Accessibility of Wheelchair Users to Residential Units

Under the National Building Code

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Abstract

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Residential buildings are buildings used for dwelling purposes with two identified types which are Houses and Multi-story buildings. The national disability rate in Canada is 14.65 per cent, with statistics expecting 25 per cent of the population to be 65 years old and more in 2051; the accessibility and usability of residential building for wheelchair users is not guaranteed under the National Building Code (NBC), which means a significant part of the population do not have suitable buildings to live in.

Universal Design (UD) Concept raises the idea of a different attitude towards design; which is consistent with human needs with all their variety and diversity.

The present thesis argues that Occupant Accessibility (OA) is one of the objectives of the National Building Code (NBC) in Canada. The analysis of the related articles illustrates that wheelchair users face barriers in their path to residential units. A list of recommendations is proposed to be adopted by NBC to have real Barrier-free requirements without any need for adaptation or segregation, and where occupants, with all their variety and diversity, get a decent habitation.

The present research also highlights on Building Information Modelling (BIM) as a revolutionary approach in the construction industry that deals with a building's life-cycle phases in a new way of thinking and execution. A proposal for the integration of Universal Design (UD) concept into the Building Information Modelling (BIM) ideology to be part of its database is suggested by creating new universal design (UD) families in Revit software which is a main BIM tool.

Acknowledgments

I would like to express my special thanks and deepest gratitude to Professor Fabriborz Haghighat, my supervisor, for his knowledgeable suggestions, time, guidance and continued support which have led to the completion of this thesis.

I would also like to extend my sincere thanks to my co-supervisor Professor Ahmad Jrade for his academic support, valuable advice and special attention for this research.

My deepest thanks go to Mrs. Isabelle Cardinal, Architect and Consultation Services Director at Société Logique, for the time and precious information she provide me, and for following-up the progress of the thesis, based on her long experience in the domain of National Building Code (NBC) and Universal Design (UD).

I wish to express my special thanks to Hussein, my life and soul partner, who supported and encouraged me, as always, to keep ongoing.

Thanks to my family; my parents, sisters and brothers for their love and support; especially my sister and teacher, Haifa, as without her guidance, support and advice, my work would not have been completed.

DEDICATION

To *Jawad*, my son and inspiration

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Chapter 1

Introduction

1.1 General

"The National Building Code of Canada (NBC) is the source and the main reference of the construction industry regulations that forms the basis for all of the Canadian provincial building codes". (National Building Code of Canada, 2012).

Occupant accessibility (OA) is one of the four objectives of the National Building Code (NBC). It is considered to limit the existence of any type of barriers that obstruct a person with a physical or sensory limitation to access or using a building as a result of the design or construction of the building. (National Model Construction Codes, 2012).

While the NBC guarantees accessibility to residential buildings for wheelchair users, under section 3.8 of the "Barrier-Free" chapter, it does not assure the usability of such buildings.

Three articles arguably consecrate the non-usability of residential units in residential buildings for wheelchair users, namely: 1) article 3.8.2.1.2.k, which underlines areas requiring a Barrier-free path of travel, 2) article 3.8.3.3.1, which describes an "acceptable" door width, and 3) article 3.8.2.3.2, which explains the "minimum provisions to accommodate a person using a typical manual wheelchair" in the bathroom.

These three articles are devoting the non-usability of residential units, in the above-mentioned residential buildings for wheelchair users.

The national disability rate in Canada increased by 1.9 per cent from its level of 12.4 per cent in 2001 to 14.3 per cent in 2006 (Disability Issues, 2011).

The Canadian population is ageing, 25 per cent of the Canadian population are expected to be 65 years old and over by 2051. Because the disability rate is higher for the

elderly than the youth, an ageing population will considerably increase the overall disability rate among the population. (Ageing Population, 2012).

The ageing society, added to the national disability rate (14.3 per cent), which is not considered negligible, will require serious steps to be made, in order to face this social and demographic phenomenon, by making changes, to factors shaping and seriously affecting the daily lives of a large part of the population, without practicing any type of segregation or discrimination against them. (Disability Information, 2011).

In the present research a procedure is suggested to be the first step on a real Barrier-free path where a sustainable environment is designed and supported to be usable by everybody, regardless of age, sex or capacity, to the greatest level possible, by suggesting modifications to be made in the National Building Code (NBC) on the accessibility requirements of residential units.

1.2 Research Objectives

The main objective of the present research is to promote full inclusion of people with disabilities in Canadian society, with special focus on people using wheelchairs and their inclusion in residential units.

The research sub-objectives are listed as follows:

1. To evaluate the different sets of accessibility and usability criteria and specifications to all types of buildings for all types of disabilities included in the National Building Code (NBC), the Canadian Standard Association (CSA) and the Accessible Facility Guidelines (AFG). Also to compare such requirements with the accessibility and usability requirements to all types of buildings for all types of disabilities provided by the Universal Design (UD) Concept.
2. To assess the criteria and specifications of accessibility and usability of residential units located in residential buildings exceeding 600 m^2 of gross area and more than three stories in height, for wheelchair users included in the National and Provincial

Building Codes, then compare them to accessibility requirements to residential buildings for wheelchair users under the Universal Design (UD) Concept.

3. To draw up a list of recommendations to introduce amendments to the National Building Code (NBC) based on the outcome of sub-objectives (1) and (2).
4. To integrate universal design (UD) concept in Building Information Modelling (BIM) approach by designing new instances within new families of the software Revit, based on the outcome of sub-objectives (3) to be stored as part of the BIM database.

1.3 Research Methodology

To achieve the research objectives, numerous steps are to be taken; these steps are briefed in figure 1 and detailed in the next paragraphs:

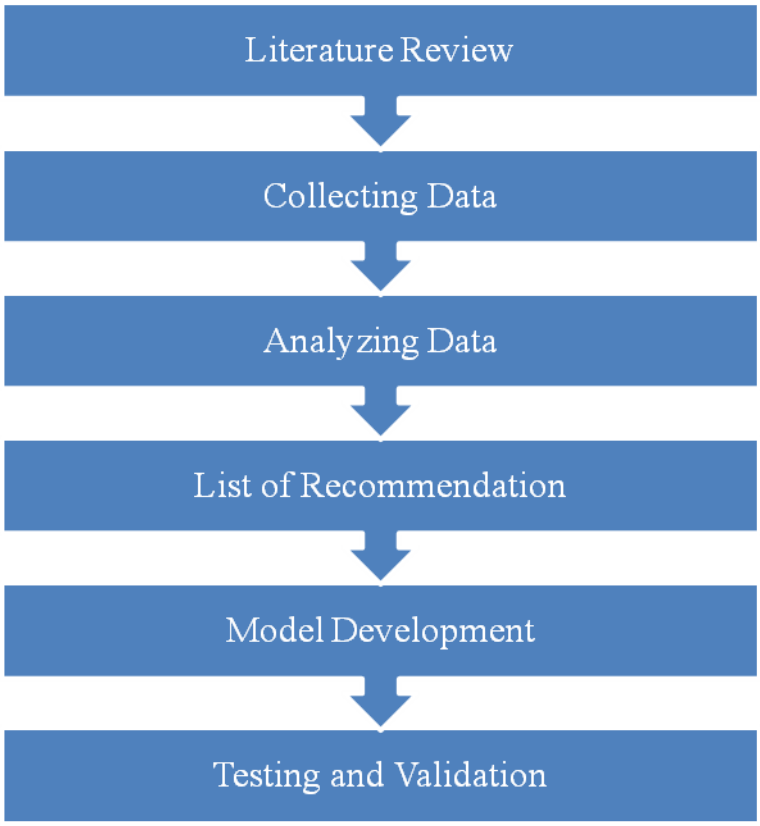

Figure 1: The research methodology

1.3.1 Literature Review

A comprehensive literature review has been undertaken to understand the state of the disability situation in Canada, and to identify to which extent Canadian legislations that protect people with disabilities are fulfilled. Recognizing the National Building Code (NBC) and its influence on buildings' accessibility is carried out with particular focus on Universal Design (UD) Concept, definition and principles also a social and economic benefit of barrier-free housing. As well, an overview on Building Information Modelling (BIM) and its integration in universally accessible design is conducted.

1.3.2 Data Collection

The required data consist of collecting information about criteria and specifications presented as dimensions, measurements and details needed to provide accessibility to building facilities for all types of disabilities, under the Universal Design (UD) Concept, National Building Code (NBC), Canadian Standard Association (CSA) and Accessible Facility Guidelines (AFG), summarized in figure 2.

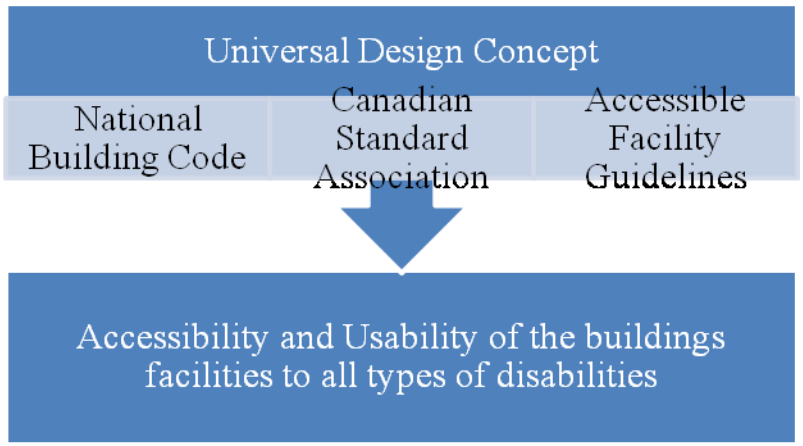

Figure 2: Step one is collecting Accessibility requirements under NBC, CSA, AFG and UD Concept

The collected data consist also of accessibility and usability requirements for wheelchair users for the two main types of homes - houses and residential buildings - set out under the Canadian National Building Code (NBC), the modified versions of the

Canadian Provinces Building Codes, and those presented under the Universal Design (UD) Concept. Figure 3 illustrates the procedure.

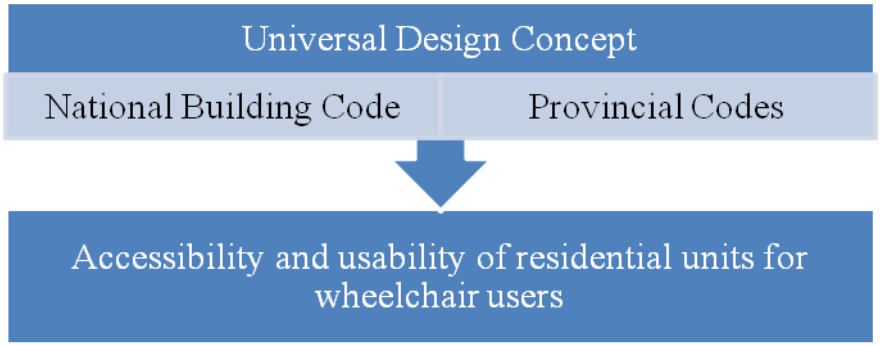

Figure 3: Step two is collecting accessibility requirements under NBC, Provincial Codes and UD Concept

1.3.3 Analysis of the Collected Data

The analysis of the collected data is done in two steps. The first step is to conduct a thorough comparison between the accessibility and usability requirements of building facilities under the Best Practice of Universal Design (UD) on the one hand, and those, on the other hand, adopted by each of the following: the National Building Code (NBC), the Canadian Standard Association (CSA) and the Accessible Facility Guidelines (AFG). The comparison aims to indicate the research and discussion level and to demonstrate the adoption level of the specifications of the Universal Design (UD) by the above-mentioned references, NBC, CSA and AFG.

The second step is to evaluate the accessibility and usability requirements for wheelchair users to residential buildings presented by the Canadian National Building Code (NBC), the modified versions of the Canadian Provinces Building Codes, and the Universal Design (UD) Concept to demonstrate their different attitudes toward the inclusion concept of wheelchair users.

1.3.4 Evaluating Results and Deriving List of Recommendations

Percentages are retrieved from the analysis of the collected data illustrating the discussion level of accessibility specifications, and also the conformity level, done by

NBC, CSA and AFG compared to the Best Practice of Universal Design's specifications. An assessment will be carried out based on the retrieved percentages, with an attempt to retrieve a list of recommendations with a precise goal: to propose minor amendments to the NBC to promote and support the full inclusion of wheelchair users to residential units.

1.3.5 Model Development

In order to make the design of accessible spaces for wheelchair users easy and available for designers at any time, without the need of studying the accessibility requirements, and to be part of the stored database of Building Information Modelling (BIM) tool, which is Revit software, new Revit Families are developed. The new Revit families simplify the process of implementing universal design (UD) criteria based on the thesis' list of recommendations.

1.3.6 Validation of the Recommendations

For the purpose of testing the effectiveness of the list of recommendations, a redesign of inaccessible residential units for wheelchair users, selected randomly from residential construction projects, is accomplished. The redesign is based on the recommendations list with the main intention to transform the inaccessible units to be accessible and usable, by people with or without wheelchairs, at the same level of functionality. The redesign is to be achieved without any modifications or changes in the area and/or the architectural concept of the selected units.

1.3.7 Experts Consultation

The findings of the research were discussed with experts to get their feedback and recommendations. The personnel of the Ordre des Architectes du Québec recommended the Société Logique.

The Société Logique (Universal Accessibility, 2012), an organization involved in universally accessible environments, is a non-profit organization, which was founded in 1981 by people with disabilities. Its main mission is to create and promote the development of universally accessible environments, and to encourage consultation during the planning process.

The clients and partners of the Société Logique are governments, community, and public institutions and private sector bodies in Quebec.

To get the required information, a questionnaire that consists of eight questions which constitute the major outcome of the present research was prepared and submitted to Mrs. Isabelle Cardinal, architect and consultation services director at Société Logique. A copy of the questionnaire is contained in appendix (A).

1.4 Thesis Organization

This thesis consists of seven chapters, as follows:

- Chapter one includes background information; it provides an introduction to the subject's objectives and an outline of the thesis chapters.
- Chapter two consists of the following: (a) Literature review on disability in Canada and on Canadian legislation against the abuse of persons with disabilities; (b) A detailed description of the National Building Code (NBC) and its role in providing building accessibility for the disabled; (c) An explanation of The Universal Design (UD) Concept and its seven principles; (d) Social and economic benefits of barrier-free housing; (e) A description of the Building Model Information and its application and practices in the fields of construction and design.
- Chapter three present two comparisons - one is between all types of disability requirements provided by four main references: the National Building Code (NBC), the Canadian Standard Association (CSA), the Accessible Facility Guidelines (AFG), and The Best Practice of Universal Design (UD). The second comparison is

presented between wheelchair accessibility requirements in the National and Provincial Building Codes and the Universal Design (UD) requirements.

- Chapter four illustrates the result of the comparisons achieved in Chapter three, presented as percentages and a list of recommendations.
- Chapter five proposes a prototype model development based on the research list of recommendations.
- Chapter six gives examples of residential units that are inaccessible by wheelchairs. It refers to the retrieved list of recommendations in order to make these units accessible and usable by wheelchair users.
- Chapter seven contains the conclusion and a number of recommendations for future expansion research.

Chapter 2

Literature Review

2.1 Introduction

Attitudes toward disability and persons with disabilities have changed over the last few decades in Canadian society. For over twenty years, the Government has been working to alter the vision of disability, along with partners who share the vision of full inclusion of persons with disabilities as full citizens and to eliminate the barriers that prevent their full participation in social life. (Advancing the inclusion of persons with disabilities, 2004).

This chapter presents a review of the definition, types, Canadian legislations and statistics on Canadians with disabilities. It also provides a description of the National Building Code (NBC) and its role in eliminating the barriers obstructing the path of people with disability, in addition to an introduction to Universal Design Concept and its implementation on the inclusion concept. It also draws a picture of the Building Information Model (BIM), which is the latest software technology being introduced into the construction and design field.

2.2 Disability

2.2.1 Definition

"Disability is a complex phenomenon, reflecting an interaction between features of a person's body and features of the society in which he or she lives." (Disabilities, 2011).

Disability is a combined fact of impairments, activity limitations, and participation restrictions. Impairment is a body's permanent or temporary, dysfunction; an activity limitation is a complexity in executing a task caused by external obstacles, while a participation restriction is a situation that limits a person from participation and

integration. (Disabilities, 2011)The International Classification of Functioning, Disability and Health, commonly known as ICF, is a classification of health and health-related domains, which looks at the concepts of health and disability from a new perspective; it concedes that every human being can experience a decrement in health and, therefore, every human being can experience some degree of disability. The ICF considers disability as a universal human experience.

Furthermore, ICF focuses on the social aspects of disability and its contribution as contextual factors surrounding the persons with 'medical' or 'biological' dysfunction, and resulting in an environmental impact on a person's functioning. (International Classification of Functioning, 2011).

The United Nations Enable (2005) defines disability as a result and consequence of the interaction between persons with impairments or illnesses, and the environmental and attitudinal obstacles they face.

People with disabilities face many barriers and challenges in the course of their simple daily life activity, while attempting to be part of the society. A shortage of their involvement in employment, education and transportation deepens the gap between them and other social groups. As a result, people with disabilities do not always have access to the same opportunities as others. Therefore, they are more likely to be socially isolated, and to suffer from a higher rate of unemployment and poverty. (General, 2010).

2.2.2 Canadian Legislations

Canada has a strong legal and legislative framework which aims to decrease barriers for people with disabilities and protect them against any kind of discrimination, to ensure them full participation in Canadian society. Some of these legislations are as follows:

1. The In Union vision of inclusion

In 1998, federal, provincial and territorial ministers responsible for social services released a report entitled "In Unison: A Canadian Approach to Disability Issues", a

description of the vision and the required long-term policy directions, for promoting the full participation of people with disabilities in three major areas: employment, income and disability supports. Disability affects an individual's ability to perform an activity, which is considered to be obviously normal or relatively easy for a human being without disabilities; however, disability does not mean that a person is less capable of fully participating and contributing as a citizen in Canadian society. (Federal, 2000).

2. Canadian Charter of Rights and Freedoms

In 1982, for the first time in Canada's history, the Canadian Charter of Rights and Freedoms mentioned clearly, the "physical or mental disability as a prohibited ground of discrimination". Section 15 of the Charter makes it illegal for governments in Canada to discriminate against persons with disabilities in their laws and programs. (Garton, 1982).

3. Canadian Human Rights Act

Under this act, federally regulated employers are required by law to avoid discrimination and to grant access and support to individuals with disabilities. (Canada D. o., The Canadian Human Rights Act, 2012).

4. "A Place For All"

"A Place for All" is a Canadian human rights commission guide to help employers understand their legal obligations regarding the duty to accommodate, and create their own workplace accommodation policies and procedures. (Commission, 2003).

5. The United Nations Convention on The Rights of Persons with Disabilities

Canada and other countries agreed to and signed the United Nations Convention on the Rights of Persons with Disabilities in March 2007, and a recent ratification concerning the same Convention was confirmed in March 2010. (Convention on the Rights of Persons with Disabilities, 2006).

6. Employment Equity Act

Under the Employment Equity Act, the Canadian Human Rights Commission takes on the responsibility to ensure the fulfilment of the Act, by inspecting and investigating the employers' performance, to ensure that federally regulated employers provide equal opportunities for employment to the four designated groups: Women; Aboriginal peoples; persons with disabilities; and members of visible minorities. (Canada D. o., Employment Equity Act, 1995).

2.2.3 Types of Disabilities

Every person with a disability is unique with needs, purposes and challenges that are influenced by many factors such as gender, kind and severity of disability, age, family, community and background. There are hundreds of different types of disabilities manifesting in varying degrees, through varying symptoms. Disabilities are divided into four main categories:

Mobility disabilities: This category includes two groups, the wheelchair users and the ambulatory mobility disabilities.

- Wheelchair users: these are people with severe mobility disabilities. They use either a power-driven or manually-operated wheelchair or the three- and four-wheeled cart or scooter to manoeuvre through the built environment. People who use wheelchairs face the most obvious access problems –manoeuvring through narrow spaces, going up or down steep paths, making use of toilet and bathing facilities, dealing with steps or changes in level at an entrance. (Taormina-Weiss, 2011).
- Persons with ambulatory mobility disabilities: this group includes people who walk with difficulty or have a disability which obliges them to use crutches, canes, walkers, braces, artificial limbs, or orthopaedic shoes. Also included in this group are people who do not have full use of their arms or hands, or who lack coordination. People with mobility disability face difficulty in walking, climbing steps, standing for extended periods of time, reaching, and fine finger manipulation. (Design T. C., 1999).

Vision disabilities: This category includes people with partial or total vision loss. People with partial vision loss can distinguish light and dark, sharply contrasting colours, or large print, but cannot read small print. People with total vision loss are blind people who depend upon their sense of touch and hearing to perceive their environment and to communicate with others. Problems experienced by people with vision disabilities include orientation, using controls that are not adequately labelled, and avoiding hazardous protruding objects which they cannot detect. (Allsup, 2012).

Hearing disabilities: This category includes people with total or partial hearing loss, where both use a variety of methods to compensate for their inability to hear. The partially deaf people depend on hearing aids and lip reading. Totally deaf people also use lip-reading but must be able to see clearly the face of their interlocutor. Others use a standard means of communication called sign language. Problems for people with hearing disabilities include communicating with others and using equipment that is exclusively auditory, such as telephones and fire alarms. Lack of sign language interpreters and inadequately trained interpreters can also be a problem. (Corporation, 2010).

Cognitive and other hidden disabilities: This type of disability may affect behaviour, understanding or communication, which results in difficulty in using facilities, particularly where the signage system is unclear or complicated. (Arc, 2011).

2.2.4 Statistics on Canadian Disabled

The national disability rate in Canada increased from 12.4 per cent in 2001 to 14.3 per cent in 2006, at a rate of 1.9 per cent. The number of people who reported having a disability in Canada between 2001 and 2006 increased by three-quarters of a million (750,000) (21.2 per cent) of the population reaching 4.4 million in 2006, compared to the non-disabled population that increased by 3.3 per cent to reach 26.2 million people on the same date. (Canada S. , 2008).

The structure of the Canadian population is passing through demographic changes; the Canadian population is ageing. In 2010 the median age in Canada was 39.7 years. In 1971 the median age was 26.2 years. In 2010 an estimated 4.8 million Canadians were 65 years of age or older, a number that is expected to double in the next 25 years to reach 10.4 million seniors by 2036. By 2051 about one in four Canadians is expected to be 65 years old or over.

About 4.4 million Canadians (14.3 per cent) reported having a disability in 2006. The percentage of Canadians with disabilities increased with age (see figure 4), ranging from 3.7 per cent for children 0-14 years old and under 56.3 per cent for those of 75 years old and over. (Population Projections, 2010).

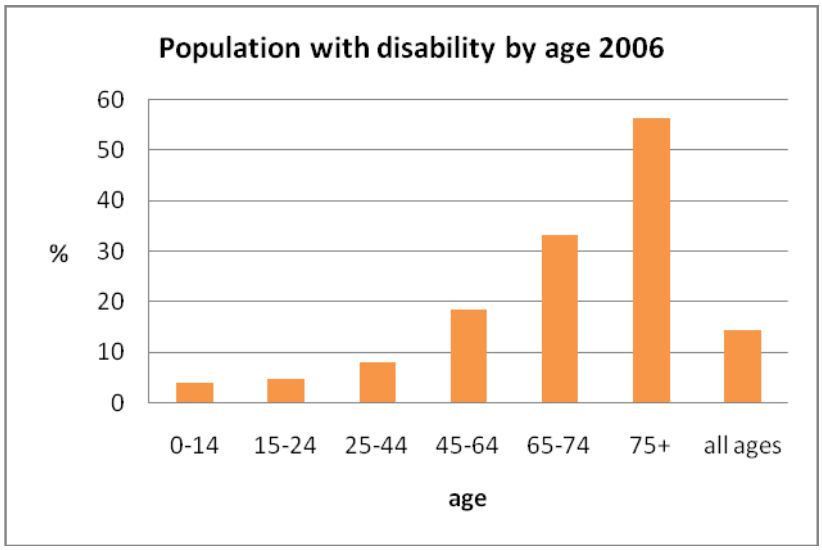

Figure 4: The percentage of Canadians with disabilities increased with age

In 2006 4.4 million Canadians living in households reported having an activity limitation while 3.6 million Canadians reported having limitations in their everyday activities due to a physical or psychological condition.

Because the disability rate is higher for the elderly than the youth, an ageing population will considerably increase the overall disability rate among the population. That requires society to be well-equipped in order to face this social and demographic phenomenon by making changes, often minor, to factors shaping and seriously affecting

the daily lives of a large part of the population without practicing any type of segregation or discrimination against them. (Canadians in Context: People with Disabilities, 2012).

2.3 The National Building Code

2.3.1 Background

The National Building Code of Canada (NBC) is the "bible" of the construction industry, prepared by the Canadian Commission on Building and Fire Codes (CCBFC). The NBC is considered to guarantee that buildings are structurally sound, safe from fire, free of health hazards and accessible. The NBC sets out technical conditions for the design and construction of new buildings. It also applies to the modification, change of use and demolition of existing buildings. (National Model Construction Code Documents, 2012). The National Building Code (NBC) is the model building code that forms the basis for all of the Canadian provincial building codes. Some provinces' authorities create their own code based on the NBC; other provinces' authorities have adopted the NBC requirements with supplementary laws or regulations. (National Model Construction Codes, 2012).

2.3.2 National Building Code 2010, Contents

The NBC is a two-volume book. Volume 1 contains two divisions, A and C. Division A describes the compliance options, objectives, functional statements and appendix. Division C contains administrative provisions and appendix as well as a new section containing the attributions to the acceptable solutions. Volume 2 contains division B acceptable solutions and appendices as well as the index. Division B contains 10 parts:

- Part 1: general
- Part 2: reserved
- Part 3: fire protection, occupant safety and accessibility
- Part 4: structural design
- Part 5: environmental separation

- Part 6: heating, ventilation and air-conditioning
- Part 7: plumbing services
- Part 8: safety measures at construction and demolition sites
- Part 9: housing and small buildings

Four appendixes are attached to NBC, are as follow:

- Appendix A: explanatory material
- Appendix B: fire safety in high buildings
- Appendix C: climatic information
- Appendix D: fire-performance ratings

The 2010 NBC is an objective-based code format in which all requirements are linked to one or more of the following objectives:

- Occupant safety (OS)
- Occupant health (OH)
- Occupant accessibility (OA)
- Fire and structural protection of buildings. (National Building Code, 2010)

2.3.3 Buildings Classifications

Buildings are classified in the NBC according to their usage; usages are residential, commercial, industrial, etc... (article 3.1.2.1. NBC 2005) and according to their size, area and height; requirements for buildings up to 600 m^2 and/or three floors of height are different than buildings larger than 600 m^2 and/or three floors of height (article 1.3.3.2).

Residential buildings are of group C (article 3.1.2.1.NBC 2005). Residential buildings larger than 600 m^2 area or three-storey buildings are covered under Part Three of the code; buildings smaller than 600 m^2 of area or less than three storeys in height are covered under Part Nine (article 1.3.3.3. NBC 2005).

2.3.4 National Building Codes and Disability

In 1941 the first edition of the NBC was released. In 1965 the National Research Council published a supplement to the National Building Code (NBC) entitled "Building Standards for the Handicapped" which was the first action taken to increase accessibility for people in wheelchairs or those facing other restrictions on their mobility to buildings and spaces open to the public. Nonetheless, the supplement merely contained guidelines and specifications, not model regulations. (Hansen, 1985).

The 1985 National Building Code (NBC) included requirements from the supplement as model regulations. Part Three was amended to provide protection for the disabled in case of emergency by adding a new Section in Division B, Part Three (3.7) on Barrier-Free design. (National Research Council Canada, 1985).

Occupant accessibility (OA) is one of the four objectives of the National Building Code (NBC). It is considered to limit the existence of any types of barrier that obstructs a person with a physical or sensory limitation to access or use of a building, as a result of the design or construction of the building. OA consists of two main categories:

- OA1 Barrier-Free Path of Travel: to ensure that a person with a physical or sensory limitation, be able to independently access and circulate within the building.
- OA2 Barrier-Free Facilities: to ensure that a person with a physical or sensory limitation, be able to independently use the building's facilities. (National Model Construction Codes, 2012).

2.4 Universal Design

2.4.1 Definition and History

"Universal Design (UD) is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design." (Ron Mace 1985).

"Universal Design is the process of embedding choice for all people in the things we design". (What is Universal Design, 2012).

"Choice" involves flexibility and numerous alternative ways of use and/or interface. "People" includes the full range of people in spite of their age, ability, sex, economic status, etc. "Things" comprises spaces, products, information systems and other things that humans create or operate. (What is Universal Design, 2012).

In the late 1950's the initial term used all over the world was "Barrier-Free Design" which demanded that barriers be removed from the way to the built environment for the disabled. In 1961 an international conference held in Sweden referred to extensive efforts exhorted throughout Europe, Japan and the United States, primarily by rehabilitation organizations, to reduce the barriers to the disabled. (Kendall, 1963).

The term Universal Design (UD) was first used and promoted in 1985 in the United States by the design pioneer and visionary of universal design (UD), Ron Mace, to communicate a design approach that could be utilized by a wider range of users. In 1997 the Centre for Universal Design at North Carolina State University developed the seven principles of Universal Design (UD) with a group of American experts, and articulated a mechanism by which the usability of design elements could be determined and evaluated. (About Universal Design, 2008).

2.4.2 Universal Design and the Social Model of Disability

Over the last few years a number of "models" of disability have been defined. The two most frequently mentioned are the "social" and the "medical" models of disability.

The Medical Model of disability deals with disability as a "problem" that belongs to the disabled individual. This problem is not seen as a concern for anyone other than the affected individual. By contrast, the Social Model of disability examines the whole community of disabled people, and seeks to make sure that through design, the society responds to the needs of all individuals including all its members. (Gill, 2010). The concept of Universal Design (UD) examines the notions of health, disability, access,

remedy, and accommodation in a new perspective; the Universal Design (UD) concept supports the broader philosophical framework of the Social Model of disability which echoes the cultural perspective, and the Universal Design (UD) concept is in contradiction with the Medical Model thinking. (Disability Services Office, 2008). A comparison of the two concepts, the Medical Model is Social Model, and the illustrated in table 1.

Table 1: Medical Model vs. Social Model

Medical Model	**Social Model**
Disability is a deficiency or abnormality	Disability is a difference
Being disabled is negative	Being disabled, in itself, is neutral
Disability resides in the individual	Disability derives from interaction between individual and society
The remedy for disability-related problems is cure or normalization of the individual	The remedy for disability-related problems is a change in the interaction between the individual and society
The agent of remedy is the professional who affects the arrangements between the individual and society	The agent of remedy can be the individual, an advocate, or anyone who affects the arrangements between the individual and society

Source: Gill, c. (1994) Two models of disability. Chicago, Institute of Disability, University of Chicago.

Universal Design concept discusses the idea of accessibility from a different perspective to the conventional accommodation concept.

Universal Design concept is presented as a social model approach that considers the accommodation approach as aligned with medical model thinking. (Disability Services Office, 2008).

A comparison of the two concepts, the accommodation and the universal design, is set out in table 2.

Table 2: Accommodation Approach vs. Universal Design Approach

Accommodation Approach	Universal Design Approach
Access is a problem for the individual and should be addressed by that person and the disability service program	Access issues stem from an inaccessible, poorly designed environment and should be addressed by the designer
Access is achieved through accommodations and/or retrofitting existing requirements	The system/environment is designed, to the greatest extent possible, to be usable by all
Access is retroactive	Access is proactive
Access is often provided in a separate location or through special treatment	Access is inclusive
Access must be reconsidered each time a new individual uses the system. i.e. is consumable	Access, as part of the environmental design, is sustainable

Source: AHEAD universal design initiative team (2001).

2.4.3 Principles of Universal Design

From 1994 to 1997, The Centre for Universal Design at North Carolina State University conducted research and demonstration projects funded by the U.S Department of Education's National Institute on Disability and Rehabilitation Research (NIDRR). The project was titled "Studies to Further the Development of Universal Design" (project no. H133a40006). One of the objectives of the project was to develop a set of universal design (UD) guidelines. The resulting principles of universal design (UD) are as follows:

Principle 1, Equitable Use: The design is fairly useful to people with diverse capacities.

Principle 2, Flexibility in Use: The design must be flexible to any modification or adaptation in order to fit a wide range of individual capacities, in the wide range of life situation changes.

Principle 3, Simple and Intuitive Use: Use of the design occurs spontaneously without any need of special skills, regardless of the user's knowledge level and its capability.

Principle 4, Perceptible Information: The design transfers essential and clear information efficiently to the user, in spite of the user's sensory-limited abilities.

Principle 5, Tolerance for Error: The design minimizes dangers and the unfavourable consequences of accidental or unintended actions.

Principle 6, Low Physical Effort: With minimum of fatigue and effort. The design should be utilized comfortably and efficiently.

Principle 7, Size and Space for Approach and Use: Regardless of user's body size, posture, or mobility, a suitable size and space are provided to permit reach, manipulation, and use of the design. (Principles of Universal Design, 2011).

2.5 Social and Economic Benefits of Barrier-Free Housing

Real estate industry represents one of the largest investments in any country. As with all investments the expected gains has to be seen in relation to the amount to be invested. Accordingly adopting accessible buildings requires evaluating costs and gains of such attitude.

Sweden was one of the first countries to adopt accessibility standards for public buildings. In 1977, the scope of its legislation was extended to cover newly constructed residential buildings, and existing buildings under renovation. This legislation stated that all structures of three floors and more in height must have wheelchair accessible elevators. All kitchens, bathrooms and hallways within apartments must be large enough for wheelchair access.

The United States Government has created barrier-free housing using several approaches such as federal subsidies for public, non-profit and private housing with accessible requirements, housing vouchers and certificates in the private market, community service housing adaptation programs, loans. (Dunn, 1991).

A number of research studies have documented some of the social and economic benefits of barrier-free housing. A cost-benefit study undertaken by the U.S. Department of Housing and Urban Development estimated that adapting existing housing reduces the

need for support services and yields benefits that amount to 13 to 22 times the levels of costs.

Another study presented at the International Congress on Accessibility in Rio de Janeiro, Brazil, June 1994 demonstates a detailed cost comparison between accessible and conventional building in two ways. The first approach is to be achieved by comparing the cost of transforming an existing inaccessible building to be accessible through renovation. The second approach is to compare the cost of the same building if it had been constructed with universal access right from the beginning. The comparison has been applied on public and residential buildings. (Ratzka, 1994).

The additional cost due to adopting accessibility in public buildings is detailed in table 3, cost of accessible Renovation and original barrier-free design compared to conventional (inaccessible) structures.

Table 3: The additional cost due to adopting accessibility in public buildings

Type of building	**A: Accessible renovation**	**B: Original barrier-free design**	**A/B**
Convention hall	0.12%	0.02 %	6
Town hall	0.2%	0.05%	4
College Class room	0.51%	0.13%	4
Shopping center	0.22%	0.006%	35

Source: Schroeder and Steinfeld (1979) the estimated cost of accessible buildings. US Department of Housing and Urban Development.

Referring to a French study by Armani (CIB W84 Report 1993), the additional cost for bringing up an existing multi-family housing to accessibility standard is between 0.5 and 1.0 per cent of total construction costs in new construction.

Research on single-family units has been carried out in Canada. In Ottawa, in a project of 54 townhouses, 9 accessible designed units cost 8-10 per cent more than the 45 other units. The additional cost is 0.5 per cent to the overall project cost, where the effect on rental scales is negligible.

The Canadian Mortgage Housing Company, based on a study of 17 case studies specified that the accessibility features cost 0.39 - 0.53 per cent to the building cost.

An average of $1,500 was spent in 1986 in Project Open House, to adapt existing inaccessible homes to make them accessible. (Champagne CIB W84 Report 1988) Dunn (CIB W84 Report 1993).

The additional cost due to adopting accessibility in residential buildings is detailed in table 4 accessible renovation and by original barrier-free design compared to conventional (inaccessible) structures.

Table 4: The additional cost due to adopting accessibility in residential buildings

Type of building	A: Cost increase due to accessible renovation	B: original barrier-free design	A/B
High rise tower multi-family	1.0%	0.25%	4
Single family homes	21%	3.0%	7
College dormitory	0.40%	0.10%	4

Source: Schroeder and Steinfeld (1979), The estimated cost of accessible buildings. US Department of Housing and Urban Development.

The results of this study indicate that the additional cost for adaptation inaccessible single-family units amounted up to 21 per cent of the total construction cost; in high rise multi-family apartments the additional cost for adaptation amounted a maximum of 1 per cent. Adopting barrier-free standards at the design phase of a project would have cost only 3 per cent in single-family homes and 0.25 per cent in the high-rise complex.

Another study conducted by Quantity Surveyors, Rider Hunt using Australian Standard 4299-Adaptable Housing (1995) for Classes B&C2 entitled «a cost benefit analysis of adaptable homes» has founded that the added cost of adaptable housing provision as a percentage of construction costs varies by house type as details in table 5. (PDA, 1999).

Table 5: comparative cost expressed as percentage of total cost

Dwelling type	Initial Cost of AS4299 Class C	Cost of adaptive upgrade with prior provision	Cost of modifications if no prior adaptive features
Single dwelling	0.5-1.0 %	0.7-1.2 %	8.7-12%
Townhouse	0.5-1.0%	5.7-6.7%	19-23%
Low-mid rise	0.3-5.8%	0.3-7%	10.3-21.9%
High-rise	0.3-0.7%	0.3-0.7	9.2-12.9%

The study has reviewed the possible savings to Government in case if adaptable housing standards are adapted universally to new house construction. The main economic savings cover the followings:

- Decrease the need to move into residential care for elderly and people with a disability.
- Decrease the cost of rehousing
- decrease government administration costs

The potential savings to Government are detailed in table 6 as follow:

Table 6: The potential savings to Government

	Potential annual savings In USD millions	Present value over 30 ys In USD millions	Savings per household In USD millions
Saving in delaying the need to move into hostel care	112.8	437	65
Saving in delaying people with disability under 65 into group home or institutional care	59	229	34
Saving in reduced Home And Community Care	75.2	291	43
Reduced expenditure on major adaptations for public housing		483	72
Saving in reduced accidents	8	31	4.61
		1.471	21.61

2.5.1 conclusion

Whether making an existing building accessible or designing it from scratch by adopting barrier-free standards, the additional cost is inversely proportional to the size. The smaller the unit of comparison, the larger the additional cost is . To make housing accessible the additional cost is higher than public buildings, and single-family housing costs more than multi-family housing. (PDA, 1999).

If accessibility is incorporated into the design prior to construction, the cost of accessible units are only slightly more than conventional ones (Dunn, 1991).

2.6 Building Information Modelling

2.6.1 Introduction

Building Information Modelling (BIM) is a new approach to building design, construction, and management; BIM provides three-dimentional information that allows all members of the building team to visualize the many components of a project and how they work together. BIM has the ability to correct errors at an early phase and accurately schedule construction. (Yodlers, 2008).

The expression BIM is used both as a noun 'Building Information Model' as well as a verb 'Building Information Modelling'(see figure 5).

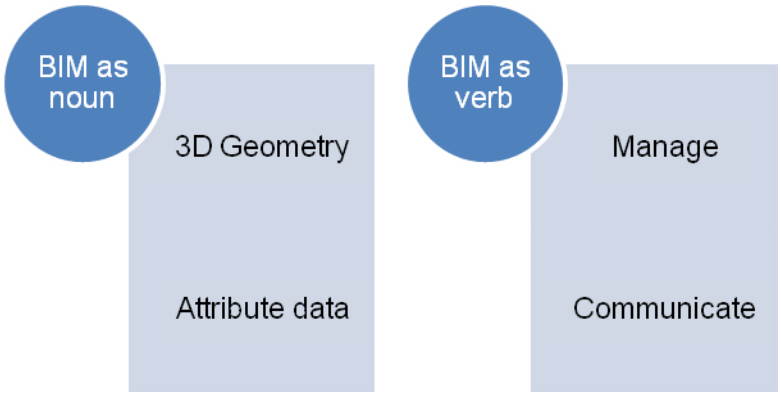

Figure 5: BIM as a noun and as a verb

As a noun, BIM is a defined digital image of the physical and functional features of a facility. The image representation is composed of digital objects matching real world components such as beams, walls, and furniture with connected relationships, characteristics and properties.

As a verb, BIM is any procedure used to create, manage, develop and communicate information among stakeholders at different levels; the procedure's tools are models generated by different project contributors at different times for different reasons to guarantee quality and efficiency all through the lifecycle of the construction process. (Environmental Scan of BIM Tools and Standards, 2011).

2.6.2 Building Information Modelling Benefits

BIM technology has the potential to enable basic changes in project delivery, promising a more integrated, efficient process. As a highly collaborative, data-rich environment, BIM has potential capability to accelerate the process in a way that decisions and changes can be made early without impact on time and cost.

BIM reduces miscommunication and reinforces understanding visually due to the accuracy of the model. The effective communication applied to the diverse parties involved in building projects and management results speed estimates and workflows generated automatically by the model (Rajendran & Clarke, 2011).

For each of the three major phases in the building lifecycle (see figure 6) which are design, construction and management, BIM confers competitive advantages.

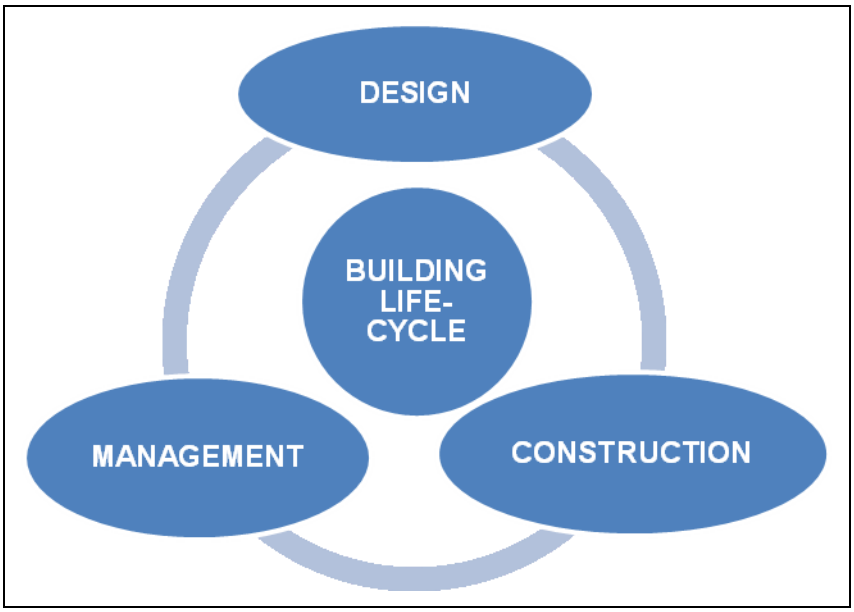

Figure 6: Life cycle of a building

2.6.3 BIM Benefits in the Design Phase

The major and essential duty of the architect during the itinerary of a building project is to balance between the project scope, schedule and cost; inappropriate changes to any of these variables can cost time and money. BIM gives the project team the ability to make changes at any time, at any level during the design or documentation process without any confusion and miscalculation that negatively affects scope, schedule and cost. Whenever a change is made to a project, all the consequences of that change are automatically coordinated throughout the project. In addition, BIM allows the design team to accomplish design and documentation work concurrently instead of serially. (Hergunsel, 2011).

2.6.4 BIM Benefits in the Construction Phase

BIM provides simultaneous information on building quality, schedule and cost which gives the builder the opportunity to accelerate the qualification of the building for estimating and value-engineering purposes and for the production of efficient estimates and construction planning. BIM means that construction schedule and cost are perfectly

controlled as well as administration issues because document quality is higher and construction planning is better. (Hergunsel, 2011).

2.6.5 BIM Benefits in the Management Phase

BIM offers concurrent information on the use or performance of the building in the management phase of the building, information related to its occupants and contents, and information associated with financial aspects of the building. BIM provides a digital record of renovations and improves move planning and management. BIM provides capability to attach an infinite range of data to components of the model and creates a potential data repository that is useful beyond construction documentation. BIM space components can be supplemented to track information such as room numbers and location, area calculation and equipment specifications, among many other elements. Reliable access to this type of information improves both revenue and cost management in the operation of the building. (Sabol, 2008).

2.6.6 Building Information Modelling's Tool

"Building Information Modelling is an approach and not a technology"; it necessitates suitable technology to be executed successfully. Examples of these technologies are, CAD, Object CAD and Parametric Building Modelling. (Autodesk Building Solution, 2003).

CAD Technology: Is software based on the well-known geometry-based Cad technology which was used several decades ago in the design and construction industry. This technology provides drafting automation very effectively. However, greater and greater levels of effort are required to increase efficiency level; also, the discipline and reliability of the users entering the data affect the quality of the information coming from the CAD-based files.

Object CAD Technology: It seeks to simulate building components in a CAD-based environment, focusing on the 3D geometry of the building and generate from it the 2D

documentation. Object CAD Technology permits the extraction of object data from the building components to provide quantities and object properties. This technology has the potential to be applied very effectively to coordinate the various representations of the building and to be extended into building information modelling (BIM); however, its effectiveness depends on user discipline and reliability and it cannot ensure the presence of the high-quality, integrated, and fully-coordinated information needed for the highest levels of building information modelling (BIM) advantages.

Parametric Building Modelling Technology (PBMT)

Parametric building modelling Technology (PBMT) is equivalent to "the decision support systems used in the financial community". These systems combine a data model with a behavioural model that gives meaning to the data through relationship providing building an integrated system to imitate the behaviour of a real-world system; Such system can provide the instant and completely coordinated representation of a project across all views, drawing sheets and schedules which is essential to remove errors and provide clearness and confidence in decision-making. (Autodesk Building Solution, 2003).

2.6.7 Summary

Moving from CAD-based technology to object CAD technology can be an incremental or evolutionary change, but moving to Parametric Building Modelling Technology (PBMT) for building information modelling (BIM) is a revolutionary way of working.

Chapter 3

Comparison Of The Different Accessibility Requirements

3.1 Introduction

This chapter is divided into two parts. The first part is a comparative study covering all types of disability to all types of buildings, focusing on four main references: the Best Practices in Universal Design (UD), the National Building Code (NBC), the Canadian Standard Association CSA/CAGGJ, and Accessible Facility Guidelines (city of London, Ontario, 2007).

The second part is a statement of the accessibility and usability requirements for wheelchair users to residential buildings and houses, presented by the Canadian National Building Code (NBC), the modified versions of the Canadian Provinces Building Codes, and the Universal Design (UD) Concept.

3.2 Accessibility and Usability of the Buildings Facilities to all types of disabilities

The four references this part is based on are the following:

1. The Best Practices in Universal Design

The Best Practices in Universal Design are the building practices and procedures that conform to the seven universal designs' principles and provide reasonable design practices which fulfil the needs of the widest possible range of people who use the facility.

This research refers to a compendium of research data about the latest trends in accessible design, prepared by Betty Dion Enterprises LTD for Agriculture and Agri-Food Canada, the firm which authored the International Best Practices in Universal Design 2006, a Global Review. The raw data, listed in tables 7-19, was confirmed by an

expert panel of a leading internationally recognized expert in the field of universal design (UD) and the built environment. These experts have analysed and determined the Best Practice upon a process of consensus. (Dion, 2006).

2. The National Building Code
3. The Canadian Standard Association (CSA/CAGGJ)

The NBC references to more than 200 standards, The Canadian Standard Association (CSA) being one of them. The Canadian Standard Association (CSA) identifies technical requirements on the way of making buildings and other facilities, accessible and safely usable by persons with physical, sensory, or cognitive disabilities without dealing with the application of these technical requirements, which remains solely the responsibility of competent other authorities having jurisdiction. (CSA, 2010).

4. Accessible Facility Guidelines prepared by city of London, Ontario, 2007

These guidelines standards address accessibility requirements for design and construction of new facilities, as well as the retrofit, alteration or addition to existing facilities, being owned or leased. These guidelines are adopted and applied by the City of London, Ontario to address the needs of persons with disabilities including, but not limited to, persons with mobility impairment, hearing impairment, visual impairment, cognitive impairment, and persons with limited stamina and/or dexterity. (LONDON, 2007).

3.2.1 Specifications of Accessibility Criteria

The following tables 3-15 provide a comparison of the accessibility specifications and criteria, retrieved from the Best Practice of Universal Design (2006) report provided by: (a) the Canadian National Building Code 2010 (NBC); (b) those established under the Canadian Standard Association 2010 (CSA/CAGGJ); (c) those determined by the Accessible Facility Guidelines Standards (AFGS) prepared by the city of London,

Ontario, 2007 (AFG), and (d) those set out under the Best Practices 2006 upon Universal Design Principles (UD).

Table 7: Floor Area's Accessibility Criteria

	Floor Area	CSA	NBC	AFG	UD
1	Minimum clear floor area to accommodate a single stationary manual wheelchair and occupant	750 x 1200	N a	760 x 1370	800 x1300
2	Minimum clear floor area to accommodate a single stationary manual wheelchair and occupant for a U-turn	1500 x 1500	N a	2440 x 2440	1500 x 1500
3	Minimum clear area to allow access for both forward and side approaches	1200 x 1200	N a	1370 x1370	1370 x1370
4	The floor area for an approach may include part of the knee clearance under an element	Yes	N a	Yes	Yes
5	Comfortable walking width for persons using crutches	920	N a	N a	1200
6	Comfortable forward detection range for person using a long white cane	900-1500	N a	N a	900-1500
7	A person who uses a guide dog requires a comfortable clear walkway width of	1200	N a	N a	1200
8	Minimum clear floor area to accommodate a single stationary power chair or scooter and occupant	750 x 1500	N a	660x 1370	800 x 1300
9	Minimum clear floor area to accommodate a single stationary walker and occupant	635x710	N a	N a	635x710

Table 8: Turning Diameter's Specifications

	Turning Diameter	CSA	NBC	AFG	UD
1	Minimum diameter for clear turning space at toe level for a wheelchair to turn 180/360	1500	1500	2440	1500
2	Minimum diameter for clear turning space at toe level for a power wheelchair to turn 180/360	2250	N a	N a	2250
3	Minimum diameter for clear turning space at toe level for a scooter to turn 180/360	3150	N a	N a	3150

Table 9: Obstruction's Specifications

	Obstruction	CSA	NBC	AFG	UD
1	No obstruction shall project into the comfortable walking width for a person using a white cane greater than	100	N a	100	No obstructions allowed
2	For a person using crutches, no obstruction shall project into the clear of the path of travel below a minimum height of	300	N a	N a	No obstructions allowed
3	To be cane detectable, obstructions shall be no higher off the floor than	680	N a	680	350

Table 10: Reach Specifications

	Reach	CSA	NBC	AFG	UD
1	From a wheelchair, the maximum forward reach height above the floor without obstructions is	1200	N a	1200	1200
2	From a wheelchair, the minimum forward reach height above the floor without obstructions is	400	N a	400	400
3	From a wheelchair, the maximum forward reach over an obstruction for touch is	600	N a	635	500
4	From a wheelchair, the maximum forward reach over an obstruction for grasp is	500	N a	N a	500
5	From a wheelchair, the maximum side reach height above the floor without an obstruction is	1400	N a	1370	1220

	Reach	CSA	NBC	AFG	UD
6	From a wheelchair, the minimum side reach height above the floor without an obstruction is	230	N a	230	300
7	From a wheelchair, the maximum side reach over an obstruction for touch is	600	N a	610	500
8	From a wheelchair, the maximum side reach over an obstruction for grasp is	500	N a	N a	500

Table 11: Controls Specifications

	Controls	CSA	NBC	AFG	UD
1	All the controls and operating mechanisms for dispensing machines for the minimum clear level floor space shall be	750 x 1200	N a	760 x 1370	800 x 1300
2	The centreline of operating controls shall be located above the floor between	400-1200	N a	400-1200	400-1200
3	Controls shall be operated with one hand and without tight grasping, pinching or twisting of the wrist	Yes	N a	Yes	Yes
4	Controls shall be operable with a force (N=Newton) of no more than	22 N	N a	22 N	19.5n
5	Control settings shall provide tactile and/or auditory information, including function and position of controls	Yes	N a	N a	Yes
6	Operating controls shall be illuminated (lx= Lux) to a level of at least	100 lx	N a	100 lx	150 lx
7	Operating controls or visual displays where reading is necessary shall be illuminated to a level of at least (lx= Lux)	200 lx	N a	100 lx	200 lx
8	The operating controls shall be colour contrasted with their background	Yes	N a	Yes	Yes

Table 12: Footprint and Knee Space Requirements

	Footprint and Knee Space Requirements at Counters, Tables, Workstations, Lavatories	CSA	NBC	AFG	UD
1	The top counter, table and work surface or similar surface height are between	730-860	865 max	710-865	730-850
2	Where a forward approach is used at a counter or table, there shall be a clear knee height above the floor of at least	680	N a	685	700
3	Where a forward approach is used at a counter or table there shall be a clear knee width above the floor of at least	750	N a	760	800
4	Where a forward approach is used at a counter or table, there shall be a clear knee depth above the floor of at least	480	N a	480	480
5	Where a forward approach is used at a counter or table, there shall be a clear knee depth which may overlap the clear floor area by not more than	480	N a	480	480
6	The clear floor area width and depth for a forward approach at a counter or table shall be at least	750 x 1200	N a	760 x 1370	800 x 1300
7	The clear floor area width and depth for a side approach (the long side parallel to the counter or table) at a counter or table shall be at least	1200 x 750	N a	1370 x 760	1300 x 800

Table 13: Wheelchair Dimension

	Wheelchair Dimension	CSA	NBC	AFG	UD
1	Folded wheelchair width	300	N a	N a	300
2	Wheelchair open width	660	N a	760	600-750
3	Height of eyes of a person sitting in a wheelchair	1100-1300	N a	N a	1000-1300
4	Lap height of a person sitting in a wheelchair	675	N a	N a	555-705
5	Seat height of a person sitting in a wheelchair	480	N a	N a	450-500
6	Handle height of a wheelchair	920	N a	N a	900-1100
7	Armrest height of a wheelchair	760	N a	N a	700-760
8	Length of a wheelchair	1200	N a	1370	1100-1300
9	Toe height of a person sitting in a wheelchair	200	N a	N a	180-220

Table 14: Access Route Specifications

	Access Routes	CSA	NBC	AFG	UD
1	The floor and ground surfaces shall be stable, firm and slip-resistant	Yes	Yes	Yes	Yes
2	The floor and ground surfaces shall produce minimal glare	Yes	N a	Yes	Yes
3	The floor and ground surfaces shall not be heavily patterned	Yes	N a	N a	Yes
4	A change in level or rise between 0-6 mm on accessible routes may be vertical (except for elevators, elevating devices, and curb ramps)	Yes	Bevelled at slope of up to 1:2	Yes	Yes
5	A vertical rise between 7-13 mm on accessible routes (except for elevators, elevating devices, and curb ramps) shall be	Bevelled at slope of up to 1:2	Bevelled at slope of up to 1:2	Bevelled at slope of up to 1:2	Bevelled at slope of up to 1:2
6	For a vertical rise over 13 mm on accessible routes (except for elevators, elevating devices, and curb ramps)	Not steeper than the ratio of 1:12	Treat as a ramp or curb ramp	Treat as a ramp	Treat as a ramp not steeper than 1:12
7	Cross slope of an accessible route not to exceed the ratio of	1:50 (2 per cent)	N a	1:50	1:50
8	Running slope of an accessible route not to exceed the ratio of	1:20 (5 per cent)	N a	1:25	1:20
9	Running slope of an accessible route becomes designated as a ramp or curb ramp if steeper than	1:20	N a	1:25	1:20
10	Grating in a pedestrian area shall be in one direction, and have spacing widths no greater than	13	N a	13	10
11	Grating shall be placed so that the long dimension is perpendicular to the primary direction of travel	Yes	N a	Yes	Yes
12	Carpet or carpet tile are securely fastened	Yes	N a	Yes	Yes
13	Carpet or carpet tiles shall have a	Yes	N a	Yes	Yes

	Access Routes	CSA	NBC	AFG	UD
	firm cushion, under padding, or backing				
14	Carpet or carpet tiles shall have a combined carpet and pad height of no more than	13	N a	13	6 (pile height)
15	Carpet and carpet tile shall have a low, firm, and level pile or loop	Yes	N a	Level loop, textured loop, level cut pile or level cut/uncut pile	Level loop, textured loop, level cut pile or level cut/uncut pile
16	The exposed edges of carpet or carpet tile shall have trim on the exposed edge, where trim 0-6 mm may be vertical, 7-13 mm bevelled but not steeper than the ratio of 1:2	Yes	N a	Yes	Yes
17	Building elements such as circulation routes and rest areas shall be illuminated at ground level to a level of at least	100 lx	N a	50 lx	150 lx

Table 15: Head Room Specifications

	Head Room	CSA	NBC	AFG	UD
1	The clear headroom height in pedestrian areas such as walkways, halls, corridors, or aisles shall be at least	2030	1980	2100	2030
2	Where headroom in a pedestrian area is less than 2030 mm from the floor, a guardrail or other barrier shall be provided with its leading edge no higher above the floor than	680	680	680	350

Table 16: Protruding Objects Specifications

	Protruding Objects	CSA	NBC	AFG	UD
1	The leading edge of a guard, barrier or protruding object shall be at a height of	680	680	680	350
2	For a protruding object at a height between 680-2030, the maximum allowable protrusion into the accessible route shall be	100	100	100	100
3	Protruding object at a height below 680 shall protrude into the accessible route a maximum of	Any amount	Any amount	Any amount	Any amount
4	Protruding objects shall not reduce clear width of an accessible route	Yes	N a	Yes	Yes
5	Minimum clear width of interior accessible route	920	920	1060	1200
6	Minimum clear width for short indentations of up to 600 mm in length, (including doorways)	810	N a	950	815

Table 17: Clear Width Specifications

	Clear Width/Clear Area	CSA	NBC	AFG	UD
1	Minimum clear width at U-turns around an obstacle less than 1200 mm wide	1100	N a	1220	1200
2	Minimum clear width at turns around an obstacle greater than 1200 mm wide	920	N a	1060	1060
3	Minimum clear width in high traffic areas shall be at least	1500	1100	1830	1830
4	Minimum clear width on exterior accessible routes shall be at least	1500	N a	1060	1500
5	Minimum clear width on exterior accessible to a curb ramp shall be at least	920	N a	950	1200
6	Exterior accessible routes adjacent to a vehicular route, shall be separated by a curb with a curb ramp, a railing or barrier, or a detectable hazard indicator	Yes	N a	N a	Yes
7	Minimum clear width required on accessible routes for two wheelchairs to pass	1500	N a	1830	1800
8	Minimum clear width required on accessible routes for one wheelchair and one walking person to pass	1500	1500	1370	1525
9	Minimum clear width required for a wheelchair and	1500	N a	N a	1800

	Clear Width/Clear Area	CSA	NBC	AFG	UD
	a person using a white cane to pass in opposite directions				
10	The minimum clear width for an accessible route except for short indentations of up to 600 mm in length	810	N a	950	1200
11	The clear floor area to accommodate a single person using a wheelchair (including area in front of operating controls and accessible signage) shall have a width by depth of at least	750 x 1200	N a	760 x 1370	800 x 1300
12	For long paths of travel, resting areas shall be provided off the path of travel at approximate	30000	N a	N a	30000

Table 18: Line-Up Guides Specifications

	Line-Up Guides/Queuing Guides	CSA	NBC	AFG	UD
1	Line-up guides shall have a clear width of at least	920	N a	1060	920
2	Line-up guides shall have a clear floor area where line-ups change direction, and where they begin and end of at least	1500 x 1500	N a	N a	1500 x 1500
3	Line-up guides shall be stable and not move easily	Yes	N a	Mounted to the floor	Yes
4	Line-up guides shall be colour contrasted with their surrounding	Yes	N a	Yes	Yes
5	Line-up guides shall have a glare-free surface	Yes	N a	Yes	Yes
6	Line-up guides shall be cane detectable from the floor at or below	680	N a	N a	350

Table 19: Other Requirements

	Other Requirements	CSA	NBC	AFG	UD
1	Detectable hazard indicators shall be located at curb ramps (see the section on curb ramps for further requirements)	Yes	N a	Yes	Yes
2	Where a curb ramp, a pedestrian street crossing, or a pedestrian crossing a traffic island/median become part of an accessible path of travel	Yes	N a	Yes	Yes
3	Detectable hazard indicators shall be located at an unprotected drop-off edge (such as a transit platform) where there is a change in elevation greater than	250	N a	N a	50
4	Detectable hazard indicators shall be located at an unprotected drop-off edge (such as a transit platform) where the slope is steeper than the ratio of 1:3 (33%)	Yes	N a	N a	Yes
5	Detectable hazard indicators shall be located at an unprotected drop-off edge of a reflecting pool	Yes	N a	N a	Yes
6	Detectable hazard indicators shall be located at an entry into a vehicular route or area where no curbs or other elements separate it from the pedestrian route travel	Yes	N a	N a	Yes

3.3 Accessibility and Usability of Wheelchair Users to Residential Buildings and Houses

3.3.1 Introduction

The comparison accomplished in this part focuses on accessibility and usability of wheelchair users to residential buildings and houses, referring to the Canadian National Building Code (NBC), the modified versions of the Canadian Provinces Building Codes, and the Universal Design (UD) Concept.

The ten Canadian provinces and three territories have jurisdiction over construction in Canada's constitution. Some municipalities have this authority through a special

relationship with their provincial authority. The provincial and territorial authorities are responsible for adopting and enforcing laws and regulations, as well as providing interpretation of such laws and regulations. (Canada's National Model Construction Codes, 2010).

3.3.2 Types of Buildings

Refering to the building classification, detailed in Chapter 2, section 2.2.3, the following comparison is covering two types of residential buildings. Residential buildings under Part Nine of the NBC, which consists of houses, including detached, semi-detached, duplexes, town houses, row houses and boarding houses; and residential buildings under Part Three of the code, which consists of buildings larger than 600 m^2 of area, or three-storey buildings.

3.3.3 Accessibility to Single-Family Homes

1. The National Building Code (NBC) Approach

In the NBC, all houses, including detached, semi-detached, duplexes, town houses, row houses and boarding houses, are exempted from Barrier-Free requirements. Also, buildings that are not intended to be occupied on a daily or full-time basis, and industrial buildings of high risk are exempted from Barrier-Free requirements (article 3.8.1.1.1. NBC 2010).

2. The Canadian Provinces Modifications

No amendments, modifications or additions have been required in the Canadian Provinces' codes concerning the accessibility to single-family homes; therefore, all houses, including detached, semi-detached, duplexes, town houses, row houses and boarding houses, are exempted from Barrier-Free requirements.(Welcome to Visitability Canada, 2007).

3. The Universal Design Concept Approach

One of the key aims of the universal design (UD) concept, which reflects its founding principles, is to make day-to-day living and home tasks possible and safer for everyone, and to make product and environment, including homes, usable by everyone. This could be materialized by creating innovative solutions in order to facilitate the daily living and independence of everyone, by making all types of residential buildings to be accessible and usable. (Residential Rehabilitation, 2006).

In collaboration with The Division of Vocational Rehabilitation, Independent Living Services, the Centre for The Universal Design (North Carolina University) established a list including fourteen items, covering the most critical housing features, which should be implemented as priority, when constructing a new residential building, and modifying or rehabilitating a single- or multi-family dwelling. (Residential Rehabilitation, 2006).

The main priority features included in the list are the following:

- At least one step-less entrance on an accessible route
- Close parking to the accessible entrance
- Short wide hallways
- A large bathroom on the ground floor.

The 14-item priority list includes selecting universal design (UD) features that should be implemented, in whole or in part, to be included in dwellings, as shown in table 16. They range over three levels of priority, varying from 1 (highest) to 3 (lowest).

Table 20: The 14-item priority list

Priority Features List			
Area	**Item**	**Priority**	**Universal Housing features**
Entrances	1	1	One entrance without steps and a flat or very low threshold
	2	1	Minimum 1500 x 1500 mm manoeuvring space at step-less entrance
General interior	3	2	Hall width of 1100 mm
	4	1	Passage doors 815 mm clear (typical provided with 910 mm door)
	5	2	Manoeuvring space at doors, in case of door that obstructs a bathroom or kitchen fixture or appliance, use offset hinges, swing door out, hinge door on opposite jamb, or widen doorway
	6	2	Increase number of electrical outlets for additional lighting and alarm indicators, especially in bedrooms
Kitchens	7	1	Clear floor space in kitchen, many configurations possible, 1500 mm minimum turning circle recommended
	8	2	Adaptable cabinets to reveal knee space at sink and under work surface near cooking appliance
Bathrooms	9	1	Clear floor space in room, modest increase in room size beyond 1500 x 240 mm
	10	2	Adaptable cabinets with under knee space
	11	2	Broadly applied bands of blocking (reinforcement) inside walls around toilets and bathing fixtures for future installation of grab bars.
	12	3	Offset controls in tub or shower to minimize stooping, bending, and reaching
	13	2	Toilet in a 1200 x 1400 mm space with centreline of toilet 450 mm from sidewall
	14	2	Curb-less showers, if installed, at least 900 x 1500 mm

The Visit Ability

Another vision for accessible single-family homes, under the concept of Universal Design (UD), is the "visit ability". Visit ability is a new vision of Canada as a country with a vibrant housing sector which aims to meet the needs of all Canadians; visit ability ensures that everyone will be able to visit someone else's home, use the washroom and exit the home, regardless of its mobility situation. (Welcome to Visitability Canada, 2007).

Visit ability refers to newly constructed single-family homes with at least the following minimum features:

- One step-less entrance of the house (located on an accessible route from the street)
- All main floor door openings to be minimum 815 mm wide
- A half bathroom on the main floor with minimum requirements. (Welcome to Visitability Canada, 2007).

3.3.4 The Accessibility to Residential Units within Residential Buildings

1. The National Building Code (NBC) Approach

Residential buildings analysed in this section are buildings covered by Part Three of the NBC, buildings larger than 600 m^2 area or three-story buildings. Such types of buildings need to be accessible. They are covered by section 3.8 on the Barrier-Free requirements.

Barrier-free requirements provide accessible entrance to residential buildings, under section 3.8 of the NBC. The requirements provide accessibility to the floors, circulation in the common areas, such as corridors (article 3.8.1.2) with several exemptions.

The Exemptions from wheelchair accessibility are spaces which are not normally public such as, 1) service rooms, 2) elevator machine rooms, 3) janitor's rooms, 4) service spaces, 5) crawl spaces, 6) attic or roof spaces, and 7) high hazard industrial occupancies. (articles 3.8.2.1(2)g, 3.8.2.1(2)l, 3.8.2.1(k), 3.8.2.3(2)(a) NBC 2010).

Residential suites within the residential buildings, to which section 3.8 applies, have been exempted from the above requirements; therefore, the whole buildings are required to be accessible, but not the residential units, within those mentioned buildings (article 3.8.2.1 NBC2010).

Washrooms within accessible buildings are not needed to conform with the Barrier-Free requirement if they are located within a suite of residential occupancy (article 3.8.2.3.2 NBC 2010).

Door width, when located in a Barrier-Free path of travel should have a minimum of 800mm clear width. (article 3.8.3.3.1 NBC 2010). Since the residential units within residential buildings are exempted from the Barrier-Free requirements, door width in the residential buildings follows the regular units' requirements, which is 810mm for entrance doors, and 610mm for bathrooms doors. (article 9.6.3.1 NBC 2005).

2. The Canadian Provinces' Approach

Different approaches have been adopted by various Canadian Provinces and Territories, to deal with Accessibility and Usability of residential units within accessible residential buildings.

Different Canadian provinces require that different percentages of units in apartment buildings be constructed as Barrier-Free or accessible units. (Moyes, 2011). The different provinces' status, regarding the adoption of Barrier-Free and Universal Design (UD) concept for residential buildings and units, are briefly listed as follow:

1) British Columbia (BC)

In 2009, new adaptable Housing Standards were adopted by the BC Building Code; Division B is amended by adding the new subsection (3.8.5) "Adaptable Dwelling Units", to section 3.8. The new standards contain additional accessibility requirements to be applied to the individual units as well as to building entrances, corridors and common areas. (Ministry of Energy and Mines, 2009).

2) Alberta

Currently Alberta uses NBC accessibility requirements, in addition to some modification revisions of article 3.8.1.1(3), which now requires that a specified number of units be "adaptable" in new government-funded residential projects. Specific requirements for adaptable units are contained in a STANDATA, the official document developed by the Alberta Municipal and Public Affairs Division, for The Development and Dissemination of Code Interpretations and Alternatives. (Building Standata, 2011).

3) Saskatchewan

Saskatchewan adopts a slightly amended version of the NBC with some modifications. In 1998 the code was amended by specifying that at least 5 per cent of the units in rental apartment buildings shall be Barrier-Free. Condominium apartment buildings are exempted from this requirement. Requirements cover accessible washrooms, space in bedrooms and kitchens, finishes in kitchens, and Barrier-Free balconies. The modifications are explained in article 3.8.1.5 under Residential Occupancies. (Saskatchewan, 2010).

4) Manitoba

On March 31, 2011, the Government of Manitoba published the Manitoba-Regulation for the adoption of the 2010 NBC. The scope of several articles has been widened in chapter 3.8 with a view to enhance the adoption of the "Universal Design" (UD) by adding additional accessibility requirements.

The city of Winnipeg adopted the universal design (UD) policy in 2001. The accessibility Design Standards 2010 addresses accessibility requirements for the design and construction of new facilities owned, leased or operated by the city of Winnipeg. (Winnipeg, 2010).

5) Ontario

Under the accessibility for Ontarians with Disabilities Act, 2005 (AODA), the Ministry of Community and Social Services has been coordinating efforts to produce a

wide range of plans and standards to achieve an "Accessible Ontario" by 2025. The current code requires 10 per cent of units in new multi-unit buildings to have an internal Barrier-Free path of travel, which triggers other requirements for door sizes and washrooms. (Accessibility for Ontarians with Disabilities Act, 2005).

6) Quebec

Quebec adopted the NBC 2005 on May 2008 without any additional accessibility requirements, which means that 0 per cent of residential units are recommended to be accessible in Quebec. Proposals for adaptability in multi-unit buildings were submitted to the Advisory Council of the Régie du Bâtiment du Québec in June 2011 at the present date, no decision has been made yet. (Moyes, 2011).

7) New Brunswick

New Brunswick adopted the NBC 2005 in 2009, by virtue of which the Government is developing new building regulations to make public buildings more accessible. Under The Community Planning Acts, one of the proposed regulations is about providing one Barrier-Free unit in apartment buildings or condominium complexes for every 20 units (5 per cent). (Accessibility News Blog, 2011).

8) Nova Scotia

There is no province-wide building code in Prince Edward Island (PEI). Three municipalities -Summerside, Stratford and Prince Edward Island - adopted the NBC 2010 in 2011. These three municipalities have added requirements such as one in every 12 units in new apartment buildings shall be Barrier-Free as defined in section 3.8 of the NBC. (Model Adoption Across Canada, 2012).

9) Newfoundland

Accessibility in Newfoundland and Labrador was not regulated through a building code, but through the Building Accessibility Act passed in 1996; under this Act, all apartment buildings with more than 15 units constructed or renovated must provide at least one accessible unit. (Moyes, 2011). In 2007, Newfoundland and Labrador adopted

the National Building Code (NBC) 2005, except aspects related to means of egress which shall comply with NFPA 101, Life Safety Code, and to one- and two-family dwellings within Group C in Part nine. (Newfoundland and Labrador, 2007), and in 2010 Newfoundland and Labrador adopted the National Building Code (NBC) 2010 except part nine for one- and two-dwelling units. (About the Codes: Model Code Adoption Across Canada, 2012).

10) The Canadian Territories

The three Canadian territories- Northwest Territories, Nunavut and Yukon - adopted the National Building Code (NBC) 2010 on April 2010 with some modifications and additions. (About the Codes: Model Code Adoption Across Canada, 2012).

3.4.3 The Universal Design Concept Approach

It is basic and essential for the universal design (UD) concept that all newly constructed multifamily housing developments to include accessible units, which shall not be segregated from other units. Two types of dwelling units are added to the conventional or traditional dwelling which are type "A", fully accessible, and type "B", accessible. (Accessible Multifamily Housing, 2000).

Type "A" units are designed to provide a higher level of accessibility to accommodate people who use wheelchairs or scooters, and offer a greater level of independent use to people whose disability significantly affects their mobility. Type "A" units provide clearer floor space, and require knee spaces in kitchens and bathrooms.

Type "B" units provide a moderate level of accessibility. Type "B" units have less required clear floor space, while knee space depends on the room size.

In 2000, the Centre for Universal Design, College of Design, North Carolina State University, produced a detailed report about Accessible Multifamily Housing. The report was prepared for the North Carolina Independence Living Rehabilitation Program, which sought a detailed explanation of its vision of "Residential Accessibility"; the requirements

for types "A" and "B", specified by the Centre for Universal Design in the above-mentioned report, are listed in table 17.

Table 21: Acceptable Requirement for Types A and B

Universal Design Accessibility Requirements	**Type "A" Fully Accessible**	**Type "B" Accessible**
Accessible parking	Minimum one for each unit	2 per cent of the overall number of unit B
Accessible entry	Minimum one	Primary entry
Accessible route into the living space	Yes	Yes
Accessible doors = at least 815 mm	Yes , to be easy to use	Yes
Environmental controls (light switches, electrical outlets, thermostats, etc.)	Must be accessible and easy to use	Must be accessible
Kitchen		
Have 1500 mm turning space	Yes	Yes
Floor space at appliances	760 x 1200 mm	760 x 1200 mm
Accessible worktop with knee space	Yes	No requirement
Sink with knee space below	Yes	In case of a narrow U shape kitchen
Accessible storage shelf to be at 1200mm	Yes	No requirement
Accessible hardware on cabinetry	Yes	No requirement
Accessible cooking appliances	Yes	760 x 1200 mm clear floor
Bathroom		
Fully accessible bathroom	The principle bathroom	No requirement
Usable bathroom (allow entry and approach to all fixtures)	All other bathrooms	Yes
Clear floor turning space	1500 x 1500 mm	760 x 1200 mm
Reinforced grab bars beside toilets and bathing fixtures	Yes	Yes

Factors affecting the selection of unit types "A" and "B"

Various factors influence the selection of a particular type of units (A or B), and the number of each type. Such factors include the type of property (public ownership or private), the purpose of the units (are for sale, for rent, or for lease). The total number of

dwelling units in the complex or development and the terrain location are major factors for the selection criteria of units' type. The selection criteria of units' type are listed in table 18.

Table 22: *Selection and Distribution of Units' Type*

Type of Ownership	For Rent or Sale	Numbers of Accessible Units	Type "A" or "B"
Privately-owned	Rent, lease or sale	1 to 3 units	None
	Rent or lease	4 to 10 units	All "B"
		11 units or more	5 per cent "A", the remainder "B"
	Sale	4 units or more	All "B"
Publicly-owned	Rent or lease	4 units or more	5 per cent "A", the remainder "B"
	Sale	1 unit or more	All "B"

The definition of "Ground Floor" is critical for the distribution of dwelling units, in case of building with or without elevator.

In buildings with one or more elevators and containing four or more units, all these units are to be type "B". Buildings without an elevator and all ground floor units are to be type "B". (Accessible Multifamily Housing, 2000).

3.4.4 Summary

The foregoing chapter has given a detailed comparison at two different levels: the first one is the accessibility requirements for all types of buildings for all types of disabilities between four references: the Best Practice of Universal Design (2006), the National Building Code (NBC), the Canadian Standard Association and the Accessible Facility Guidelines (CSA/AFG), London, Ontario 2007.

The second level has presented a comparison of the accessibility requirements for residential units for wheelchair users, between the Universal Design (UD) Concept, the National Building Code (NBC) and the Canadian Provinces Codes.

Chapter 4

Analysis Of The Accessibility Requirements

4.1 Introduction

The subsequent chapter is an analysis of the accessibility requirements described in the previous chapter by different references at two different levels: Accessibility and Usability of Building Facilities to all Types of Disabilities and Accessibility and Usability of Residential Buildings for Wheelchair Users. Based on the analysis results, conclusions are made, followed by a list of recommendations.

4.2 Analysis of the Accessibility and Usability of Building Facilities for all Types of Disabilities

In light of the comparison presented in tables 2-14, which covered all types of disabilities for all types of buildings, the focus was on four main references: the Best Practices in Universal Design (BPUD), the National Building Code (NBC), the Canadian Standard Association CSA/CAGGJ, and Accessible Facility Guidelines (AFG) (city of London, Ontario, 2007). Percentages are retrieved from each table to illustrate the following: (1) "X" is the level of research and discussion conducted by the NBC, CSA and AFG on accessibility and usability of building facilities; (2) "Y" is the conformity requirements level of the discussed ones, done by NBC, CSA and the AFG.

In each table there are a total number of requirements, number of contributions of each of the references and number of requirements that conform to the Universal Design (UD) requirements.

T= total number of requirements

U= number of contributions

V= number of requirements that conform to the UD requirements

"X" is the percentage of the discussed specifications done by each of the three references - NBC, CSA AND AFG.

"X" = U (number of contribution)/T (number of requirements) per cent

"Y" is the percentage of the specification's conformity to the best practice of universal design's specifications, of the discussed ones.

"Y" =V(number of confirmed requirements to UD requirements)/U (number of contribution) per cent

tables 19-21 represent the percentages "X" and "Y" concerning the accessibility and usability of buildings facility requirements

Table 23: The Level of Discussion (X) and of Adoption (Y) by NBC

Accessibility and Usability Requirements Adopted by The National Building Code (NBC)						
No.	**Requirements**	**T**	**U**	**V**	**X**	**Y**
1	Floor area	9	0	0	0%	0%
2	Turning Space	3	1	1	33%	100%
3	Obstruction Specifications	3	0	0	0%	0%
4	Reach	8	0	0	0%	0%
5	Controls specifications	8	0	0	0%	0%
6	Footprint and knee space requirements	7	1	1	14%	100%
7	Wheelchair Dimension	9	0	0	0%	0%
8	Access route specifications	17	4	4	24%	100%
9	Head room specifications	2	2	0	100%	0%
10	Protruding Objects	6	4	2	67%	50%
11	Clear width specifications	12	2	0	17%	0%
12	Line-up guides specifications	6	0	0	0%	0%
13	Other requirements	6	0	0	0%	0%
14	Total				20%	27%

Table 24: *The Level of Discussion (X) and the Level of Adoption (Y) Provided By CSA*

Accessibility and Usability Requirements by The Canadian Standard Association (CSA)						
		T	**U**	**V**	**X**	**Y**
1	Floor area	9	9	5	100%	56%
2	Turning Space	3	3	3	100%	100%
3	Obstruction Specifications	3	3	0	100%	0%
4	Reach	8	8	4	100%	50%
5	Controls specifications	8	8	5	100%	63%
6	Footprint and knee space requirements	7	7	2	100%	29%
7	Wheelchair Dimension	9	9	9	100%	100%
8	Access route specifications	17	17	13	100%	76%
9	Head room specifications	2	2	1	100%	50%
10	Protruding Objects	6	6	3	100%	50%
11	Clear width specifications	12	12	3	100%	25%
12	Line-up guides specifications	6	6	5	100%	83%
13	Other requirements	6	6	5	100%	83%
14	Total				100%	59%

Table 25: The Level of Discussion (X) and the Level of Adoption (Y) Provided by AFG

Accessibility and Usability Requirements Adopted by the Accessible Facility Guidelines (AFG)						
		T	**U**	**V**	**X**	**Y**
1	Floor area	9	5	3	56%	60%
2	Turning Space	3	1	1	33%	100%
3	Obstruction Specifications	3	2	0	67%	0%
4	Reach	8	6	2	75%	33%
5	Controls specifications	8	7	3	88%	43%
6	Footprint and knee space requirements	7	7	2	100%	29%
7	Wheelchair Dimension	9	2	0	22%	0%
8	Access route specifications	17	16	11	94%	69%
9	Head room specifications	2	2	0	100%	0%
10	Protruding Objects	6	6	3	100%	50%
11	Clear width specifications	12	9	4	75%	44%

Accessibility and Usability Requirements Adopted by the Accessible Facility Guidelines (AFG)						
		T	U	V	X	Y
12	Line-up guides specifications	6	4	4	67%	100%
13	Other requirements	6	2	2	33%	100%
14	Total				70%	48%

Based on tables 19-21 total percentages are retrieved to show the conformity level of the accessibility requirements listed by NBC, CSA and AFG compared to the ones listed by the Best Practice of Universal Design (UD). Z is the percentage of the percentages.

"Z" = percentage of conformity to the Best Practice of Universal Design = "Y" x "X" /100 as detailed in table 22 and figure 7.

Table 26: Conformity to the Best Practice of Universal Design

Conformity to the Best Practice of Universal Design			
	"X"	"Y"	"Z"
NBC	20%	27%	5.4%
CSA	100%	59%	59%
AFG	70%	48%	33.6%

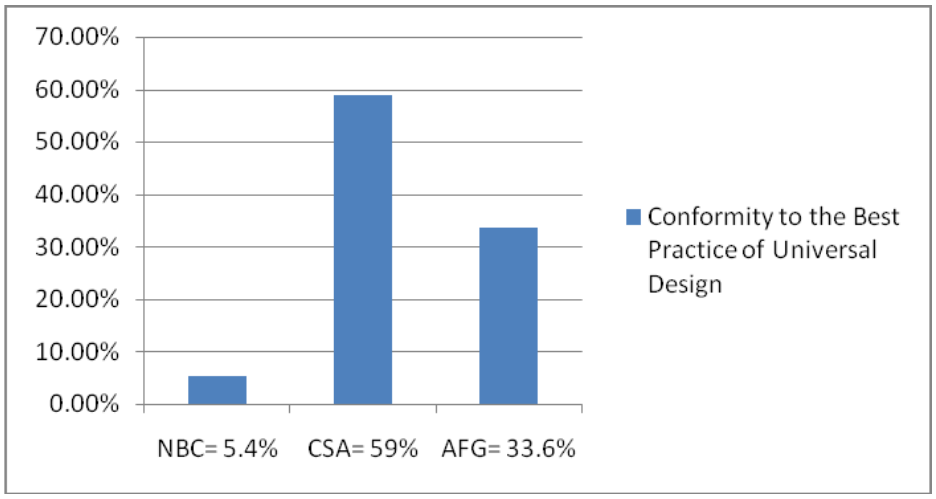

Figure 7: Conformity of the accessibility requirements of NBC, CAS and AFG to UD

4.2.1 Conclusion

In Canada, the national disability rate was 14.3 per cent in 2006. By 2051, about one of four Canadians is expected to be 65 years or over. (Population Projections, 2010). It is not proportional that the National Building Code (NBC), which is the official authority to "guarantee" Occupant Accessibility (OA) (National Model Construction Code Documents, 2012), adopts just 5.4 per cent of the accessibility and usability requirements of building facilities, even though the CSA, which is one of the main references of the NBC, adopts 59 per cent of the accessibility requirements. The AFG, which represents an example of accessible facility guidelines (AFG) adopted and applied in a Canadian city - London, Ontario - the mentioned guidelines adopts 33.6 per cent of the UD accessibility requirements.

4.3 Analysis of the Accessibility and Usability of Residential Buildings for Wheelchair Users

4.3.1 Accessibility to Single-Family Homes

Under the National Building Code (NBC) and the Canadian Provinces' Codes, the vision for accessible Single-Family Homes is clear; private residences have been radically exempted from such a view. The universal design (UD) vision is totally different; it implies that product and environment, including homes, are to be usable by all people without the need for adaptation. The three visions to Accessibility of Single-Family Homes adopted by the UD Concept, the NBC and Canadian Provincial codes, are listed in figure 8.

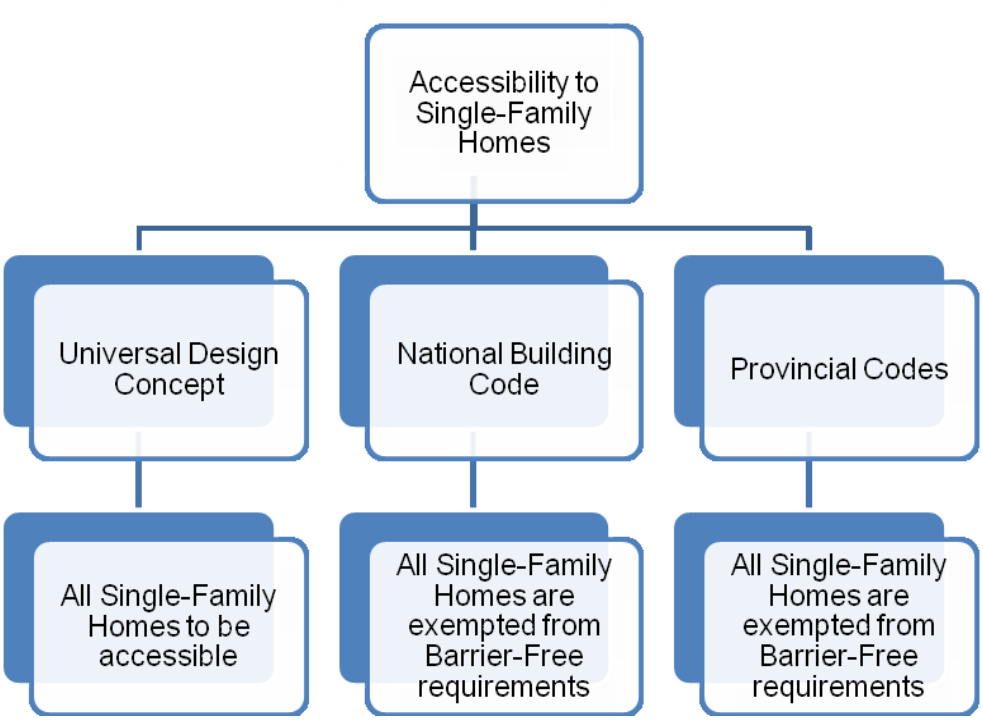

Figure 8: Different visions for accessibility to Single-Family Homes

4.3.2 Accessibility to Residential Units within Residential Buildings

Under the NBC, wheelchair users face obstacles in their path to access and use residential units within residential buildings. Such obstacles are addressed mainly under the three articles of the NBC 2010 (3.8.2.1, 3.8.3.3.1 and 3.8.2.3.2) table. Canadian provinces adopted different approaches to modify or suggested modifications to the NBC, and to improve the inclusion and integration of persons with disabilities in society, as detailed in the next paragraph.

The universal design (UD) vision is always different and encourages the full inclusion of people with disabilities; to achieve the inclusion goal, two types of residential units are presented by the UD Concept, "A" and "B", taking into consideration all factors affecting the selection of such types. The different visions are detailed in figure 9.

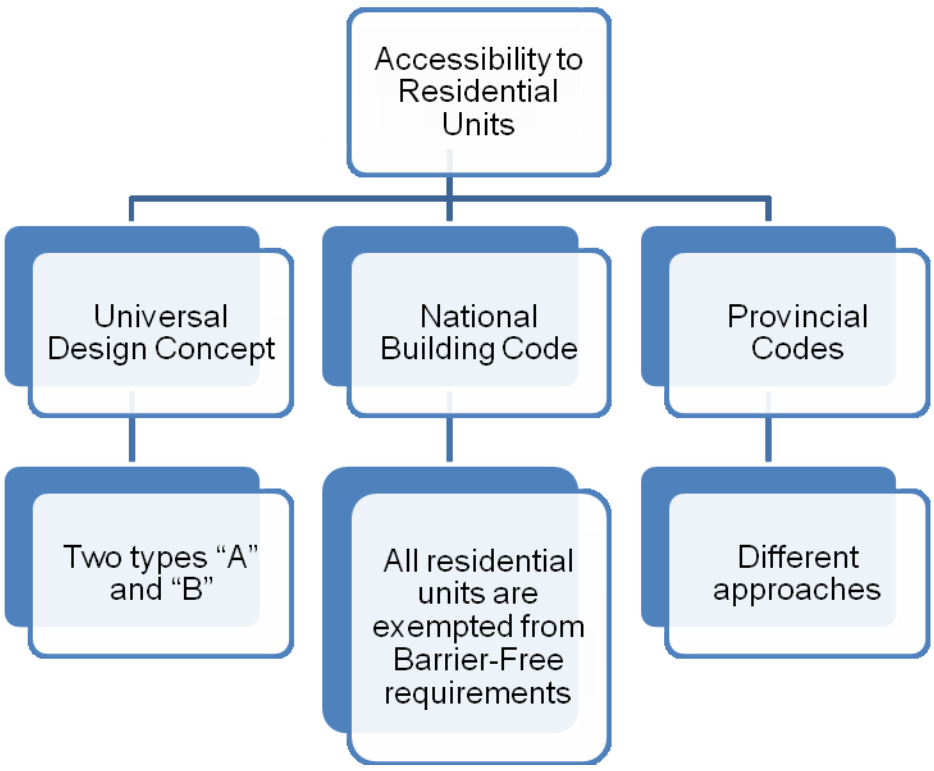

Figure 9: The different visions to accessibility to residential units

Canadian Provinces Approaches

The different approaches of Canadian provinces are listed in the following:

- British Columbia: additional requirements without specifying any percentage of units to be accessible
- Saskatchewan: 5 per cent of units to be accessible
- Ontario: 10 per cent of units to be accessible
- Alberta: additional requirements without specifying any percentage of units to be accessible
- Manitoba : additional requirements without specifying any percentage of units to be accessible
- Quebec: 0 per cent of units to be accessible
- New Brunswick: 5 per cent of units to be accessible
- Newfoundland: one unit if total number of units is greater than 15 units
- P.E.I: 1/12 of units to be accessible

- Nova Scotia: 5 per cent of units to be accessible
- Territories: additional requirements without specifying any percentage of units to be accessible

4.3.3 Conclusion

One hundred per cent of the population reside in residential buildings in Canada and everywhere in the world. Residential buildings are buildings used for dwelling purposes. Two types of residential buildings can be distinguished: a) Houses, including detached, semi-detached, duplexes, town houses, row houses and boarding houses; and b) all residential buildings other than ground-oriented residential buildings, including multi-storey buildings and high-rise buildings.

Under the Canadian National Building Code (NBC), all houses are exempted from the accessibility requirements, as well as all residential units within residential buildings. Under the Canadian National Building Code (NBC) 0 per cent of residential units (homes and apartments) are accessible. The Canadian national disability rate and the ageing population rate are expected, in the near future to represent more than one quarter of the population; The Canadian National Building Code (NBC) does not guarantee any accessibility to residential units (homes and apartments) for 25 per cent of the population.

4.4 List of Recommendations

This research proposal consists that all residential units be accessible and usable by wheelchair users, based on universal design (UD) concept; it proposes 100 per cent of units to be accessible, differently than the UD vision where a changeable percentage related to the number of units in the building is demanded; 100 per cent of units to be accessible regardless if units are within privately or publicly owned buildings, for rent or for sale. Figure 10 represents a conclusion of the requirements needed to provide full accessibility and usability of residential units by wheelchair users.

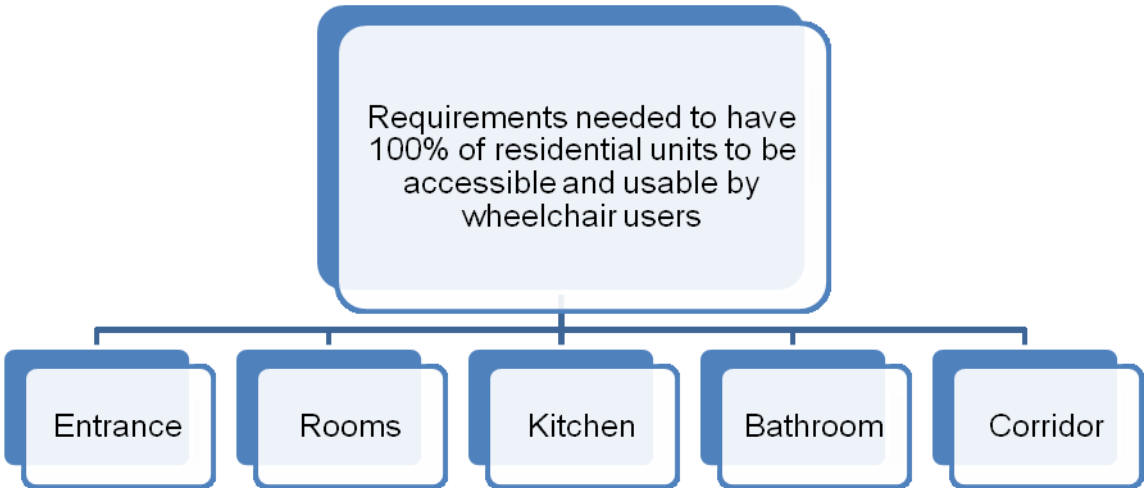

Figure 10: The suggested requirements to have all residential buildings to be accessible

The main elements of residential units are the followings: Entrance, Rooms, Kitchen, Bathroom and Corridor. The requirements needed to provide accessibility and usability of residential units is listed as follow:

Entrance:

- Door:
  1. 450 mm clear floor space at latch jamb
  2. minimum 915 mm width
  3. Threshold height to have vertical rise between 7-13 mm, to be bevelled at slope up to 1:2

- 1500 mm turning space (everywhere except corridors)

Rooms:

- Door:
  1. 450 mm clear floor at latch jamb
  2. minimum width 815 mm

3. Threshold height (in case of balconies' doors) to have vertical rise between 7-13 mm, to be bevelled at slope up to 1:2

Kitchen:

- 1500 mm turning space
- knee space under sink, height= 730 - 850 mm and width = 600 - 750 mm

Bathroom:

- Door:

  1. 450 mm clear floor at latch jamb
  2. minimum width 815 mm

- Turning space: 1500 mm
- Toilet:

  1. to be centred in 900 x 1200 mm
  2. 450 mm from any side wall
  3. broad blocking wall around toilet

- Lavatory:

  1. to be centred in 760 X 1200 mm
  2. 350 mm from any side wall
  3. Knee space to be , height = 730 - 850 mm and width = 600 - 750 mm

- Bathtub:

  1. 1500 mm turning space in front of it
  2. broad blocking wall around bathtub

Corridor: 1200 mm minimum clear width

A list of recommendations is concluded from the previous paragraph to provide full inclusion of wheelchair users in all residential units (100 per cent). The 10-item list is as follows:

1. Door openings shall provide a clear width of 815 mm minimum for interior doors and 915 mm for exterior doors.
2. A 1500x1500 mm turning space.
3. 760x120 mm clear floor space at each fixture; spaces may overlap.
4. Toilet to be centred in a minimum 900mm wide space, 450 mm from any side wall.
5. Broad blocking in walls around toilet, tub, and shower for future placement and relocation of grab bars.
6. Lavatory and sink counters height to be between 730-850 mm.
7. Lavatory centred in a minimum 760 mm wide space, 380 mm from any side wall.
8. All lavatories and sinks to have either open knee space below, or cabinets with retractable doors and removable.
9. Clear floor space of 450mm minimum beside door at latch jamb.
10. Minimum clear width of interior accessible routes to be 1200 mm.

Chapter 5

Model Development

5.1 Introduction

Parametric Building Modelling is the technology adopted by Building Information Modelling (BIM); Revit software is an example of parametric building technology. It is inherently a building information modeller which delivers only a fully integrated, self-coordinating building information model. (Hergunsel, 2011)

All the elements added to Revit Architecture projects such as walls, roofs, and windows are created with families. A family is a group of elements with a common set of properties, called parameters, and a related graphical representation. (Imperial Tutorials, 2010).

5.2 Development Methodology

Based on the list of recommendation concluded from the present research, new models are developed to create new categories in Revit Software representing universal design (UD) requirements. The methodology is divided into two phases. The first phase consists of designing the models needed for universal design (UD) elements; the second comprises customizing BIM's tool (Revit Architecture) by creating new families for architectural components. (Jrade, 2012).

5.2.1 Phase One

The data used in the implementation and creation of new instances are based on the list of recommendations concluded from the present research and it is detailed as follows:

A. Doors

- Clear floor space of 450mm minimum beside door at latch jamb (figures 11-12)

- Interior door openings (rooms, bathroom, and kitchen) shall provide a clear width of 815 mm minimum

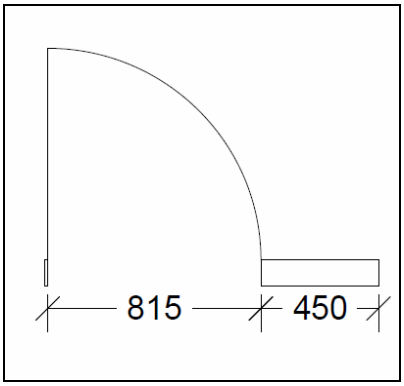

Figure 11: Interior door opening

- Exterior door openings (Entrance) shall provide a clear width of 915 mm minimum (figure 21).

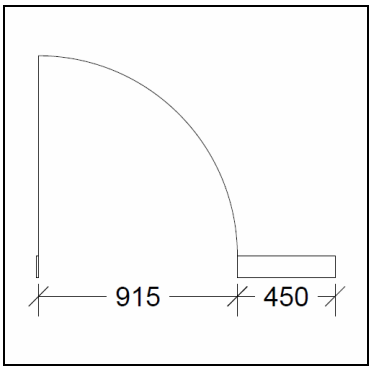

Figure 12: Exterior door opening

A. Bathrooms

- Toilet: To be centred in a minimum 900 mm wide space, 450mm from any side wall (figure 13).

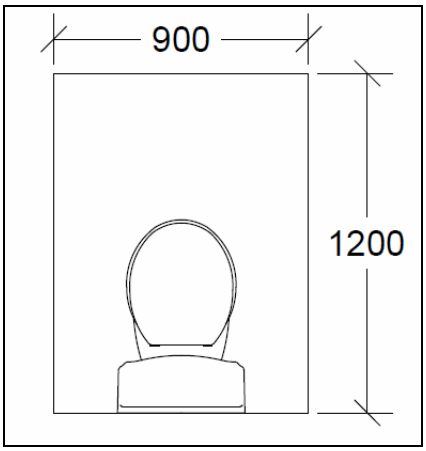

Figure 13: The allowable clear space for toilet

B. Lavatories

- Lavatory centred in a minimum 760mm wide space, 380mm from any side wall (figure 14).

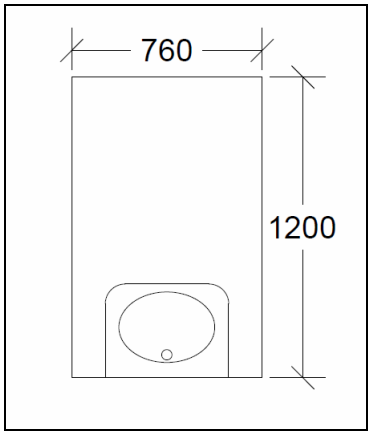

Figure 14: The allowable clear space for lavatory

- All lavatories to have either open knee space below or cabinets with retractable doors and removable (figure 15).

C. Bathtubs

- A 1500x1500 mm turning space in front of the bathtub (figure 34).

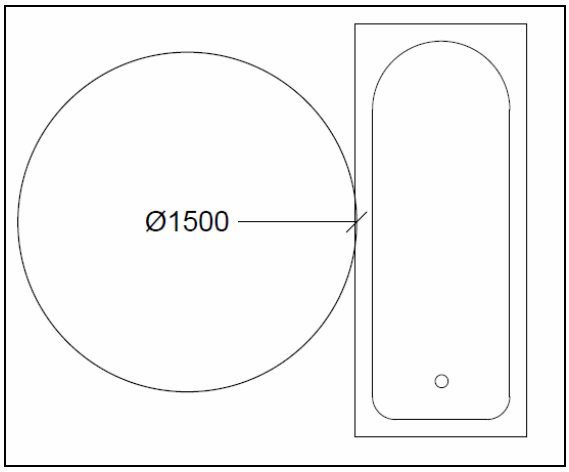

Figure 15: Turning space required for bathtub

D. Kitchens

- Sink: To have either open knee space below or cabinets with retractable doors and removable (figure 16).

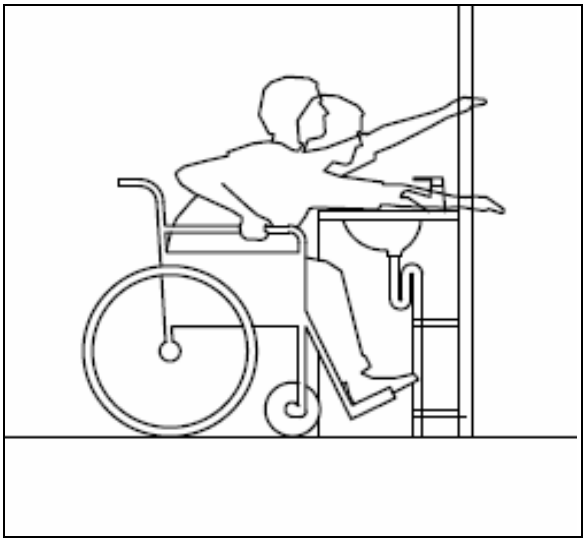

Figure 16: Knee space required under sink and lavatory

- A 1500x1500 mm turning space (figure 17).

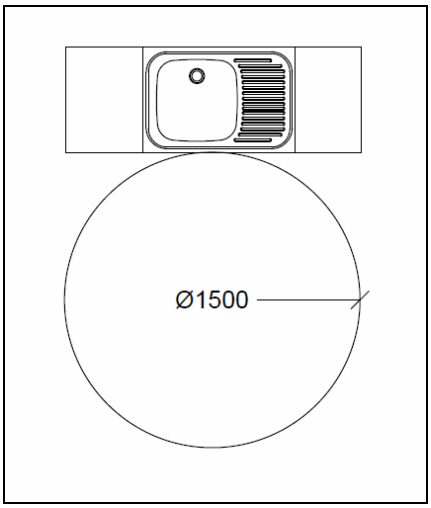

Figure 17: Turning space needed for sink

5.2.2 Phase Two

This phase focuses on customizing Revit Architecture as a BIM tool by creating and adding new families, which have 3D elements for architectural components reflecting all the universal design (UD) needs for residential requirements based on the pre-defined components designed in Phase One. (Jrade, 2012).

When creating an element in a project, that element is organized within the project with a particular hierarchy. It starts first by element category, then by family, family type, and by instance (see figure 18). (Imperial Tutorials, 2010).

Figure 18: The hierarchy system in Revit library

The above-mentioned hierarchy is adopted to create and download the proposed universal design categories; such categories are: doors, bathroom fixtures and kitchen fixtures (see figure 19-21).

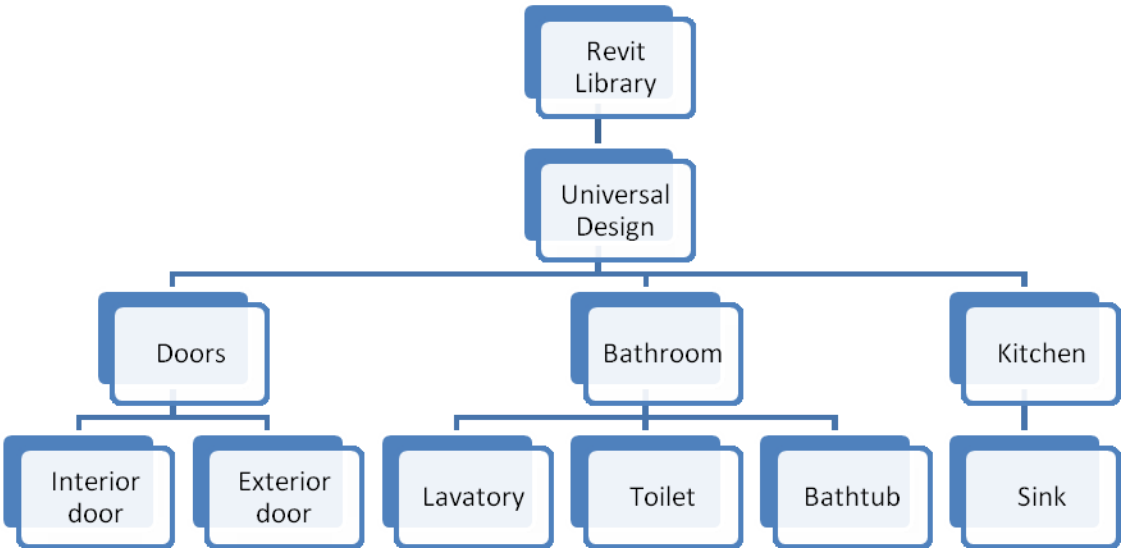

Figure 19: The suggested universal design families' diagram

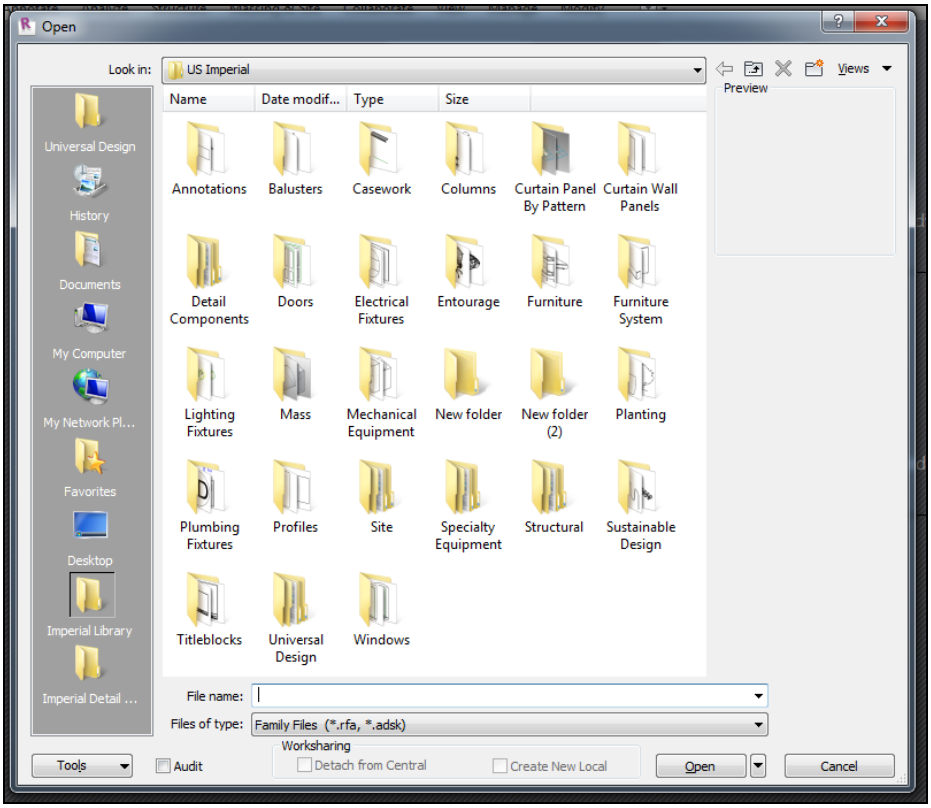

Figure 20: Universal design data in Revit software

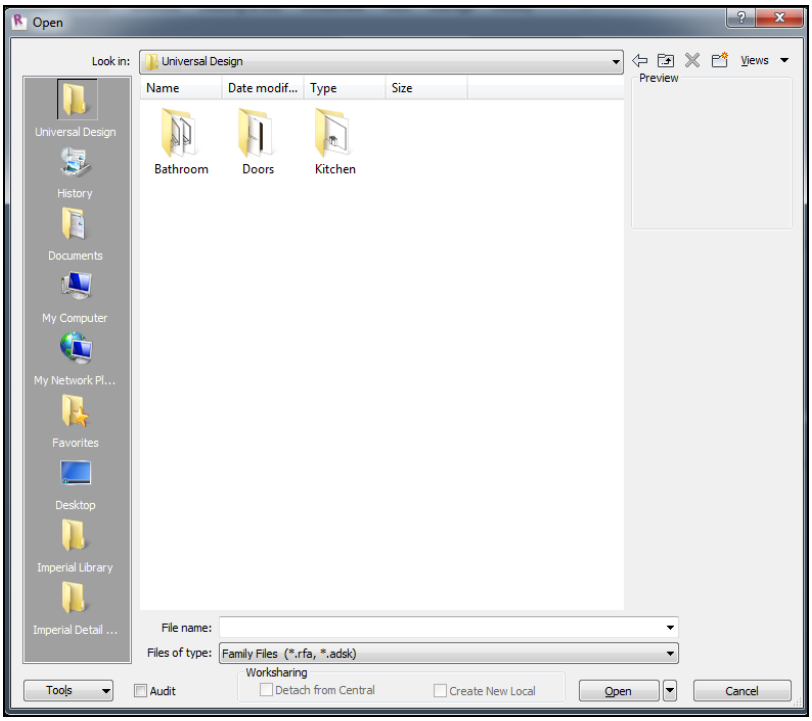

Figure 21: Universal design families

The new instances, described in figures 22-34, are composed of two types of layers:the first layer is for the predefined instance (e.g toilet, door) and the second layer is the limit of the minimum allowable space to provide universal design (UD) requirement. The second layer has the possibility of being turned ON and OFF . The new instances will be listed under the following families: Doors, Bathroom and Kitchen.

Doors Family: Two types of doors are presented, interior and exterior; the dimension shown is the minimum acceptable with the possibility of infinite doors sizes (see figures 22-23).

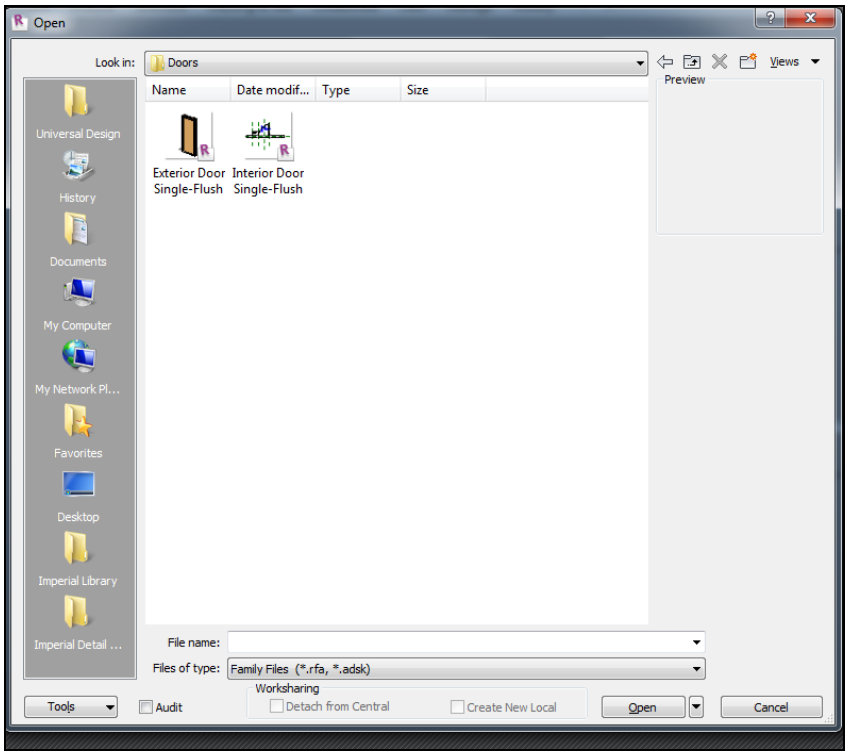

Figure 22: Doors' family coding system

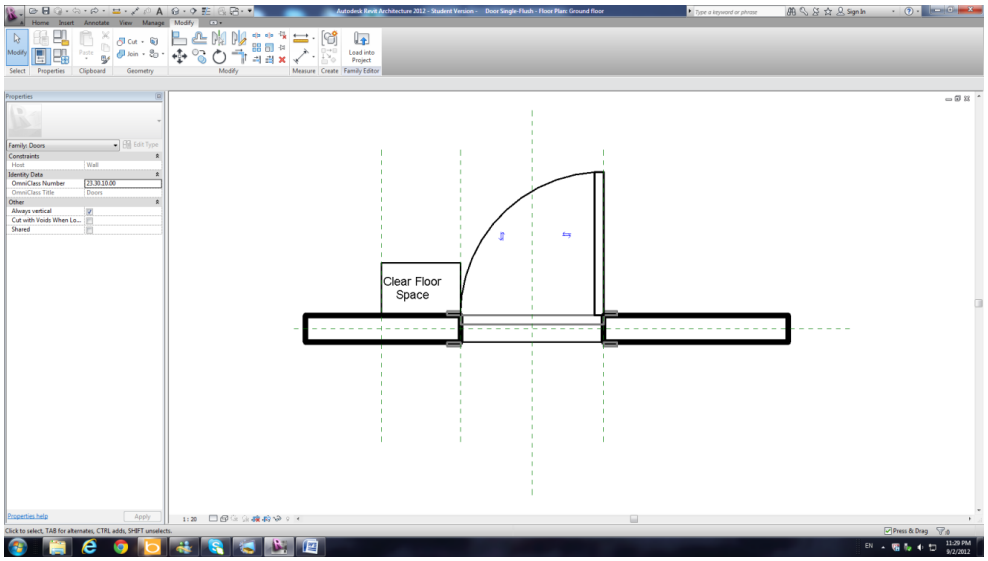

Figure 23: Door with the minimum clear floor space at the latch jamb

Bathrooms Family: It contains three family types; Toilet, Lavatory and Bathtub (see figure 24), one or more models are presented for each family type (see figures 25-32).

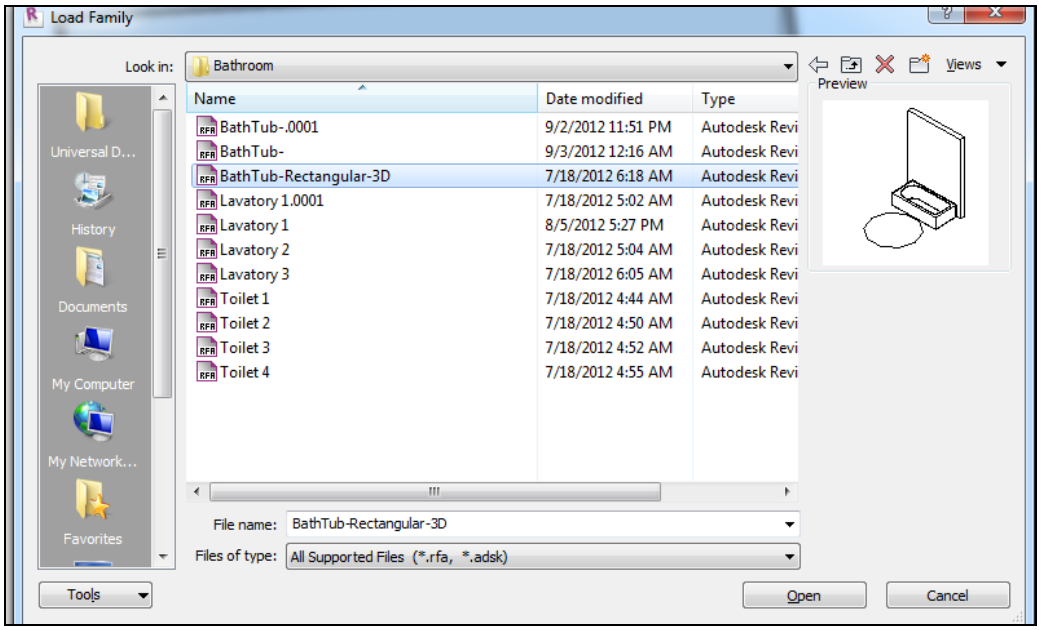

Figure 24: Bathroom family

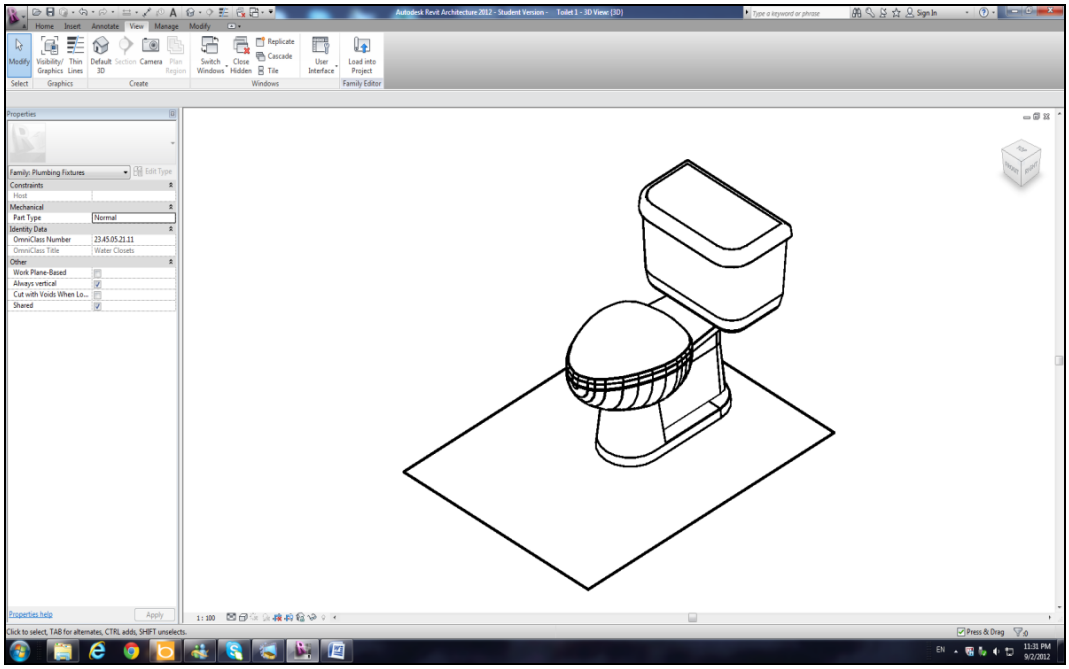

Figure 25: Toilet 1 with the minimum allowable space

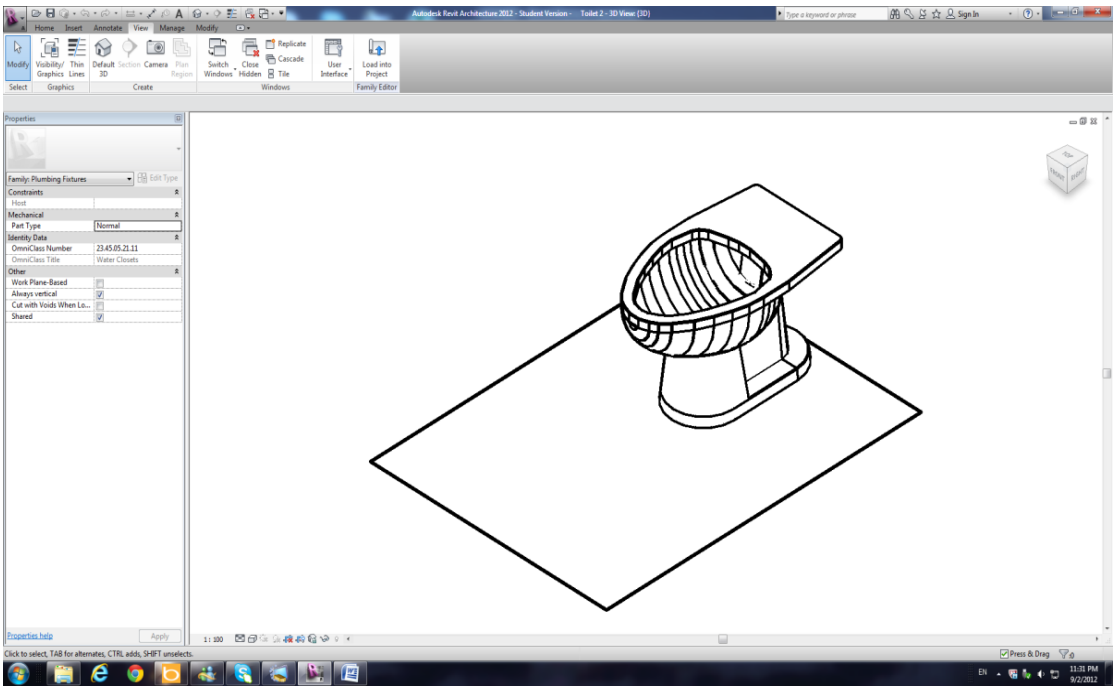

Figure 26: Toilet 2 with the minimum allowable space

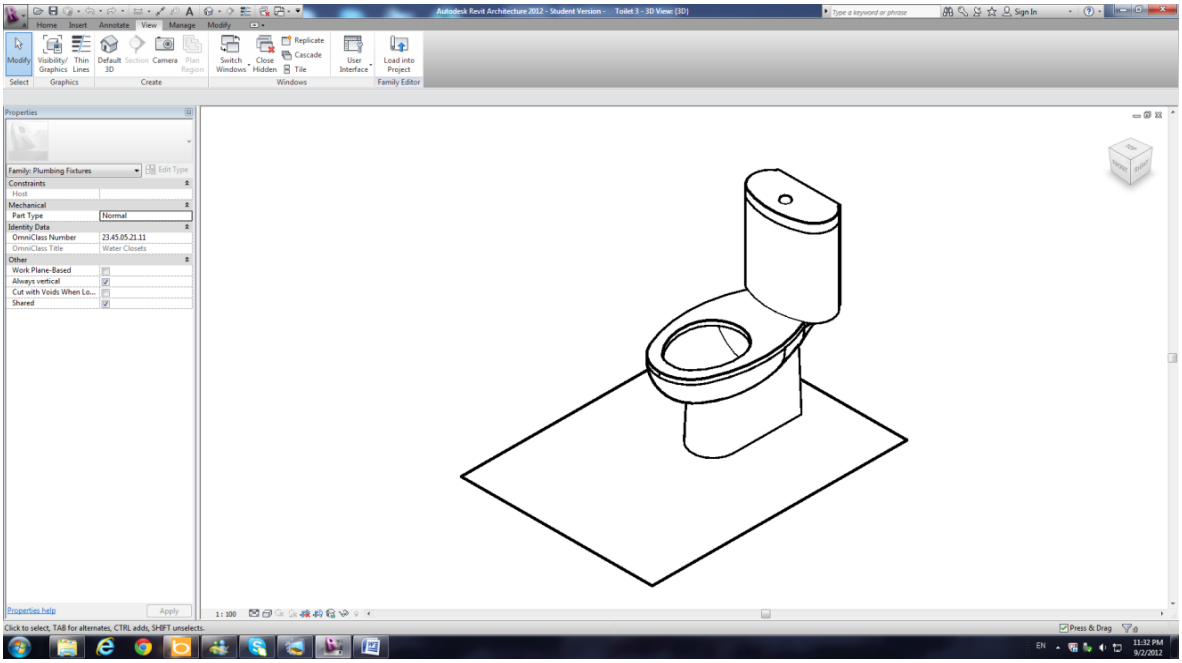

Figure 27: Toilet 3 with the minimum allowable space

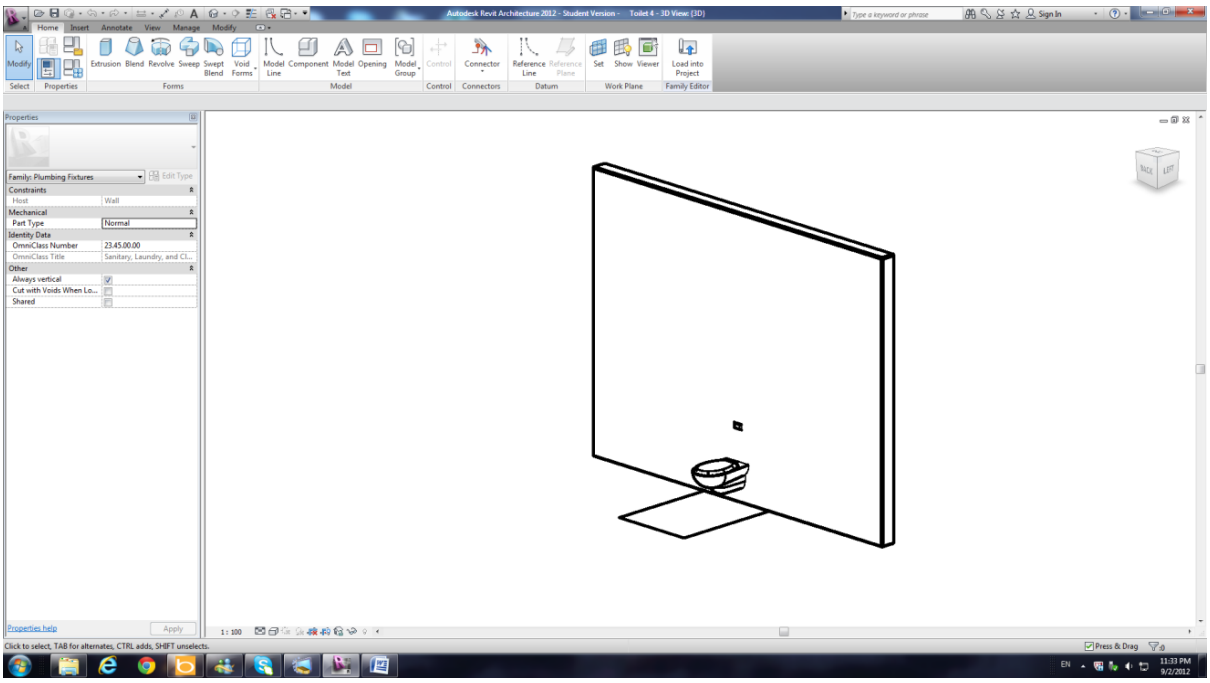

Figure 28: Toilet 4 with the minimum allowable space

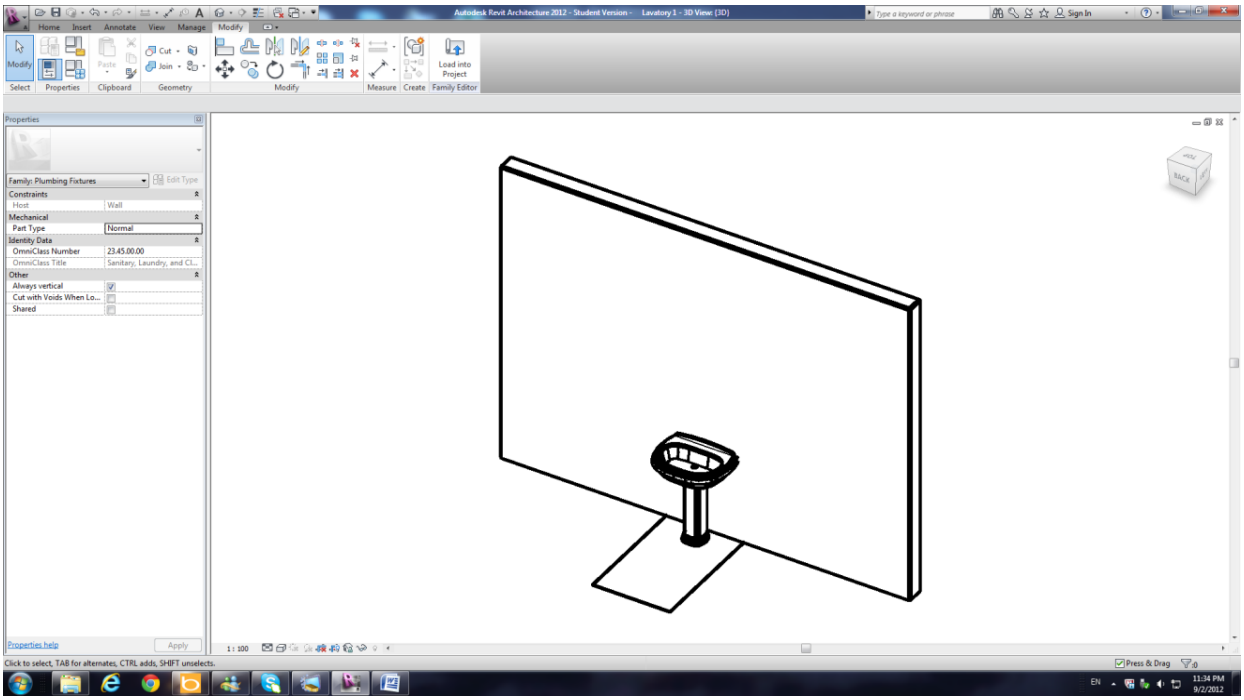

Figure 29: Lavatory 1 with the minimum allowable space

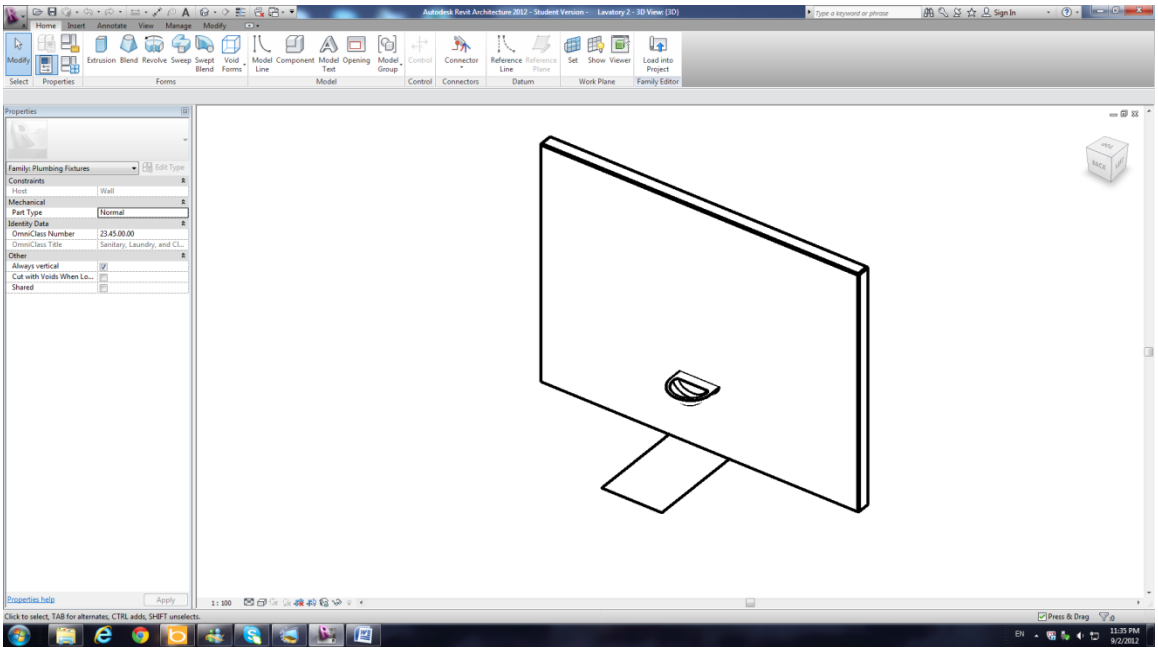

Figure 30: Lavatory 2 with the minimum allowable space

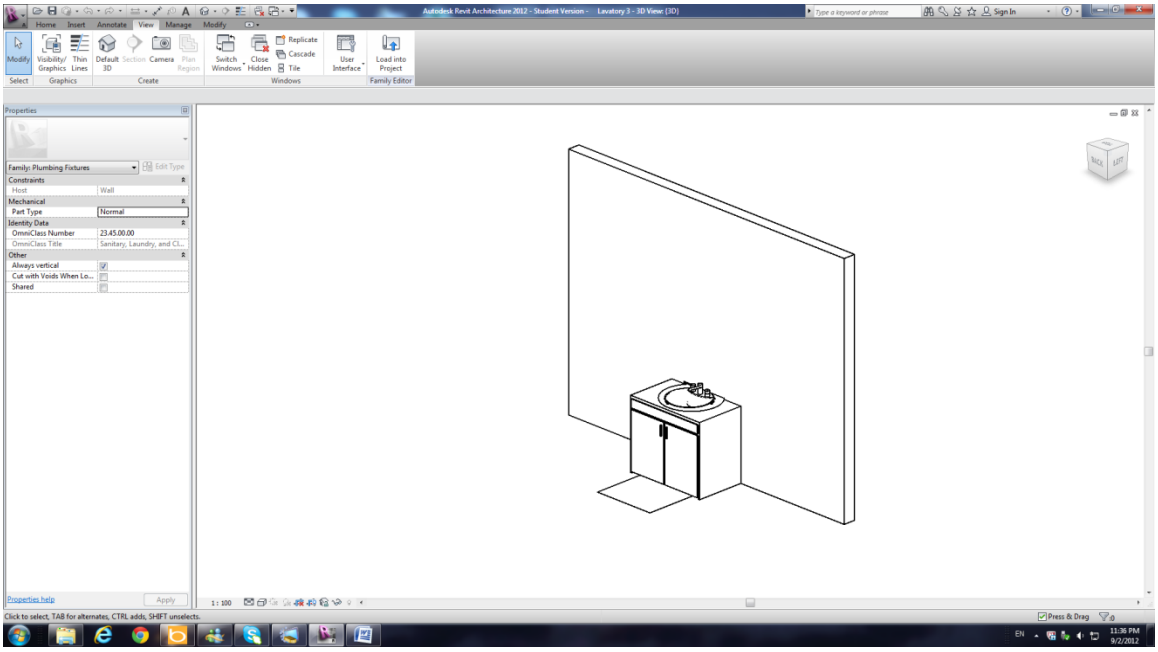

Figure 31: Lavatory 3 with the minimum allowable space

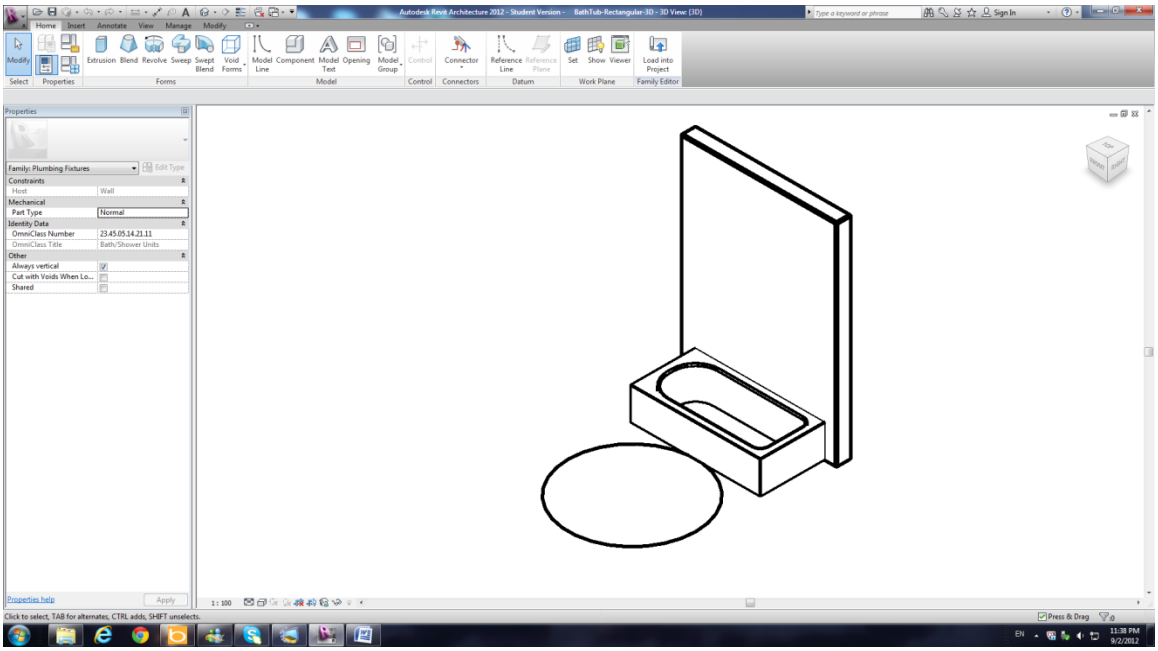

Figure 32: Bathtub with the needed turning space

kitchens Family: It contains a sink with the needed turning space (see figures 33-34).

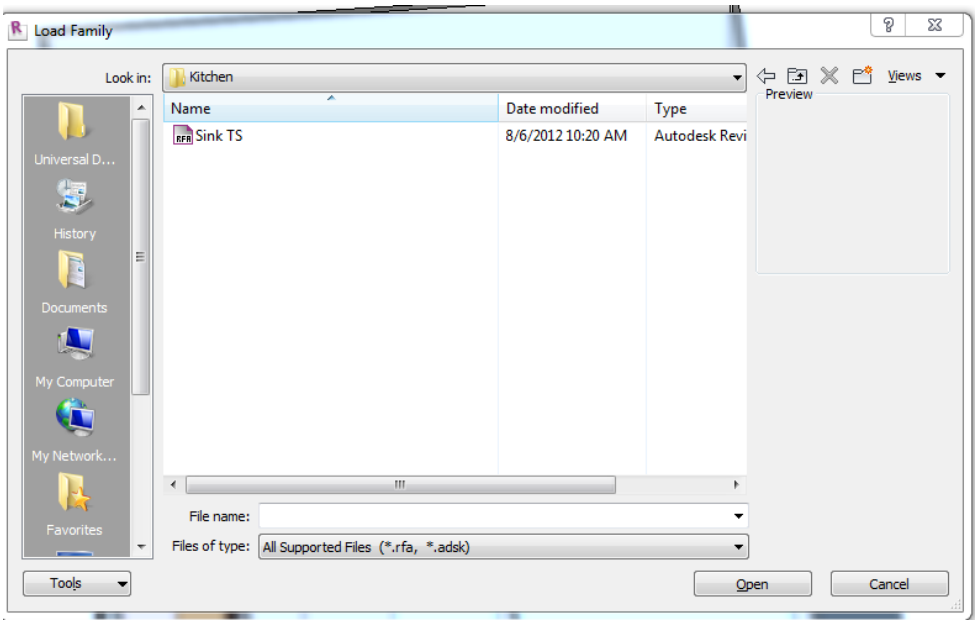

Figure 33: The kitchen family

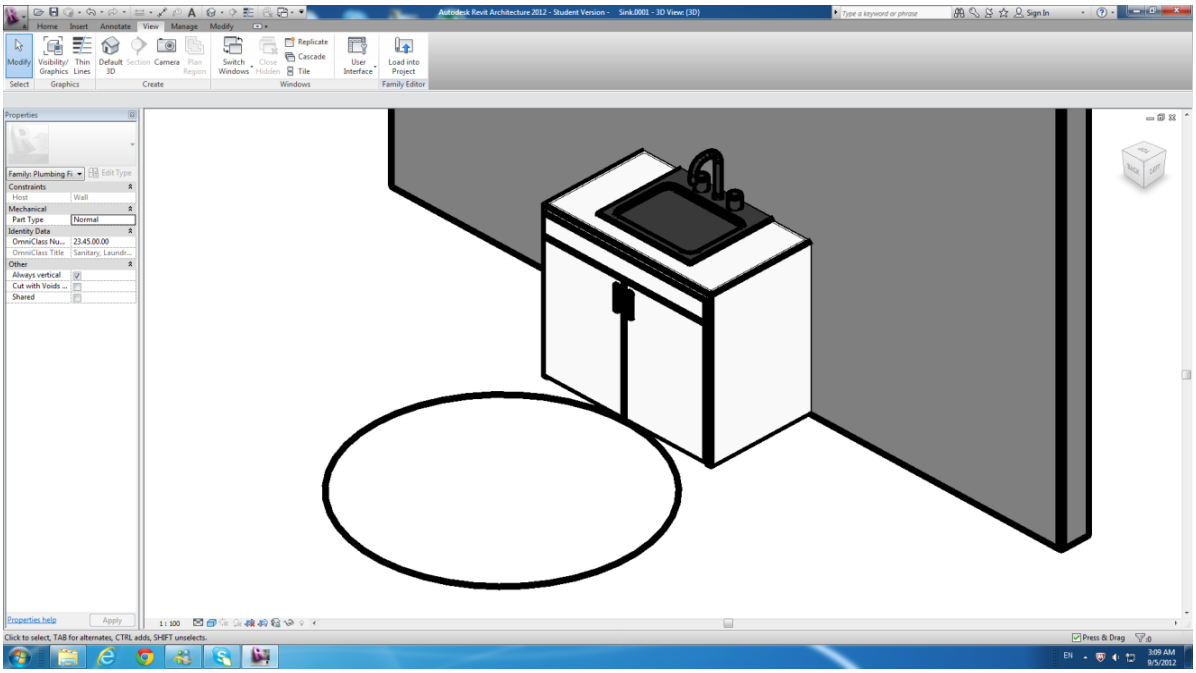

Figure 34: UD sink with the needed turning space and knee space

5.3 Summary

The preceding chapter presents a Model development by designing new instances created in new Revit families to be stored and part of the database of Building Information Modelling. The main goal of the mentioned model is to integrate the Universal Design (UD) concept in BIM approach to be included in its database as well as Universal Design (UD) Concept beliefs that wheelchair users must be included in residential units, also to give designers the opportunity to easily access UD requirements during buildings' design phase.

Chapter 6

Testing and Validation

6.1 Introduction

The main concern of this research is the inclusion of wheelchair users to residential units based on the Universal Design (UD) requirements, with one difference: within accessible residential buildings ALL residential units must be accessible, not just a percentage of the total number of units. This chapter is to prove and test the capability of the list of recommendations, if adopted, to provide full inclusion of wheelchair users to residential units without any additional conditions; also to test and validate the new instances created in new Revit families to provide designers the opportunity of easily access UD requirements during buildings' design phase.

To realize this objective, inaccessible residential units were selected randomly from residential construction projects carried out in a number of different Canadian cities. These buildings are under construction; therefore, they are subject to the latest version of the National Building Code (NBC). The selected buildings are bigger than 600m^2 in area, and more than three floors in height; as such, they are considered as accessible buildings. The selected units are condos of one bedroom, two bedrooms and three bedrooms in different sizes.

A redesign of the units is suggested, in order to make them accessible and usable by people with or without wheelchairs, at the same level of functionality. The suggested re-design is based on the list of recommendations detailed in section 4.4.

The suggested re-design shall take the following into consideration:

- No changes in the architectural concept
- No changes in the area of the units
- No additional special materials are required

6.2 First Example

Type: One bedroom. Area: 60.7 m^2. Location: Montreal (see figure 35).

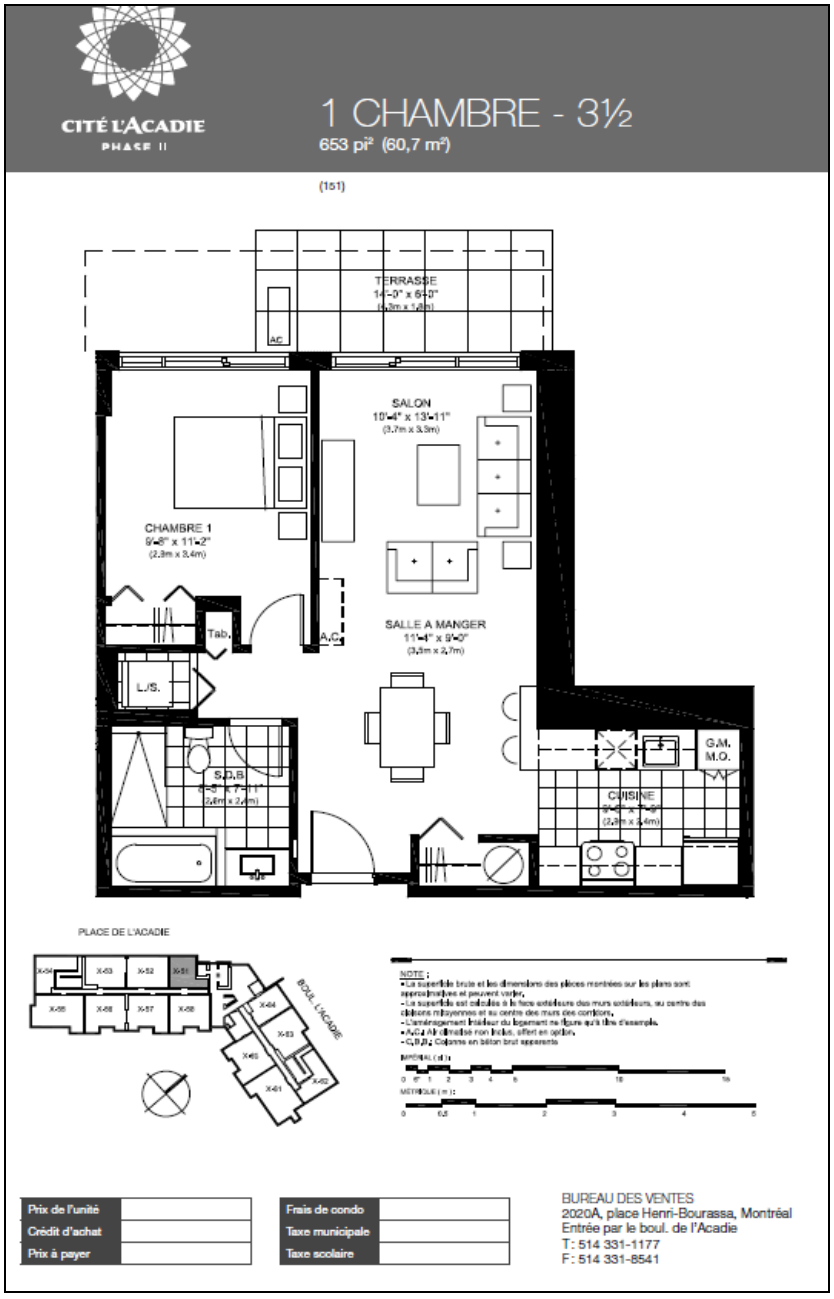

Figure 35: First example, one bedroom

1. Analysis of the Current Situation

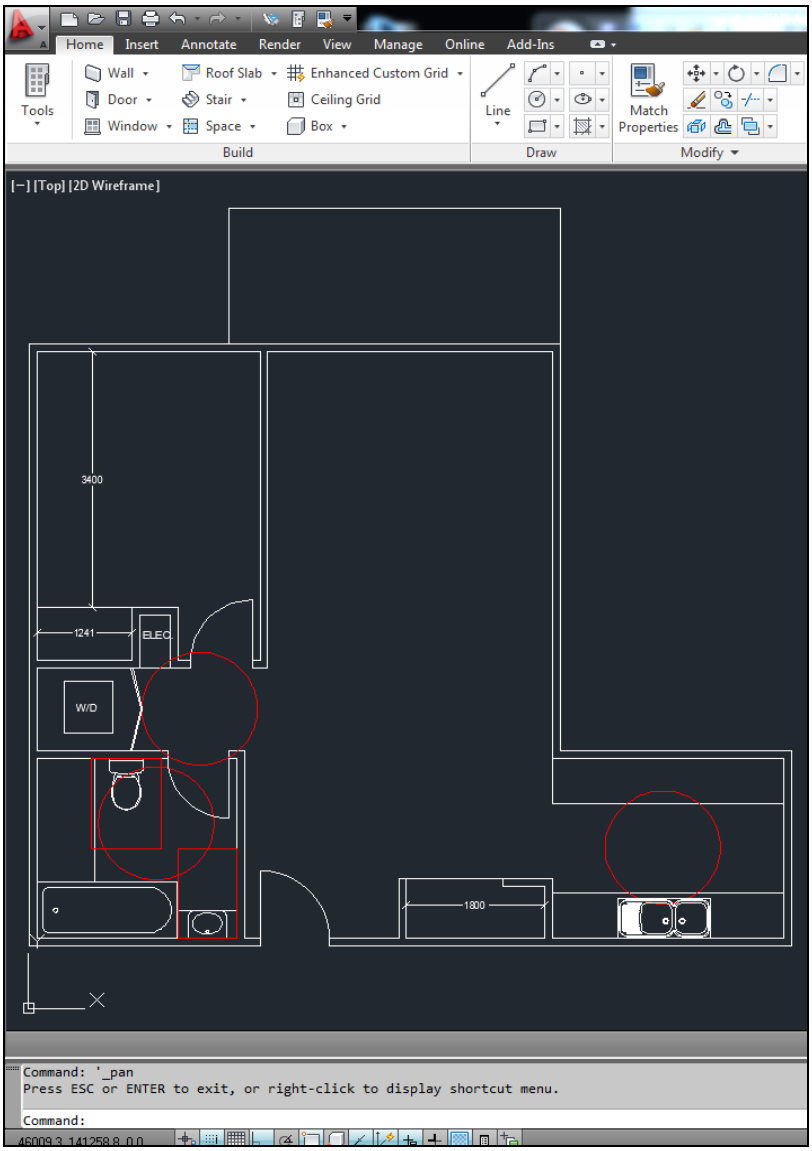

Figure 36: First example, the current situation. SC: 1/100

The obstacles are (see figure 36):

- Doors do not follow UD requirements. No turning space in the kitchen
- No turning space in the lobby between the bathroom and the bedroom, so both are not accessible
- No turning space in the bathroom
- No knee space under the sink and the lavatory

2. Suggestions (see figure 37):

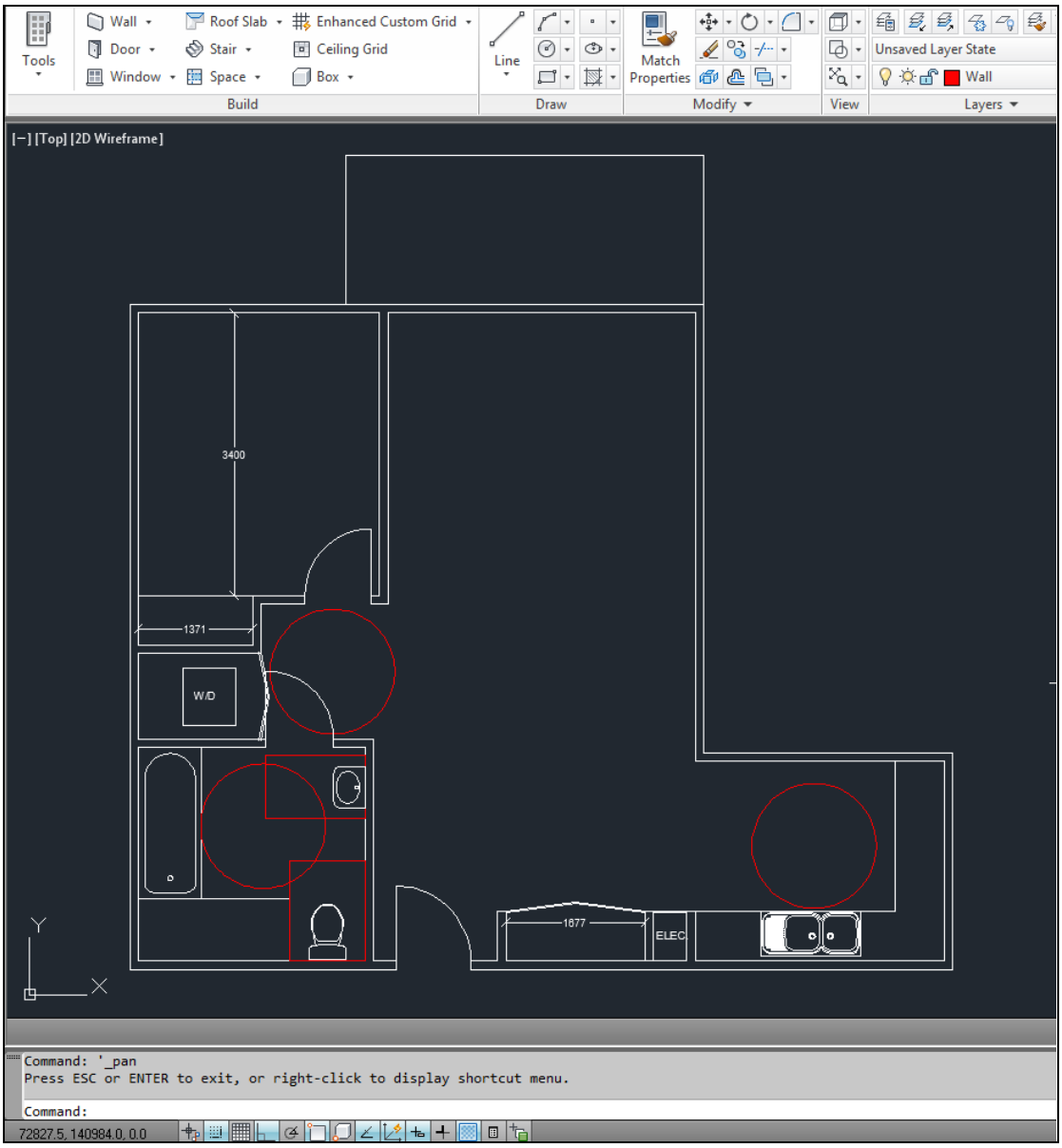

Figure 37: First example, suggestion. SC: 1/100

- Doors to follow UD requirements
- Kitchen counter to be L shape
- Moving the electrical panel to the kitchen side
- Relocate the bathroom fixtures.
- Sink and lavatory to have knee space.

6.3 Second Example

Type: One Bedroom (see figure 38). Area: 57.7 m^2 Location: Toronto

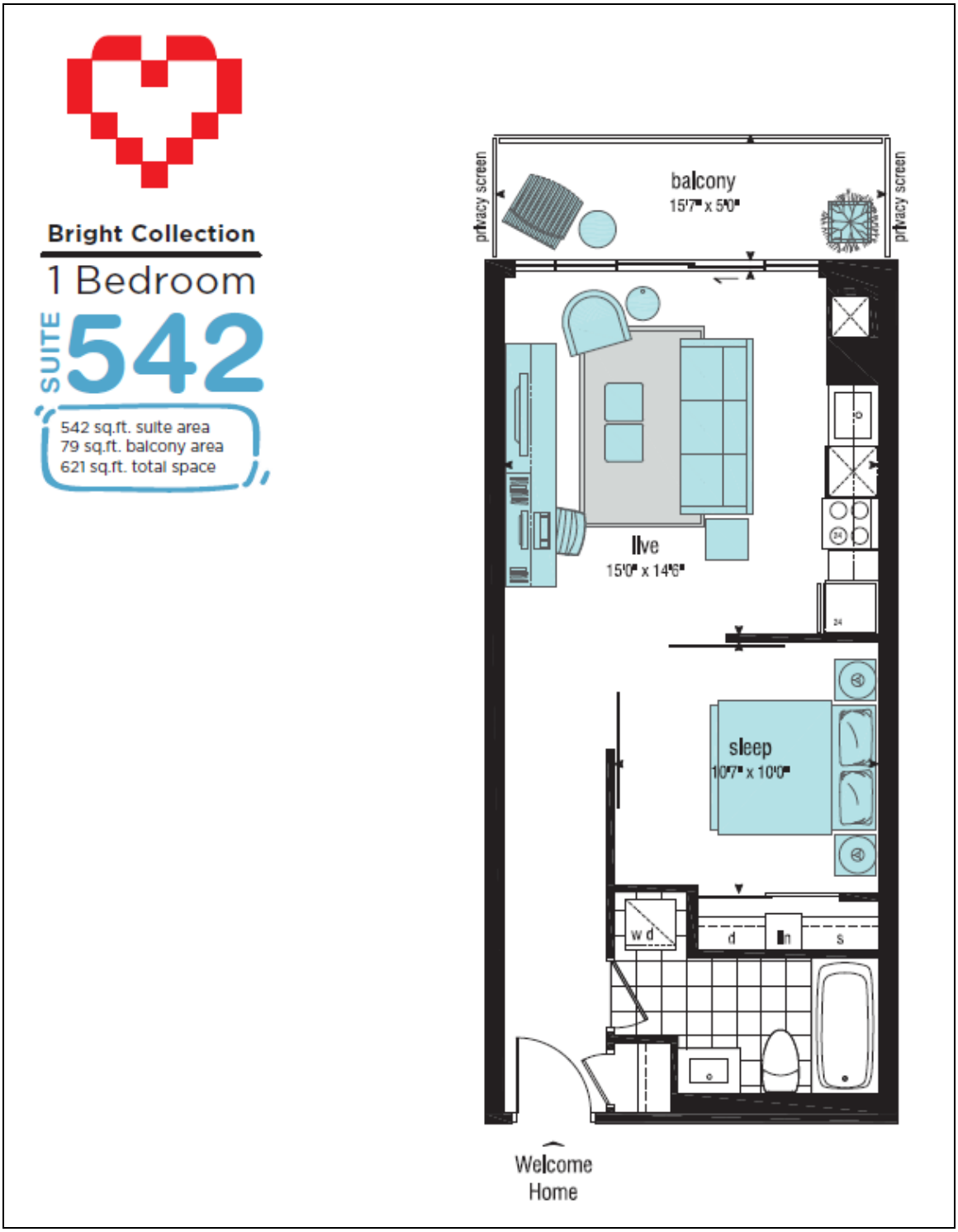

Figure 38: Second example

1. Analysis of the Current Situation (see figures 39-41).

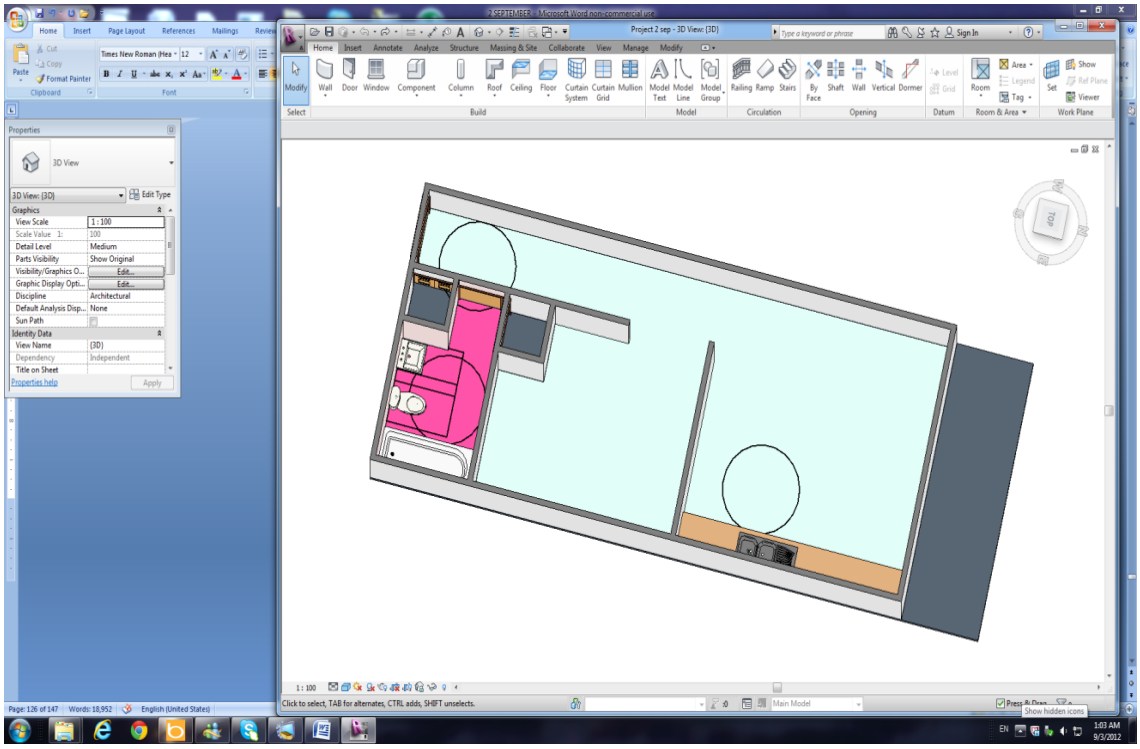

Figure 39: Second example, the current situation

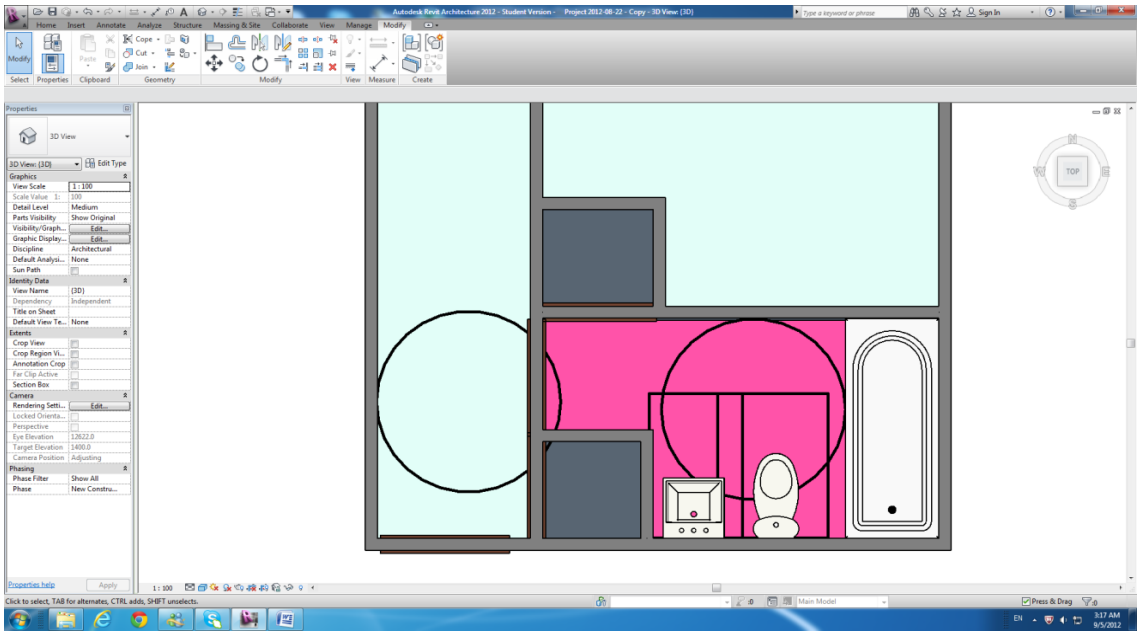

Figure 40: Second example, 2D view of the critical area

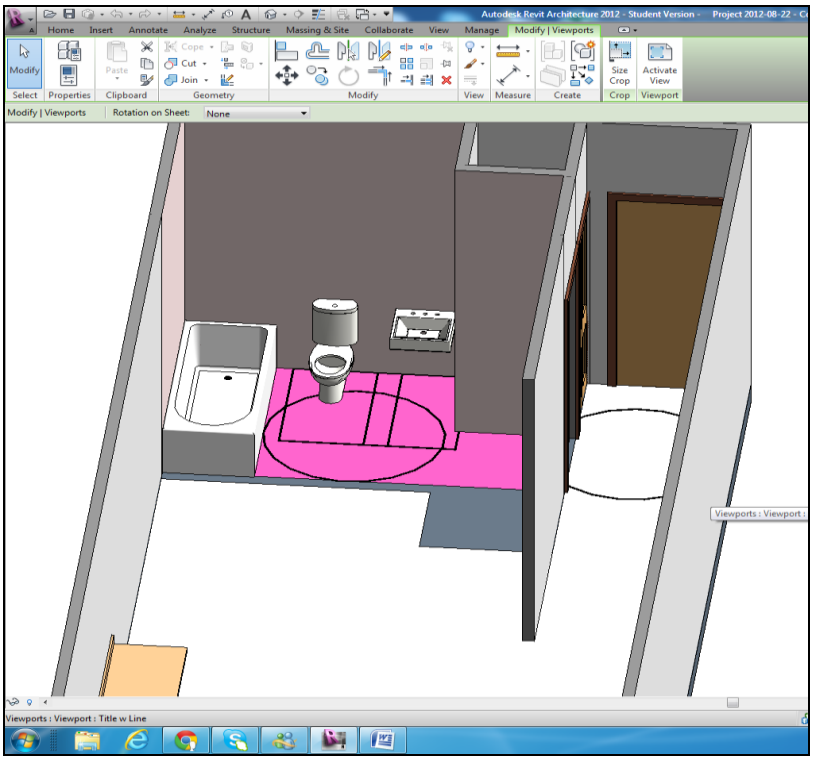

Figure 41: Second example, 3D view of the critical area

The obstacles are:

- Doors do not follow UD requirements
- No turning space in the entrance, so the bathroom is not accessible
- No turning space in the bathroom
- No knee space under the sink and the lavatory

2. Suggestions (see figures 42-44):

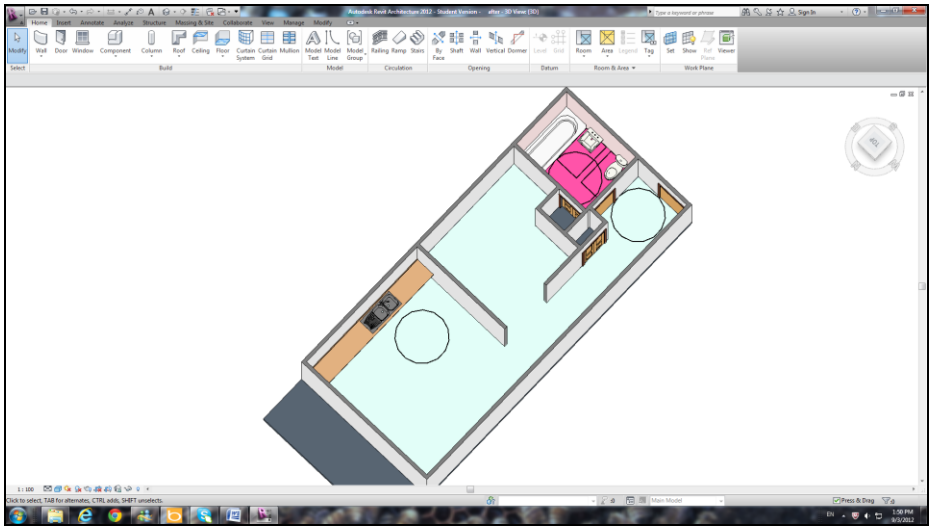

Figure 42: Second example, the suggestion

The Suggestions are:

- Doors to adopt UD requirements
- In the entrance, relocate the cabinet to be at the other side of the bathroom door, to have turning space.
- Bathroom door to open outward, relocation of the fixtures
- Knee space under sink and lavatory

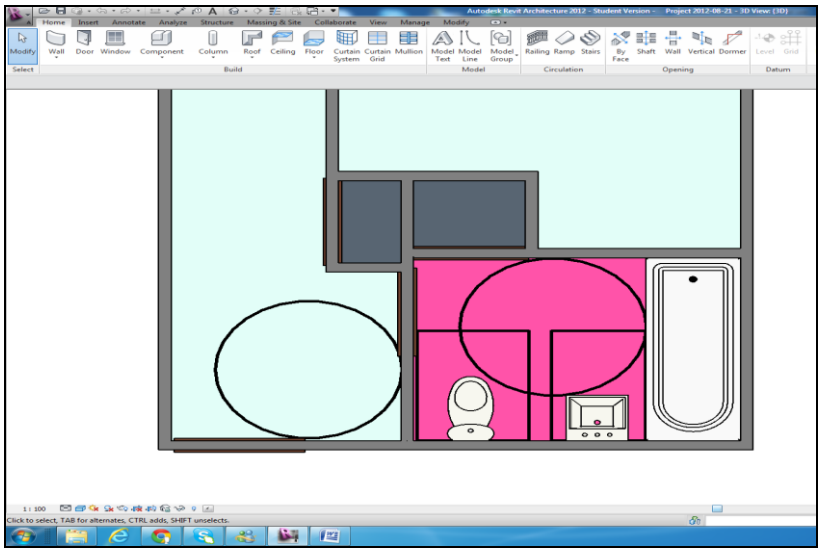

Figure 43: Second example, 2D view

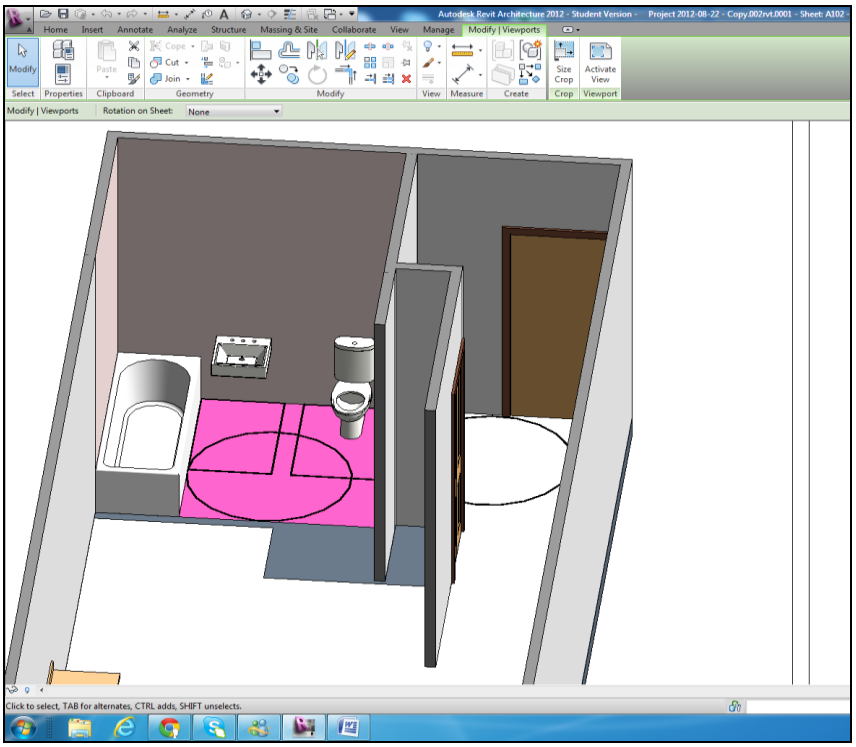

Figure 44: Second example, 3D view

6.4 Third Example

Type: Two Bedrooms (see figure 45)

Area: 63 m^2 Location: Toronto

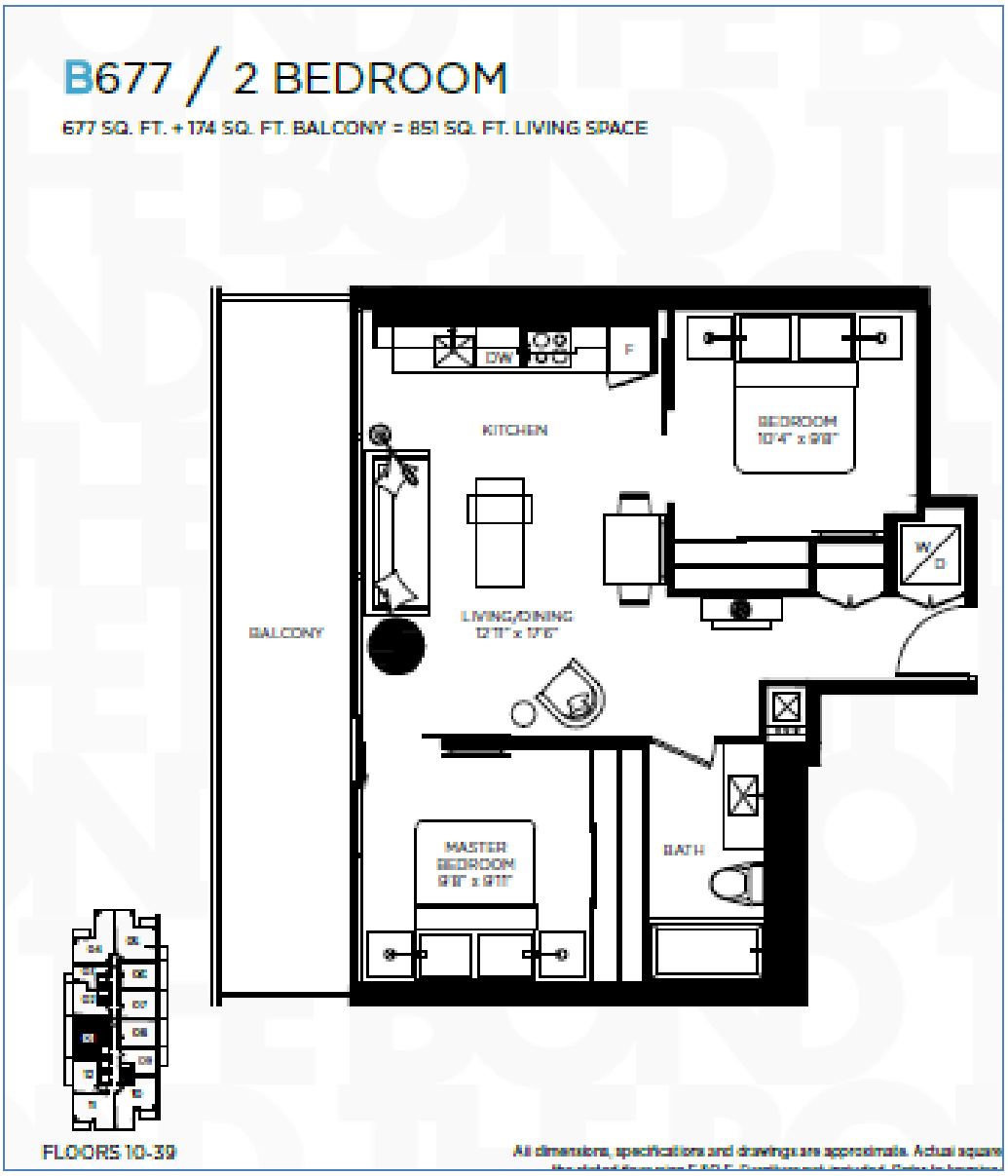

Figure 45: Third example

3. Analysis of the Current Situation (see figure 46).

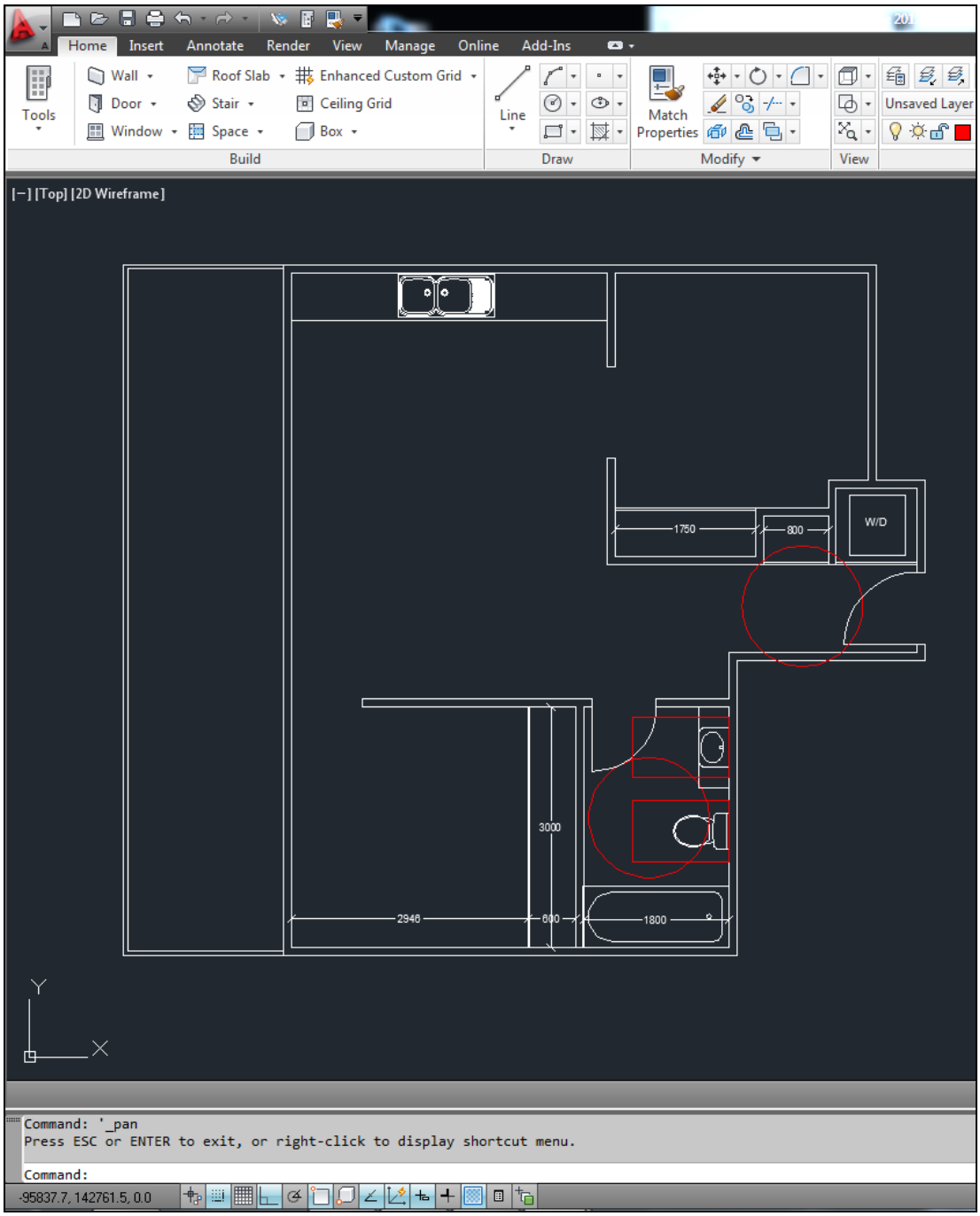

Figure 46: Third example, the obstacles. SC: 1/100

The obstacles are:

- Doors do not follow UD requirements
- No turning space in the entrance
- No turning space in the bathroom

- No knee space under the sink and the lavatory

4. Suggestions (see figure 47-48):

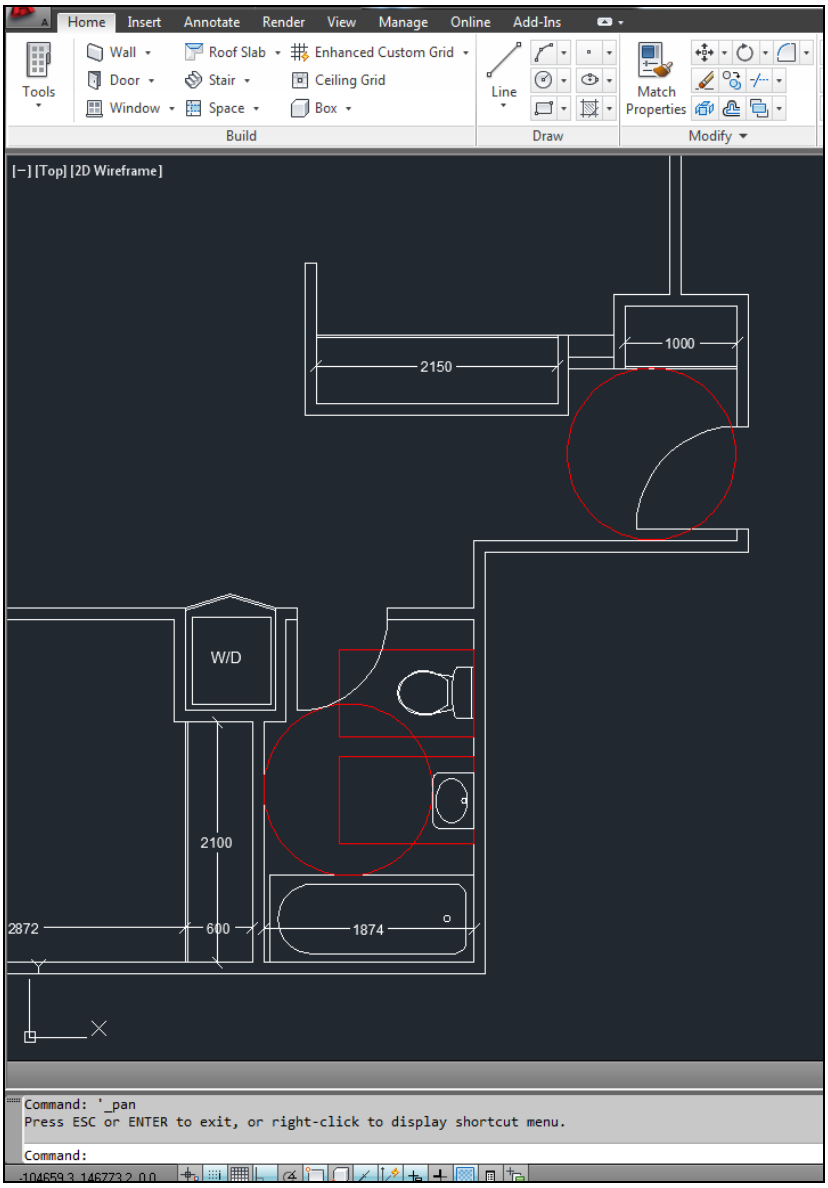

Figure 47: Third example, suggestion A, SC: 1/100

Suggestions A (figure 47):

- Doors to adopt UD requirements
- Create turning space in the entrance

- Relocate bathroom fixtures
- To have knee space under sink and lavatory

5. Suggestions B (figure 48).

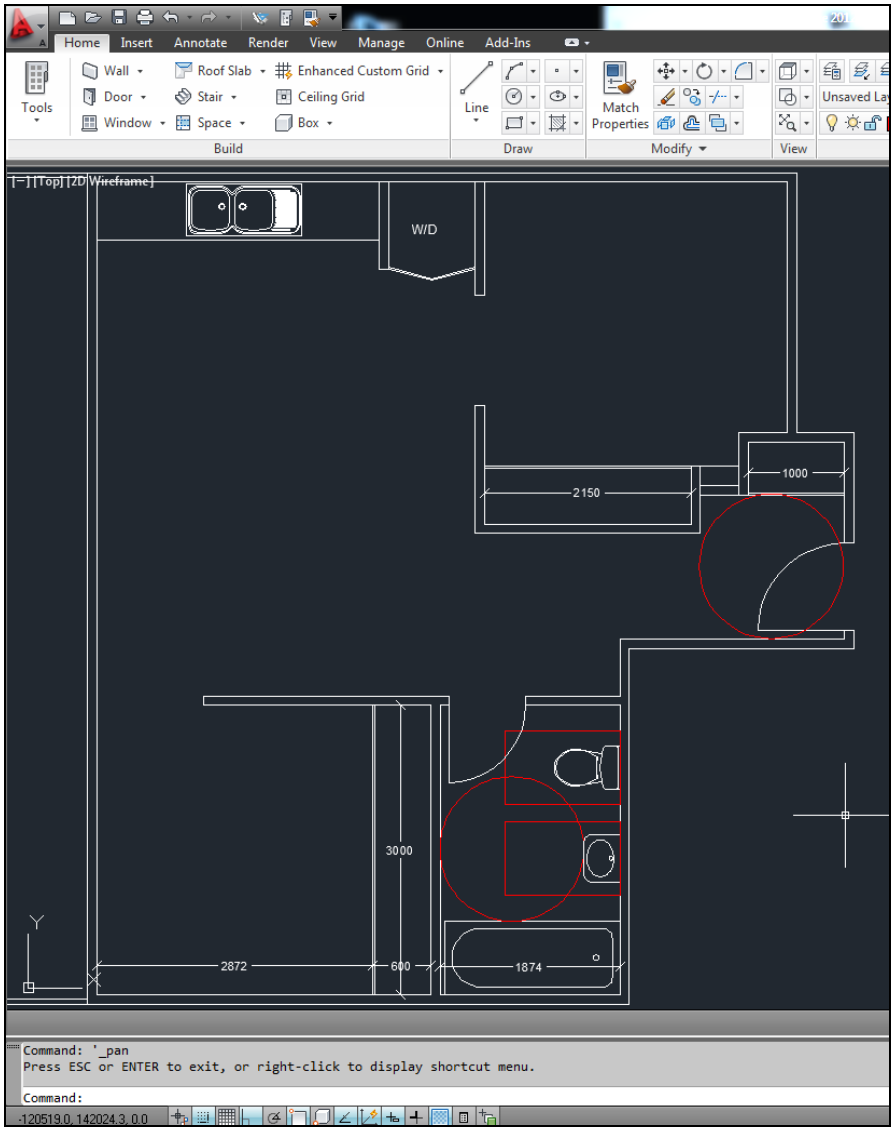

Figure 48: Third example, suggestion A, SC: 1/100

6.5 Fourth Example

Type: Two Bedrooms (see figure 49)

Area: 137 m^2 Location: Laval

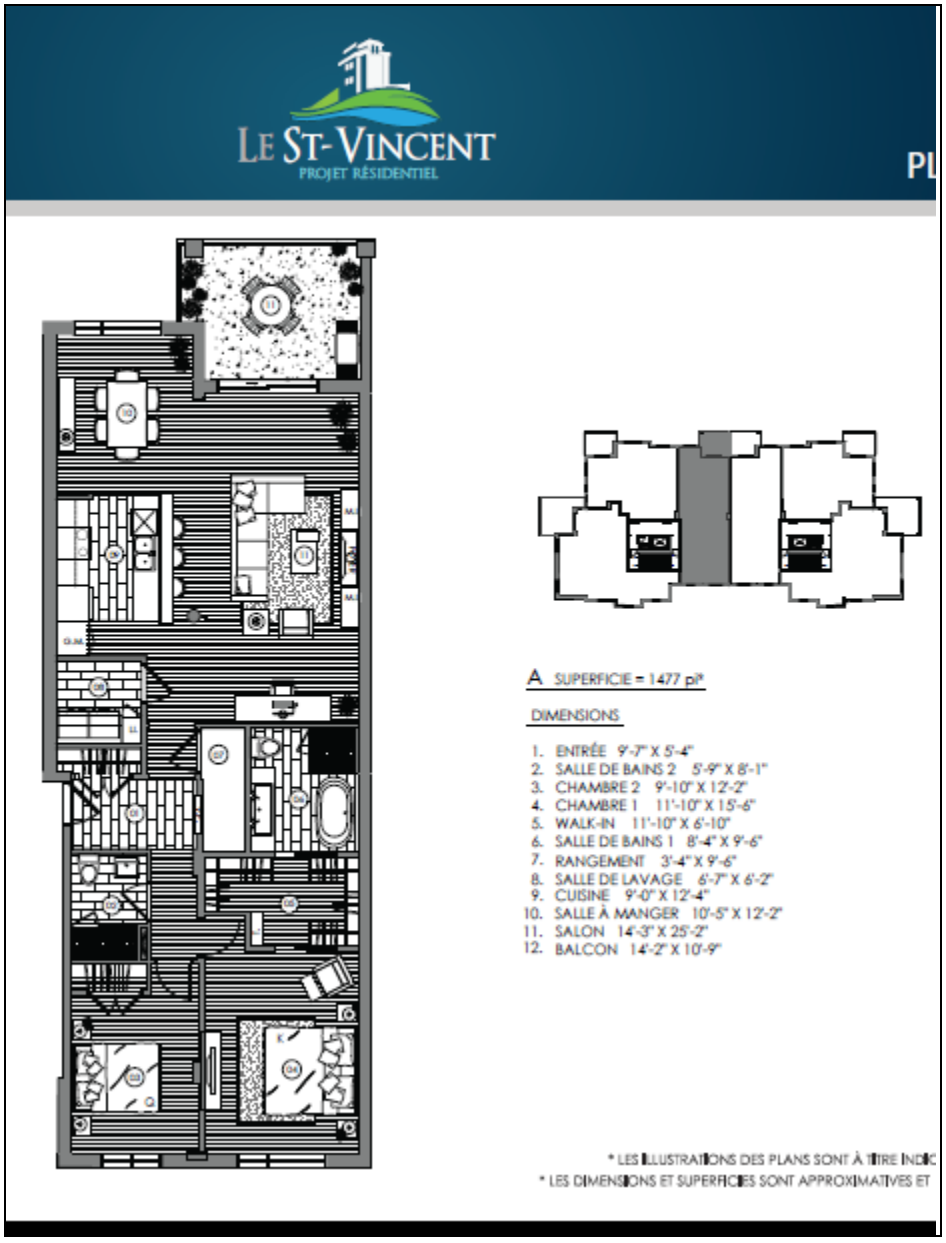

Figure 49: Fourth example

1. Analysis of the Current Situation (see figure 50).

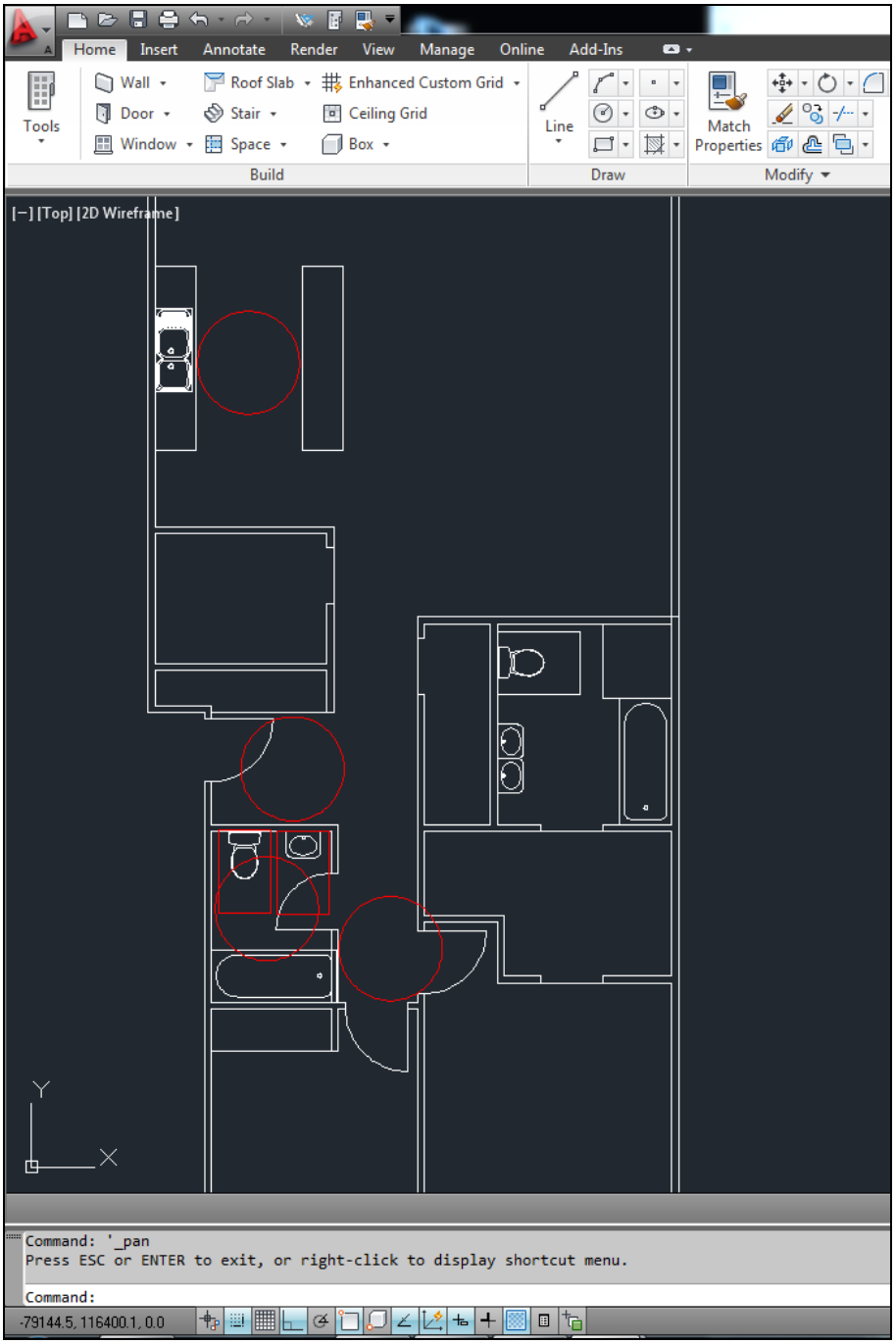

Figure 50: Fourth example, the obstacles. SC: 1/100

The obstacles are:

- Doors do not adopt UD requirements

- No turning space in the corridor in front of the bathroom and bedroom doors, so both rooms are not accessible
- No turning space in the bathroom (the one in the corridor)

2. Suggestions (see figure 51).

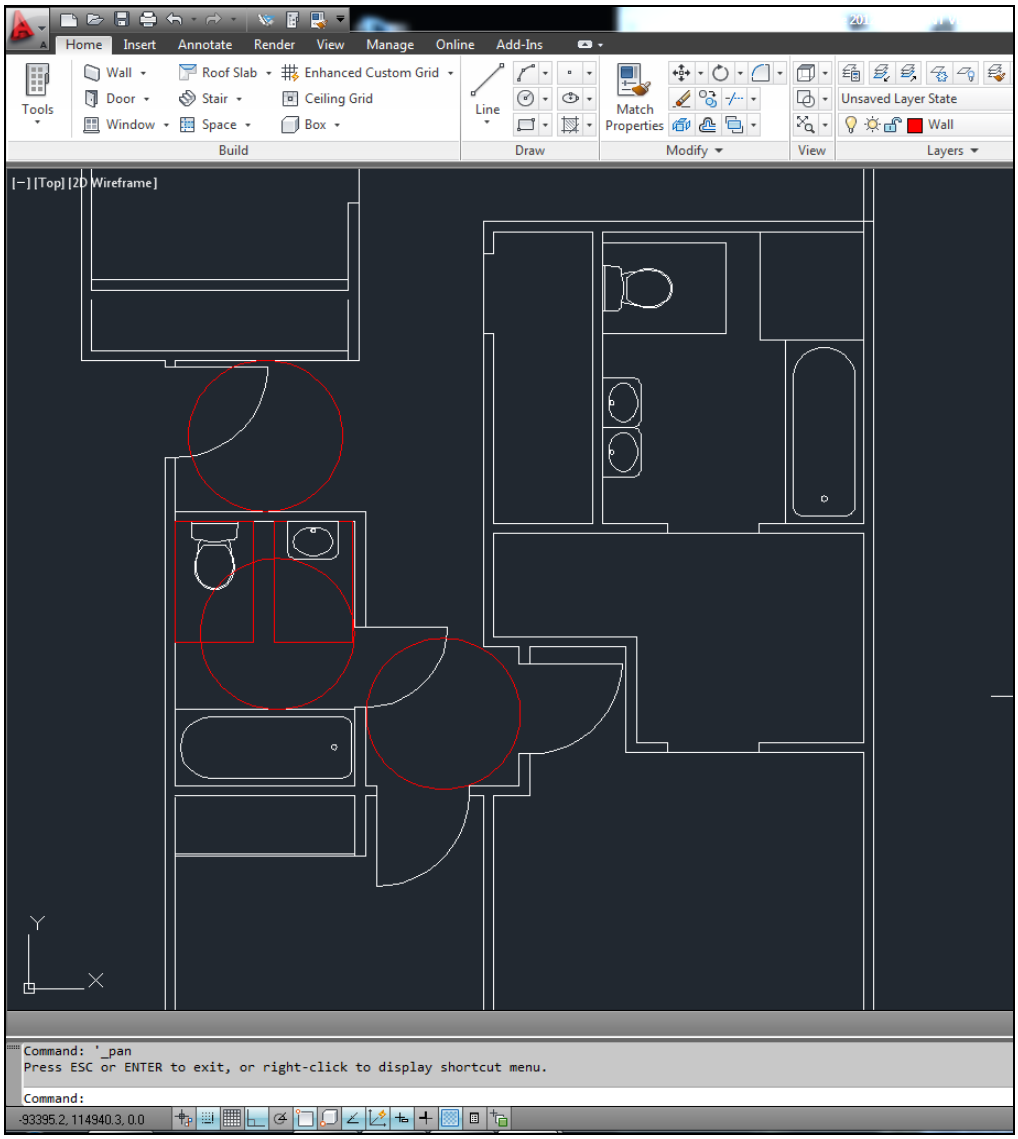

Figure 51: Fourth example, the suggestion. SC: 1/100

The suggestions are:

- Doors to follow UD requirements
- Create turning space in the corridor in front of the three doors of bathroom and the two bedrooms, to allow accessibility
- The bathroom door to open outward
- Add 450 mm at latch jamb of one of the bedrooms

6.6 Fifth Example

Type: Three Bedrooms (see figure 52).

Area: 118 m^2 Location: Lachine.

Figure 52: Fifth example

1. Analysis of the current situation (see figure 52).

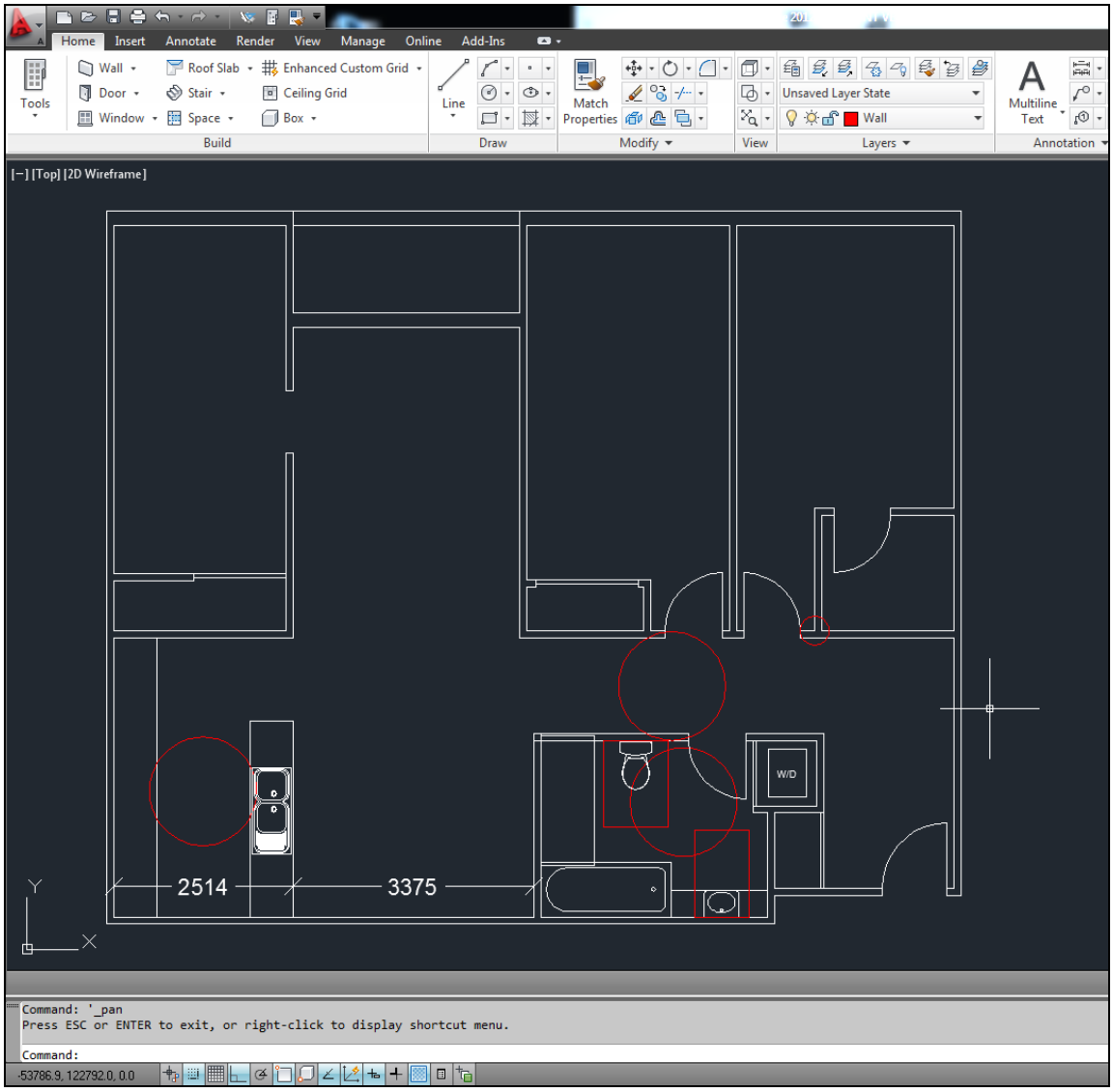

Figure 53: Fifth example, the obstacles. SC: 1/100

The obstacles are:

- Doors do not follow UD requirements
- No turning space in the bathroom
- No turning space in the kitchen
- No knee space under the lavatory and the sink
- No turning space to access the bathroom and bedroom

2. Suggestions (see figure 54).

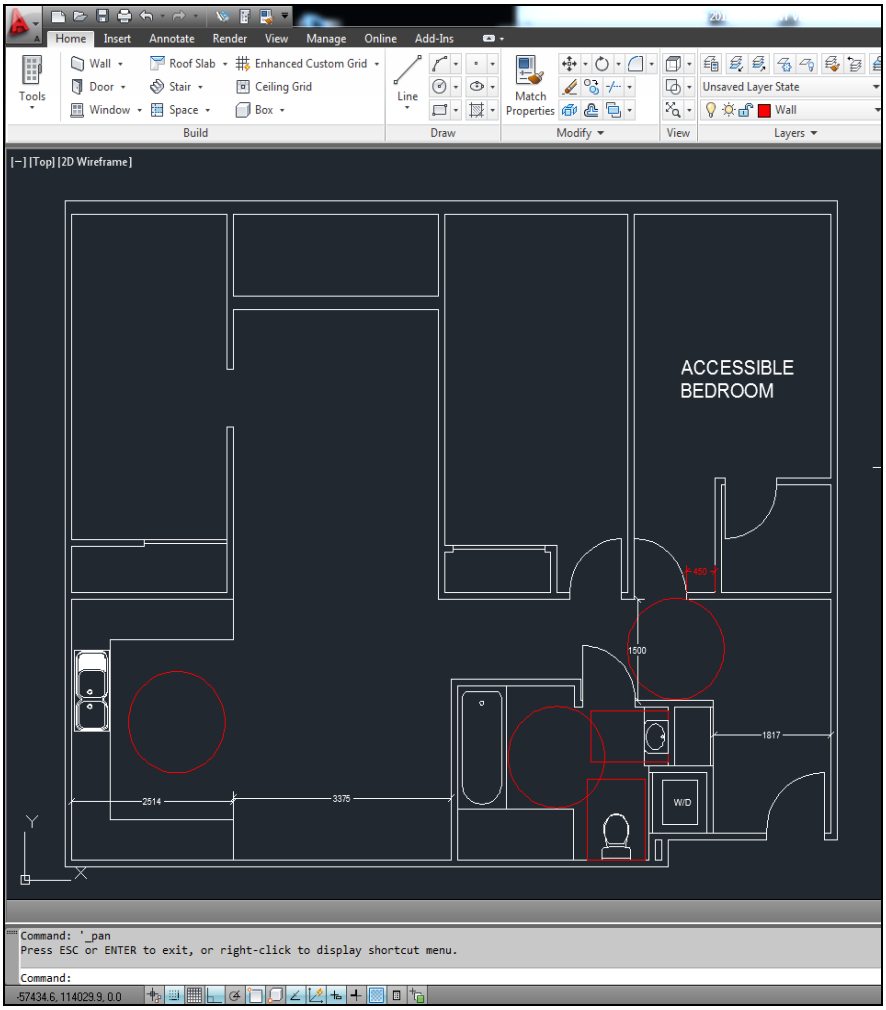

Figure 54: Fifth example, the suggestion. SC: 1/100

The suggestions are:

- Doors to follow UD requirements
- Create turning space to access the bathroom and the accessible bedroom
- Bathroom door to open outward
- Exchange the location of the washer/dryer cabinet and the clothes cabinets
- Relocate the bathroom fixtures
- In the kitchen, change the sink counter to be U shape

6.7 Sixth Example

Type: Three Bedrooms (figure 55).

Area: 114 m^2

Location: Montreal

Figure 55: Sixth example

1. Analysis of the Current Situation (see figure 56).

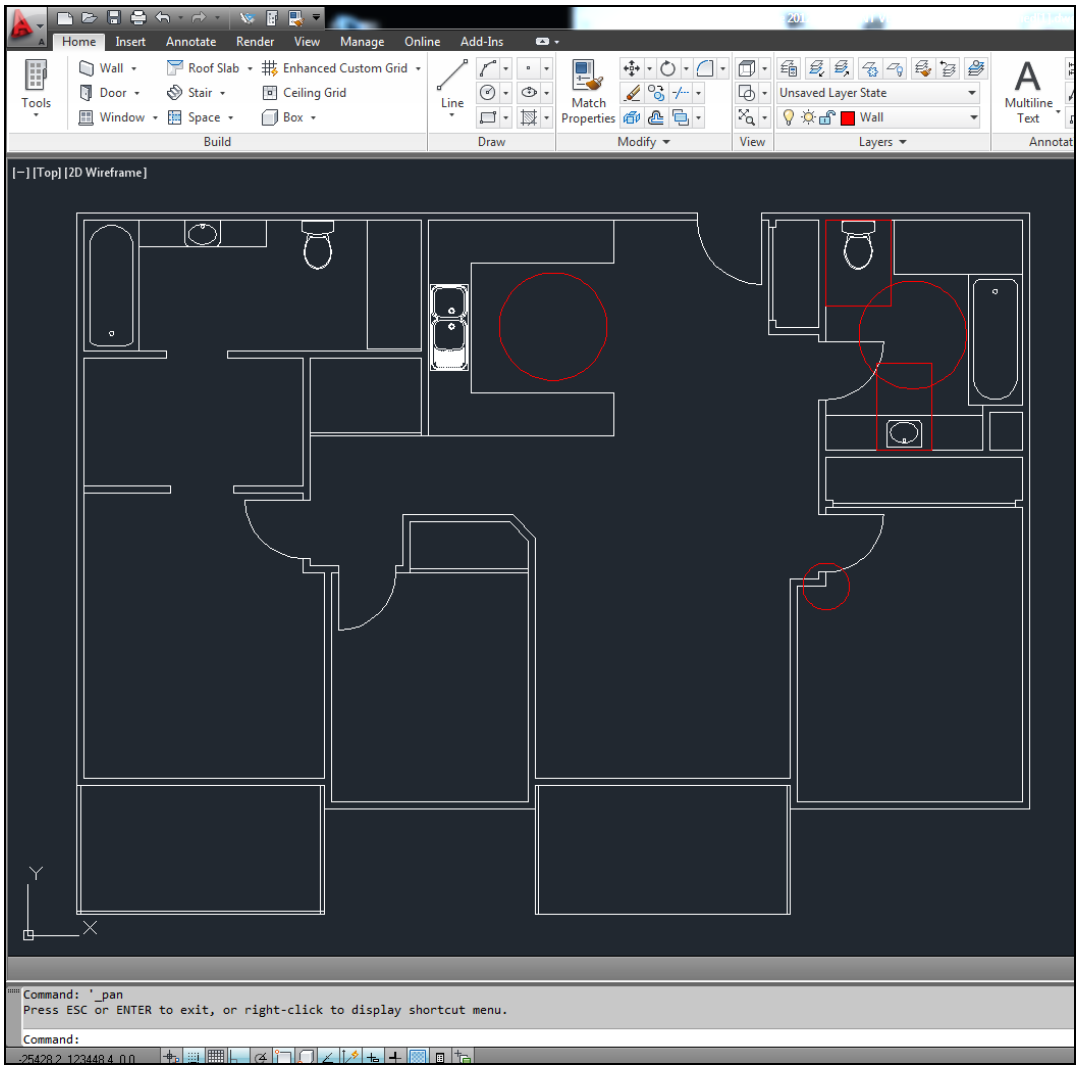

Figure 56: Sixth example, the obstacles. SC: 1/100

The obstacles are:

- Doors do not follow UD requirements
- No turning space in the bathroom
- No sufficient clear space at the latch side of the accessible bedroom door.

2. Suggestions (see figure 57)

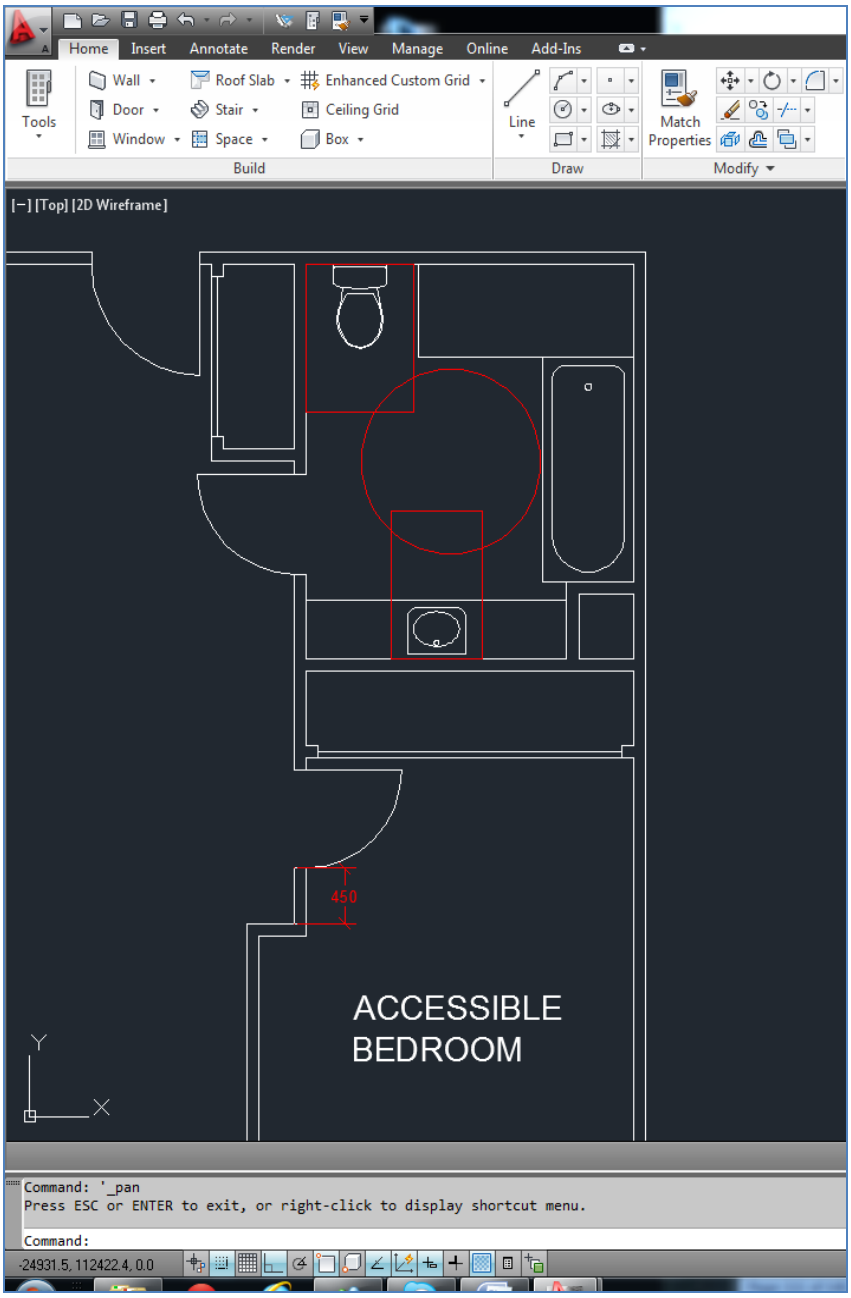

Figure 57: Sixth example, the suggestion. SC: 1/100

- Doors follow UD requirements
- A clear space of at least 450 mm is recommended at the latch side.
- Bathroom door to open outward

6.8 Summary

The six examples introduced in the foregoing chapter are inaccessible residential units for wheelchair users. A redesign has been made to the mentioned units, Adopting the list of recommendations concluded from the present research, and applying the new instances created in new Revit families, has transformed the inaccessible units to accessible ones without any additional area, with no changes in the architectural concept or the area of the units, without any additional material to be required.

Chapter 7

Conclusion

7.1 Conclusion and Recommendations

The NBC provides accessibility to residential units within accessible buildings for wheelchair users. Nevertheless, it does not provide the usability of those units, nor does it address the possibility of entering the bathroom easily, using it conveniently, and then leaving it safely. The NBC does not guarantee for any circulation space for wheelchair users, through all these units around, and especially in the kitchen.

The present thesis discusses the NBC articles, related to the above-mentioned residential units, from the Universal Design (UD) perspective. The suggested changes aim to ensure the accessibility and usability of residential units within accessible residential buildings.

The suggested changes are as follows:

1. Door openings shall provide a clear width of 815 mm minimum for interior doors and 915mm for exterior doors. Threshold height to have vertical rise between 7-13 mm, to be bevelled at slope up to 1:2.
2. 1500x1500 mm turning space everywhere except corridors.
3. 760x120 mm clear floor space at each fixture; spaces may overlap.
4. Toilet centred in a minimum 900mm wide space, 450mm from any side wall .
5. Broad blocking in walls around toilet, tub, and shower for future placement and relocation of grab bars.
6. Lavatory and sink counters height between 730-850 mm.
7. Lavatory centred in a minimum 760mm wide space, 380mm from any side wall.
8. All lavatories and sinks to have either open knee space below or cabinets with retractable doors and removable.
9. Clear floor space of 450mm minimum beside door at latch jamb.

10. Minimum clear width of interior accessible routes to be 1200 mm.

Also, the present research provides a design of new instances created in new Revit families to be stored as a part of the database of Building Information Modelling. The new instances are accessible buildings' elements, such as interior and exterior doors, bathroom fixtures including toilets, lavatories and bathtub, and kitchen fixtures such as sink.

7.2 Summary of the Expert Consultation

The meeting with the consultation services director at Société Logique aimed to get an impartial criticism of the thesis and its outcomes, by an organization involved in universally accessible environments. The questionnaire filled out by the consultation services director (see Appendix A) highlights the list of recommendations concluded from the present thesis.

One of the questions is about the level of adoption of the suggested requirements in today's residential buildings; the evaluation concluded that 2/10 requirements are adopted in today's residential buildings.

The priority given by Société Logique to the implementation of the suggested requirements is 8/10 of the total requirements.

What is missing in the list of recommendations, from the point of view of the consultant, is the fire prevention which is outside the scope of the present research. The concept of Building Information Modelling (BIM) through 3D Modelling has not yet been adopted by Société Logique; 2D is the used tool in the meanwhile.

7.3 Research Contribution

The main contribution this research provides concerns the attitude toward people with disabilities, and its implementation in the National Building Code (NBC); Precisely, wheelchair user. A wheelchair user is not an ill person, and the need to move with a

wheelchair is not a disease. Wheelchair users don't need to be hospitalized, or to live in special buildings built especially for them and equipped with highly sophisticated tools.

But wheelchair users' path, under National Building Code (NBC), is full of barriers to residential buildings, houses or multi-storey buildings; in this research, a vision has been provided to have 100 per cent of residential units to be accessible and usable by wheelchair users if, the suggested list of recommendations, inspired by Universal Design (UD) Concept, was adopted by the National Building Code (NBC).

On the other hand, this research highlights on Building Information Modelling as a digital representation of physical and functional characteristics of a facilty which is considered as a revolutionary way of working during a building's life-cycle phases, from design to construction until management phase. This research made a path for Universal Design (UD) Concept to be barrier-free to the latest trend of building technology, and to be integrated in the main BIM tools, Revit software, to contribute and enrich the library of the construction industry.

7.4 Future Research Expansion

The current research focuses on residential units within accessible residential buildings, which are larger than 600 m^2 area or three storey-buildings.

Adopting the same building's classification in the National Building Code (NBC), the recommended future research expansion is to focus on Accessibility and Usability of residential buildings smaller than 600 m^2 or less than three storey-buildings. This includes, more precisely, all houses, be they detached, semi-detached, duplexes, town houses, row houses and boarding houses.

A first step would be to adopt the "Visit ability" concept, with a view to moving forward towards the adoption of the universal design (UD) concept and therefore, to attaining a completely convenient life environment, usable by everyone.

References

(2000). *Accessible Multifamily Housing.* North Carolina: the Center for Universal Design.

Autodesk Building Solution. (2003). Retrieved 2012, from Building Information Modelling in Practice: www.autodesk.com/buildinginformation.

Advancing the inclusion of persons with disabilities. (2004). Retrieved 2012, from Supporting Persons with Disabilities: http://www.cndd.ca/assets/research%20documents/Canadian%20Government/Supporting%20Persons%20with%20Disabilities%20-%20Can%20Govt.pdf.

(2005). *Accessibility for Ontarians with Disabilities Act.* Ontario: Ministry of Community and Social Services.

Convention on the Rights of Persons with Disabilities. (2006). Retrieved 2011, from Convention on the Rights of Persons with Disabilities: http://www.un.org/disabilities/convention/conventionfull.shtml.

Newfoundland and Labrador. (2007). Retrieved 2012, from Government of Newfoundland and Labrador: http://www.gov.nl.ca/fes/publications/guidance_doc_complete.pdf.

Welcome to Visitability Canada. (2007). Retrieved 2011, from Canadian Center on Disablity Studies: http://www.visitablehousingcanada.com/index.html#whyimportant.

About Universal Design. (2008). Retrieved 2011, from The Center for Universal Design: http://www.ncsu.edu/www/ncsu/design/sod5/cud/about_ud/udhistory.htm.

CANADIAN CENTRE ON DISABILITY STUDIES. (2008). Retrieved 01 5, 2012, from http://www.visitablehousingcanada.com/#visitabilitydefinition.

CANADIAN CENTRE ON DISABILITY STUDIES . (2008). Retrieved 01 5, 2012, from http://www.visitablehousingcanada.com/#visitabilitydefinition.

Disability Services Office. (2008, 2011). Retrieved from NC STATE UNIVERSITY: http://www.ncsu.edu/dso/general/universal-design.html.

Publications: Housing. (2008). Retrieved 2011, from The Center for Universal Design: http://www.ncsu.edu/www/ncsu/design/sod5/cud/pubs_p/phousing.htm.

Ministry of Energy and Mines. (2009). Retrieved 02 01, 2012, from British Columbia: http://housing.gov.bc.ca/building/reg/accessible/index.htm.

ADA Standards for Accessible Design. (2010). Retrieved 2012, from The American Institute of Architects: http://www.aia.org/practicing/akr/AIAB093914?dvid=&recspec=AIAB093914.

Canada's National Model Construction Codes. (2010). Retrieved 01 05, 2012, from Government of Canada: http://www.nationalcodes.nrc.gc.ca/eng/code_development.shtml.

CSA. (2010). Retrieved 01 5, 2012, from http://shop.csa.ca/en/canada/accessibility/cancsa-b651-04-r2010/invt/27021232004/ .

Imperial Tutorials. (2010). Retrieved 2012, from Revir Architecture 2010 Families Guide: http://faculty.scf.edu/gouldca/Courses/Revit/FamiliesGuideArchitectureImpENU[1].pdf.

National Building Code. (2010). Ottawa: National Research Council Canada.

Population Projections. (2010). Retrieved 2011, from Statistics Canada: http://www.statcan.gc.ca/daily-quotidien/100526/dq100526b-eng.htm.

Accessibility News Blog. (2011). Retrieved 2012, from SPH Planning and Consulting: http://www.sph-planning-consulting.ca/blog/bid/67577/New-Brunswick-introduces-new-regulation-for-accessibility

Building Standata. (2011). Retrieved 2012, from Alberta Municipal Affair: http://www.municipalaffairs.gov.ab.ca/cp_building_standata.cfm.

Disabilities. (2011). Retrieved 2011, from World Health Organization: http://www.who.int/topics/disabilities/en/.

Disability Information . (2011). Retrieved 2012, from Disabled World: http://www.disabled-world.com/disability/.

Disability Issues. (2011). Retrieved 2012, from Human Resources and Skills Development Canada: http://www.hrsdc.gc.ca/eng/disability_issues/index.shtml.

Environmental Scan of BIM Tools and Standards. (2011). Retrieved 2012, from IBC Institute for BIM in Canada: http://www.ibc-bim.ca/documents/Environmental%20Scan%20of%20BIM%20Tools%20and%20Standards%20FINAL.pdf.

International Classification of Functioning. (2011). Retrieved 2011, from World Health Organization: http://www.who.int/classifications/icf/en/.

Nova Scotia. (2011). Retrieved 2 2012, from Nova Scotia Building Regulations: http://www.gov.ns.ca/just/regulations/regs/bcregs.htm.

Principles of Universal Design. (2011). Retrieved 2011, from Universal Design Institute: http://www.udinstitute.org/principles.php.

About the Codes: Model Code Adoption Across Canada. (2012). Retrieved 2012, from Government of Canada: http://www.nationalcodes.nrc.gc.ca/eng/code_adoption.shtml.

Ageing Population. (2012). Retrieved 2012, from Human Resources and Skills development Canada: http://www4.hrsdc.gc.ca/.3ndic.1t.4r@-eng.jsp?iid=33.

Canadians in Context: People with Disabilities. (2012). Retrieved 2012, from Human Resources and Skills Development Canada: http://www4.hrsdc.gc.ca/.3ndic.1t.4r@-eng.jsp?iid=40.

Model Adoption Across Canada. (2012). Retrieved 2012, from NRC.CNRC: http://www.nationalcodes.nrc.gc.ca/obj/doc/model_code_adoption.pdf.

National Building Code of Canada. (2012). Retrieved 2012, from Federal Publications Inc.: http://www.fedpubs.com/subject/construction/natbuilding.htm.

National Model Construction Code Documents. (2012). Retrieved 2012, from Government of Canada: http://www.nationalcodes.nrc.gc.ca/eng/national_codes_home.shtml.

National Model Construction Codes. (2012). Retrieved 2012, from Government of Canada: http://www.nationalcodes.nrc.gc.ca/eng/nbc/index.shtml.

Universal Accessibility. (2012). Retrieved 2012, from Societe Logique: http://www.societelogique.org/contenu?page=bienvenue&langue=en.

Universal Design. (2012). Retrieved 2012, from The Center for an Accessible Society: http://www.accessiblesociety.org/topics/universaldesign/.

What is Universal Design. (2012). Retrieved 2012, from Universal Design.Com: http://www.universaldesign.com/about-universal-design.html.

Allsup. (2012). Vision Disability Information. *Disabled World*.

Arc, T. (2011). Cognitive Disability. *Disabled World*.

Canada, D. o. (1995). *Employment Equity Act.* Minister of Justice Canada.

Canada, D. o. (2012). *The Canadian Human Rights Act.* Minister of Justice Canada.

Canada, S. (2008). Disability Statistics Canada. *Disabled World*.

Commission, C. H. (2003). *A Place for All.* Minister of Public Works and Government Services .

Corporation, L. H. (2010). Hearing Impairment Information. *Disabled World*.

Design, T. C. (1999). *Accessible Multyfamily Housing.* North Carolina, USA: NC State University.

Design, t. C. (2006). *Residential Rehabilitation.* North Carolina: the Center for Universal Design.

Dion, B. (2006). *International Best Practices in Universal Design.* Commission, Canadian Human Rights.

Dunn, P. A. (1991). *Accessible housing legislation and policies.* Budapest: Independent Living Institute.

Elaine Ostroff, M. L. (2002). *Building a World Fit for People.* USA: Adaptive Environments Center .

Federal, P. a. (2000). *A Canadian Approach to Disability Issues.* Human Resources Development Canada.

Garton, G. (1982). *Canadian Charter of Rights and Freedoms.* Department of Justice Canada.

General, A. (2010). *Realizing the Millennium Development Goals for persons with disabilities toward 2015 and beyond (A/65/173).* United Nations.

Gill, C. (2010). *Universal Design.* Retrieved 2011, from Missouri State University: www.missouristate.edu/assets/fctl/FCTL_2final_presentation.pdf.

Hansen, A. T. (1985). *Accessibility Requirements in the National Building Code.* Retrieved 2011, from National Research Council Canada: http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/bpn/53_e.pdf.

Hergunsel, M. F. (2011). Retrieved 2012, from http://www.wpi.edu/Pubs/ETD/Available/etd-042011-135239/unrestricted/MHergunsel_Thesis_BIM.pdf.

Jrade, A. (2012). Integrating Building Information Modelling With Universal Design Requirements for High Accessible Homes. *Construction Research Congress 2012*, (p. 9).

Kendall, H. (1963). International Society for Rehabilitation of the Disabled. *International Society for Rehabilitation of the Disabled* (p. 416). Copenhagen: http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8749.1963.tb05056.x/abstract.

LONDON, C. O. (2007). *Accessibility.* Retrieved 01 5, 2012, from London Canada: http://www.london.ca/d.aspx?s=/Accessibility/2007FADSHTMLversion.htm#acknowledgement.

Moyes, R. (2011). *Housing Accessibility Regulation In Canada.* Canadian Home Builders' Association.

PDA, H. (1999). *A cost benefit analysis of adaptable homes.*

Rajendran, S., & Clarke, B. (2011). Building Information Modelling: Safety Benfits & Opportunities. 44-51.

Ratzka, A. (1994). Congress on Accessibility. *International Congress on Accessibility.* Rio de Janeiro: Independent Living.

Sabol, L. (2008). *Building Information Modelling and Facility Management.* IFMA World Workplace.

Saskatchewan, G. o. (2010). *Proposed Adoption, National Building Code.* Saskatchewan: Building Standards.

Senate, G. (2012). Promoting Better Community Based Care by Updating Disability Laws. *Disabled World*.

Taormina-Weiss, W. (2011). Family menbers, friends and caring for people with mobility disabilities. *Disabled World*.

Winnipeg, C. o. (2010, may). *Universal Design.* City of Winnipeg.

Yodlers, J. (2008). Integrated Project Delivery Using BIM. *Building Design and Construction*.

Appendix A

National Building Code and Universal Design

This study assesses the extent to which the National Building Code (NBC) adopts the principles of Universal Design Concept. In particular, the study focuses on the provisions of the National Building Code (NBC) dealing with the disability requirements established under the Universal Design Concept, with special focus on accessibility of wheelchair users to residential units. The suggestions made by the research, with a view to adopting them by the NBC, were compiled in a 10-item list.

Furthermore, the study aims to develop and create new families that incorporate the suggested 10-item list in Revit Software families to give designers easy access to Universal Design requirements.

Your participation is voluntary and appreciated, what is your name, your position and responsibilities?

----------Isabelle Cardinal, Architect, consultation services director at Société Logique--

A. For the next 10-item list, please choose a number from 0-10 and write it next to each statement to indicate how much the mentioned requirements are considered in today's residential buildings.

0	1	2	3	4	5	6	7	8	9	10
Not at all									Extremely	

1. Door openings shall provide a clear width of 815 mm minimum for interior doors and 915mm for exterior doors, Threshold height to have vertical rise between 7-13 mm, to be bevelled at slope up to 1:2 -----2----------

2. 1500x1500 mm turning space whenever a turn is needed----------0----------

3. 760x120 mm clear floor space at each fixture.----------10----------

4. Toilet to be centred in a minimum of 900mm wide space, 450mm from any side wall ----------0 ----------

5. Broad blocking in walls around toilet, tub, and shower for future placement and relocation of grab bars. ----------0----------

6. Lavatory and sink counters height between 730-850mm .-----10----------

7. Lavatory to be centred in a minimum of 760mm wide space, 380mm from any side wall----------2----------

8. All lavatories and sinks to have either open knee space below (width 660mm, height 730-860) or cabinets with retractable doors and removable. ----------0----------

9. Clear floor space of 450mm minimum beside door at latch jamb.------0----------

10. minimum clear width of interior accessible routes to be 1200mm .---1----------

B. For the same 10-items list using the same scale, please choose a number from 0-10 and write it next to each statement to indicate the level of priority you give, to the implementation of the mentioned requirement in the buildings.

1) Door openings shall provide a clear width of 815 mm minimum for interior doors and 915mm for exterior doors Threshold height to have vertical rise between 7-13 mm, to be bevelled at slope up to 1:2 ------10-------

2) 1500x1500 mm turning space .----------10----------

3) 760x120 mm clear floor space at each fixture, spaces may overlap.------0--------

4) Toilet centred in a minimum 900mm wide space, 450mm from any side wall .---------
---------10----------

5) Broad blocking in walls around toilet, tub, and shower for future placement and relocation of grab bars. ----------10----------

6) Lavatory and sink counters height between 730-850mm .----------10----------

7) Lavatory centred in a minimum 760mm wide space, 380mm from any side wall------
----------10 ----------

8) All lavatories and sinks to have either open knee space below (width 660mm, height 730-860) or cabinets with retractable doors and removable. ----------
----8----------

9) Clear floor space of 450mm minimum beside door at latch jamb.-------10----------

10) minimum clear width of interior accessible routes to be 1200mm. ----0, to be 1100mm

C. Do you have any suggestions to add to this research? -------Balconies are living spaces, so specifications of the balconies' doors types and dimensions are important. Also safety and fire prevention are a major concern, to be taken into consideration. ----
----

D. Do you suggest any additional requirements you think are important to add to the previous list?----------see (B)----------

E. Will you consider adopting the concept of Building Information Modelling through 3D Modelling?-------Not in the present time, because all our work is with AutoCAD, 2D ----------

F. Are you willing to implement the 10-item list in buildings you design? Why? --------
----------Yes, we already adopted part of the mentioned list and are still working to increase accessibility to residential buildings and units. This has been our work for 30 years.