. The technology component of BIM helps project stakeholders to visualize what is to be built in a simulated environment to identify any potential design, construction or operational issues. The process component enables close collaboration and encourages integration of the roles of all stakeholders on a project (Azhar, 2012).

BIM provides a common way to store information that creates a data-rich, parametric, and digital representation, and it also provides rich information for building elements that can be accessed by software applications. This allows architects to share with code official's important information about the building design while allowing them to get an overall feel of the building through 3D visualization.

The growing implementation of BIM has been beneficial in the construction industry, and across the different stages of a building life. However, BIM is rarely used in the code-checking process during the plan review. This research studies ways in which BIM can be helpful to code officials during the plan review process, as well as to understand why architects and code officials are hesitant to use it.

5.3 Methodology

The purpose of this research was to identify the potential benefits and limitations of implementing the use of BIM in the plan review process. Due to the exploratory nature of the research, a case study approach was used with a supplemental survey.

A case study, involves "an intensive study of a single unit for the purpose of understanding a larger class of (similar) units … observed at a single point in time or over some delimited period of time" (Gerring, 2004). Case studies provide an opportunity for the researcher to gain a deep

holistic view of the research problem, and may facilitate describing, understanding and explaining a research problem or situation (Baxter and Jack, 2008).

It was determined that it was also necessary to understand the architects' opinion on the topic since they are responsible for generating the models that are used for plan review. The data was collected through the different sessions in the case study and also from a survey. Each method is explained in greater detail in the sections to follow.

5.3.1 The Case Study

The first set of data came from a case study that was performed by a Utah licensed code official and a BYU professor who specializes in BIM technology. The purpose of the case study was to replicate a typical plan review process and include BIM as part of the documents used. It would also help the code officials gain greater insight as to how the process can be modified and how technology such as BIM may prove to be suitable for plan review.

The project used for the case study was a fast food restaurant located in Arizona. The building was a single story structure with a dining areas and a drive through window. The software used for the plan review included: Bluebeam Revu to view the 2D plans, and Navisworks Manage 2016 to navigate the 3D model. The restaurant was designed by an architectural firm located in Utah. The code official used the 2012 International Building Code as the code reference to conduct the plan review. Three sessions were conducted for the case study. All sessions were recorded, and their content was analyzed and categorized for this research.

5.3.2 The Survey

The survey was given to local architectural firms in Utah. The survey consisted of 14 semi-structured questions allowing for specific questions to be asked, but it was also open to clarifications and additional input if necessary. The questions in the survey were pilot-tested to ensure that the appropriate questions were asked, and the research objectives met. This would allow an accurate representation of the constructs of interest, and ensure the usefulness of the data (Roller, 2015).

The survey's objective was to understand what is currently being done in preparation for a plan review and to understand the level of information contained in BIM and discover any reservations they may have about using BIM in the plan review process. The survey was distributed through the AIA State of Utah chapter newsletter, and in conjunction with the University of Utah's Architecture program in an effort to reach a broader population. A total of 10 responses resulted from the survey. The low responses may indicate that this topic has not been considered by architects and may not be considered by architects as a pressing issue. While the statistical value of the survey is very limited, the survey was insightful in identifying general thoughts from architects regarding the topic. Below are the interview questions that were asked.

1. When using BIM on a project, how do the documents for the city plan review differ from the 3D model?
2. What factors are keeping the BIM models from more closely approximating the level of detail in the 2D drawings?
3. When documents are submitted for the city to review, what percent of the time are the following scopes modeled, and to what Level of Development (LOD)?

4. Do you know of any jurisdictions that ALLOW BIM models to be submitted with permit applications/plan sets?
5. Do you feel submitting a Revit model or a Navisworks type of model would be better for city plan review?
6. Do you feel using a model to SUPPLEMENT the plans submitted to the city for review would be beneficial for the plan reviewer? Yes/No
7. What advantages would this create?
8. What challenges would this create?
9. Do you feel that the BIM models could be used for plan review IN PLACE of 2D plans? Yes/No
10. What advantages would this create?
11. What challenges would this create?
12. Would you feel comfortable submitting models to the city for plan review? Yes/No
13. How could using BIM affect the turnaround time for the plan review?

5.4 Results

5.4.1 Case Study Results

The first session was conducted on January 29th, 2016. The purpose of the session was to use BIM as the primary source of data for the review, and determine if it was possible to be done with the information provided in the 3D model. Upon the conclusion of the session it was determined that BIM alone is not sufficient to perform the review, rather than replacing the 2D documents the BIM modeled was more helpful as a supplement tool. Below are the encounters

and finding. The session lasted approximately 45 minutes, after it was finished it was determined that:

1. Without a code analysis sheet the review would be virtually impossible. Although the model is very useful it does not adequately communicate the designer's approach to code compliance. The following assumptions had to be made, which could or could not be accurate, and resulted in time delays prior to being able to get started.

2. Supporting documentation standard to 2D plans was not easily available. For example:

- Site plans were not included.
- Exiting plans/code plans did not exist.
- A list of deferred submittal items was not included.
- Structural calculations, geotechnical reports, energy code compliance documents were not included.

3. The benefit with using the BIM model was with determining true visibility of exit signage with respect to dropped ceilings, interfering walls, and partial height walls. Depending on the level of detail in the model, conflicts with furniture could also be detected.

4. A number of fire alarm devices were modeled. This was a surprise. As the fire review is often handled by the fire authority, the code official performing the plan review does not always see the fire alarm plans. In this instance, BIM would provide better information for the code reviewer.

5. From an accessibility standpoint, BIM appears to have depicted accessible components such as grab bars etc., however, additional effort on the part of the reviewer would be required in order to determine code compliance, involving physically measuring clearances, grab bar sizes, heights, etc. Standard 2D drawings generally provide boiler plate details outlining many aspects of accessibility that may or may not be relevant to the project. BIM would help in identifying potential problems, as they would be visible in a more true-to-life prospective view, which could then be verified.

The following elements were modeled:

- Grab Bars
- Benches
- Toilets
- Urinals
- Sinks
- Partitions

What was not modeled, or clear in the BIM model:

- Shower and sink controls
- Shower heads
- Knee and toe clearances
- Toilet heights
- Flush valve locations
- Toilet seats (open front/closed front)
- Toilet paper dispenser
- Clear floor spaces

- Maneuvering clearances
- Signage

From this session it was determined that a second attempt at a review needed to be undertaken, with the help of a complete code analysis, and supporting documentation. The day's experiment resulted in the following findings from the reviewer:

The BIM model helps in gaining a quicker/more accurate understanding of the project/building enabling a more accurate review. A lot of time is spent simply reading the plans initially, in order to understand the project before you can really get going with the review (in 2D plan review).

The BIM model offers a number of advantages, as well as a number of disadvantages. As this point, with the current model, the BIM review concept appears more useful as an aid to the reviewer, or as a plan review tool, as opposed to a replacement for the traditional 2D approach.

Navigating the model is more complicated than originally thought, and would require a fair amount of familiarity by the reviewer in order to be effective. This would come over time, but would be met with resistance from the older generation that currently perform a large percentage of plan reviews.

The use of the BIM model to create 3D. pdf's needs to be looked into as a possible hybrid between the two methods. This allows the design team to hand select specific perspectives within the model as well.

With the current state of the models, the BIM plan review does not yet provide significant time saving, but does provide potential quality improvement potential.

The plan review process as a whole would need to be modified in order to accommodate a 3D BIM review. Using the established 2D methods, in a 3D world would be problematic. The transition to BIM reviews would have to go hand in hand with a complete overhaul of the current system.

From talking with an architect, it was discovered that they have ADA maneuvering clearances pre-loaded into their modeled such as: door blocks, etc. so that when they insert a door into the Revit model, a 2D image of the required clearances is included.

After determining from the first session that the model alone was not sufficient to perform the plan review, but rather could be used as a tool to supplement the 2D plans, both the 2D plans and the 3D models were used when conducting session two.

Session two was started by replicating a typical plan review, using primarily the 2D plans. The focus was to identify the areas where the 2D plans was not as effective, and where the model would be more helpful. Session two included the review of the architectural sheets of the model. Since the code official in a usual review does not focuses on structural drawings, little time was spent on it.

The reviewer started by looking at the Design Criteria section found on the first page of the set of plans. By reading this section the reviewer extracts important information such as square footage, building height, construction type, and occupant load. They rely only on this sheet to get a general idea of the building.

One note about 2D plans is that they are not organized in a logical fashion for plan review. From the reviewer's experience, he has found that the reviewer needs to create their own outline that is works better for their plan review process. Since the design team is not laying out

information at the specific order for them. They have found it is easier to follow their system rather than getting in the habit of following the plan.

For more conventional type of buildings, it is easier to have a mental picture of the type of building since it is very likely someone has been inside a similar building, where in more unique/complex buildings this is not the case. This is a situation where the 2D drawings are not as helpful, and a model would be beneficial.

The amount detail the design team takes to bookmark the plans has a huge impact on how easy the review goes, since it is often necessary to have to switch back and forth through different pages in the plan.

Often on the 2D plans, bits of detail are often left off the plans. One example to illustrate this is that the code requires flush levers on the toilet to be on the wide side as opposed to be tucked in the corner. A lot of times this is not drawn on the plans and the reviewer is left guessing or making a comment to the architect to make a note on the plans. It was determined that the model would remove the need of unnecessary comments from the reviewer since it would allow them to visually see what needs to be checked rather than relying on the notes which are often missing.

The final session was a continuation of session two. This session focused on looking at the mechanical, electrical and plumbing plans of the buildings.

Like the previous session, the purpose of this session was to replicate a plan review just like the reviewer would do in his day-to-day work, and identify the areas where the 2D plans are not as effective, and where the model would or wouldn't be more helpful.

Some information such as the location of gas lines feeding through roof top units and where are they placed, isn't necessarily shown correctly on the 2D plans. A reviewer often has to question if these lines are elevated off the roof or right on the roof.

On the 2D plans it is often very confusing to see duct work coming down from a roof, since it can gets confusing to see what's above what, especially if the ductwork is overlapping. The more complex the plan the harder it is to identify.

A reviewer can get a pretty good idea of layout of ductwork on plan view from a 2D. However, it is harder to see interferences, changes in ceiling elevation, and truss chords that may be the way.

All regular ductwork is drawn on the 2D plans as black lines, and it is hard to see overlapping lines since they are the same color.

When talking about the challenges of using the 2D models the code official said the following in instances where it was necessary to reference several pages to gather the information:

> "You need to flip back and forward on 2D models to gather the information you need. Obviously in the model you can just click on the wall element and you can find out what type of wall it is, as well as the material"

During this session it was determined that the model was helpful in looking at:

- Outlet elevations
- Floor drains
- Hoods
- Required clearances around boxes/panels
- Cord drops for electrical kitchen equipment
- Dedicated spaces inside walls

- Indoor plumbing
- Parapet walls
- Fire hoses in the way of door jamb – issue easy to view
- Clearance zone for lights
- Roof drain locations
- Goosenecks
- Combining views
- Interferences
- Changes in ceiling elevation

Not so easy to see or might be missing:

- Air balance schedules
- Natural gas Pressure Release Valve (PRV) details

The day's experiment resulted in the following findings from the reviewer:

Mechanical sets of plans usually contain key notes with an extensive amount of information, if the code official was able to quickly visualize it in the 3D model rather than taking the time to read the fine print it could potentially be translated into time savings for the reviewer.

The fact that 2D plans contain an extensive list of notes which code officials rely on to obtain the necessary information might prevent architects from fully developing the 3D model. This might also be associated with protecting themselves from legal issues.

The primarily benefit of using BIM models to check the mechanical portion of the plans is the fact that while using 2D plans the inspector needs to constantly switch through the

architectural and the mechanical plans in order to find a detail, and measure elevations; the model would allow the reviewer to look at several views at the same time.

Using a model would be beneficial in checking mechanical details. On the 2D plans there is often a disconnect between the architect's design and the mechanical detail. Mechanical sets of plans often include generic "boiler plate" details that might not accurately represent the final design intention. Because of this, architects have tried to cover their bases by adding notes to the plans, but this often translates into an overwhelming amount of description left for the reviewer to read, and interpret.

Reviewers with less experience seem to be the ones that would benefit the most from being able to visualize things with the 3D models, since those reviewers with more experience are able to quickly interpret notes from just looking at the 2D plans. Since the focus should be geared towards the rising generations of building inspectors, and training is expected

Model could help identify potential problems long before they are built. What is the incentive for architects to up their models?

Using the models in the plan review process would help change the chain of communication between the designer and the reviewer

Perhaps the area where BIM would add the least amount of value would for the plumbing section in the plans. Plumbing on 2D plans are typically drawn in only a few pages, versus the amount of time it would take a designer to model all the plumbing features in the model.

Upon the conclusion of the Case Study, the code official said the following after realizing the potential benefits of BIM in the plan review process:

> "I could start that plan review probably 40 minutes ahead if I just sat down with set of plans and started looking through, cause really until you reach that base level of I know what I am working with here, it is really hard to do the review. I mean you make random notes but it does not really all come together to get that feel. And just looking at this model in five to six minutes I already know the design intent" and if there was a major issue with the building anything that would be required substantial redesign I could identify it really quickly".

5.4.2 Survey Results

No respondents were aware of a jurisdiction that allows BIM to be submitted with plan. Since there are no jurisdictions who currently allow submitting BIM as part of the documents, this may indicate that this has not been explored.

Most architects agreed that there are potential benefits of using the model for plan review but feel that municipalities are far from being able to take advantage of the models because of their lack of knowledge of BIM.

Architects seem to be reluctant to share the BIM model, out of concern that the model might not be sufficiently complete, and it might not contain all the elements intended in the final design. Because of this, relying on a model that is not complete could present a liability issue for the architect. The architects do not feel that it is worth the amount of effort required to complete the model, compared to the usage the model will receive.

Some architects fear that if this were to become a reality and they started submitting models to the city, the reviewers will start dictating how the models should be done to make the review easier for them and failing to consider the amount of effort required by architects. This could lead to implications like, required LODs, additional modeling not typically performed by architects, and a forced shift to BIM software.

These various concerns arise because this is a new field of research. As such, fear of the unknown should be anticipated. Understanding the concerns that architects might have, and finding ways to address them is key to a successful implementation.

5.4.3 A Needed Culture Change

A cultural transformation strategy needs to happen in order to ensure a successful implementation of BIM in the plan review process. "A cultural transformation is a greater challenge to the construction industry than any technological transformation resulting from BIM" (Smith and Tardif, 2009).

Architects fear that sharing the amount of information contained in BIM will translate into more liability. Code officials and architects like any other stakeholder in the building process must learn to view themselves as partners and collaborators rather than adversaries and potential litigants. "It will require that the industry reach beyond technology and business practices to alter the prevailing legal framework, particularly with respect to dispute resolution" (Smith and Tardif, 2009).

The potential impact of this new mindset will have benefits far greater than simply adding new technology to the process. If after understanding the limitations of the BIM models, city officials opened the possibility of including them as part of the submittal documents, while keeping the same requirements of 2D documents it will invite for a more collaborative approach, and it would help architects and designers ease their fears and concerns.

The changing demographics may offer an opportunity to "help facilitate attempts by code departments to shift from a perceived adversarial process to a more cooperative engagement with the design, construction and overall business communities" (ICC, 2014).

5.4.3 An Aging Workforce of Code Officials

According to a previous research conducted in the state of Utah (Williams, 2015) it was determined that approximately half of all licensed code officials in the state will reach retirement age within the next ten years. The growing concern of a reduced workforce should serve as a motivator to find new and improved ways of performing the plan review more effectively. This concern is not unique to the State of Utah. A national study conducted by the ICC and the NIBS found that more than 80 percent of the existing code professional workforce is planning on retiring in the next 15 years, with more than 30 percent in the next five years (ICC, 2014).

Introducing new technology such as BIM could prove beneficial in addressing the issue of a reduced workforce of code officials in the future. This could allow the remaining body of code officials to perform their day-to-day operations faster and more effectively.

Although this research was specific to Utah, it has potential implications for the code official profession. This situation becomes more alarming especially in small, more rural jurisdictions where new talent is not so easily found.

5.4.4 Additional Training

The survey indicated that the degree of BIM's usefulness in the review process is dependent upon the plan reviewer's knowledge of the software, and capability of the model interpretation. If local code officials wanted to require BIM as part of the submittal documents, reviewers need to be trained on how to use it. This is a major investments of hardware/software and need to be considered in order to make the architect's effort of time and money be worthwhile.

Since the likelihood of a substantial cost of training new generations of code professionals is imminent, it should be seen as an opportunity to introduce the use of new technology such as BIM. This update in technology and practices in conjunction with the change in personnel, could help in limiting disruption in the existing workforce. “Model code developers, code professional organizations, building information modeling (BIM) advocates, smart city product providers and other stakeholders may wish to come together to work collectively in realizing such a cross-industry transformation” (ICC, 2014).

As the industry expands, new technologies become essential to perform job duties. This training would serve not only as a vehicle to transfer business knowledge among generations, but also to increase productivity and effectiveness through technology.

5.5 Conclusions

After the conclusion of the study it was determined that on one side jurisdictions lack the knowledge of the potential benefits of 3D models, and up to this point are comfortable with continuing to request 2D plan sets to perform the plan review, and on the other side architects have not considered this possibility, and from their opinions are hesitant about embracing this idea.

Since there is no information of BIM being used by code officials in the review process, this research becomes a blank slate where the possibility of new methods is explored, and were researchers can look for answers as to understand why things are done the way they have been done, and what new things can be done to make these processes more effective.

For the past years BIM has demonstrated to be generating productivity gains in the construction processes through the collective efforts of all stakeholders. Even though it has been

widely used throughout the different building processes, it has not been used in the plan review process. This presents a unique opportunity for BIM to play a role in the review process.

Allowing architects to submit their 3D models as part of the submittal documents to the city or jurisdiction could be of great benefit to ensure a more accurate, standardized and faster process.

The research discovered that BIM has the potential of helping code officials visualize the project, extract important information from selecting objects, and allow them to have a better understanding of unique building features and how they relate to other elements. While BIM exposed the benefits mentioned above other challenges such as the accuracy, and level of detail in the models, fears from architects about legal implications, and a lack of knowledge of BIM technology from the reviewers hinder its immediate implementation.

Training opportunities were found to be key in obtaining full benefits of using the model however since a change of demographics in the building code industry is expected it should be seen as an opportunity to bring procedures up to date with technology.

A limitation with this study was associated with the survey responses. The survey, although secondary to the research was key in understanding architects and designer's practices when it comes to generating the models, as well as their opinion on the topic. Although valuable feedback was obtained from the 10 respondents, in order to acquire a better understanding, of what's common in the industry versus what's unique to each firm a bigger sample is needed.

Since the study research was mainly exploratory further research is needed. Since the implementation of BIM is dependent upon the reviewer's knowledge of the program additional research is needed with respect to quantifying the investment cities will have to undertake both

in personnel training and software installation in order to assure the expertise of the reviewer with the program. Additionally, it becomes necessary to develop a standard for 3D models to ensure it contains the necessary information needed for to the plan review, and that is consistent among the different jurisdictions. This would be valuable in order for architects to know what is expected from the models.

Further research about the legal implications of using BIM should be undertaken. Through additional research a legal and contractual framework can be developed in order to foster collaboration and allocate responsibility and risk appropriately.

Additional research on new methods of how to better the processes, as well as how to attain a more collaborative approach from architects and city officials will be necessary in order to further progress in this field of study.

Perhaps a number of years still need to pass before a full realization of BIM in the plan review becomes a reality. For now, the code industry must work to find ways to bridge the gaps, and must take advantage of opportunities that are being presented to advocate for a more collaborative approach from all those that intervene in the building processes.

6 CONCLUSIONS

The Plan review process has remained mostly unchanged despite the continual technological advances, this process is complex, and prone to human error. The purpose of this study was to explore the benefits of implementing BIM in the plan review process. It was also deemed important to understand how accurate the 3D models are, and what information could be extracted from the model depending on the level of detail.

Allowing architects to submit their 3D models as part of the submittal documents to the city or jurisdiction could be of great benefit to ensure a more accurate, standardized and faster process.

The research discovered that BIM has the potential of helping code officials visualize the project, extract important information from selecting objects, and allow them to have a better understanding of unique building features and how they relate to other elements. While BIM exposed the benefits mentioned above other challenges such as the accuracy, and level of detail in the models, fears from architects about legal implications, and a lack of knowledge of BIM technology from the reviewers hinder its immediate implementation.

Training opportunities were found to be key in obtaining the full benefits of using the BIM model. Since a change of demographics in the building code industry is expected it should be seen as an opportunity to bring procedures up to date with technology.

6.1 Limitations

A limitation with this study was associated with the survey responses. The survey, although secondary to the research, was key in understanding architects and designer's practices when it comes to generating the models, as well as their opinion on the topic. Architects seemed to not yet be ready to embrace this new approach possibly explaining the low response on the survey. Although valuable feedback was obtained from the 10 respondents, in order to acquire a better understanding, of what is common in the industry versus what is unique to each firm a bigger sample is needed.

6.2 Advice for Future Research

Since the study research was mainly exploratory further research is needed. The implementation of BIM is dependent upon the reviewer's knowledge of the program because of this additional research is needed with respect to quantifying the investment cities will have to undertake both in personnel training and software installation. Additionally, it becomes necessary to develop a standard for 3D models to ensure it contains the necessary information needed for to the plan review, and that is consistent among the different jurisdictions. This would be valuable in order for architects to know what is expected from the models.

Further research about the legal implications of using BIM should be undertaken. Through additional research a legal and contractual framework can be developed in order to foster collaboration and allocate responsibility and risk appropriately.

Additional research on new methods of how to better the processes, as well as how to attain a more collaborative approach from architects and city officials will be necessary in order to further progress in this field of study.

Perhaps a number of years still need to pass before a full realization of BIM in the plan review becomes a reality. The code industry must work to find ways to bridge the gaps, and must take advantage of opportunities that are being presented to advocate for a more collaborative approach from all those that intervene in the building processes

REFERENCES

Akin, Ö. "Building Codes". *In Embedded Commissioning of Building Systems*, 178. Boston: Artech House, 2012.

Autodesk 2007. "Revit Building Information Modeling" *BIM and Cost estimating.* http://images.autodesk.com/apac_grtrchina_main/files/aec_customer_story_en_v9.pdf. (accessed January 15, 2016).

Azhar, S., M. Khalfan, and T. Maqsood. 2012. "Building Information Modelling (BIM): Now and beyond." *Australasian Journal of Construction Economics and Building* 12 (4): 15–28. doi:10.5130/ajceb.v12i4.3032.

Baxter, P., and, S. Jack, 2008. Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, 13 (April), 544-559.

Borrmann, A., and E. Rank, *Query Support for BIMs using Semantic and Spatial Conditions*, Handbook of Research on Building Information Modeling and Construction Informatics : Concepts and Technologies , IGI Global , 2010

Building Performance, The building code and Compliance http://www.building.govt.nz/about-the-building-code (accessed December 15, 2015)

Chowdhury, K. "Building Information Modeling in Site Management. HTW Berlin. http://www.academia.edu/2065272/BIM_in_Site_Management (accessed date April,25 2016)

Clayton, M. J. "Automated Plan Review for Building Code Compliance Using BIM."Paper presented at the EG-ICE Conference,Vienna, Austria, July 2013.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2008) *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors* Wiley, New York.

Gerring, J. 2004. What is a case study and what is it good for? *American Political Science Review*, 98 (May): 341-354 https://fekmekci.files.wordpress.com/2014/11/gerring-case-study.pdf (accessed April 25, 2016).

International Code Council. International Building Code 2006, New Jersey Edition. http://www2.iccsafe.org/states/newjersey/nj_building/PDFs/NJ_Bldg_Preface.pdf (accessed February 15, 2016)

International Code Council 2014. The Future of Code Officials http://www.iccsafe.org/about-icc/periodicals-and-newsroom/survey-of-code-professionals-predicts-substantial-retirement-exodus/ (accessed January 13,2016).

International Code Council 2015. International City Council Fact Sheet. http://www.iccsafe.org/wp-content/uploads/fact-sheet.pdf 1st ed. International Code Council, 2016. Web. (accessed 18 May 2016).

International Code Council 2016 Building Codes: How They Help You https://www.iccsafe.org/safety/Documents/BSW-BldgCodes-How.pdf (accessed January 13, 2016).

Jackson, S. L. 2008. Research methods and statistics: A critical thinking approach. Belmont, CA: Wadsworth Cengage Learning.

Listokin, D., and D. Hattis. 2005. Building Codes and Housing. *Cityscape: A Journal of Policy Development and Research* 8, no.1 https://www.huduser.gov/periodicals/cityscpe/vol8num1/ch2.pdf (accessed May 25, 2016)

Martins, J. P., and A. Monteiro. 2013. "LicA: A BIM Based Automated Code-Checking Application for Water Distribution Systems." *Automation in Construction* 29 (23). Elsevier B.V.: 12–23. doi:10.1016/j.autcon.2012.08.008.

Martins, J. P., and V. Abrantes. 2010. "Automated Code-Checking as a Driver of BIM Adoption." *International Journal for Housing Science and its Applications*.

Ministry of Business, Innovation and Employment 2016. The Building Code and Compliance. http://www.building.govt.nz/about-the-building-code (accessed March 20, 2016).

Nawari, N. 2013. "SmartCodes and BIM." *Structures Congress 2013*, 928–37. doi:doi:10.1061/9780784412848.082.

NYC Department of Design and Construction, 2012. BIM Guidelines. http://www.nyc.gov/html/ddc/downloads/pdf/DDC_BIM_Guidelines.pdf (accessed February 24, 2016).

Provo City 2016. Building Permit FAQ http://www.provo.org/departments/community-development/building/building-permit-faq (accessed March, 20, 2016).

Rosenman, M. A. & Gero, J. S., 1985. Design codes as expert systems. Computer-Aided Design 17(9), p. 399– 409.

Smith, Dana, and Tardif Michael. BIM Implementation Strategies. In *Building Information Modeling: A Strategic implementation guide for architects, engineers, Contractors, and Real State Asset Managers.* New Jersey: John Wiley & Sons. 2009

Strauss, A., & Corbin, J. 1994. "Grounded theory methodology". In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 273-286). Thousand Oaks, CA: Sage.

Vaughan, E., and J. Turner. "The Value and Impact of Building Codes". Environmental and Energy Study Institute. September 30, 2013. http://www.eesi.org/papers/view/the-value-and-impact-of-building-codes. (accessed March 20, 2016).

Williams, G., Assessing the Repercussions of a Mass Departure of Building Inspectors from the Code Professional Industry in Utah, master's thesis. Brigham Young University, 2015.

Willis, B. The Advantages and Limitations of Single Case Study Analysis. EInternational Relations. University of Plymouth. 2014. http://www.e-ir.info/2014/07/05/the-advantages-and-limitations-of-single-case-study-analysis/. (accessed March 20, 2016).

APPENDICES

APPENDIX A THE SURVEY

1.1 When using BIM on a project, how do the documents for the city plan review differ from the 3D model? (Examples could be things like is each wall type modeled as different objects or are generic wall types used for all walls; are the walls model to the correct height? Is all the note information found on the plans included in the modeled objects? Future phasing?)

1.2 What factors are keeping the BIM models from more closely approximating the level of detail in the 2D drawings?

1.3 When documents are submitted for the city to review, what percent of the time are the following scopes modeled, and to what Level of Development (LOD)?

When documents are submitted to the city:	How often are the following scopes typically modeled (%)	Level of Development (LOD) 100-500
Architectural		
Metal Stud Framing		
Insulation		
Interior Finishes		
Furniture Plans		
Building Signage Room number, Exit Signage		
Structural		
Mechanical		
Equipment		
Piping Major pipe not sloped		
Ductwork		
Plumbing		
Pipes/(Waste/Vent)		

When documents are submitted to the city:	How often are the following scopes typically modeled (%)	Level of Development (LOD) 100-500
Traps		
Fixtures		
Electrical		
Emergency Lighting		
Exit Signage		
Panel Locations		
Site Grading		
Distances to property lines		
Accessible parking, routes, and signage		

1.4 Do you know of any jurisdictions that ALLOW BIM models to be submitted with permit applications/plan sets? YES/NO
If, Yes, where?

1.5 Do you feel submitting a Revit model or a Navisworks type of model would be better for city plan review?
Please Explain

1.6 Do you feel using a model to **SUPPLEMENT** the plans submitted to the city for review would be beneficial for the plan reviewer? Yes/No
a) What advantages would this create?
b) What challenges would this create?

1.7 Do you feel that the BIM models could be used for plan review **IN PLACE** of 2D plans? Yes/No
a) What advantages would this create?
b) What challenges would this create?

1.8 Would you feel comfortable submitting models to the city for plan review? Yes/No

1.9 How could using BIM affect the turnaround time for the plan review?

1.10 What other comments do you have regarding BIM for plan review?

Part 2 Background Information

2.1 Are you a licensed Architect? Yes/No

a. How many years have you been licensed?
b. How many years have you used BIM?

2.2 Approximately, how many architects are in your firm?

2.4 Are you ok if we contact you for further clarifications to your answers Yes/No

2.5 If Yes, What is the best phone number to contact you?

APPENDIX B WRITTEN SURVEY RESPONSES

Q1. When using BIM on a project, how do the documents submitted for city plan review differ from the 3D BIM model? (Examples could be things like is each wall type modeled as different objects or are generic wall types used for all walls; are the walls model to the correct height? Is all the note information found on the plans included in the modeled objects? Future phasing?)
Almost all loaded generic walls require modification to be accurate with the planned project. Local Building Plan Review Officials for a Building Permit regard Modelling at this time as an asset. BIM models are generally requested by the Contractors to aid in Quantity Take Off. Currently sharing modelling files can be dangerous, as there are few contractors with BIM skills.
Documents are typically submitted in a 2D format, very similar to what would have been submitted before the advent of BIM.
All wall assemblies in our models are generated per the wall type (minus the finish - paint, wall covering, tile, etc.) and are represented to the desired heights (just above ceiling or up to deck) . We feel these are important attributes, especially when it comes to rated walls. Finishes are sometimes not modeled when they only appear in a few views/sheets in the drawings. Some furniture and accessories are not modeled.
We as a firm we have not fully embrace BIM but we model our models to a pretty good extend, they are things we model and don't, so that we can take off surface areas and get information from the model
This doesn't apply to our firm since we don't submit plans to the city using BIM models
Construction details in BIM do not always reflect actual conditions. This could include every aspect of building-- soffit, fascia, roof, walls, floors, foundation, footing, etc.
Many of the highly detailed portions of the model are still drawn in two dimensions such as guard rails and handrails. We model all wall types with the exact wall assemblies, but the transitions between wall types and to window systems is not modeled but drawn in 2d to achieve the level of detail required.
Still just hard copies. There was a change from wet stamp to digital stamp.

The BIM model will only show elements modeled correctly where shown on the 2d plans. For example, the model will be incomplete in areas not being printed. It would take way to long to model everything perfectly.
Site plans are not in 3d (Revit) but rather 2d (Autocad). Some roof plans sloping issues are shown as model lines and therefore not.
3D accurate. Fear of files having complex issues when opening by Plan Checker – ie. Worksets, linked files, etc.

Q2. What factors are keeping the BIM models from more closely approximating the level of detail in the 2D drawings?
BIM Modelling should be able to achieve the same level of detail. However, BIM Modelling requires complete modelling to illustrate detailing with to issues, such as more cost in preparation, which leads to exposure to indicated 'means and methods'. Contractors use of drawings and details is necessary, however, high levels of detail can lead to 'entrapment' and increased risk.
Translation of BIM model elements into representational line types that are consistent with best drafting practices. Also, the model must be sufficiently detailed such that inconsistencies or disconnects in the 3D model do not show up as blanks in the 2D drawings.
There are many aspects to a project that just don't need to be modeled. People could waste a lot of time trying to precisely create moldings, trims, unique decorative design elements, etc. which are covered represented as line work, group elements, or 2D components. Project schedules and deadlines always seem to be fast and furious so the most important components related to the project are modeled, while some of these other elements are covered as 2D components. Some of things do not appear frequently or are not commonly visible enough in the completed drawings to be modeled throughout the project. There is not enough time or fee to have these things modeled and they don't provide much added value to the project delivery. BIM is only a tool; our liability is within the construction documents. Consultants have to make the same decisions noted above as it related to what is important to be modeled in their drawings. Also, the ability of consultants to utilize BIM varies drastically. Some provide fairly accurate and complete models, while others stumble and trip through the process and provide models with limited information. We also have to remember that many objects in the consultant drawings are shown schematically (piping, plumbing, etc.).
Its primarily software limitation, and the time and energy it takes to get to that level of detail, we use Revit in our office, for as good as it its, they are difficult to model accurately, things like: stair cases, railings. Even some of the topography and other items, its not as smooth as it needs to be in order to make it efficient.

We do use Revit on occasion, its difficult to create details using Revit and that could cause limitations.
Time. It is much faster to use standard 2d details than to create an exact replica of a building in 3d.
Almost any building element can be modeled, but most offices have found by doing so the files become too large and slow, so the strategy has become to model the major elements, and use drafting details to achieve the level of detail in 2d drawings.
Many people still learning BIM.
Time!!! For example, Revit forces one to make sure everything is perfect in order for it to show things correctly (schedules, doors etc.) Where AutoCAD will let you show or note things where you do not have to model every individual door that differs from another.

Q5. Do you feel submitting a Revit model or a Navisworks type of model would be better for city review? Please explain.
Yes. Some Plans Examiners don't exhibit skill at visualization. Modelling can help. I have shared Modelling Details with Plans Examiners by making an appointment and found it to be a helpful option.
It can only be better to the extent that the plan reviewer is knowledgeable and competent to access and interpret the model for compliance with codes. Translation of the model to 2D format facilitates communicating those specific features of the design that demonstrate code compliance.
They could be helpful in the review process, but I don't think using BIM models is for review is the answer. I think simplifying their process and becoming more up to date technologically would need to be a great first step. Improving communication with the design team and between their various agencies would be glorious. Getting back to the topic...all firms and companies do things a little differently, and vary in levels of application and sophistication when it comes to BIM, but even the more advanced BIM models would have gaps. I don't want to cities to start dictating how the models are generated as a result of how they want to review the project or because what they feel is easiest for them. A big challenge I see is also the city's capabilities to conduct such a review. They would have to make a major investment in personnel, training, and hardware/software. There are some jurisdictions that are stuck in the stone age with employees that struggle with technology.
Not yet, because I don’t feel tools are streamlined enough to allow efficient production of a model that can utilized completely, in order words right now we model the building and get to choose what they see.

No, because of the incomplete information
The city should be reviewing the documents or model that the contractor will use to create the building. To this point all the contractors I have worked with rely on 2d drawings/documents for construction information. At this point most plan review items can be identified on 2d drawings
I think that it might be useful as supplemental information and to get a quick understanding of the building, but the review be based on the produced documents that might have a combination of modeling, drafting and notation to give a more detailed representation of the construction than just the model offers.
Yes, it would help clarify unique situations.
No, because no model is ever perfect, and it would one drive the city plans examiner nuts, and most city plans examiners would need the training to know how to use it. They would come back with more unecesary comments. Second is liability and copyright, that is why Architects and their insurance companies try and limit who has access to the plans. Now of course the city could sign agreements with the Architects to resolve those concerns.
I'm not sure it is a deliverable that is easy to scan (page turn) easy enough. The files are heavy but could very useful to understand elements in 3d.

Q8. Do you feel using BIM to SUPPLEMENT the plans submitted to the city for review would be beneficial for the plan reviewer? If yes. What advantages would this create?
See Q5
None, given current technology and lack of competence on the part of plan reviewers.
for starters it would be easier to understand the plan rapidly,
allows you to manipulate three dimensionally
It would make it easier for the plan reviewer to understand the volume of space, to visualize the entire building.
if the reviewer is familiar with BIM software they can get a quick 3d understanding of the scope of the building, use the model to check areas, travel distances etc. Eventually plan reviewers might have their own software, or a plugin to the same software, that could run calculations based on the model to check for code violations, check energy & sustainability, etc.
Yes, it would help clarify unique situations.

Understanding the larger design intent... however, remember that not only do the building officials need to understand the documents on paper / PDF but also the laborers.

Q9. Do you feel using BIM to SUPPLEMENT the plans submitted to the city for review would be beneficial for the plan reviewer? If yes. What challenges would this create?
Expectations for continued effort without the Owner and Contractor necessarily benefitting.
It would take time, knowledge, and strict standardization of modeling practices to make the needed information available to the plan reviewer in a useful and efficient way.
I see more problems than advantages. BIM is a tool and now we are putting the tool we use in the reviewer's hands as part of their review. It may be helpful to see the project holistically, but I'm afraid that it would create a lot of challenges. BIM is a tool and models aren't all inclusive and 100% accurate and complete as noted in my earlier responses. Going to a BIM review would make a false expectation that they are. This leads in to the issue about what is or isn't required in a BIM model review submission and how the model is created and represented. Cities could start to try and dictate work flow and project process to get a BIM model a particular way to make their review easier.
A building inspector would have to minded in order to navigate the model.
It could contain incomplete information
Standard architectural details would need to be created in 3d resulting in more time and higher costs for the architectural firm. Computer compatibility issues. Many firms (especially small ones) do not keep current with available BIM software. Different cities may require different BIM versions. Cost for architect could be significant.
Each design office has their own set of graphic & modeling standards which can vary on a wide range. Also there are various BIM softwares in use. Which modeling information is required and how the model is set up etc. would need to be clarified by the plan reviewer. A comprehensive BIM standards & requirements would need to be developed and issued by the building plan reviewers.
Would cause designers to work in BIM.

Same as above. The plans examiner mostly. Confirms that that building meets all the many codes. My opinion would be that it would slow the review process down raising plan review fees for the owner, and delay the start of construction which cost $$$. I know now the computers that many plans examiners use at there desks would not be able to support Revit. The processing speed is slow with Revit and I know I could easily find what I am looking for fast in a PDF or printed set of plans.
Not only do the building officials need to understand the documents on paper / PDF but also the laborers.

Q11. Do you feel that the BIM models could be used for plan review IN PLACE of 2D plans? YES/NO What advantages would this create?
Fewer misunderstandings. Faster review process.
See response to Q6.
I suppose it would help with understanding model quickly, it would allow for more efficient communication with model, if they reviewer would be willing to communicate directly with the firm, annotate in the model, it would help with the ability to search for questions, by being in the computer, and being a searchable model.
allows you to manipulate three dimensionally
Yes, it would help clarify unique situations.
Save paper = save cost in printing. So would a PDF.
Not sure.

Q12. Do you feel that the BIM models could be used for plan review IN PLACE of 2D plans? YES/NO What challenges would this create?
Expectations by the Building Inspector to see the project develop accordingly, and the Contractors not utilizing the Modelling during the build process.
See response to Q6.

I see more problems than advantages. BIM is a tool and now we are putting the tool we use in the reviewer's hands as part of their review. It may be helpful to see the project holistically, but I'm afraid that it would create a lot of challenges. BIM is a tool and models aren't all inclusive and 100% accurate and complete as noted in my earlier responses. Going to a BIM review would make a false expectation that they are. This leads in to the issue about what is or isn't required in a BIM model review submission and how the model is created and represented. Cities could start to try and dictate work flow and project process to get a BIM model a particular way to make their review easier.
Would need to do both, even with increased in the technical knowledge, they will still have paper plans, they will have to have equipment and knowledge to manipulate digital plans, it will take two different methods of knowledge for the plan review, both technological knowledge and paper knowledge.
It could contain incomplete information
Would cause designers to work in BIM.
Same as above.
Full construction team needs to be using the same files...

Q14. Please use the type of model you described in Question 5 as reference. How could using BIM affect the turnaround time for the plan review?
Could be faster with an experienced Plan Review Official.
Unless existing obstacles to efficient use of BIM by plan reviewers are resolved, turnaround time will only become longer as reviewers wrestle with extracting the info they need from a plethora of non-standardized models.
I think it would complicate the process.
To eliminate the need to deliver and return plan sets, eliminates the need of the city or regulating authority to have to submit plans to, facilities communication,
I have no idea, you would have to talk to the city for that.
Initially it would probably slow things down. After an adjustment/training period there would probably be little difference.
If software or plugins could check the model for code violations, energy, etc. and the code official then reviewed the list of results to rule out any errors it would increase the turnaround time significantly.

It could make it faster. However, I think it would create more comments, since more information would be shown.
Slower.

Q16. How many years have you been licensed?
43
10
0
0
38
1
5
3
1

Q17. How many years have you used BIM?
7
12
8
5
We use about 20% of the time but we don't use to create BIM
9
8
10
3

Q18.Approximately how many architects are in your firm?
1

20
14
1
3
2
20
7
12

Q19. What other comments do you have regarding BIM for plan review?
The time will come in the not too distant future.
Our firm is primarily residential, comments might make more sense, commercial in a limited basis
I think it will eventually become the norm and things will become more and more automated by computer analysis. It will take time to establish and maintain digital submission standards.
How would we submit? Files are massive and what about all the links? I'm sure that this has potential to be something of the future, but with all the plans examiners I know with all the cities I have worked with, they would struggle greatly as most have zero drafting and BIM experience.