Evaluation of Current Construction Permitting Process in City of Toronto and Future of Permitting in the Global Construction Industry

by

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A thesis submitted in conformity with the requirements for the degree of Master of Applied Science
Department of Civil Engineering
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Abstract

In this research, an evaluation of the construction permitting process for tall buildings in City of Toronto over the last decade was conducted, including gathering of a detailed database on the approval process of 174 tall residential buildings. This investigation identified e-permitting and automated code compliance checking as viable solutions to address many of the existing challenges with the current permitting process at City of Toronto. These recommendations were then investigated from a global perspective which resulted in development of a framework for automated model-based e-permitting system. This framework takes advantage of the recent technological advancements in the industry, including using BIM for automated code compliance checking and integrating BIM and GIS information for smart urban management applications. The three-level e-permitting framework is envisioned as a road map for advancing from traditional paper-based permitting practices to fully integrated city planning capabilities required to support the future of our built infrastructure.
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Chapter 1. Introduction

Growing populations in major developed cities around the world, despite their social and economic benefits, have triggered several interesting challenges for their respective government agencies and municipal jurisdictions, including the need for the sustainable physical growth of their infrastructure. The federal government of Canada estimates that the population of Greater Toronto Area (GTA) will increase by 2.9 million (or 42%) to reach 9.6 million people in 2041 (Ontario Ministry of Finance, 2017), which translates to an average of over 120,000 new residents every year. The municipalities in GTA are facing pressure to maintain a healthy supply of new housing units to balance the substantial increase in housing demand, which has already contributed to a mounting housing affordability problem in the region.

In addition to responding to the demands for new housing supply, the government agencies in most developed countries, including Canada, have been improving and extending their regulatory requirements for obtaining new construction permits, as part of their commitment to achieving more sustainable built infrastructure. The increased number of proposals for new housing units coupled with the increasing number and complexity of permitting requirements have put tremendous pressure on the manual, labour-intensive, and sometimes inefficient permitting processes at municipalities. These challenges have contributed to significant delays in obtaining a construction permit for a new housing project, particularly in dense urban areas, thus delaying the supply of the much-needed new housing units.

In response to these challenges, and over the last decade, government agencies and the architecture, engineering, and construction (AEC) industry around the globe have focused on finding solutions for expediting and streamlining the manual and labour-intensive construction permitting processes. These efforts have generally included replacing the paper-based permitting system, with a centralized document management platform, often with a built-in workflow engine in the background (Fiatech, 2008). There have also been several attempts for automating some of the code compliance checking that needs to be performed as part of the permitting process (Solihin & Eastman, 2015).

In this research, a detailed evaluation of the construction permitting process for tall buildings, as an example of a complex permitting process, in City of Toronto was conducted. The
performance of the current permitting system over the last decade was analyzed and recommendations were provided to address several existing challenges. These recommendations included the use of e-permitting and automated code compliance checking to expedite the permitting and review processes. The second phase of this research provided a review of the existing e-permitting and code-compliance checking methodologies and implementations in several international jurisdictions. A framework was then developed to address the gaps of the existing systems by offering a more advanced, automated, and model-based e-permitting system, that is better aligned with the technological advances that are being implemented within the AEC industry.

1.1 Objectives

This research was motivated by the lack of existing academic literature on the performance of current construction permitting processes in the City of Toronto and the need for aligning the permitting processes with the technological advances that are being implemented in the architecture, engineering, and construction (AEC) industry. Two main objectives were identified for this research:

1. To evaluate and model the construction permitting process in City of Toronto and to identify the challenges with the existing permitting practices

2. To develop a framework for construction permitting processes that would be able to take full advantage of the available technological advances in the AEC industry to overcome many of the challenges with the existing permitting systems

The investigation of these objectives resulted in two papers, each addressing one of the above main objectives.

1.2 Industry Partners

This research was funded by a Collaborative Research and Development grant through National Science and Engineering Research Council of Canada (NSERC) and the Residential Construction Council of Ontario (RESCON). RESCON represents most of the large residential builders and developers in Ontario, and its membership is responsible for the construction of
over 80% of all new housing units in the Greater Toronto Area (GTA) over the last three decades.

RESCON membership was very supportive of this project and provided guidance, support, and their experience and insights towards the first phase of this research, which focused on evaluating City of Toronto’s permitting system for tall residential towers. While the data used in this research were taken exclusively from open-access data sources of the City of Toronto and the Ontario Municipal Board, the experience of our industry partners were very helpful in understanding the existing permitting processes and some of the challenges of the local construction industry.

The recommendations of the first phase of this research included the investigation of e-permitting systems, which was thoroughly conducted in the subsequent phase of this research. One of the mandates of RESCON is to promote innovation in the Ontario construction industry and to remove the barriers for the implementation of these innovations. The framework for an automated model-based e-permitting system, presented in Chapter 3, is an example of such innovation and therefore RESCON’s involvement in this research is expected to help expedite the implementation of the recommendations made in this research.

1.3 Thesis Structure

This is a publication-based MASc thesis, consisting of two papers, and has been structured accordingly. In Chapter 1, the background, motivations, and the two main objectives of this research are presented. Each objective of this research has been addressed in a separate publication, which are included in Chapters 2 and 3 of this thesis.

In Chapter 2, Evaluation of Tall Building Construction Permitting Process in Toronto is presented which tackles the first objective of this research. This conference paper was published and presented in CSCE Annual Conference 2017 in Vancouver. In this paper, an evaluation of the permitting process for the construction of new tall buildings in City of Toronto, as an example of a complex permitting process, was presented. This research included gathering a database of 162 towers in the City of Toronto, including data related to their permitting timeline. Based on the analysis of this database, several challenges within the current system were identified, which included inconsistencies between governing agencies, lack of freedom of the
prescriptive design guidelines, and issues specific to the efficiency and accuracy of the permitting process itself. This paper also provided several recommendations, which included using e-permitting practices, encouraging and supporting innovation, and providing better visibility on the decision-making process to the public.

The recommendations of the first paper informed the second phase of this research, which resulted in a journal paper entitled A Framework for Automated Model-based e-permitting System for Municipal Jurisdictions, which is presented in Chapter 3 and was submitted to the Elsevier’s Journal of Automation in Construction on November 26th, 2017. In this paper, the development and implementation of e-permitting systems in specific jurisdictions around the world were investigated and a framework was presented for an advanced, automated, and model-based e-permitting system. This e-permitting framework is better aligned with the technological advances that are being implemented within the AEC industry. The model-based approach of this framework was also shown to facilitate the integration of Building Information Models (BIM) with Geographic Information Systems (GIS), and thus allowing a building project to be evaluated in its urban context. It further enabled several smart urban management applications, including integrated planning review, integrated construction logistics planning, and urban asset management capabilities, which are all discussed in Chapter 3. Finally, several barriers to implementation of this framework and recommendations to address some of these barriers were provided.

The findings and conclusions of each phase of this research are clearly presented in Chapters 2 and Chapter 3, corresponding to the first and second objectives of this research. Chapter 4 provides a brief summary of the overall conclusions and recommendations of this research.

1.4 Research Methodology

In this research, the acts, rules, regulations, plans and guidelines, together referred to as regulations from this point onwards, that directly affect the construction of tall buildings in City of Toronto were investigated. These regulations include those imposed by municipal and provincial governments and regulating bodies. Specific regulations for the downtown core of the City of Toronto were also included. Figure 1 provides a timeline indicating the year each regulation was implemented as well as the jurisdictions that they affect.
The increasing number of regulations affecting the construction of tall buildings in City of Toronto has led to delays in construction permitting processes. At the time this research was conducted, there was no publicly available database on the performance of permitting processes in Toronto. Therefore, as part of the first phase of this research, a database of 174 tall buildings in Toronto was collected, which included information regarding the rezoning processes of these towers. This dataset was originally based on the information about Toronto’s tall building inventory from the Council for Tall Buildings and Urban Habitat (CTBUH), and was complemented with information extracted from City staff reports, City Council meeting minutes, and Ontario Municipal Board (OMB) decision reports. A copy of the data is included in Appendix A and will be made available to other researchers on request.

The City of Toronto specifies a nine-month review process for Official plan and zoning by-law amendments. If the City fails to make a decision in this nine-month period, or if the proposal is...
rejected at the City, the developers would be able to appeal to the Ontario Municipal Board (OMB). OMB was founded in 1906 for the purpose of supervising the rail transportation system and financial affairs of municipalities in Ontario. In 2005, and after the enactment of the Planning and Conservation Land Statute Law Amendment Act (Bill 51, 2005), OMB became a provincial planning authority, responsible for appeals to official plan amendments, zoning bylaw amendments, plan subdivisions, and minor variances.

Every tall building in Toronto has been approved by either City Council or OMB. The authority that approved each of the 174 tall buildings studied in this research was identified, and in most cases, the reasons for appeal to OMB were also recorded. The results and detailed analysis of the database collected in this research is presented in Chapter 2.

For the second phase of this research, the construction permitting process in several international jurisdictions was investigated and the successful implementation of electronic permitting (e-permitting) practices in specific locations around the globe were identified. Based on these international developments, a three-level framework for an advanced integrated model-based e-permitting system was developed. Building Information Model (BIM) was identified as an essential component of the developed framework, and therefore successful BIM implementations in different Asian, European, and North American countries were studied. Based on the success of these countries, several recommendations were made for the effective implementations of BIM practices and the developed e-permitting framework for Canadian jurisdictions, including the City of Toronto. The results of these investigations are presented in Chapter 3.

1.5 Research Limitations

The process of gathering information for building the database for the first phase of this research had several limitations. The initial dataset, upon which our database was created, consisted of towers that were built between 2006-2016 and those under construction in 2016, for a total of 320 towers. There was no information on the tower proposals that were rejected and never built. Another missing category were the projects that were approved for rezoning, either at City Council or OMB, but did not receive the remaining permits or were not built for other reasons. The analysis presented in Chapter 2 of this thesis would have provided a more thorough and complete analysis if the information for the rejected towers or those approved and not built were available.
The database on the original 320 towers was populated from information extracted from City staff reports, City Council minutes, and OMB decision reports. However, a large number of these towers had missing information on one or more key aspects of their permitting process, and therefore the dataset was reduced to only 174 towers with complete information. The lack of access to a complete dataset for towers built, proposed, or rejected in city of Toronto was a major limitation of this research, however, the database with complete information on 174 towers resulted in several key findings, as summarized in Chapter 2.

In the second phase of this research, a review of e-permitting systems and successful BIM implementations around the world was conducted. This review was limited to the leading global jurisdictions and does not provide an exhaustive review of all e-permitting system or BIM implementations, due to resource limitations of this project. A further limitation of this research was due to proprietary nature of many e-permitting platforms, thus complicating the access to unbiased and objective performance criteria for these systems. Therefore, the claims made by various e-permitting system providers need to be further verified with jurisdictions in which they are implemented.
Chapter 2. Evaluation of Tall Building Construction Permitting Process in Toronto

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2.1 Abstract

The City of Toronto is one of the fastest growing municipalities in North America, attracting many developers to invest in its physical growth. As the major employment centre and surrounded by the contiguous cities that comprise the Greater Toronto area, downtown Toronto has no option to grow except upwards in the form of mixed-use tall buildings. The rapid increase in construction of tall buildings all over the city raises concerns among city planners, architects, engineers, and citizens about the way in which the city grows. To prevent undesirable or incompatible developments in the city, there have been numerous policies and regulations imposed. These, coupled with complex processing practices, have resulted in significant and increasing delays in the processing of new applications for the construction of tall buildings. These delays have slowed the supply of new units to the market and resulted in enormous opportunity costs for the City. In this research, detailed information for 174 towers in the City of Toronto are collected and their permitting process evaluated. A number of challenges with the current system are identified and recommendations for improvement are provided. Finally, a Bayesian Network is developed to assess the probability of a new building proposal being rejected at the City Council and having to appeal to Ontario Municipal Board for approval, based on a number of proposal characteristics.

2.2 Introduction

With growing populations in major cities around the globe, municipalities are implementing new policies to avoid urban dispersion and sprawl. Intensification and gentrification in the form of
Mixed-use tall buildings is the new trend in community transformations all over the world (Rosen & Walks, 2015; Scott, 2013). Mixed-use tall buildings in dense urban centers are transit-oriented, providing a promising solution for sustainable development of major urban cores. Compared to the same number of households living in lower density neighbourhoods, high-rise living provides a larger number of households with access to public transit while reducing the cost of municipal services.

City of Toronto is the largest urban centre in Canada, and the fourth largest urban area in North America (Toronto Foundation, 2016). Toronto houses 8% of Canada’s total population, while 18% of all Canadians live in the Greater Toronto Area (City of Toronto, 2012). The rate of population growth in the city is on the rise and therefore the demand for housing has consistently increased over the last decade. This has resulted in a very competitive housing market, which has in turn dramatically decreased the affordability of housing across the city (Toronto Real Estate Board (TREB), 2016). Unique geographic features have further reduced the lands available for new development (Saiz, 2010). Although most of the city is covered with low-rise and single-family dwelling units (Toronto City Planning, 2015), the densification developments that are needed to accommodate the physical growth of the city face numerous challenges.

This research investigates the challenges that exist at the municipal and provincial levels for issuing building permits, specifically for residential towers within the City of Toronto. For the purposes of this research, a tall building is defined as a building with more than 12 stories, based on definitions offered by Tall Building Design Guidelines (City of Toronto, 2013). In this paper, a summary of the existing permitting process in the City of Toronto is provided, followed by some of the challenges that exist and recommendations to address these challenges. To provide an objective evaluation of the current permitting process, a database was developed and populated with data on 174 residential towers in Toronto. The data include the number of floors, number of units, overall height of each building, submission date for the Official Plan and Zoning Bylaw amendment application, rezoning approval authority (Ontario Municipal Board (OMB) or City Council), the reason for the appeal to OMB (where applicable), the OMB decision date, and, the approval date for the Official Plan and Zoning Bylaw amendment. The name of the developer, architect, the start and completion dates of construction (where applicable), and energy performance category were also collected, but not used in the analysis reported. This paper also presents preliminary results of a Bayesian Network model that was
developed to assess the probability that a building permit application would be rejected at the City Council and therefore need to appeal to the Ontario Municipal Board.

2.3 Permitting Process in City of Toronto

Obtaining necessary permits to construct a residential building in Ontario, and particularly within the limits of the City of Toronto, is a complex undertaking as there are numerous regulations that affect the permitting process. This section provides a brief overview of the permitting process for a building in City of Toronto.

As Figure 2 illustrates, upon the completion of drawings and application forms, the application is reviewed for compliance with the Ontario Municipal Code, Zoning Bylaws, and all other applicable laws. The review of the Zoning Bylaw is one of the challenging aspects of the process, as the Zoning Bylaw map is not updated regularly. Therefore, most of the new proposals are not in compliance with the existing Official Plan and Zoning Bylaws. In these cases, an application for Official Plan and/or Zoning Bylaw amendment needs to be submitted for approval by City Council. A number of other applications including “plan of subdivision”, “site plan control” and “part lot control exemption”, also known as STAR applications, may be required.

For reviewing the Rezoning applications, a pre-consultation with city planners at one of the four civic centres is strongly advised. After the pre-consultation session, a complete Official Plan and/or Zoning Bylaw amendment application is submitted to the building division. The new proposal is then concurrently circulated to the applicable city departments, to some external agencies, such as school boards and energy providers, as well as the community council to get their feedback. The feedback is returned to the developer, who must then address all of the comments in their design. The application is revised, resubmitted, and re-evaluated at the City. A public meeting is also held at community council before the City Council will make a decision about the proposal.
Figure 2: Steps for reviewing new proposals in City of Toronto
To move forward, each proposal has to get final approval from City Council. The City has nine months to review the applications and provide the applicant with its decision. If the City refuses the application or does not provide a decision within that time frame, the applicant has the right to appeal to the Ontario Municipal Board (OMB) and seek the rezoning approval from this tribunal. The OMB was created in 1906 for the purpose of supervising the rail transportation system and financial affairs of municipalities in Ontario, and in 2005 after the enactment of the Planning and Conservation Land Statute Law Amendment Act (Bill 51 2005), became a provincial planning authority.

The above procedure has a number of challenges, produces conflict, and results in extended delays in the permitting process. The following section highlights some of these challenges and offers recommendations to improve the current practices.

2.4 Challenges with Current System

The data collected for the 174 towers in the City of Toronto clearly show that the time it takes for applications to receive their Official Plan and/or Zoning Bylaw Amendment approvals has increased substantially over the last decade. Figure 3 shows that the average rezoning approval was less than a year in 2006 but it has gone up to more than three years in 2016. There are a number of factors that have contributed to this tremendous increase in the average approval time, some of which include inconsistent evaluation of proposals at City Council, prescriptive regulations at both the provincial and municipal levels, and inefficiencies in the current processes.

![Figure 3: Average Rezoning Duration for Tall Buildings in City of Toronto](image)
2.4.1 City Council versus Ontario Municipal Board

OMB has long been criticized for overturning the City’s decisions and allowing uncontrolled growth within the City (Matlow, 2016). The data confirms that the number of successful appeals to OMB is on the rise. As shown in Figure 4, in 2013 only 20% of all successful proposals came from OMB, but in 2016, 70% of all proposals approved in that year came from OMB and only 30% were approved at City Council.

The City, however, published a report in September 2016 that indicated 83 percent of new residential developments are proposed in areas targeted for growth by Toronto’s Official Plan (City of Toronto, 2016a). This means that even though 70% of the successful tall building permits had to appeal to OMB to receive their permit, 83% of all permits were, in fact, consistent with City’s Official Plan.

![Figure 4: Percent of approvals that came from OMB by year](image)

Further evaluation of the reasons for the appeal of each case to OMB showed that 42% of the towers that successfully appealed to OMB indicated that the “failure of the City to announce a decision” was their reason to appeal. Although the City has nine months to respond with rezoning decisions, Figure 3 illustrates that the average rezoning application in 2016 took more than three years. Therefore, a large number of applications would go to OMB, just because the City was not able to respond to their application in time. However, this causes a number of challenges for both the City and the province. First, the City loses its influence to control what
will and will not be built. The OMB, which is a provincial entity, needs to step-in and make decisions that the City and its residents would have to live with. This also creates a number of challenges for the developers. The applications that get approved at City Council from 2006 to 2016 take on average just less than two years (1.85 yrs.) and those that get approved at OMB take approximately 2.5 years (Figure 5). So, by forcing more applications to go to OMB, the average duration of rezoning applications increases. This observation is consistent with the trend shown in Figure 4, where, as the number of OMB applications have gone up in 2016, so did the average duration of the rezoning applications.

![Figure 5: Average Rezoning Duration at City Council vs. OMB from 2006 to 2016](image)

Figure 6 summarizes the breakdown of rezoning application durations for both OMB and City Council between 2006 and 2016. Figure 6(a) shows that only 16% of all applications were able to get approved in less than one year, even though the goal of the City Council is to make a decision on all applications within nine months. It also shows that 35% of all applications take more two years. The breakdown in Figure 6(b) shows that more than 44% of all applications that go to OMB take more than two years, which is a contributing factor to the total average of rezoning applications having a much longer duration.
2.4.2 Prescriptive Regulations at the Provincial and Municipal Levels

To obtain a building permit for a tall building in City of Toronto, the proposed application needs to be in compliance with all Acts, Bylaws and regulations at provincial and municipal levels. Figure 7 illustrates a very limited number of the regulations that directly affect the permitting process and construction of tall buildings at provincial, regional (GTHA: Greater Toronto and Hamilton Area) and municipal levels. The total list of regulations would not be feasible to list in this paper, but each of the Acts listed have a number of regulations within them and many of the regulations have subsections that apply to tall building construction.

Figure 7: Sample of Acts and Regulations for Tall Building Construction

In addition to Acts, regulations and building Codes, the city has many standards and guidelines that need to be considered in designing new projects. The City has provided comprehensive...
policies and regulations over the years to guide the developers to accommodate the design requirements in their applications. For example, in 2006 “Design Criteria for the review of tall building proposals” was adopted by City Council, which was later replaced in 2012 by “Downtown Tall buildings vision and Performance Standards design guidelines” for evaluation of tall buildings within downtown boundaries (City of Toronto, 2017). Tall building design guidelines (TBDG), which was adopted in 2013, is the latest documentation of all regulations for tall buildings across the entire city. TBDG is a well-organized and informative document that provides all the necessary design requirements by City of Toronto. The initial purpose of preparing this document was to identify the approved location and height ranges for tall buildings as well as to provide building typology studies (City of Toronto, 2017). TBDG, however, along with implementing Toronto Official Plan policies for tall buildings, incorporated many more of the City guidelines, including Toronto Green Standards (TGS), Toronto Development Guide, Development Infrastructure Policy and Standards, Accessibility Design guidelines, Urban Design Streetscape Manual, Vibrant Streets, Green Roof Standards, becoming a comprehensive guide on the design of tall buildings for Toronto.

It has been criticized that the prescriptive design restrictions imposed by TBDG and other similar mechanisms stifle the creativity of architects in designing more attractive towers in the city (McPherson, 2016). With continuous changes in new technologies and building materials, and the increasing demands of the new generation of condo buyers, it is imperative that the design practices be flexible enough to not only encourage but also empower innovative design solutions and construction practices. Tall buildings are most desirable in vibrant uptown and downtown areas that are close to public transit stations and provide a better access to employment and entertainment areas. However, land is limited for new developments and each site has unique characteristics that affect the design of a tower. With these limitations, it is often difficult or counter-productive to incorporate all of the guidelines.

With the tremendous housing market that exists for tall residential buildings in Ontario, and specifically in Toronto, and with the fast pace of technological advances in the industry, the current prescriptive design methodologies are not keeping pace. There needs to be alternative solutions that provide options outside of the current system, such as performance-based design guidelines. Performance-based guidelines allow designers and builders to implement innovative
design solutions and achieve or exceed the minimum guidelines, while having the opportunity to explore the state of the art technological tools and building material advances.

2.4.3 Processing Inefficiencies

After the submission of an application, it is circulated through a large number of city divisions, such as transportation and fire services. It is also shared with external agencies such as school boards, and utility providers for feedback, which is also returned to the applicant for further revisions in the proposal. Unfortunately, feedback is often inconsistent between departments and sometimes provides contradictory recommendations (McPherson, 2016). Trying to satisfy all the divisions and agencies, while incorporating all the policies and guidelines is not easily achievable by designers and developers. Any contradiction with these policies may result in rejection of the proposal. This is one of the contributing causes for the increase in the percentage of applications that appeal to OMB. As the alternative authority for approving Zoning Amendment applications, OMB does not treat the guidelines the same way it treats laws and policies. Therefore, the developers have more flexibility in satisfying the board members with their design. However, it is still ideal for developers to get their approval during negotiations with the City as it reduces the total process duration.

An alternative approach would be to take advantage of automation in evaluating designs against established codes, regulations, and standards. Currently, many of the sophisticated owners, such as government agencies, require that all the design components reside in a Building Information Model (BIM) and therefore many builders have started using BIM in their design phase, even for residential towers that do not necessarily require it. The move to BIM implementation would allow for e-permitting applications to replace the current complex and time consuming manual review processes. E-permitting is currently being investigated around the world as a more efficient design review mechanism with reported success (Ho & Rajabifard, 2016). Using automated systems, such as e-permitting, would allow faster and more reliable design review and permitting processes, which would also be more transparent, more reliable, and certainly more efficient. Of course, there will be a cost associated with the implementation of such a system, but as explained in the next section, the opportunity cost that is being imposed on the City with the current system is far greater.
2.4.4 Opportunity Cost of the Current Inefficiencies

The process for rezoning delays the permitting process, which in turn increases housing prices by adding extra costs (Paciorek, 2013). This is true of any delay in the permitting process, including those associated with site plan approval, and any other approvals that are required before construction can begin. Any kind of regulation that delays housing construction adds tens of thousands of dollars to the cost of building a single unit (Paciorek, 2013). However, the true costs may be far greater than those directly associated with the construction process, as explained in this section.

There are a number of reasons why the City should be interested to resolve the issues resulting in long permitting durations. First, the demand for housing in Toronto has continually outpaced supply in recent years, with prices of homes rising between 15-20% annually (Toronto Real Estate Board (TREB), 2016). This, coupled with increased immigration into the region, has resulted in a significant shortage of housing units, which in turn has fueled the escalation of the housing market. The demand experienced in the housing market and the lack of supply has eroded housing affordability within the City. Therefore, streamlining the permitting process would, in turn, result in more available units earlier in the market and help with the current shortage of housing units in the region.

Secondly, there is a tremendous tax revenue opportunity that is currently being lost due to the delays in construction of high-density buildings. Take for example a typical 50-storey building with 500 units. The average unit is worth $471,256 (Tencer, 2016) and it generates approximately $3,242.11 in property tax for the City (City of Toronto, 2016b). That is $1.621 million in lost property tax revenues for the City just for one-year delay. Therefore, by delaying a project for three years due to the permitting process, the lost income opportunity per tower would be about five million dollars. Compounding this impact over the large number of towers that are delayed at any point in time, one can see the tremendous opportunity cost to the City. Therefore, implementing an e-permitting system that would streamline the permitting process for the entire city would result in significant added revenues for the city.
2.5 Modelling the Permitting Process using Bayesian Network

This research has shown that on average the duration of the permitting process for a new tall building would be increased substantially if the application was sent on appeal to the Ontario Municipal Board. Therefore, it would be beneficial if a system could be developed to determine, with some certainty, the likelihood of a proposal being rejected by City Council. As discussed, there are many factors that contribute to this event and no single factor can be identified as a deciding factor. Bayesian networks have been used extensively to model the relationships in complex systems for forecasting and diagnosis applications (McCabe, AbouRizk, & Goebel, 1998). Therefore, a Bayesian network was developed with the aim to model the variables in the permitting process to give an indication if a new tall building proposal would need to be appealed to OMB. Once fully developed and validated, this model could be used to run what-if analysis to decide what combination of factors could be modified to reduce the probability of the proposal being rejected at the City Council, based on historical statistical data.

This model could also be used by the authorities to evaluate their current practices and to streamline the processes both at City Council and at OMB, so that the projects that have a high chance of getting approved at OMB, be given more careful consideration at City Council. The e-permitting process would eliminate the need for a network like this, as the decision and recommendations could be readily available through an online application, shortly after submission of all plans and drawings through a BIM-enabled platform. In the meantime, however, this Bayesian network could prove useful. The details of the model development are beyond the scope of this paper, but some of the considerations in the development of the model, as well as some of its validation results, are presented next.

2.5.1 Model Development

A total of 120 tall buildings from the 174 towers in the original dataset were used for the analysis. Figure 8 shows the network. The connections between the nodes are based on the applicable Acts and regulations that affect the permitting process for a tall building application. Figure 8 illustrates the Bayesian network which was developed; the node “appeal to the OMB” represents the outcome of the model in which the city refuses a proposal or does not provide the applicant with the decision and the applicant would, therefore, appeal to the Ontario Municipal
Board. The other nodes in this model represent the causes that each application may get the refusal by reviewers. The following paragraphs explain key variables in the network.

Conflict with Official Plan: This node captures the impact that a noncompliance with OP (Official Plan) has in forcing the developers to seek approval from OMB, due to the refusal by City Council. This node has two states: Conflicts and Complies (with Official Plan). To calculate the probability of this node, the database that was previously collected on tall buildings in City of Toronto were used. Of the 120 buildings, 62 had conflicts with OP. Therefore, the base probabilities at the node were calculated as 62/120=0.5166 for “Conflicts” and 58/120=0.4834 for “Complies”.

Secondary Plan Exists: For some of the areas in the City, a secondary plan was defined, which includes additional regulations and definitions that further limit new developments in those areas. According to the database, 43 of the 120 buildings were proposed in a location where a secondary plan existed. Therefore, the base probability of Secondary plan existing was calculated as 43/120=0.3583 and for no secondary plan, the base probability is 1 – 0.3583 = 0.6417.

![Bayesian Network for Appeal to OMB](image)

**Figure 8: Bayesian Network for Appeal to OMB**
Conflict with TBDG: Tall building design guidelines (TBDG) have specified regulations for the design of tall buildings in the City of Toronto to implement the design objectives of the Official Plan. There are a number of factors that should be considered in analyzing whether a new development conflicts with Tall building design guidelines. In this network, four of the main factors were considered: Improper Transition, Improper Tower Separation, the building being Taller than Adjacent Buildings, and Floor Plate More than 750 m², which refers to the requirement that the footprints for buildings should be less than 750 square metres. Gathering specific data for the first three of these four nodes was not feasible, and therefore a nominal base probability of 50/50 was adopted, which can, of course, be modified in the future. However, sufficient information was available to calculate the probabilities for “Floor Plate more than 750 m²”, which resulted in a probability of 0.846 for the floor plate passing the limit, and consequently, a probability of 1-0.846 = 0.154 was assigned for a tall building having a smaller floor plate.

Since none of these four factors interacted with each other, the distribution of “Conflict with TBDG” was changed to a Causally Independent distribution and the probabilities were calculated based on data and expert opinion. The expert opinion components will be revisited in the future, but for now, the experience of the first author was used to estimate some of the probabilities where sufficiently varied data were not available.

2.5.2 Model Validation

The model was validated using a number of specific tall building proposals in the City of Toronto. This section includes a number of validation cases, followed by the limitations of the current model.

1. Grid Condos, located at 181 Dundas Street East, was approved by OMB. The input evidence for this building are: 1) it conflicts with Official Plan, 2) a secondary plan exists, and 3) the application for demolition of rental housing is needed.

- The OMB appeal probability calculated by the network is 0.5566, which is slightly above 0.5, indicating that the application was expected to be appealed to OMB.
2. Axiom Tower, which was approved by City Council, is located at 460 Adelaide Street East. Its input evidence are: 1) it conflicts with Official Plan, 2) a secondary plan exists, 3) its floor plate is greater than 750 square metres.

- The OMB appeal probability of Axiom Tower based on the evidence 0.5012. The reason the model predicted over 50% is that it had a floor plate greater than 750 square metres, which is typically a very strong indicator of non-compliance with tall building design guidelines, and often results in the project going to the OMB. However, in this case, the builder managed to get the proposal approved by City Council.

3. One Bloor Street East, which was approved by City Council: 1) conflicts with Official Plan, 2) complies with the Growth Plan, 3) has a compliant floor plate, and, 4) requires an application for demolition of rental housing.

- The OMB appeal probability of One Bloor Street East based on the Bayesian network is 0.367. The model performed very well in this particular case. One of the reasons is that there was sufficient input information available about the project, which is essential in calculating reliable probabilities.

These three cases provide support that the model is working, however, there are a number of limitations and concerns that need to be taken into account going forward.

2.5.3 Model Limitations

The main limitation of the Bayesian model is that the probabilities were estimated at several nodes since the 120 building database had considerable discrepancies. To populate a more reliable model, a much larger dataset is required. This could easily be facilitated if City data were more readily available. The underlying problem is the lack of transparency by the City Council and Ontario Municipal Board about the applications. The data used in this research should be available from each governing body, and accessible by the general public. Instead, there are numerous logistical, practical, and organizational barriers to accessing the databases. If the dataset, or at least the meta-data used in this research was provided by OMB and City Council for all building applications, it would allow for a better evaluation of the current system, which in turn would make it possible for improvements to be identified. Therefore, one of the
recommendations of this research is to expand the dataset to build a more reliable predictive model.

Another limitation is that all of the data were based on approved projects. In fact, there is no mechanism by which the data for rejected proposals at OMB could be accessed. Therefore, while the number of projects that were approved by OMB is already alarmingly high compared to the ones approved by the City Council, it should be noted that an even larger number of applications have unsuccessfully appealed to OMB. If that dataset was available, the model could have been built more reliably and the probabilities at a number of nodes could be calculated more accurately.

2.6 Conclusions and Recommendations

This paper presented an evaluation of the current permitting process for the construction of new tall buildings in the City of Toronto, with an emphasis on Official Plan and Zoning Bylaw amendment approvals. A database of 174 towers in the City of Toronto was gathered and their permitting process was evaluated based on the duration and the authority that provided the approvals. This research identified some of the challenges within the current system, which included inconsistencies between City Council and OMB, over-regulation and prescriptive design guidelines, and issues in processing practices. A number of recommendations were also made, including using e-permitting, implementing performance-based guidelines to encourage and support innovation, and providing better visibility on the decision making process to the public.

Finally, a Bayesian network was developed to estimate the probability of a proposal for construction of a new tall building in City of Toronto having to go to OMB for approval. This process allowed for the impact of a number of factors to be quantified and carefully analyzed. Most importantly, the resulting network performed well for three validation scenarios, and recommendations were provided to better improve the network by collecting more data and therefore increasing the confidence in the probabilities used at the nodes.
Chapter 3. A Framework for Automated Model-based e-permitting System for Municipal Jurisdictions

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3.1 Abstract

Recent technological advances in the architecture, engineering, and construction (AEC) industry, including the implementation of Building Information Modelling (BIM) and automated data capturing tools, have enabled the AEC industry to commence its digital journey in the era of big data. Despite these advancements, several processes within the AEC industry, starting with the permitting procedures for a new project, remain manual, labour intensive, and inefficient. With the increased demand for housing supplies in major cities and the objectives for sustainable development within these cities, municipalities and their limited resources have been under immense pressure. Over the last decade, e-permitting practices have been implemented in many countries, aimed at replacing the traditional paper-based systems. In this research, these recent efforts have been reviewed and a framework is presented for an advanced automated model-based e-permitting system that takes advantage of the latest technological advancements within the construction industry. The three-level e-permitting framework developed in this research is envisioned as a roadmap for advancing from traditional paper-based permitting practices to a fully integrated city planning tool. This framework aims at improving the permitting process through digital submission of BIM for e-permitting and automated code compliance checking of the building model. In addition, through the integration of BIM and GIS information, the highest level in the developed framework enables several smart urban management applications, including advanced city-level planning reviews, integrated logistics planning, and smart urban asset management. Finally, the barriers to implementation of this framework are discussed along with recommendations to address some of these barriers.

3.2 Introduction

Growing populations in major cities have increased the demand for the construction of new housing supply. Focused on achieving more sustainable built infrastructure, regulators are continually looking to improve and extend requirements for obtaining construction permits. These factors have placed a tremendous pressure on municipalities and their limited resources to
keep pace with the demands of their local construction industry. Analysis of the permitting process of 174 tall residential towers in the City of Toronto, Canada, showed that the average duration for a successful rezoning permit increased from less than a year in 2006 to over three years in 2016 (Shahi, McCabe, Shahi, Berardis, & Lyall, 2017). With over 100,000 new residents moving to the Greater Toronto Area (GTA) every year (Ontario Ministry of Finance, 2017), the growing timeline of obtaining construction and rezoning permits delay the supply of much needed new housing units (Shahi et al., 2017). The increased demand of housing coupled with the lack of supply of new units have also created significant volatilities in the housing market (Clayton & Amborski, 2017) and have contributed to a mounting affordability problem in North America’s fourth-largest city (Statistics Canada, 2015).

Obtaining permits and approvals for building construction in large urban cities is a complex undertaking, and often involves a wide range of regulatory agencies. These approvals range from official plan and zoning amendments to demolition, construction, and inspection permits. Traditionally, these processes included heavy paper trails, time consuming and manual review procedures, and a lack of transparency to the review and approval process.

Increased emphasis on improving productivity in the architecture, engineering, and construction (AEC) industry in recent years has drawn attention towards expediting and streamlining the manual and labour intensive permitting processes. Jurisdictions around the globe have adopted and implemented a range of strategies to improve their review processes for construction permits. These generally include the implementation of an information and document management system that aims at reducing or replacing the paper-based permitting system with digital submission of drawings. These have commonly been referred to as ‘e-permitting’ systems (Fiatech, 2008).

A recent technology with strong promise of revolutionizing the architecture, engineering and construction (AEC) industry is building information modelling (BIM) (Eastman, Teicholz, Sacks, & Liston, 2008). In addition to providing an accurate 3D representation of the building, and providing other dimensions of information such as schedule and cost for a project, BIM also captures semantic information such as material properties and relationships between elements within the model. The benefits of BIM have been extensively studied by many researchers in the
construction domain, which range from clash detection analysis and quantity take-offs to more advanced applications of using 4D, and 5D models (Azhar, 2011).

While the advantages of BIM are more widely exploited by architects in the design stage, there is tremendous potential in using BIM during the construction phase and perhaps most importantly during facility operation and management, highlighted by the emergence of market demands around model-based facility monitoring applications (Khan & Hornbæk, 2011). An annual BIM implementation survey reported a 300% increase in BIM implementation on projects in UK between 2011 and 2017, and a 30% increase since 2015, which clearly shows that BIM utilization is on the rise (NBS, 2017). Interestingly, 84% of the respondents in this survey believed that they need to be able to automatically check the compliance of a BIM with standards and 79% agreed that guidance provided in standards will need to link to building models in the near future (NBS, 2017).

This paper investigates the development and implementation of e-permitting systems in specific jurisdictions around the world and presents a three-level framework for an advanced, automated, and model-based e-permitting system, which will be better aligned with the technological advances that are being implemented within the AEC industry. Elements of this framework are presented in this paper, including building information model (BIM) submissions, automated model checking, and advanced planning review, along with the incremental developments that have been achieved in each element. Finally, the barriers to implementation of this framework and some of their potential solutions are discussed.

3.3 Traditional Permitting vs. Electronic Permitting (e-permitting) Systems

In a traditional building permit office, government agencies require applicants to submit paper copies of all drawings and specifications for rezoning, new building, engineering, inspection, and occupancy permits. Multiple copies are often needed so that different divisions, such as fire prevention and traffic control, can review the application simultaneously. Drawings that were revised to address previous comments and recommendations by numerous internal and external reviewers may be part of that package. However, most if not all the drawings submitted on paper for the application submission and review process are designed and prepared using computers and advanced software packages. The disadvantages of the traditional system extend beyond the
environmental costs of using tremendous amounts of paper to include storing and managing documents, difficulty in distributing documents, and manual and time-consuming reviewing procedures. Finally, the lack of co-ordination between internal and external parties that need to review the documents often results in inconsistent and contradictory review decisions (Shahi et al., 2017).

E-permitting systems comprise an online platform and document workplace that connects municipalities and other government agencies with AEC professionals to complete building permit submissions, reviews, and approval processes (Sing & Zhong, 2001). It provides a one-stop shop for permitting with reported success at municipal jurisdictions around the world (The World Bank, 2014).

Given its global success, e-permitting systems have been growing in popularity in recent years. While there are many variations, most existing systems are built on a centralized document management platform, often with a built-in workflow engine in the background. The goal is to connect all of the stakeholders, including agencies that need to approve the drawings and plans, in one platform and manage the electronic distribution and flow of documents within the system. Once the documents are digitally submitted, they would be routed to the appropriate agencies and stakeholders, allowing simultaneous review when appropriate, and enabling effective communication between the agencies and stakeholders. The improved communication between AEC professionals and governing agencies and the increased transparency in the review and approval process are important advantages that effective e-permitting platforms could provide. Specifically, the increased transparency can be achieved through dashboards and reports to the applicant regarding the status of their application and through meta-data reports to the industry and the public on performance metrics related to the review process itself.

In this research, a framework with 3 levels of e-permitting systems is developed and compared to the traditional permitting practices. These levels and their differentiating elements corresponding to the design, review, construction, and operation and maintenance phases of a project are illustrated in Figure 9. Level 0 refers to the traditional paper-based permitting process, with no automation and no electronic submission capabilities. Levels 1 to 3 indicate increasing levels of sophistication, automation, and integration into the e-permitting system, and can be used as a road-map for advancing from traditional paper-based permitting practices to a fully integrated e-
permitting system. The transition from Level 0 to Level 3 is not crisp, and the completion of one level is not required before an agency can move to the next level; nor must all aspects of one level be implemented.

![Figure 9: Framework for different levels of e-permitting](image)
3.3.1 Level 1: Basic e-permitting Systems

As shown in Figure 9, Level 1 represents basic e-permitting systems. At this level and without regard to how the drawings are produced in the design stage, they are submitted in a 2D digital format (Level 1.A), either by email or through a web interface. The key step is that paper is no longer needed for the application submission. This facilitates immediate, cost-effective, and systematic distribution of the documents to all agencies that need to review them, allowing the simultaneous review of drawings when appropriate.

During manual review of drawings by authorities (Level 1.B), some systems facilitate digital mark-up on the electronic documents, allowing reviewers to embed their questions or comments in the documents, making it easier to communicate their concerns to the applicant. Alternatively, the reviewers may prepare a report with their comments. Special workstations with very large or multiple display screens or smart boards to facilitate viewing of complex and detailed drawings can provide the reviewers with the tools to undertake a comprehensive analysis of the design and the degree to which it complies with the relevant codes and regulations.

Communication opportunities for stakeholders may be available, but may not be included in all Level 1 systems. For example, video conferencing, email correspondence, or webcams could be used by reviewers to discuss issues effectively and in a timely manner to reconcile conflicts or other issues.

The document management platform and a work-flow engine are unique characteristics of Level 1 e-permitting systems and allow for manual and paper-based reports to be digitally associated to the application, ensuring their timely retrieval when needed. For example, while the inspection permits are typically completed manually, reports can be integrated with the document management system in the software platform (Level 1.C). In this manner, the inspectors could upload their reports remotely, providing immediate verification of their findings.

Level 1 e-permitting systems are operated by government agencies and while they accept digital drawings, there are no outputs provided to the applicant that could benefit the operation and maintenance phase of a facility (Level 1.D). Therefore, they provide no added functionality to the traditional paper-based system. However, work flow algorithms could be put in place to support the analysis of how long each authority takes to review, comment, and respond to the
application. These statistics could be very useful in automating the identification of bottlenecks in the system.

In Level 1 e-permitting and upon the submission of building drawings to governing agencies, drawings are reviewed by engineers, designers, and staff for compliance with regulations and codes that are in place, including building codes. For the most part, this process is currently manual, error-prone, time-consuming, and resource-dependent. There are also concerns with the transparency and consistency of this review process (Solihin & Eastman, 2015). Unfortunately, the manual review checking of plans against various codes and guidelines by different departments at agencies often result in inconsistent recommendations, which are mostly due to the misinterpretation and different interpretation of rules and guidelines (Fiatech, 2013). Finally, there are concerns with the accuracy of the traditional review processes given the error-prone nature of manual checking procedures.

3.3.2 Level 2: Automated Model-based e-permitting Systems

Automated model-based (Level 2) e-permitting is built around a building information model (BIM), which is developed during the design phase and maintained throughout the project. In Level 2.A, a comprehensive BIM of the facility is submitted instead of discrete 2D drawings, which enables a wide range of applications as explained in this section.

Figure 10: Automated Code Compliance Checking (Level 2.B) inspired by (Eastman et al., 2009)
An alternative approach to manual reviews of 2D drawings is the use of automated code compliance checking technologies (Level 2.B). These technologies would not be bound by traditional time and resource constraints and could provide consistent, reliable, and transparent reviews. This approach provides the user with summary compliance reports and tools to expedite decision making by plan examiners. This functionality has been validated using automated code compliance checking against the International Building Code (IBC 2009) (Fiatech, 2012). Figure 10 illustrates the process and steps that are required in any automated code checking system.

The first step of automated code compliance checking is to represent and formulate building codes, standards and regulations, which are translated from natural language into a computable form. Advancements have been made in the automation of the extraction and transformation of rules directly from codes and regulatory documents. Different modeling techniques have been adopted by researchers to generate computer-executable rules from natural language regulations. These methods could be categorized into two main approaches:

1- Artificial intelligence (AI) methods that use natural language processing algorithms such as text analytics, content monetization, automatic classification of content, and text mining. These AI methods aim to enable computers to automatically derive meaning from the text and generate logical rules for checking purposes.

2- Mark-up language methods like extensible markup language (XML) to semi-automate the translation of codes which are available in hypertext markup language (HTML), portable document format (PDF) or hardcopy (Nawari & Alsaffar, 2015).

Regardless of the method, the goal of this first step is to translate the codes and regulations into a language that a computer-based platform could use. To implement any code compliance checking methodology, a digital, 3D representation of the building with adequate semantic information and level of detail is needed. BIM, with sufficient level of detail, easily satisfies this requirement (Solihin & Eastman, 2015). With the increase in the implementation of BIM in construction projects, automated compliance checking has become more practical than before.

The code compliance checking would need to be performed outside of any BIM specific platform, and Industry Foundation Classes (IFC) have long offered a promising means of domain-independent solutions for BIM applications. The current IFC standards are flexible and
allow for extraction of types, attributes, and relationships between objects that can be extracted from any BIM platform (Pauwels et al., 2011).

With the BIM extracted in IFC format and rules, regulations, and guidelines translated into a computable language, a reasoning tool or a software solution can efficiently conduct virtually all of the checks that need to be performed for a given building. This process can take place within an application attached to a design software, such as a BIM platform plug-in, as a stand-alone software for code compliance checking, or a web-based application (Eastman, Lee, Jeong, & Lee, 2009).

Government agencies and municipal jurisdictions around the world have started to implement code compliance checking in their systems, which have mostly focused on building code compliance. Table 1 summarizes the extent of automated code compliance checking and the jurisdictions for which they were originally developed.

Table 1: State of Automated Code Compliance Checking in International Jurisdictions

<table>
<thead>
<tr>
<th></th>
<th>Energy Code</th>
<th>Fire Code</th>
<th>Building Code</th>
<th>Initially Developed for</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORNAX</td>
<td>✓</td>
<td>Partial</td>
<td></td>
<td>Singapore</td>
</tr>
<tr>
<td>Solibri Model Checker</td>
<td>Partial</td>
<td>Partial</td>
<td></td>
<td>Finland</td>
</tr>
<tr>
<td>EDModelChecker</td>
<td></td>
<td>Partial</td>
<td></td>
<td>Norway</td>
</tr>
<tr>
<td>Design Check</td>
<td></td>
<td>Partial</td>
<td></td>
<td>Australia</td>
</tr>
<tr>
<td>ComCheck/ ResCheck</td>
<td>✓</td>
<td></td>
<td></td>
<td>United States</td>
</tr>
<tr>
<td>SMARTCodes</td>
<td></td>
<td>Partial</td>
<td></td>
<td>International</td>
</tr>
</tbody>
</table>

In 2002, Singapore started developing and implementing a code checking system called FORNAX as a part of their CORENET system (Lam, 2004). FORNAX consists of a library of objects that extend the building component information of the IFC models with additional information that is needed for code checking by the rule checking engine (Eastman et al., 2009). FORNAX checks proposed building plans for compliance with fire code specifications, including fire-escape routes, material use, ceiling heights, and fire rating. It also checks building services components such as ventilation, hydraulic, and fire protection systems. The system further allows for evaluation of digital drawings against prescription-based development plan guidelines and regulations, such as plot ratio and land use type.
Originally developed in Finland, Solibri model checker (SMC) offers automated code checking capabilities that can operate on IFC exports from BIM platforms (Preidel & Borrmann, 2015). SMC checks the model against fire code and building accessibility codes. Solibri is empowered by a rule manager, which allows the development of customizable rules and rulesets for model checking. This is not currently available in the FORNAX system.

EDModelChecker was developed in Norway and utilizes a commercial library of objects, similar to Fornax, but based on EXPRESS modelling language, which is an ISO certified open standards compatible with IFC schema (Eastman et al., 2009).

DesignCheck was developed by the Australian Cooperative Research Centre (CRC), and is capable of checking building plans for access and mobility in different stages from sketch design to detailed drawings (Ding, Drogemuller, Rosenman, & Marchant, 2006). SMARTCode was a project by the International Code Council in 2006 to check BIM for compliance with international, federal and state codes (Lee, Lee, Park, & Kim, 2016).

Automated code checking has not been limited to construction related codes and regulations. USA Department of Energy (DOE) has been supporting and maintaining the International Energy Conservation Code (IECC) energy codes (for minimum energy efficiency of design and construction) and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1 (energy standard for buildings except low-rise residential buildings). In recent years, they launched COMcheck for compliance checking new commercial or high-rise residential buildings against the energy requirements of IECC and ASHRAE standards, as well as some state-specific codes (U.S. Department of Energy, 2014). DOE also developed REScheck, which performs partial automated compliance checking for small residential projects against existing energy codes (Halverson, Shui, & Evans, 2009). Interestingly, DOE made these platforms available through their own website, thus encouraging users to evaluate their designs before they submit an application.

Even though a fully automated code compliance checking platform capable of analyzing a building model against all relevant building, fire, and energy codes simultaneously has not yet been developed, the progress of software companies and government agencies demonstrates the industry’s inclination for such a solution. Singapore and US governments’ approach in
developing and readily providing the solutions could be used as a successful model for offering such services in the future by government agencies around the world.

While the focus of this research and the developed framework are based on the e-permitting system itself, the consequences of implementing higher levels of e-permitting systems on the entire lifecycle of a project, starting from design to construction and operation and maintenance of a facility are also considered. For example, by implementing Level 2 e-permitting framework presented in this research, a reliable and updated BIM of the facility with sufficient level of detail is developed and updated during the design and review phase of a project. This model can then be used for automated inspection during the construction phase (Level 2.C) and as the basis for model-based building management during operation (Level 2.D), thereby leveraging the efforts in the development of BIM to benefit the entire lifecycle of a facility from design to operation and maintenance.

Automated inspection of construction sites is an optional component of the proposed framework (Level 2.C). In the context of this framework, automated inspection refers to the use of automatic and semi-automatic data capturing tools, such as photogrammetry and 3D laser scanners (Golparvar-Fard, Bohn, Teizer, Savarese, & Peña-Mora, 2011), captured using unmanned aerial vehicle (drones) (Hamledari, McCabe, Davari, Shahi, et al., 2017). Such technologies would provide automatic schedule updates and inspection reports directly in BIM (Hamledari, McCabe, Davari, & Shahi, 2017).

By transferring BIM to the operation and maintenance phase of a facility (Level 2.D), all the data captured during the design, review, and construction phases can be transferred to facility managers. This transferred knowledge may range from semantic information attached to equipment (manufacturer, parts information, etc.) to inspection reports submitted during construction, enabling more informed decision making during the operation and maintenance phase.

### 3.3.3 Level 3: Fully Integrated e-permitting Systems

The increase in BIM implementation in the construction industry and the advantages of automated data-driven analysis has already motivated several municipalities around the world to take advantage of automated code compliance checking (Level 2.B). However, these
technologies have also paved the way for new capabilities that were not previously feasible. A range of these new capabilities stems from the integration of BIM and geographic information systems (GIS), which captures geodetic coordinates, spatial information, and relationships between objects (Liu et al., 2017). In this research, fully integrated e-permitting systems, capable of integrating BIM with GIS, are classified as Level 3 e-permitting systems. A Level 3 e-permitting is presented as the future of permitting systems and is compatible with the requirements of intelligent building systems and smart cities in providing a meaningful digital connection between a facility with its urban context.

Used in the GIS platform, City Geography Markup Language (CityGML) is the comprehensive semantic standard for exchanging urban information. Despite having different modeling languages, IFC and CityGML share several similarities, as both are object-based and recognize infrastructure, buildings, and plans as components, which allows for their mapping and integration (Level 3.A). However, differences in application domains and user expertise complicate collaboration between these two platforms. In the latest version of IFC standards, IFC4, higher level of interoperability was considered to support the integration of IFC-based BIM and GIS information. The current versions of IFC and CityGML, however, are not yet sophisticated enough to capture the information of the entire built environment of urban and infrastructure projects (Liu et al., 2017).

Through the integration of BIM and Geographic Information Systems (GIS) in Level 3.A, municipalities could also provide a much more meaningful review of proposals. Examples include advanced city-level planning reviews (Level 3.B), integrated construction logistics planning considering all urban activities in the neighbourhood (Level 3.C), and smart urban asset management capacities across the entire asset portfolio of the municipality (Level 3.D). The integrated approach of the Level 3 e-permitting could also inform intelligent policy making and regulation drafting, which is essential in keeping up with the demands of future smart cities (Marsal-Llacuna & Segal, 2017).

In Level 3.B, instead of analyzing buildings as standalone entities, the integration of BIM and GIS information would allow buildings to be evaluated in the context of their urban settings and with consideration to their spatial relationship with other buildings, both during and after construction. Researchers have shown that adjacent buildings and their shading on a proposed
building would significantly impact its energy performance (Pisello, Taylor, Xu, & Cotana, 2012). Specifically, shading increases heating and lighting loads and decreases cooling loads, while reflection off other buildings could increase cooling energy requirements (Han, Taylor, & Pisello, 2017). It is also suggested to use BIM and GIS integration for analyzing view corridors, and other urban planning considerations to fully understand the impact that a new development might have (Rafiee, Dias, Fruijtier, & Scholten, 2014). Architectural acoustic analysis of the BIMs in their urban setting and with the help of traffic and noise mapping would allow for analysis of noise levels within a building, which affects the quality of life for building occupants.

Dealing with construction site logistics has long been a challenge for the construction industry, particularly in dense urban environments (Ali et al., 2016). For example, Toronto’s Tall Building Design Guidelines (TBDG) require that towers in the City of Toronto be built to the edge of their property line (City of Toronto, 2013), thus complicating site logistic planning including the optimized location of tower cranes, storage areas for construction material, and traffic management around the construction site. In Level 3.C, the integration of GIS information with BIM would allow traffic patterns to be considered in logistics planning, site optimization, and traffic management of construction sites. More importantly, a city-level planning review could be performed and site logistics activities for different construction sites in an area could be coordinated to minimize the overall disturbances to their neighbourhood. Finally, such integration could dramatically enhance the automatic tracking of materials and deliveries of critical items, which are currently being performed with a combination of barcode, RFID, UWB and GPS technologies (Ergen, Akinci, & Sacks, 2007; Razavi & Haas, 2010). The latter application is more applicable to pre-fabricated and pre-assembled construction strategies, taking advantage of lean construction practices and therefore requiring a more advanced level of logistics planning (Sacks, Koskela, Dave, & Owen, 2010).

Using BIM for automated building and facility management (Level 3.D) was identified as one of the advantages of investing in BIM from design through to review, construction, and operation and maintenance phases of a facility. In Level 3.D of the developed framework, the integration of BIM and GIS information allows the facility management capabilities of BIM to extend beyond a single facility and to encompass the entire asset portfolio of a municipality, thus providing a range of smart urban asset management functionalities. These applications could
range from energy sharing between buildings (Kayo, Hasan, & Siren, 2014) to emergency response systems and disaster relief efforts (Yamada, 1996).

### 3.4 Examples of e-permitting Implementation

Successful implementations of e-permitting practices include those in Singapore, USA, Finland, and Canada. Singapore, a city-state in Southeast Asia, is a pioneer in the development and implementation of e-permitting systems. In 1995, Singapore launched CORENET system (Construction and Real Estate Network) with the aim of allowing building project stakeholders to readily exchange information digitally (Sing & Zhong, 2001). In 2002, CORENET was equipped with e-submission capacity to accept 2D drawings for planning and engineering permits over the internet. By 2009, Singapore reduced the time for processing construction permits from 102 days to 38 days (CITYNETS, 2017). Their success led to continued improvements and innovations. In January 2010, CORENET moved to Level 2 e-permitting when it started accepting architectural BIM, followed by structural, mechanical, electrical, and plumbing models in 2011 (Building and Construction Authority, 2011b). Their processing time was further reduced to 25 days (CITYNETS, 2017). In 2015, BIM submission for all new construction projects in Singapore became mandatory. These changes in submission formats would not have been possible without Singapore’s phased-in mandate for BIM e-submission starting from July 2013. The government’s requirement for the construction industry to use BIM resulted in AEC-wide benefits by 2015 (Building and Construction Authority, 2013). Today, Singapore is leading the way in automated code checking.

The success of Singapore can be attributed in part to their city-state structure in which a centralized agency oversees the permitting process of the entire country of 5.6 million people. In contrast, Finland has approximately the same population as Singapore but comprises 311 municipalities (Official Statistics of Finland, 2017), some of which have fewer than 6,000 residents. Most of the municipalities have their own process to approve permits, which understandably complicates the implementation of a national system. Despite these complications, Finland introduced an e-permitting system in 2013, and by 2017 it had buy-in from 60% of Finnish municipalities (Evolta, 2017a). Part of the success of Finland was the comprehensiveness of their implementation; their system could manage 100 different permit application types and a volume of over 8000 applications per month (Evolta, 2017b).
North American municipalities have been following the footsteps of Singapore. United States started to mandate BIM for some government projects in 2008, and for public projects over $5 million USD and all new construction projects over $2.5 million in 2010 (Singh, 2017). In 2011, New York City, USA, launched The Development Hub, a digital platform that enabled online submission of plan review applications along with required forms and payments. New York’s system was similar to Finland’s approach, where plan examiners were able to review the applications in their technologically advanced offices with large television screens and smart boards. Webcams and video conferencing tools were used to facilitate communication between plan examiners and applicants (New York City, 2017). The New York’s system currently only accepts drawings in PDF format, which limits the capabilities of the system. While New York has not published any metrics, City of Boston, USA started using a similar system in 2014 and was able to process 21% more applications in 18% less time in their first year (Lawerence, 2015).

In January 2016, City of Mississauga, Canada, implemented e-plans, an online e-processing platform for submission and review of building plans for building permits, zoning certificates, site plan approvals, and preliminary development applications. While e-plans does not currently support BIM submission, it has many of the elements of CORENET and Evolta systems, including a workflow engine, simultaneous reviewing, and plan mark-up capabilities. It also provides a client-facing dashboard with status updates on applications (City of Mississauga, 2017). As a result of implementing e-plans, Mississauga reported that the time needed for the first review of applications reduced by 30%, and the overall time to issue a building permit reduced by 8% in the first year of implementation (Hinton, 2017). Amongst other reported benefits of e-plan are a drastic reduction of storage space for printed plans, improved reviewing capacity, reduced time for each application to transit between city staff for review, and improved quality and efficiency in permit services (City of Mississauga, 2017).

Mississauga’s lead was followed by other Canadian cities. For example, City of Markham is implementing e-plans in 2017 for building permits and zoning preliminary review applications (City of Markham, 2017). Vancouver, Edmonton, and Hamilton were reportedly investigating alternatives for implementing an e-permitting system for their communities (Avolve, 2017).
3.5 Barriers for Implementation of Automated Model-based e-permitting Systems

Despite the proven advantages of using automated model-based e-permitting systems, there are still several implementation barriers to information technology solutions in the construction industry that most municipalities need to resolve, including cultural resistance to change, cost, and data sharing concerns (Fiatech, 2007). While these concerns need to be addressed for any IT-application implementation, the discussions in this section are focused on the barriers specifically related to the implementation of the automated model-based e-permitting framework of this research. These specific challenges include BIM implementation, managing the transition, and addressing the legal concerns.

3.5.1 BIM Implementation is Key

The construction industry’s inertia and resistance to the adoption of new technologies have been acknowledged and well documented (Nikas, Poulmenakou, & Kriaris, 2007). However, for successful implementation of a model-based e-permitting system in which BIM implementation is a key component, the change needs to go beyond the construction industry and into government agencies and municipalities, which would be a much more difficult undertaking. Having said that, there are countries around the world that have been more successful than others in adopting new technologies and innovative processes, particularly as it relates to the implementation of BIM practices. Singapore has effectively implemented a top-down approach, in which the use of BIM for design and later for e-permitting was mandated across all projects nationally. UK is the most successful country for BIM adoption amongst western countries. They also implemented a top-down approach by mandating that the industry to move to BIM (Kassem & Succar, 2017). Governments in Hong Kong and UAE have followed their lead.

Canada, on the other hand, has a middle-out dynamic approach to BIM implementation, which means that large organizations adopt BIM and then push for regulatory bodies and their supply chain to follow (Kassem & Succar, 2017). This creates a substantial gap between the municipalities using traditional paper-based and manual permitting and review processes on one hand and the AEC industry slowly but surely adopting BIM for design and internal code compliance checking on the other hand. This gap creates significant inefficiencies in the review and construction permitting process, and frustrations within the industry leaders who have
adopted BIM practices but are unable to capitalize fully on their investment due to the lack of government support.

The benefit of Canada’s middle-out approach is that once the municipalities and the federal government start mandating BIM for new projects and for e-permitting processes, the learning curve of the industry would be much smaller than those experienced by other countries and the costs that it would incur in terms of training the local industry would be substantially lower. Having said that, while Canada has been slow in joining other world leaders in adopting BIM practices broadly, its mandate of BIM seems inevitable.

3.5.2 Managing Transition

Implementation of the entire automated model-based e-permitting system, or even its partial implementation, requires both a process and a technology over-haul. As with any other major over-hauls in an industry as diverse as the AEC industry, the transition period is critical and needs to be carefully managed.

The top-down approach of Singapore, UK, Hong Kong, UAE, and others provide more control but could prove to be expensive for the authorities, whereas the transition period in a middle-out approach may be associated with long durations of uncertainty, but may incur less direct costs to the government. Despite the higher direct cost of the top-down approach and the level of structure and control that it provides, top-down provides leadership and may be the preferred strategy for managing the transition towards the implementation of an automated model-based e-permitting system.

Managing the transition includes training of the highly qualified personnel that could lead the industry during the transition. There are many international and national organizations around the world that support governments and organizations for implementation of BIM practices, such as BuildingSMART International.

Singapore’s transition provides a number of lessons for any municipality or government agency that may want to engage in a top-down transition. In addition to the software and hardware costs of implementing their e-permitting system at the government level, Singapore’s Building and Construction Authority allocated $4.2 million USD specifically for BIM adoption, covering training, consultancy, and software costs in the construction sector (Building and Construction
Authority, 2011a). That translates to approximately $0.75 USD per capita. This cost would be much higher if larger countries were to provide the same level of support. On the other hand, the middle-out approach has the lowest direct cost to the government as industry leaders and consequently their supply chain absorbs the training and transition costs prior to any mandate from the government. Of course, this results in substantial inefficiencies in the system, which may add up to a much higher overall costs to the industry. Regardless, the costs of implementation and transition remain significant barriers to implementation of automated model-based e-permitting systems.

3.5.3 Legal Concerns

There are a number of legal concerns that need to be addressed prior to any successful implementation of an automated model-based e-permitting system; some more challenging than others. For example, submitting and transferring files over the internet originally raised concerns of confidentiality and security of drawings by AEC industry professionals. This concern has been substantially mitigated by using digital signatures and through mandatory encryption of files in the submission process (Letch & Teo, 2015). There are also regulations and norms that are specific to a country or a region, such as those related to privacy, governmental transparency and responsiveness. For example, some Canadian provinces require local governments to store their online information in servers located in Canada (Afzalan, Sanchez, & Evans-Cowley, 2017).

Another legal challenge is the lack of a single integrated system for plan submission that would be adopted by all involved agencies. While this is a significant challenge, harmonizing and standardizing the rules and the way drawings are delivered to different agencies would substantially improve efficiency and reduce confusion. For example, in Singapore, a set of industry standards by Singapore Chapter of International Alliance on Interoperability (IAI(S)) was suggested and embraced by the Construction Industry Standards Committee (CITC). Professional institutions and associations also signed a memorandum to commit to the use of those standards (Letch & Teo, 2015). The UK government implemented a similar approach, but included a phased implementation plan, slowly bringing different sectors of the industry on-board, which has proved to be very successful (McAuley, Hore, & West, 2017). There are now a number of international standards that can be adopted, and based on which national guidelines can be developed for every country to address their unique needs.
3.6 Conclusions

This paper presents a 3-level e-permitting framework that provides a gradual transition path from traditional paper permitting practices to a fully integrated e-permitting platform by taking advantage of the recent technological advancements in the architecture, engineering, and construction (AEC) industry. In this framework, Level 1 e-permitting represents systems that take advantage of a centralized document management system with an embedded workflow engine. In Level 2 of the framework, an advanced, automated, model-based approach was developed based on the submission of building information models (BIM) for e-permitting and automated code compliance checking. It was also shown that Level 2 e-permitting could enable other applications during the construction and operation and maintenance phases of a facility. The integration of BIM with GIS information in Level 3, would allow a building project to be evaluated in its urban context, which enables several smart urban management applications. Specifically, a design of the building would be evaluated based on its surrounding urban context, its construction would be planned with respect to other urban features and activities in its neighbourhood, and its building model would feed into the city’s smart urban asset management platform, providing valuable information that would otherwise not be captured, communicated, and analyzed at a city-level.

While the fully integrated e-permitting framework of this research has not been implemented, successful implementations of basic e-permitting frameworks around the world were investigated as part of this research and barriers for their implementation were identified. It was concluded that a successful implementation of an e-permitting framework would require the full support of local governing agencies.

3.7 Acknowledgments

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This work was undertaken through University of Toronto’s Building Tall Research Centre.
Chapter 4. Conclusions and Recommendations

In this research, the current construction permitting process for tall buildings in City of Toronto was investigated with an emphasis on Official Plan and Zoning Bylaw amendment approvals. This investigation included the compilation of a database on the permitting timeline and approval agencies for 162 tall residential towers in Toronto. It was concluded that while the average processing time has increased substantially over the last decade, the government agency that approved a project, City Council versus Ontario municipal board (OMB), had a significant impact on the duration of the process. A Bayesian network was then developed to estimate the probability of a proposal for a new tall building development in City of Toronto to have to appeal to OMB for approval. The significance of this model was that factors contributing to a proposal having to appeal to OMB were identified and their impact was quantified and carefully analyzed. Developers could now use this model to manage the risk associated with their project having to appeal to OMB, based on various design specification combinations.

The evaluation of the permitting process in City of Toronto also identified several challenges with the existing system, which included inconsistencies between decisions of City Council and OMB, limitations caused by prescriptive design guidelines and inefficiencies in the processing practices. Finally, specific recommendations were made to improve the existing permitting process, which included using e-permitting practices, further implementing performance-based guidelines to encourage and support innovation, and providing better visibility on the decision-making process to the public.

The second phase of this research provided a global perspective to the permitting process and provided a thorough review of the recent advancements in permitting practices in international jurisdictions, including the implementation of e-permitting and automated code compliance checking systems. A framework was then developed for an automated, model-based e-permitting system that would take full advantage of the recent technological advancements in the AEC industry, including the use of BIM for e-permitting and code compliance checking. The traditional paper-based permitting system was compared to three levels of e-permitting framework, including basic, model-based, and fully integrated e-permitting systems. The later included the integration of BIM with GIS information, which allows a building proposal to be evaluated in its urban context and enables several smart urban management applications. For
example, a design of the building would be evaluated based on its surrounding urban context, its construction would be planned with respect to other urban features and activities in its neighbourhood, and its building model would feed into the city’s smart urban asset management platform, providing valuable information that would otherwise not be captured, communicated, and analyzed at a city-level.

While the fully integrated e-permitting framework of this research has not been implemented anywhere in the world, successful implementations of basic e-permitting frameworks were investigated and barriers and best practices for their implementation were identified. It was concluded that a successful implementation of an e-permitting framework would require the full support and leadership of local governing agencies. Also, beyond the basic e-permitting level, this support would also include a top-down approach of requiring the local industry to adopt BIM practices and submit BIM for e-permitting and automated code compliance checking as well as for GIS integration. There are several successful top-down BIM adoption case studies presented in this research, including those in UK and Singapore, which can be referenced by other jurisdictions interested in pursuing BIM adoption.

The recommendations of this research include the gradual implementation of the three-level e-permitting framework presented in Chapter 3. The basic e-permitting (Level 1) of the developed framework would address many of the challenges with the existing permitting processes at City of Toronto, while levels 2 and 3 e-permitting would advance any municipality, such as City of Toronto, towards the leading edge of integrated city planning and city management practices, an uncontested position currently pursued by the likes of Singapore and UK.
Chapter 5. References


City of Markham. (2017). Markham’s Building and Development Plan Review Goes Online. Retrieved September 26, 2017, from https://www.markham.ca/wps/portal/Markham/BusinessDevelopment/PlanningAndDevelopmentServices/ePlan/?ut/p/a1/jdBBDolwEAXQs3CCfmgdpVnbCAWUFLEbgwrQqLownh-kbC1OLuZvJ_JDHGkl27q3-PQv8bH1N--veNXVqVKla2oo4YBxug2Puk65Ds-g8sMVCozIpQAkphknpvq2NBYfh_efwoiSWfG6hQFsi


Lee, H., Lee, J. K., Park, S., & Kim, I. (2016). Translating building legislation into a computer-


Appendix A

Appendix A is a copy of data gathered for the study of rezoning process in city of Toronto. The database is originally based on tall building inventory from the Council for Tall Buildings and Urban Habitat (CTBUH), and consists of rezoning information of 174 tall buildings extracted from Toronto’s city staff reports, City Council meeting minutes, and Ontario Municipal Board (OMB) decision reports.
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<th>End Time</th>
<th>Location</th>
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<td>555-1234</td>
<td>Residential</td>
<td>Family</td>
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<td>Anytown</td>
<td>555-4567</td>
<td>555-4567</td>
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Note: The above table is a simplified example of how the data might be presented in a readable format.
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<td>Bob Lee</td>
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<td>596</td>
<td>Mary Johnson</td>
<td>Programming 6</td>
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</tr>
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</table>

*Note: All courses are located in the City Classroom, with the following instructors:

- John Doe: Programming 1
- Jane Smith: Programming 2
- Bob Lee: Programming 3
- Lisa Green: Programming 4
- Tom Brown: Programming 5
- Mary Johnson: Programming 6*
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<td>23456</td>
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<td>34567</td>
<td>999-0123</td>
<td>789000</td>
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</tr>
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<td>000 Pine St</td>
<td>Goldfield</td>
<td>45678</td>
<td>888-9012</td>
<td>888777</td>
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<td>Richmond</td>
<td>56789</td>
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<td>67890</td>
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<td>999-0000</td>
<td>999999</td>
<td><a href="mailto:blackfieldsportinggoodsstore@example.com">blackfieldsportinggoodsstore@example.com</a></td>
</tr>
<tr>
<td>Lighting Store</td>
<td>999 Elm St</td>
<td>Greenfield</td>
<td>34567</td>
<td>444-5555</td>
<td>444444</td>
<td><a href="mailto:greenfieldlightingstore@example.com">greenfieldlightingstore@example.com</a></td>
</tr>
<tr>
<td>Pharmacies</td>
<td>000 Maple Ave</td>
<td>Brownfield</td>
<td>45678</td>
<td>333-4444</td>
<td>333333</td>
<td><a href="mailto:brownfieldpharmacies@example.com">brownfieldpharmacies@example.com</a></td>
</tr>
</tbody>
</table>

*Note: All phone and fax numbers are fictional.*