Effect of Open Space Distribution on Spatial Accessibility and Park Management Costs in the Context of Urban Neighbourhoods

by

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Abstract

Preserving open space in residential areas has been proven to have numerous physical and mental health benefits for the residents. Parks, playgrounds, and walking trails for pedestrians and cyclists are primary designed open spaces in a neighbourhood structured plan (NSP) that promote active living lifestyle regardless of a resident's personal attitude towards fitness. The City of Edmonton has established a Municipal Reserve (MR) plan and strategy to allocate open green space for public recreational facilities in NSP. In the subdivision development process, 10% of gross developable land is allocated as MR, which is designated for public recreational facilities and school/park development.

This study focuses on how accessibility to neighbourhood parks (MR) could be enhanced through the suitable distribution of MR. Spatial interaction index (SI_x) for 18 case study neighbourhoods is assessed using a spatial accessibility model. Results show a skewed distribution of SI_x in most cases. Hedonic pricing analysis for these neighbourhoods shows positive correlation of property value with MR. As the distance from well-developed MR with playgrounds or recreational parks increases by 1%, property value decreases by 1.02% for neighbourhoods located in the southwest region of Edmonton. The study also reveals that proximity to open space reserved as storm management facilities has a significant effect on the housing value (price elasticity is 1.5%) for the same neighbourhoods.

A hypothetical neighbourhood design is created to simulate the effect of various policy scenarios on neighbourhood design. The results reveal that distributed design of MR increases the accessibility to this reserved public space, overall property value increases by $5,686,924, and the corresponding additional municipal tax revenue is $43,133. Cost analysis of park maintenance operation in the hypothetical design scenario reveals that this additional revenue is sufficient to recover annual park management costs. Also, mowing duration optimization is possible by using an alternative machine size in the case of the new hypothetical design.

Preface

This thesis is an original work by Md Saiful Islam. No part of this thesis has been previously published.

Acknowledgements

First, I would like to express my deepest gratitude to my supervisors, Dr. Mohamed Al-Hussein and Dr. Ahmed Bouferguene, for being a great source of expertise throughout this study and for their invaluable support and encouragement. This thesis could not have been completed without their help and contributions. Thank you for believing I could succeed and for giving me the opportunities to do so. I would also like to extend my gratitude to the City of Edmonton Sustainable Development Team: Mr. Kalen Anderson, Mr. Dennis Wilkie, and Mr. Charlie Barton for their collaboration, data support, and assistance. Special thanks to Mr. Anand Pye of Urban Development Institute (UDI), Edmonton chapter for his valuable suggestions in collecting information.

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List of Abbreviations

ARPA	Alberta Recreation and Parks Association
CBD	Central Business Districts
CMHC	Canada Mortgage and Housing Corporation
CSEP	Canadian Society for Exercise Physiology
GIS	Geographic Information System
MR	Municipal Reserve
NSP	Neighbourhood Structured Plan
NAD83	The North American Datum of 1983
OLS	Ordinary Least Square Method
UTM	Universal Transverse Mercator
VIF	Variance Influence Factor
WHO	World Health Organization

Chapter One

Introduction

1.1 Introduction and Motivation:

The health status of urban residents is influenced by the planning and design of the built environment of a community (Ministry of Municipal Affairs and Housing, 2009; Healthy Spaces and Places, 2009; Edwards and Tsouros, 2008; Toronto Public Health, 2012). Land-use components such as street connectivity, accessibility to the built environment, natural surroundings and biodiversity, recreational facilities, and green space availability all affect physical activity, health, and mental wellness of the population (Ministry of Municipal Affairs and Housing, 2009). Through much research in recent decades, it has been established that public health should be a primary focus in the planning stage of any land development projects in order to create healthy living spaces (City of New York, 2010). Many residents will consider living in certain types of neighbourhoods based on specific features of the built environment of a residential neighbourhood such as suitable walking paths and green space, and accessibility for commuting to work (Franka et al., 2007). The implementation of an active living planning strategy may benefit the lives of residents in a neighbourhood on a personal and community level, for example, the frequency of residents walking either for exercise or as a mode of travel may increase if functional open spaces are designed (Healthy Spaces and Places, 2009). Studies also show that communities have a higher tendency to consume healthier food if grocery stores selling healthy and affordable foods are accessible (Morland et al., 2002). Design of active neighbourhoods with a focus on public health can thus be regarded as a solution that will promote healthy and active lifestyles among communities (Healthy Spaces and Places, 2009;

Transport Canada, 2011; Edwards and Tsouros, 2008; Ministry of Municipal Affairs and Housing, 2009; City of New York, 2010).

The City of Edmonton's built environment is distinctive within Canada. It is a growing city with a central downtown core, and both mature and developing neighbourhoods. Since parks, green open spaces, and playgrounds are prominent design components in a neighbourhood structured plan that promote active living (Healthy Spaces and Places, 2009), the City of Edmonton has established a plan and strategy to preserve natural open space and allocate green space for public recreational facilities. In fact, the City of Edmonton has implemented a Municipal Reserve (MR) plan that reserves open spaces for community use in new neighbourhood structured plans. In the process of developing new neighbourhoods, the structured plan is initiated by private developers and then finalized through joint cooperation with the City's Planning Administration and other related agencies and service providers (Figure 1) (City of Edmonton, 2013b). This step is critical for the shaping of the built environment of a neighbourhood. The scope of this research encompasses this planning stage.

Figure 1: Stages in neighbourhood development (Source: City of Edmonton, 2013b)

The Municipal Government Act (MGA) authorizes the City of Edmonton to preserve 10% of land for a proposed land development project as MR during the neighbourhood structure planning phase; MR land is designated for public recreational facilities and school/park development. When a developer proposes to develop a space, *gross developable area* is determined by subtracting *environmental* and *special reserve area*[1], then MR is allocated from this net developable area. Spatial observation and Neighbourhood Structured Plan (NSP) evaluation reveals that a large number of mature and developed neighbourhoods in Edmonton have this MR concentrated in one place where mostly school sites are located. Despite the municipal strategy for preserving open space and allocating it into NSP, this focus on MR for neighbourhood parks has failed to maximize benefit due to lack of proper spatial assessment and has raised the following questions:

- How accessible is this recreational space for homes in a neighbourhood?
- Is the land properly distributed?
- What percentages of homes are receiving intangible advantage of proximity to these spaces?
- Can better design be implemented that would maximize MR usage by the residents?
- How could a new NSP promote physical activities for residents?
- If scattered pattern of MR is introduced, how it will affect the park management cost and maintenance works?

These questions demand further exploration of the relationship between green space and community health, as well as financial gain by the municipality. In summation, this study addresses the accessibility of MR in current neighbourhood design practices, evaluates its usage in terms of spatial interactions probability, how this open space could be utilized to optimize

[1] These may include wetlands, natural drainage areas, watersheds, river valley, natural vegetation, or flood-prone land areas.

physical activity opportunities, and intangible economic achievement through alternative forms of design and planning

1.2 Objective of Research:

To find answers to the questions posed above, the specific objectives of this study are as follows:

a) Evaluate the magnitude of accessibility of parks with respect to housing lots in a given neighbourhood.

b) Construct spatial interaction maps to observe the current design practice outcomes on spatial interaction proficiency.

c) Observe the spatial interaction distribution in the current design practice.

d) Develop a hedonic pricing model to identify the major variables affecting property values.

e) Quantify the effect of proximity to open spaces (e.g., neighbourhood parks, storm management facilities, green spaces, small pocket parks) on property value.

f) Design a hypothetical case study neighbourhood considering the distributed MR concept which enhances accessibility to open spaces in order to promote physical activity.

g) Predict property value in a new hypothetically designed neighbourhood.

h) Compare new predicted value with actual worth and estimate the additional municipal revenue from alternative design.

i) Enumerate the park maintenance cost in both actual and new hypothetical design.

j) Assess the sensitivity analysis of maintenance cost for hypothetically designed scenario.

k) Develop simulation model to analyze the change in mowing duration for the distributed design of MR in a case study neighbourhood.

1.3 Organization of the Thesis:

This thesis consists of five chapters. Chapter 1 introduces the topic and research objectives, and provides an overview of the thesis.

Chapter 2 (Literature Review) provides an overview of the reviewed literature and discussions on how public open spaces, reserved green space, neighbourhood parks and playgrounds affect the aspiration of people to become physically active, as well as the influence these spaces have on mental and physical health. This chapter also summarizes the economic aspect of open space in terms of enhanced property value and additional municipal revenue generation.

The third chapter (Methodology) presents details of the methodology used in this study. Mathematical modelling to measure spatial interactions of homes with respect to neighbourhood parks and property value assessment model development are explained in detail in this section.

Chapter 4 (Analysis and Results) discloses findings and some analysis from spatial interaction modelling and the hedonic pricing model for housing property. The developed hedonic model is used to predict property value in a hypothetical neighbourhood development plan for a case study residential area. Also, change in park maintenance costs has been analyzed for this hypothetical design to observe the sensitivity for a scattered MR option.

Finally, Chapter 5 (Discussion) comprises recommendations, conclusions, and future scope of research.

Chapter Two

Literature Review

2.1 Introduction:

The obesity rate in Canada doubled between 1981 and 2009 (Government of Canada, 2011). According to a report published by the Public Health Agency of Canada in 2011, one in four Canadian adults and 8.6% of children and youth (ages 6 to 17) are obese (Government of Canada, 2011). Furthermore, between 2000 and 2008, the annual economic burden of obesity in Canada increased by $735 million (Government of Canada, 2011). To address this issue, Health Canada and the Canadian Society for Exercise Physiology (CSEP) recommend 60 minutes of moderate to vigorous physical activity (MVPA) per day for children (ages 5 to 11) and youth (ages 12 to 17), but unfortunately only 7% of children in Canada achieve this standard (Active Healthy Kids Canada, 2012). A Canadian Community Health Survey conducted in 2013 revealed that one in five youth (ages 12 to 17) is overweight (Statistics Canada, 2013). In Alberta, the number of people who are obese has grown from 1.2 million in 2009 to approximately 1.6 million in 2013 (Figure 2).

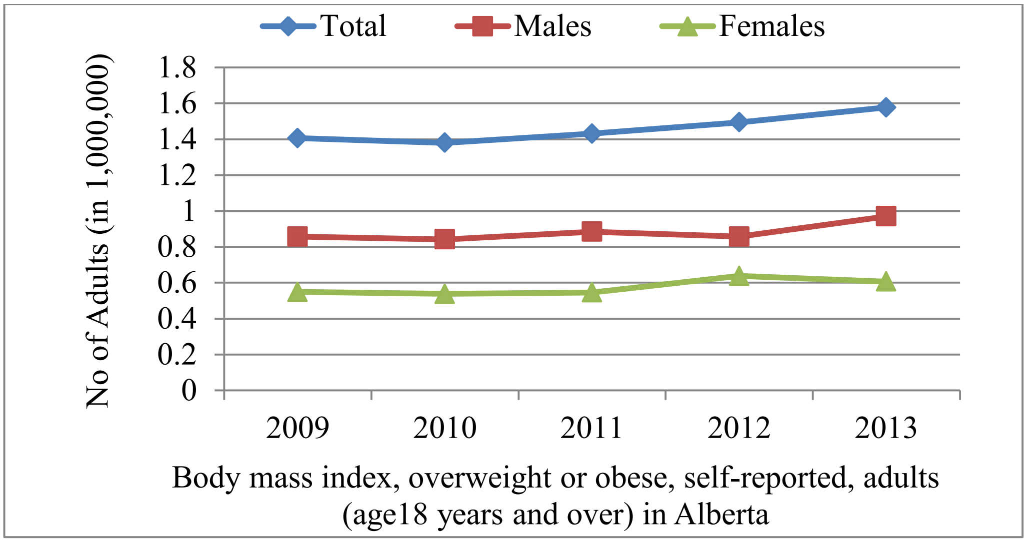


Figure 2: Obesity rise in Alberta (Data Source: Statistics Canada, 2013)

Promoting physical activity in an individual's day-to-day routine is an important part in the process of reducing the obesity rate.

2.2 Built Environment and Health:

The surrounding living space of the built environment influences one's aspiration toward physical activity. In this context, the Planning Institute of Australia defines the "built environment" as the structure and space where people live, work, and play; it may comprise land use, transportation systems, and design topographies (Healthy Spaces and Places, 2009). In modern urban engineering the functional relationship between planning built environments and public health has become a critical issue. Figure 3 illustrates the variation of obesity rates in a number of developed countries; as show in Figure 3 countries with active built environments face low obesity rates whereas Canada has the second-highest obesity rate. Decades of research have established a concrete functional relationship between urban planning and its effect on public health. At present, modern cities (e.g., Toronto, Los Angeles, New York and London) realize the importance of physical activity-friendly urban design and are willing to change city policies to promote these design practices. Even the World Health Organization (WHO) has defined guidelines to build active cities and defines active city as:

"A healthy, active city is one that is continually creating and improving opportunities in the built and social environments and expanding community resources to enable all its citizens to be physically active in day-to-day life" (Edwards and Tsouros, 2008).

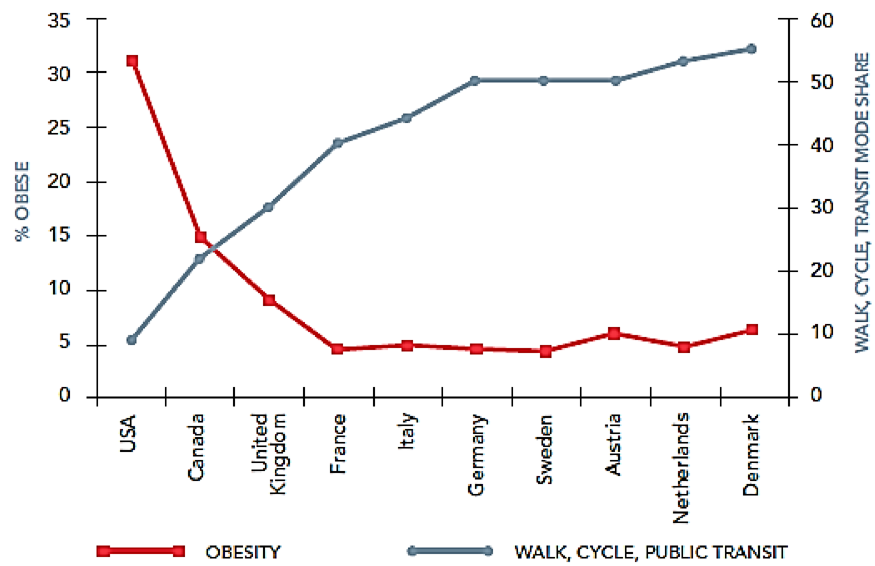


Figure 3: Effect of active environmental design (Bassett et al., 2008; Transport Canada, 2011).

Active city is a macro-scale concept which deals with several connected factors; this research focuses on one of the active city components: the neighbourhood built environment. The built design of urban neighbourhoods is one of the major components in the formation of an active city. Major variables of this component such as neighbourhood design pattern, mixed land use practice, pedestrian facility, and transportation system practice all play key roles in the enhancement of physical activity in an urban community (Craig et al., 2002; Heath et al., 2006).

In the U.S and Canada, it is believed that readily accessible recreational facilities and the design of urban built environments (such as traffic, pedestrian walking facility maintenance, and lighting) impact the percentage of the population that are physically active (Craig et al., 2001; Brownson et al., 2001). Aesthetic design and resident-friendly spaces encourage active lifestyles by promoting walking, bicycling, and other physical recreation, as well as the use of public transportation systems (Healthy Spaces and Places, 2009). The most common form of physical activity (walking) has been found to be dependent on the size of the available open/recreational space; parks up to 2.0 ha (5.0 ac) in size that are within a 1 km radius have been highly associated with youth between the ages of 5 and 20 years (Figure 4) (Frank et al., 2007).

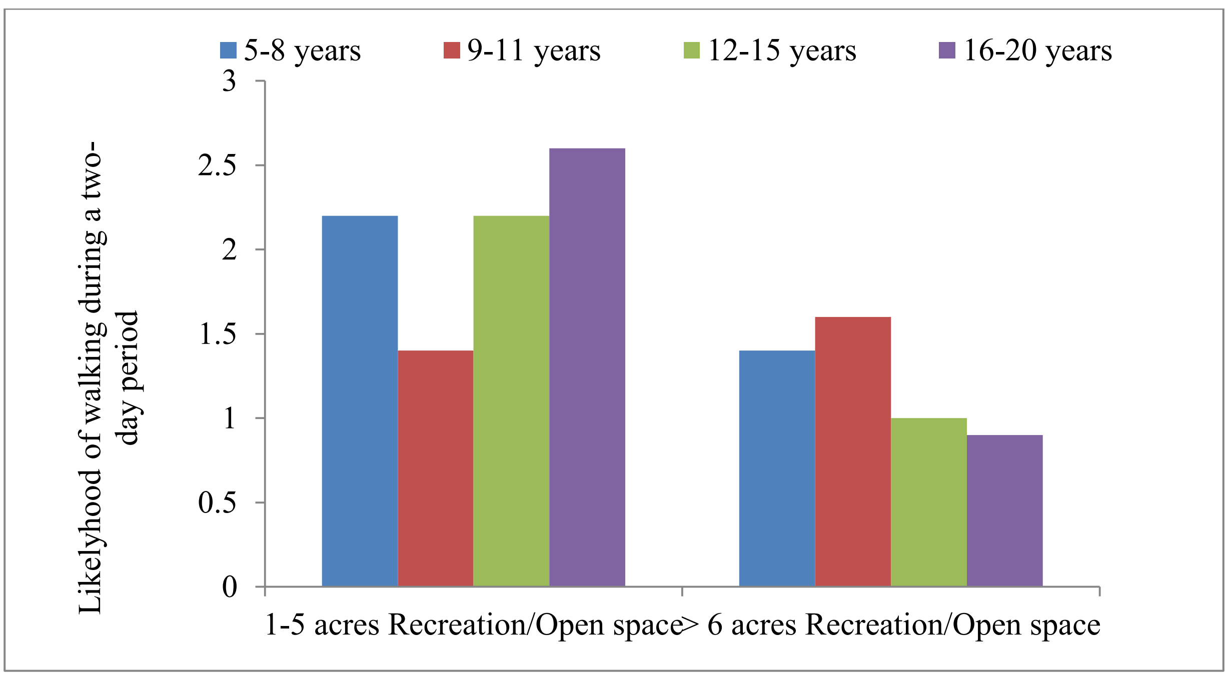


Figure 4: Effect of open space size on walking at least once in a two-day period (Frank et al., 2007).

One study that focused on Canada found that walking to work is highly correlated with the built environment: a one-unit increase in the score being associated with a 25% increase in the proportion of people walking to work (Figure 5) (Craig et al., 2002).

Figure 5: Sensitivity of walking with the built environment in Canada (Craig et al., 2002).

A systematic review by Heath et al. (2006) shows how the built environment, municipal finance, and institutional support increased the size of the population living within a buffer zone comprising commercial, workplace, and school environments. The same study also suggests that better inter-connectivity of pedestrian walkways and roads combined with availability of green space for active recreation may positively affect the rate of physical activity (Figure 6) (Heath et al., 2006). All of these factors facilitate an enhanced and active lifestyle. The effect of the highlighted attributes in Figure 6 is assessed in detail in this thesis. All factors mentioned in this model collectively encourage neighbourhood residents to increase their level of physical activity (Heath et al., 2006). Extrapolating from these findings, it may be suggested that if more funds are available to create and/or improve open spaces for residents in the neighbourhood structured plan, it would ultimately increase the overall physical activity levels of residents (Heath et al., 2006). The relationship between the built environment and public health can irrefutably be established by surveying the research literature connecting several fields of study, including public health, urban planning, transportation design, and health promotion (Quayle and Hamilton, 1999). Planners and design professionals must thus consider the multidimensional aspects of a neighbourhood in order to create active lifestyle-friendly spaces.

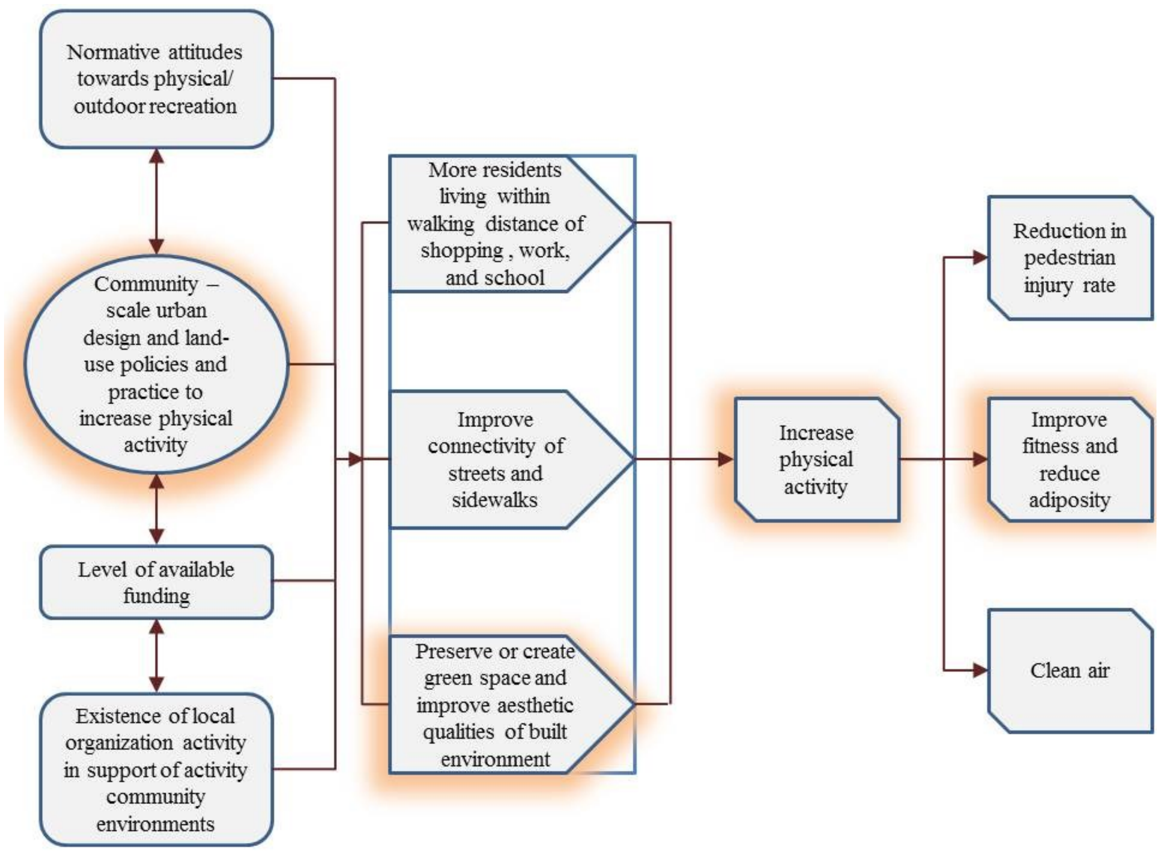


Figure 6: Model illustrating how community-scale urban design/land use policies and practices promote physical activity (Heath et al., 2006).

Community parks play a primary role in the promotion and implementation of health benefits for residents. To build an active city, neighbourhoods should be planned and designed in a manner that encourages a high utilization of parks and open spaces, which in turn would promote more physical activity among the residents. The health benefits of preserving and allocating open space in neighbourhood development is explained in later sections.

2.3 Effect of Neighbourhood Open Green Space on Resident Health:

Residents are affected by interactions with the surrounding environment in which they live. Research on urban planning and public health shows that the physical attributes of a neighbourhood affect the level of physical activity as well as mental health of residents (Kaczynski et al., 2008; Kaczynski et al., 2009; Besenyi et al., 2014). Personal awareness as well as availability and proximity of open green space in a neighbourhood are factors that play a large role in the physical activity levels of residents.

The walking distance from homes to the nearest park is a metric closely related to mental health. According to a recent study, for instance, residents living in close proximity to parks show a higher 5-item mental health inventory (MHI-5) score (Sturm and Cohen, 2014). In a 2005 study, a Danish health interview survey of a region-stratified random sample of 21,832 adults showed that living in close proximity to green space positively impacts health and health-related quality of life among Danish adults (Stigsdotter et al., 2010). The results concluded that individuals who have not visited a park within a given week have a 1.57 times higher chance of experiencing mental stress. A cross-sectional study on 3,416 female residents of the city of Kaunas, Lithuania found a correlation between urban park proximity and blood pressure levels for women aged between 20 and 45 years; for every 300 m increase in distance from parks, the likelihood of having normal blood pressure levels among the participants increased by 9%, whereas for high-normal blood pressure the increase was 14% (Grazuleviciene et al., 2014). Proximity to residential parks has also been related to prevalence of chronic diseases. People aged 40 to 59 years living a half mile away or further from parks are more likely to suffer from two or more chronic diseases (e.g., heart disease, heart attack, high blood pressure, cancer, diabetes, osteoporosis, depression and other mental health concerns, asthma and allergies, disability) in contrast to those living near parks (Besenyi et al., 2014).

Stigsdotter et al. (2010) claimed that people residing at a distance greater than 1 km from parks and green space are 1.42 times more likely to experience mental stress than those living less than 300 m away from parks and green space. Cohen et al. (2007) sampled a population of 1,849 persons per location in the case of eight public parks in Los Angeles, and found that 43% were residing within 0.25 miles, 21% between 0.25 and 0.5 miles, and 13% of park users lived more than 1 mile away.

Level of physical activity and frequency of park use are significantly correlated to travel distance from home to park (Sturm and Cohen, 2014). Research carried out among students in 291 public elementary schools in Nova Scotia confirmed that children in neighbourhoods with superior access to playgrounds, parks, and other recreational facilities are highly involved in physical activity and are expected to have a lower risk of becoming overweight or obese (Veugelers et al., 2008). A recent survey-based study in Montréal, Québec found that socio-demographic and economic factors are interrelated with the physical activity level in parks located within walking distance from residences (Moore and Kestens, 2011). The study defined *walking distance* as a 100 m road network buffer zone around a residence. The findings revealed that the older adult population and high income households were more conscious of having parks within walking distance for their physical activity level. In the case of children younger than 12 years of age, proximity to neighbourhood green space is prevalent to the use of that facility; as the number of recreational/open spaces increases, the frequency of walking to those places increases for young people between the ages of 9 and 20 years and the highest possibilities were observed if two to three open spaces are available in the neighbourhood (Figure 7) (Frank et al., 2007).

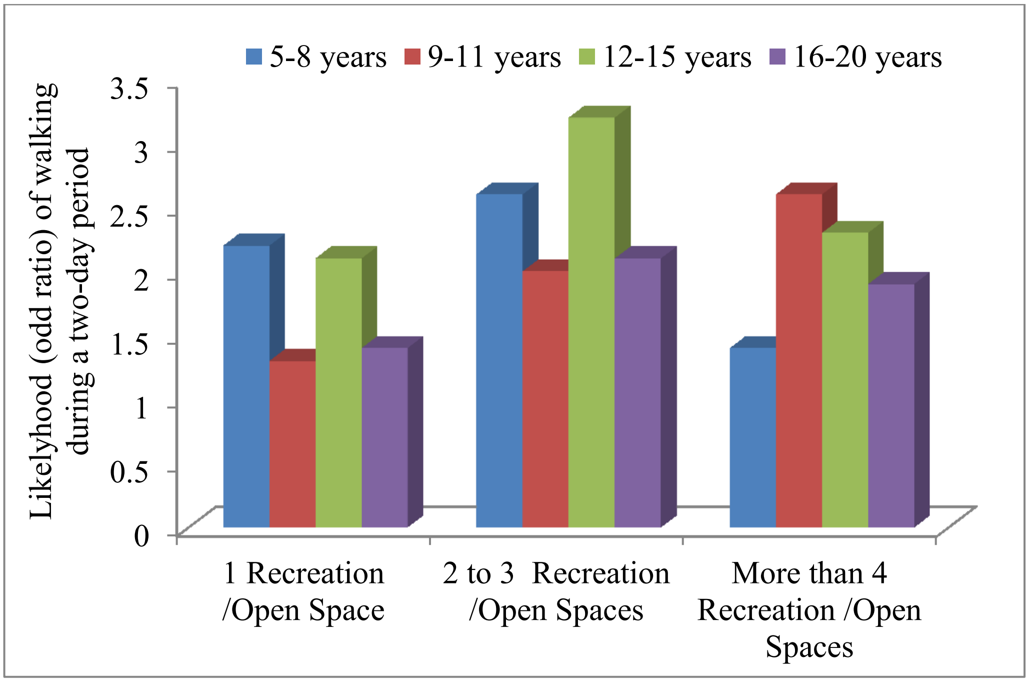


Figure 7: Likelihood of walking activity by different age group (Frank et al., 2007).

Availability of a playground within a 300 m buffer zone in neighbourhoods is an influencing attribute that is likely to increase biking for both pleasure and commuting regardless of gender, age, or educational level of the user, while walking relates to the area of parks in a 500 m buffer zone (Wendel-Vos et al., 2004); for every 0.4 ha (1.0 ac) increase in park size, 95 additional people have been found to visit the park. A significant change in the average number of visitors per park was observed through different seasons of the year (Figure 8) (Cohen et al., 2010).

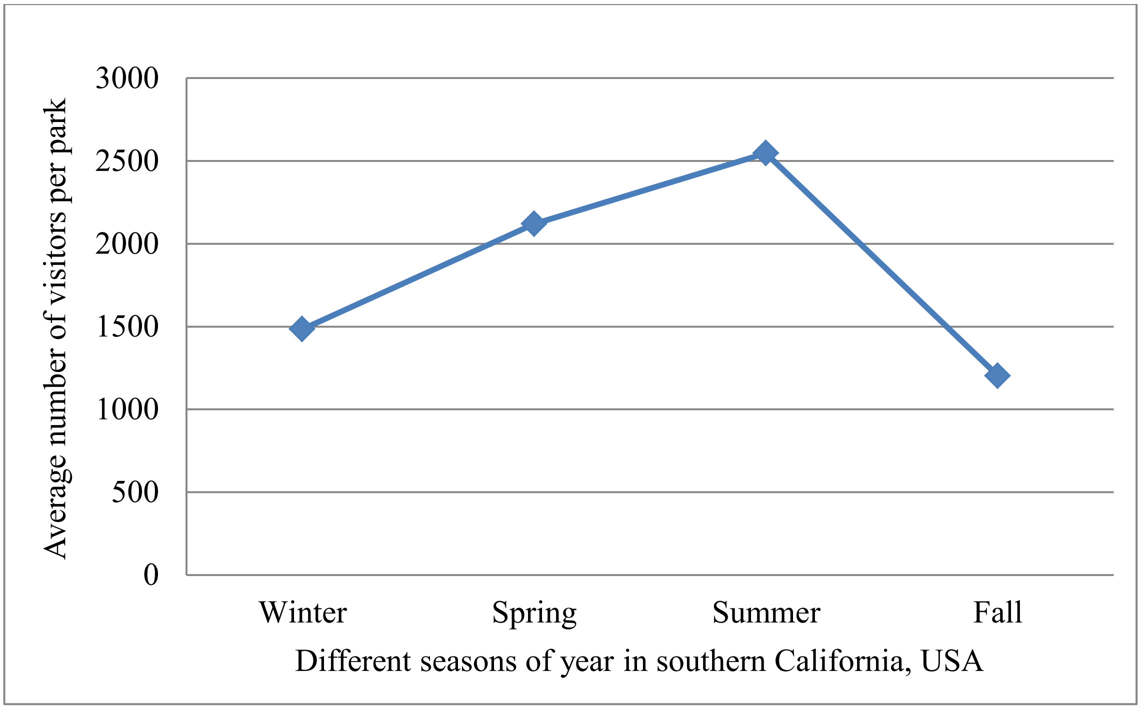


Figure 8: Seasonal variation in number of individuals in parks for Southern California, USA (Cohen et al., 2010).

However, a study in Ontario confirmed that parks with features such as paved and unpaved trails, wooded areas, playgrounds, basketball courts, and multipurpose rooms have a more significant effect on park-based physical activity than the distance from the park (Kaczynski et al., 2008). The study observed 33 parks from 0.10 ha to 232.82 ha in size and a mean distance from the participants' homes was 970 m. The use of parks with paved trails, unpaved trails and wooded areas increases more than seven times compared to those missing the above mentioned attributes (Kaczynski et al., 2008). A recent study in Kansas City by Kaczynski et al. (2014) found statistically weaker correlation between park proximity and park-based physical activity (PA); however, the number of available parks within a one-mile boundary of the case study area showed positive relevancy. Socio-demographic characteristics were key controls of the park related variables for this case.

Through a literature search, only one study has been found in Alberta which observed different types of physical activity for the following four parks in the City of Calgary: West Hillhurst, Meadowlark, Martindale, and Taradale (McCormack et al., 2014). For the City of Calgary, the authors claimed that type of physical activity is linked with physical and social environmental attributes and socio-demographic composition of the neighbourhood. The survey statistics of this study show that walking is the most popular physical activity, which specifies that adults (76.6%, $p < 0.05$) are more active in Taradale (Figure 9) while in Martindale, the sample population comprising 58.7% teenage visitors indicates that the absence of physical facilities (such as playground, baseball diamond, running track, etc.) governs the behaviour of activity type with different demographic compositions. The neighbourhood design principles should consider the park attributes required to meet the demand of different age group compositions (Wilkerson et al., 2005).

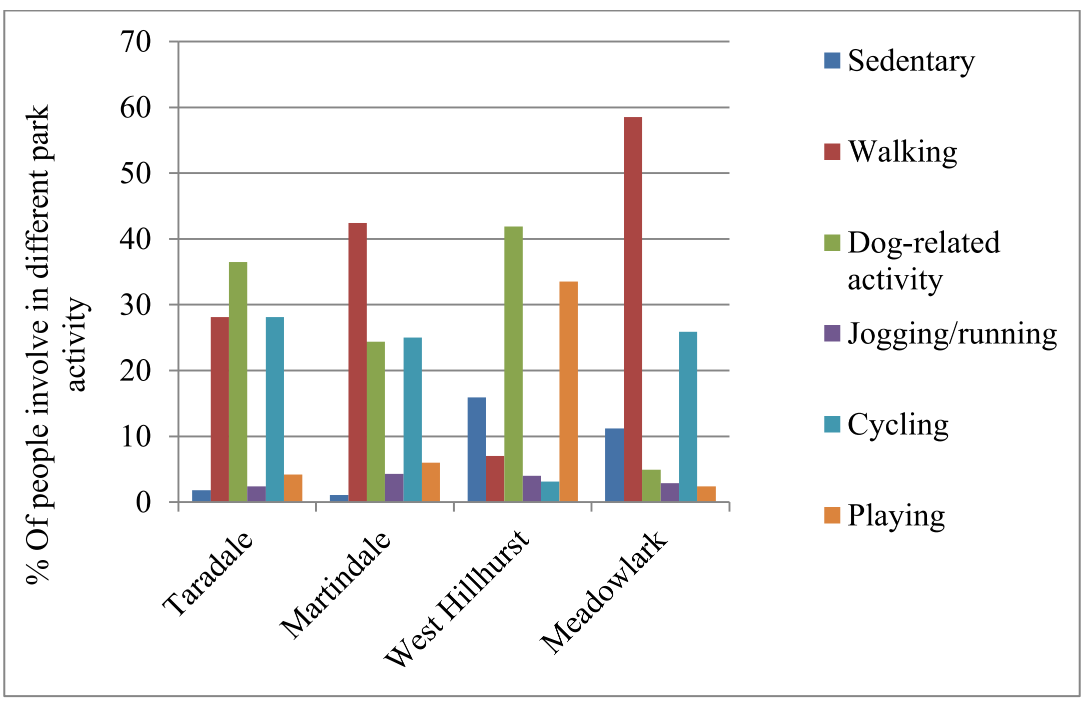


Figure 9: Types in physical activity in four parks in the City of Calgary (McCormack et al., 2014).

An extended socio-ecological model developed by Bedimo-Rung et al. (2005) explains the complex interactions involved in extent and nature of park usage factors and outcomes. The individual′s motivating factor for physical activity as well as park characteristics trigger the behaviour of park use, which generates physical, social, psychological, economic, and environmental benefits (Figure 10) (Bedimo-Rung et al., 2005). Figure 10 shows the scope of this thesis. Figure 11 illustrates the various details of park attributes. This model provides a theoretical background to understand the methodological procedure to map this current research. The park characteristics affect the number of park visits, which increases the potential of physical activities that in turn improve health benefits for the population. A significant number of recreational, public health, and urban planning studies explored and supported the association of park characteristics with health benefit and sustainable neighbourhood design (Kaczynski et al., 2014; Giles-Cortia and Donovan, 2002; Bassett et al., 2008; Edwards and Tsouros, 2008; Healthy Spaces and Places, 2009) and encouraged researchers to further assess the implementation of policies in order to create sustainable community design.

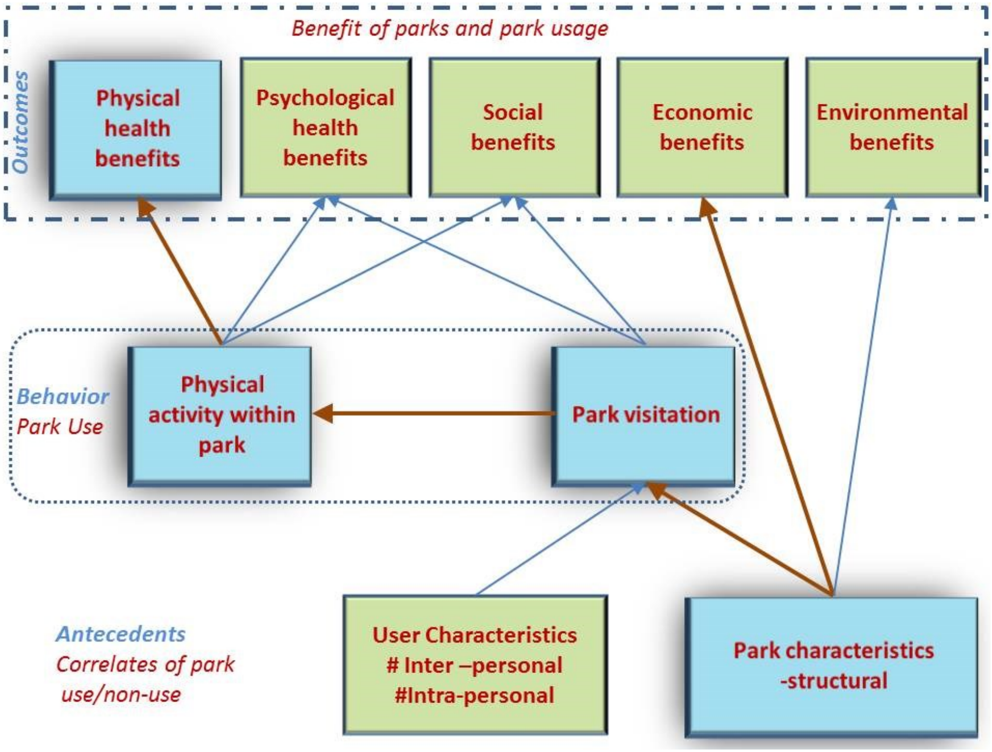


Figure 10: The relationship between parks and physical activity (Bedimo-Rung et al., 2005).

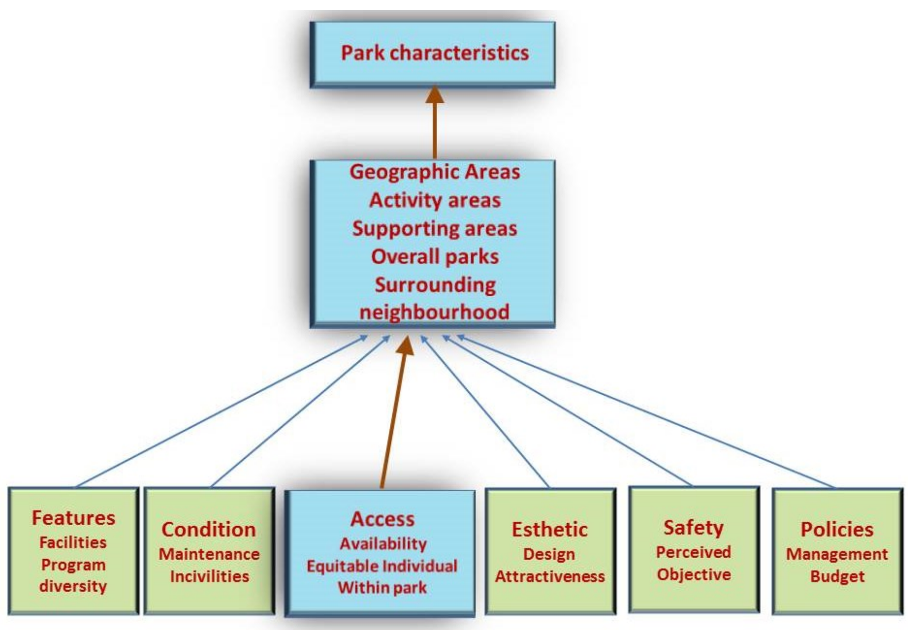


Figure 11: Different type of park attributes that affects park accessibility (Bedimo-Rung et al., 2005).

For the case study, this research focuses on the prime characteristics of parks—proximity and size—to observe the level of accessibility available in the neighbourhood that may improve health benefits for residents.

2.4 Open Spaces and Property Value:

Planning neighbourhood parks to promote physical activity is not only beneficial for health, but it also has economic prospects. Proper pedestrian walking facilities, open green spaces, parks, and playgrounds increase the quality of life as well as yield financial benefit through increased surrounding property value and associated property assessment tax in a neighbourhood (Shoup and Ewing, 2010).

Espey and Owusu-Edusei (2001) conducted a study on single-family homes sold between 1990 and 1999 in Greenville, South Carolina, and concluded that the value of park proximity to homes differs with respect to park size and amenities. They classified parks into four groups depending on size, attractiveness, and availability of recreational facilities and revealed the effect of small attractive neighbourhood parks closer to homes lies within a 600-foot buffer zone; they also discovered that small parks with basic facilities infer a 7% increase in housing prices within 500-1500 feet of the nearest park. Permanent open space is preferable to developable open space (land is properly graded and usable for recreational purposes); in fact, the proximity effect of permanent open space is more than three times in contrast to developable open space (Geoghegan, 2002).

Modelling the household preferences for Wake County, North Carolina revealed that people are willing to pay an additional $4,104 (in 1992 dollar value) for a home located within a quarter mile distance from open spaces compared to those located within a half mile (Walsh, 2007). Nicholls and Crompton (2005) found that homes immediately neighbouring the Barton Creek Greenbelt had an average price $44,332 higher than homes in other areas; this figure accounts for 12.2% of the mean home price (Nicholls and Crompton, 2005). Miller (2001) conducted an extensive study on the effect of travel distance to neighbourhood parks in the Dallas metropolitan area. The author showed that properties neighbouring to parks had nearly 22% price premiums in contrast to the homes a half mile away. The study encouraged private developers to increase the number of parks in new neighbourhoods to make them more attractive and increase the quality of life of the residents. As a design rule, Miller (2001) proposed that land subdivision could be done in the smallest possible lots proximate to parks; and, instead of creating a large park in the centre of a neighbourhood. Miller (2001) also suggested that dispersing several small parks throughout the neighbourhood would maximize the benefits of the space (Figures 12 and 13).

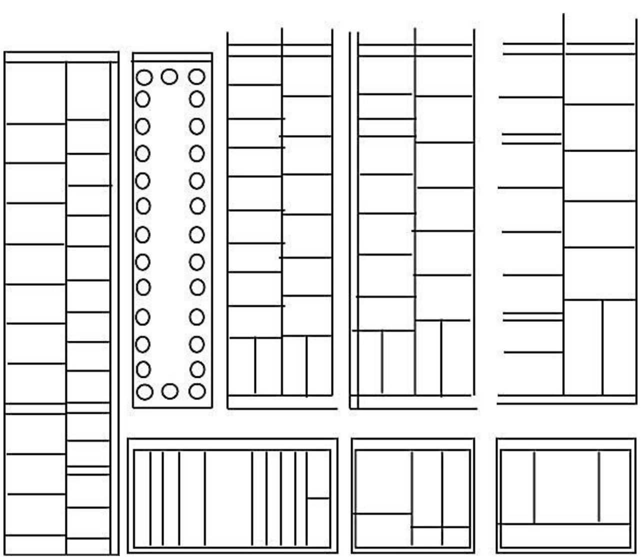


Figure 12: Creating smaller possible lots near parks design rule (Miller, 2001).

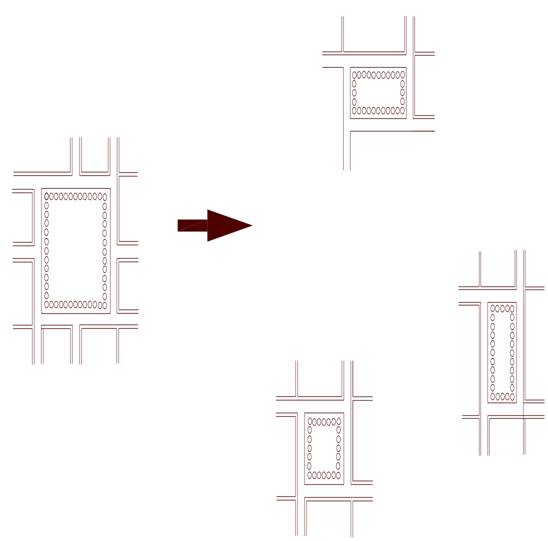


Figure 13: Creating smaller parks design rule (Miller, 2001).

The utility derived from preserving open spaces or creating new green areas in a neighbourhood can be best understood with reference to the *proximate principle* (introduced by Crompton, 2001). Crompton (2001) concluded that individuals prefer to live nearby parks and open spaces, which increases the demand for such locations, hence leading to higher real estate prices. This intrinsic characteristic ultimately generates additional tax revenue from these properties, which can leverage the cost of developing these open spaces. In fact, to further prove the *proximate principle*, Crompton (2001) used a hypothetical 20.2 ha (50.0 ac) neighbourhood park to show that the presence of the park generates an addition $98,000 per year in tax revenue (in 2001 year value), which is sufficient to pay the annual bond debt charge of $90,000 that had been accrued in order to acquire and develop the park. This principle has been proven by other studies such as Miller (2001), who found that, as the travel distance to a park decreases, the home price increases (Figure 14).

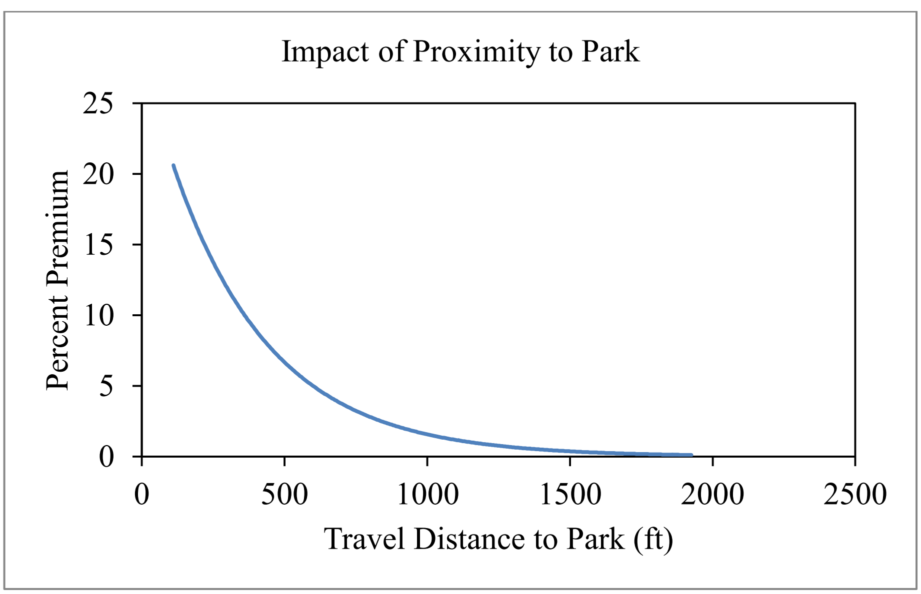


Figure 14: Effect of distance from park in Dallas metropolitan area (Miller 2001).

As land development occurs, it reforms the scenic quality of existing landscapes, which subsequently affects property values (Sandera and Polasky 2009). Home sale prices correlate with the percentage of view of open green space or water. In this context, Sandera and Polasky (2009) showed that improving the view by 10% (by adding vegetation or water) in Ramsey County, MN, USA, increases the marginal willingness of the homebuyer to pay more for view variable changes to $7,417 from $5,517. They concluded that some home buyers prefer a home with large view coverage of open spaces. The study also confirmed the expectation of an elevated home price if it is near a body of water such as a lake or wetland; every 100 m increase in proximity generates an additional $216 (dollar value in 2005) in home sale price, which is the greatest proximate value increase of all types of open spaces considered by the authors.

A questioner survey performed in British Columbia in 1997 shows the perceptions of Canadians on preserving green spaces near residential development (Quayle and Hamilton, 1999). The survey was carried out in the Richmond, Delta, and Maple Ridge municipalities of Vancouver, and the suburban community of Saanich in metropolitan Victoria, BC. (Table 1). Accessibility to reserved green space was one of the factors for choosing a particular municipality by the residents; more than 50% of respondents were in favour of this factor for selecting their residence. Moreover, proximity to green belts, parks, playgrounds, and schools were the highest ranked distance features according to the residents within the four selected municipalities (Figure 15) (Quayle and Hamilton, 1999). Hedonic pricing analysis of the same case studies by the authors found that existing greenways added 12% to 15% property value depending on the municipality.

Table 1: Neighbourhood preference based on the mentioned factors (Quayle and Hamilton, 1999)

Factors	Richmond	Delta	Maple Ridge	Saanich	Total
Proximity to work	49.70%	43.40%	26.10%	47.90%	42.30%
Proximity to family	30.60%	20.70%	19.60%	21.90%	23.00%
Affordability	49.70%	54.00%	55.80%	61.50%	55.50%
Access to greenway	Not Available	51.30%	54.30%	49.10%	51.20%

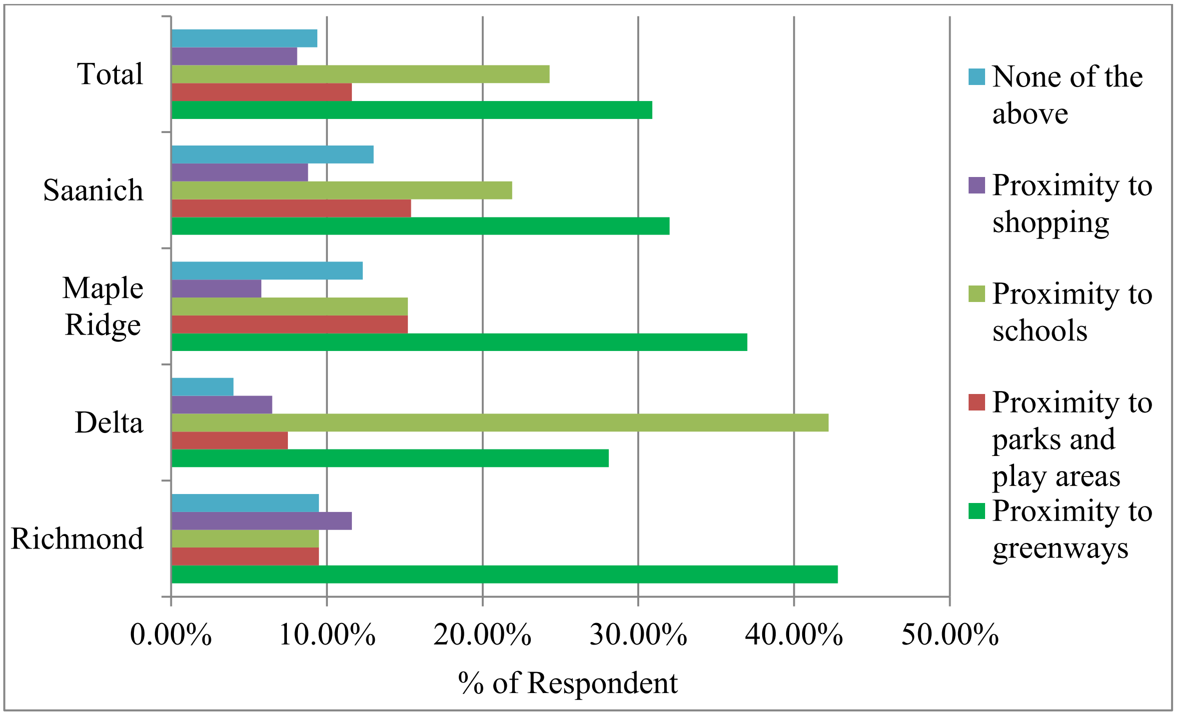


Figure 15: Distance from Amenity features that controls selecting particular homes (Quayle and Hamilton, 1999).

Table 2: Survey results in four case study areas on willingness to pay more money for proximity to green space (Quayle and Hamilton, 1999).

Factors	Richmond	Delta	Maple Ridge	Saanich	Total
Yes	80.90%	81.90%	78.30%	61.50%	75.00%
No	17.00%	13.60%	19.60%	38.50%	21.10%
If yes, is effect positive?	98.40%	99.40%	94.40%	98.10%	98.60%
If yes, is effect negative?	1.60%	0.60%	5.60%	1.90%	1.40%

Therefore, it is critically important to incorporate green spaces into residential land development projects in growing cities such as Edmonton, Alberta. The importance of this economic prospect of open green space in terms of land development is such that it may encourage developers to rethink their design and planning process when developing a neighbourhood. Private developers may design new neighbourhoods by including more park space as a way of increasing the overall attractiveness as well as to accelerate sales for the newly developed residential lots (Miller 2001).

2.5 Municipal Revenue Generation from Open Space:

Preserving open spaces for community use has another lucrative aspect related to municipal tax generation. Municipal authorities are often concerned with the cost of new park creation and corresponding maintenance costs. But, additional tax generation is possible through an intangible benefit: that proximity to parks increases property value. As previously mentioned, Crompton's (2001) *proximate principle* explains this phenomenon from a hypothetical park development study (Figure 16). The City of Chattanooga, TN gained and additional annual property tax revenue of $592,000 between 1988 and 1996 by purchasing open space, and creating parks and green trails in developed neighbourhoods, which was a 99% increase from the level in the early 1980s (Lerner and Poole, 1999).

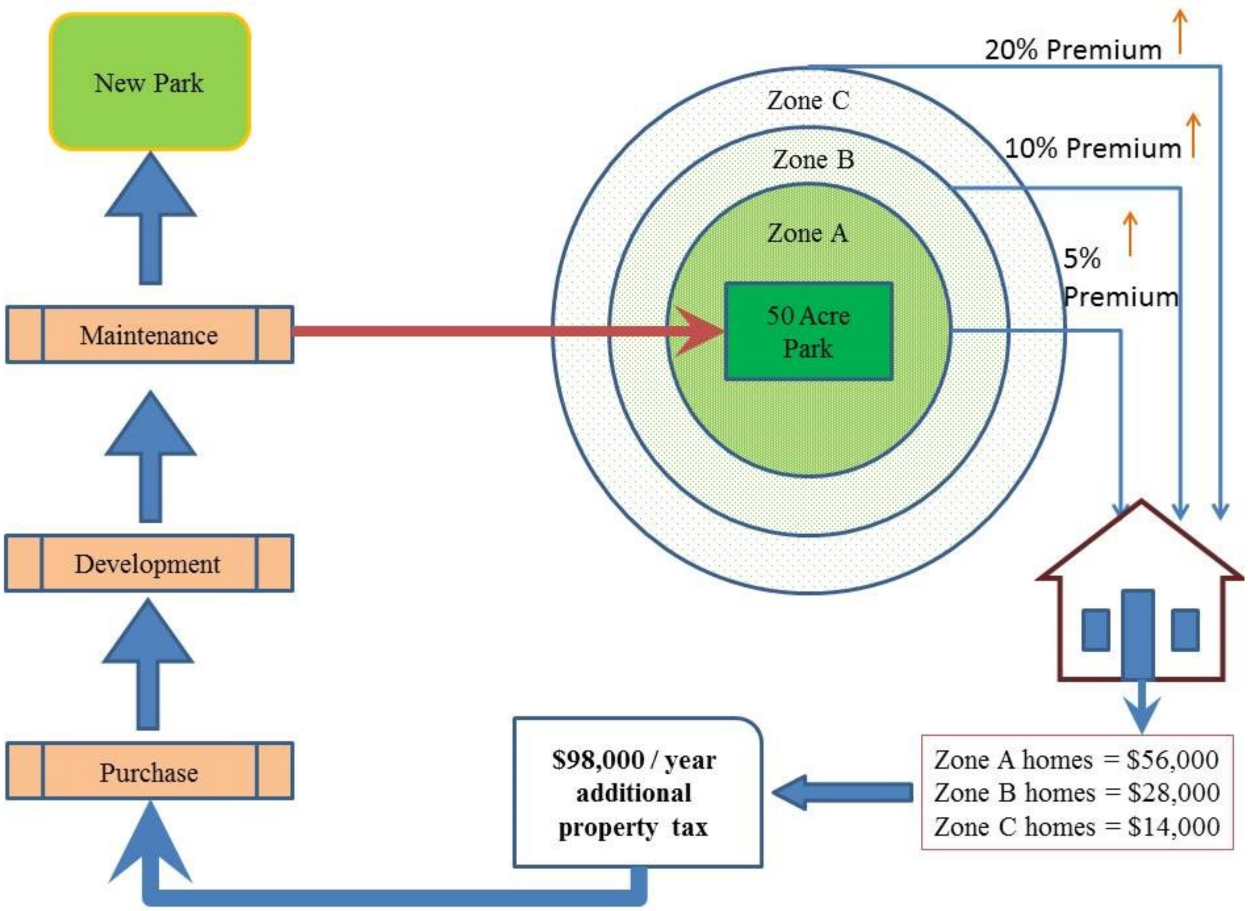


Figure 16: How municipalities can finance cost of park development and maintenance cost using proximate principle

Renowned urban planner Frederick Law Olmstead applied proximate principle to New York City's Central Park; analyzing neighbouring property value from 1856 to 1873 revealed that, over this 17-year time period, $209 million was raised from tax, while only $13 million was spent on development of this open space and recreational facility (Edwards, 2007). Another study in Boulder, Colorado, revealed that the implementation of the greenbelts construction project in a neighbourhood increased the surrounding home values by $5.4 million (in 1978 dollar value) and generated $500,000 extra tax returns per year; consequently, the project investment of $1.5 million was recovered in three years (Correll et al., 1978). Moreover, the allocation of neighbourhood parks in land development projects is not only important for the developer and residents, but is also equally important for municipal authorities as a source of revenue.

2.6 Conclusion:

Open spaces, parks, and natural preserved spaces provide numerous public health benefits including physical and mental wellness. Preserving open space for public recreational facilities may help reduce obesity by creating options for the residents to become physically active. However, the spaces need to be in close proximity to homes for the residents to benefit from these spaces. The importance of proper planning and design of open green spaces for public recreation should be taken into consideration when developing new neighbourhoods in order to promote active lifestyles among Albertans. Policy to allocate parks affects public health and economic aspects of land development from intangible gain of monetary value due to proximity effect.

The aim of the present study is to assess how the distribution of urban green spaces in current neighbourhood design patterns in the City of Edmonton affects the spatial interactions in neighbourhood parks with respect to home and property values.

Chapter Three

Methodology

3.1 Introduction:

In this chapter, the methodology used in this research is explained in detail. Figure 17 illustrates the steps performed during this research, the first of which is to collecting the data.

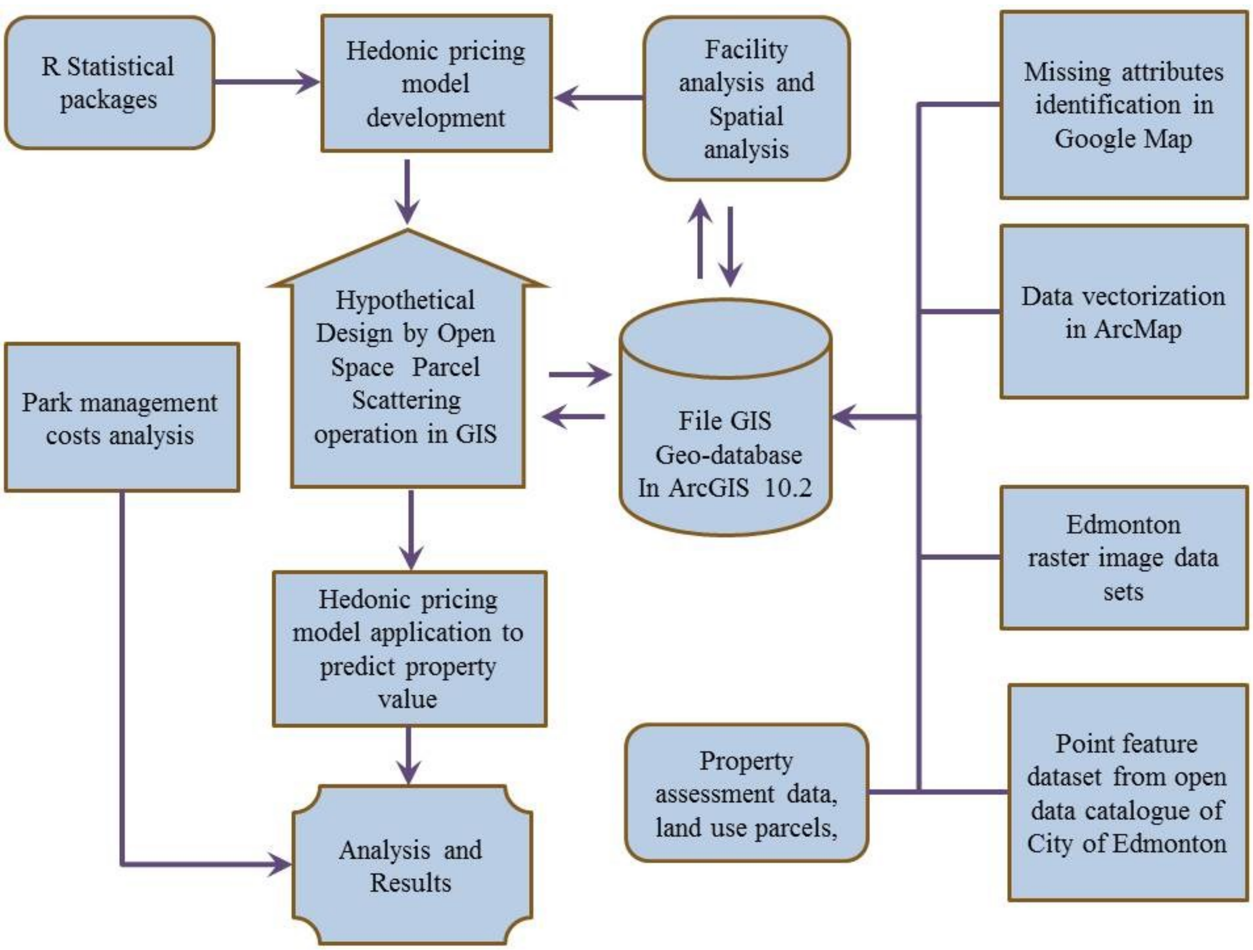


Figure 17: Process map followed in the study

The datasets are obtained from the following sources:

a) Sustainable Development Department, City of Edmonton

b) Neighbourhood Parks and Community Recreation Department, City of Edmonton

c) GIS Library, University of Alberta

d) City of Edmonton Open Data Catalogue

GIS applications are the most useful tool for land use planning and the neighbourhood subdivision process. It is the most applicable and effective baseline tool for the present research, which involves the processing of large volumes of land parcel datasets and capturing the multidimensional aspects of different space-related attributes. The core advantage is incorporating various types of data that can be added in layer by layer, which is optimal for process mapping in land use planning systems. It also provides tools by which to perform spatial analysis to account for, and measure accurately, parameters such as closest point section and travel distances. The multidimensional aspects of different space-related attributes required for statistical analysis are calculated using proximate analysis tools from ArcGIS 10.2. Extensive GIS analysis is necessary in order to produce accurate distance calculations (±1.5 m) for the open space related variables. For hedonic price model development, R 3.1.2 (R Development Core Team, 2008) is chosen as the employed software since this open source statistical package is known to be reliable and widely used among the scientific community.

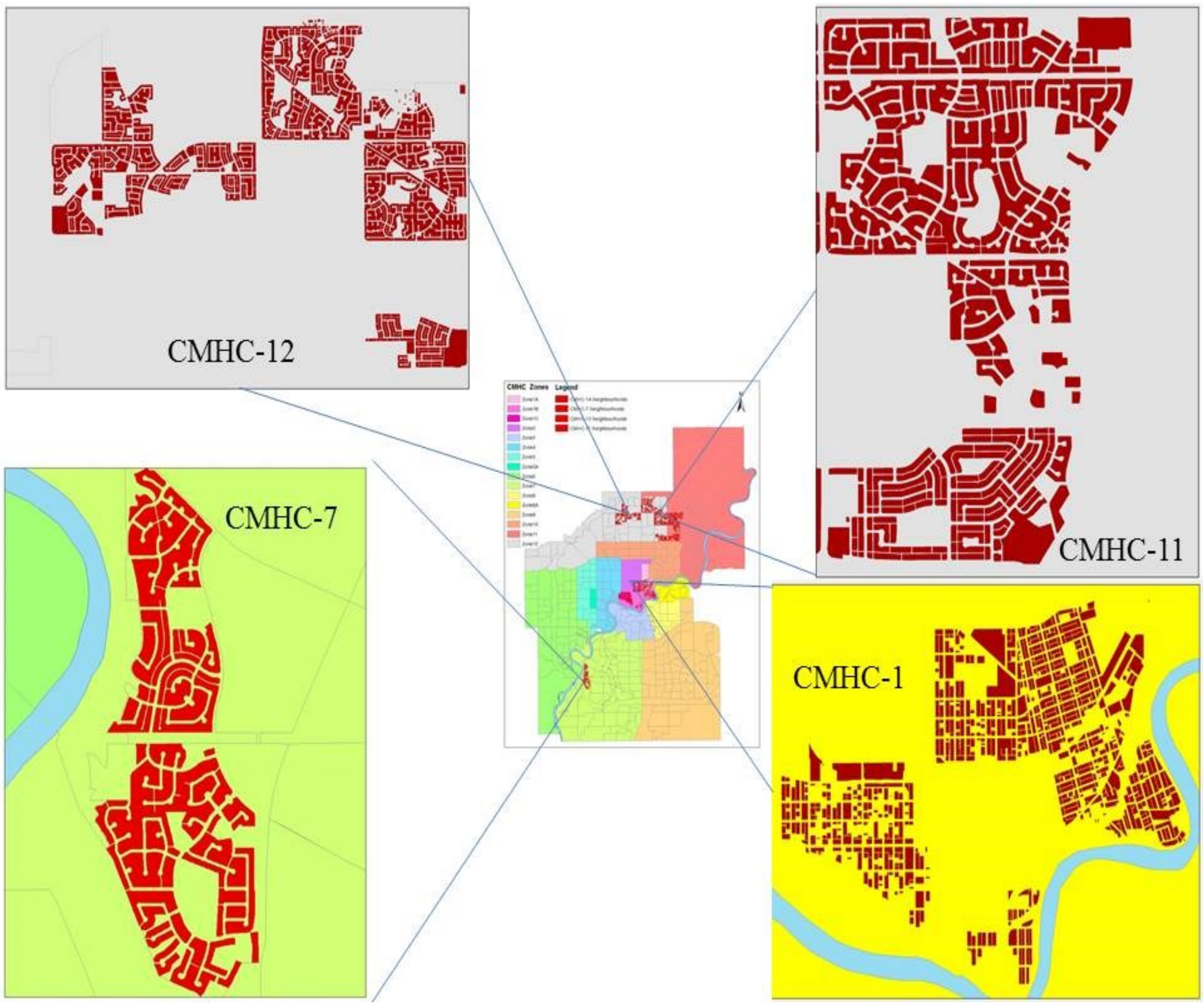


Figure 18: Case study area locations

3.2 Case Study Area:

The metropolitan region of Edmonton, Canada, comprises 9,532 km^2 (3,680 miles^2). Edmonton is a young and growing city; as of December, 2013, there were 42 neighbourhoods actively under development and 20 neighbourhoods at the planned stage (i.e., no NSP has yet been developed) (City of Edmonton, 2013a). Furthermore, out of the 42 actively developing neighbourhoods, 7 neighbourhoods had no development started, 11 were less than 25% complete, 18 were between 25% and 75% complete, and 6 neighbourhoods were 76 to 94%

complete. The study boundary in this research is limited to developing, mature, and established parts of the city. Since Edmonton's neighbourhoods are classified as "central core", "mature", "established", and "planned or developing" depending on the extent of development (Figure 19), random sampling is preformed to represent samples from these neighbourhood classifications. Sample case study areas from CMHC zone 1A, 7, 11 and 12 are selected satisfying the above mentioned criteria.

Table 3: Case study neighbourhood Selection

Case Study Neighbourhoods	**Status**
CMHC-7 Zone	
Henderson Estates	Established
Haddow	Established
CMHC-12 Zone	
Dunluce	Established
Canossa	Developing
Lorelei	Established
Lago Lindo	Established
Klarvatten	Developing
Schonsee	Developing
Ozerna	Developing
Mayliewan	Developing
Kildare	Mature
CMHC-11	
Matt Berry	Developing
Hollick-Kenyon	Developing
Casselman	Established
York	Mature
CMHC-1A Zone	
McDougall	Central Core
McCauley	Central Core
Boyle Street	Central Core

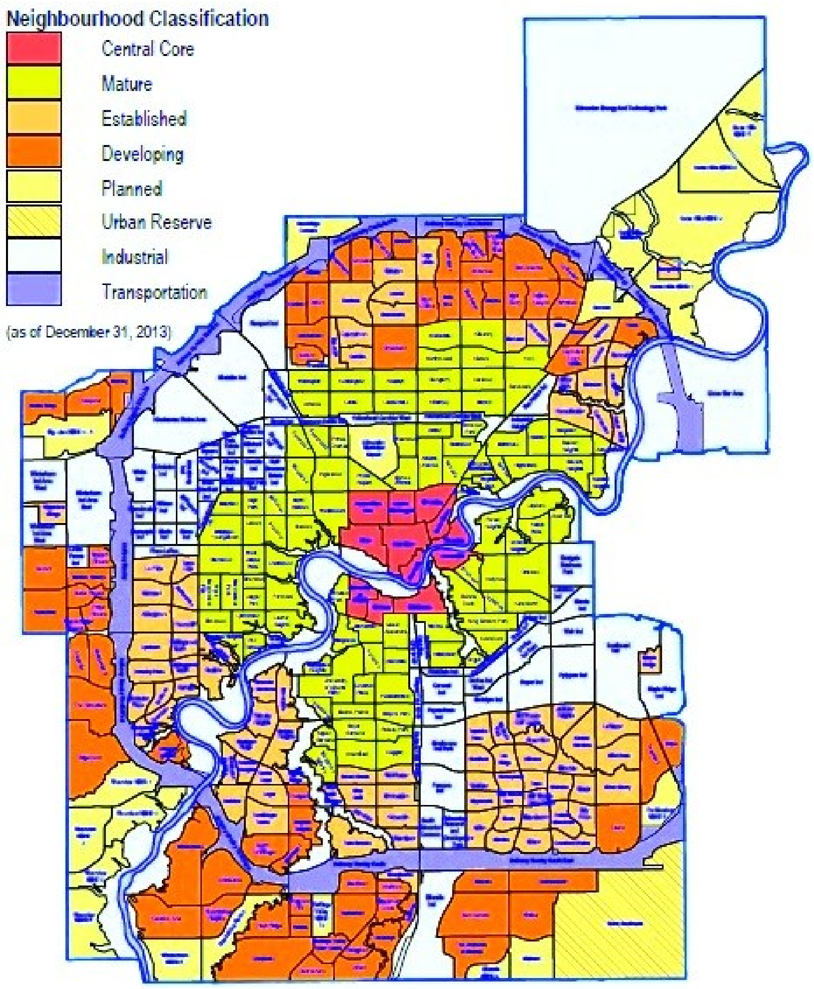


Figure 19: Neighbourhood classification of Edmonton (Source: City of Edmonton, 2013a)

3.3 Data Required for this Study:

The core focus of this study necessitates the processing of different types of datasets to allow them to be imported into a single geo-database. The following sections explain how a geo-database is created by processing the raw datasets.

3.3.1 Edmonton Image Data:

Aerial photography of the City of Edmonton in scale 1:2000, taken on May 13 and May 20, 2012 is retrieved from the GIS library at the University of Alberta. The dataset is projected with respect to Horizontal Datum NAD83 and Projection 3TM_CM114_UTM_Zone_12; horizontal accuracy is +/- 1.5 m. This raster provides the reference for creating essential feature layers.

3.3.2 Land parcel assessment datasets:

The second step of the methodology involved processing the raw datasets and creating files within a geo-database, which provides the base platform to connect all information required for statistical modelling as well as spatial interaction analysis. Land parcel data with assessable legal lots in vector format is obtained from the City of Edmonton assessment database. This dataset is missing some important parcel information such as the neighbourhood parks, small pocket parks, district parks, convenience stores, and commercial places. To capture the effect of different types of open spaces available in the neighbourhood, each space is located in a separate layer. Using Google Maps and the neighbourhood interactive map service provided by the City of Edmonton, the locations of missing attributes are determined; then, from the georeferenced aerial image, corresponding parcel layers are created for these locations.

Latitude and longitude coordinates of different parks, recreation centres, and other facilities are collected from the City of Edmonton's open data catalogue and point features are created in ArcMap. By tracing overlaid georeferenced Edmonton imaginary layers, missing facilities are transported to a vector dataset. The search facility of Google's map application is employed to locate shopping centres, major business districts, and convenience stores in order to create a Central Business District (CBD) layer for the case study neighbourhood. Collected location information is imported into ArcMap and the parcel associated layers for CBD are created from the georeferenced aerial photographs provided by the City of Edmonton (Figure 20).

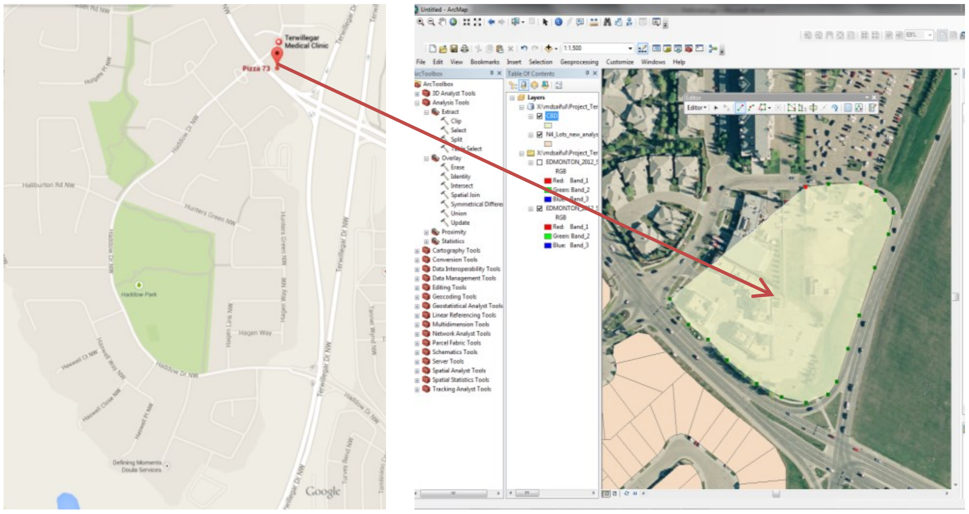


Figure 20: CBD identification and parcel construction in ArcMap.

3.4 Nearest Features Distance Calculation:

To achieve some objectives of this study, measuring the distance from individual housing lots to the nearest open space is the most important phase as the accessibility assessment analysis and property value model require this variable to be incorporated. Euclidean distance is preferable for the case study neighbourhoods since a portion of the road network dataset is missing parts of the networks. By assessing the Neighbourhood Structured Plans (NSP) for the study area, different types of open space are identified, and corresponding GIS layers are constructed in the ArcGIS mapping platform. For analysis, three types of open space groups are considered with potential for a public recreational facility (Table 3, Figure 21 and 22).

Table 4: Open space classification for this study

Type A Parks	Open Green Space / Parks: Recreational open space facility without Play Grounds
Type B Parks	Open Space / Parks with Play Grounds
Type C Parks	Open Space / Parks: for Storm Water Management Facility

Figure 21: Typical storm water management facility in Edmonton (Source: Google earth, 2015).

Figure 22: Typical neighbourhood park with play facilities in Edmonton (Source: Google earth, 2015).

ArcGIS provides a comprehensive tool to calculate the distance between varieties of park/green space features. The algorithm uses the shortest separation between features in order to find the distance between two them; the measurement logic depends on the type of geometries of each feature (Figure 23). For instance, to find the closest distance between two parcels, the algorithm first determines the two proximate edges of the polygons (or the specific types of geometries of the parcels being measured) and then returns to the Euclidean distance as a result of the analysis.

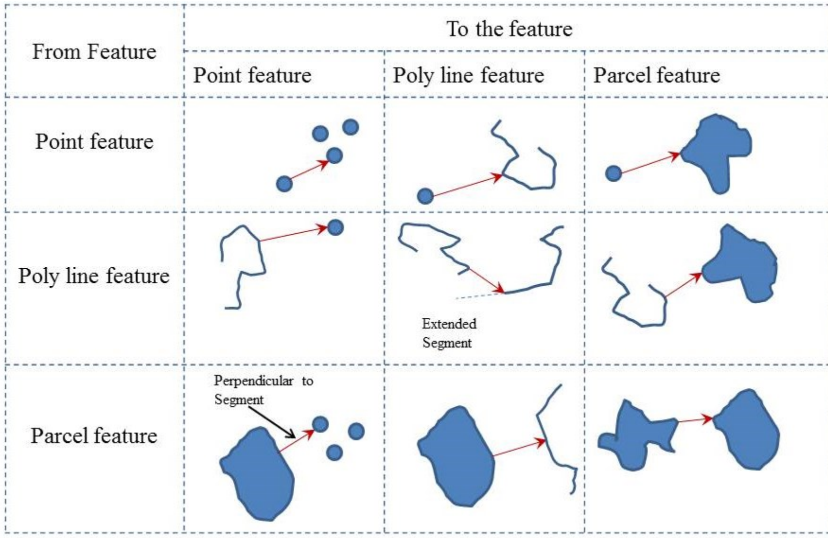


Figure 23: Algorithm for closets distance calculation (ESRI, 2014).

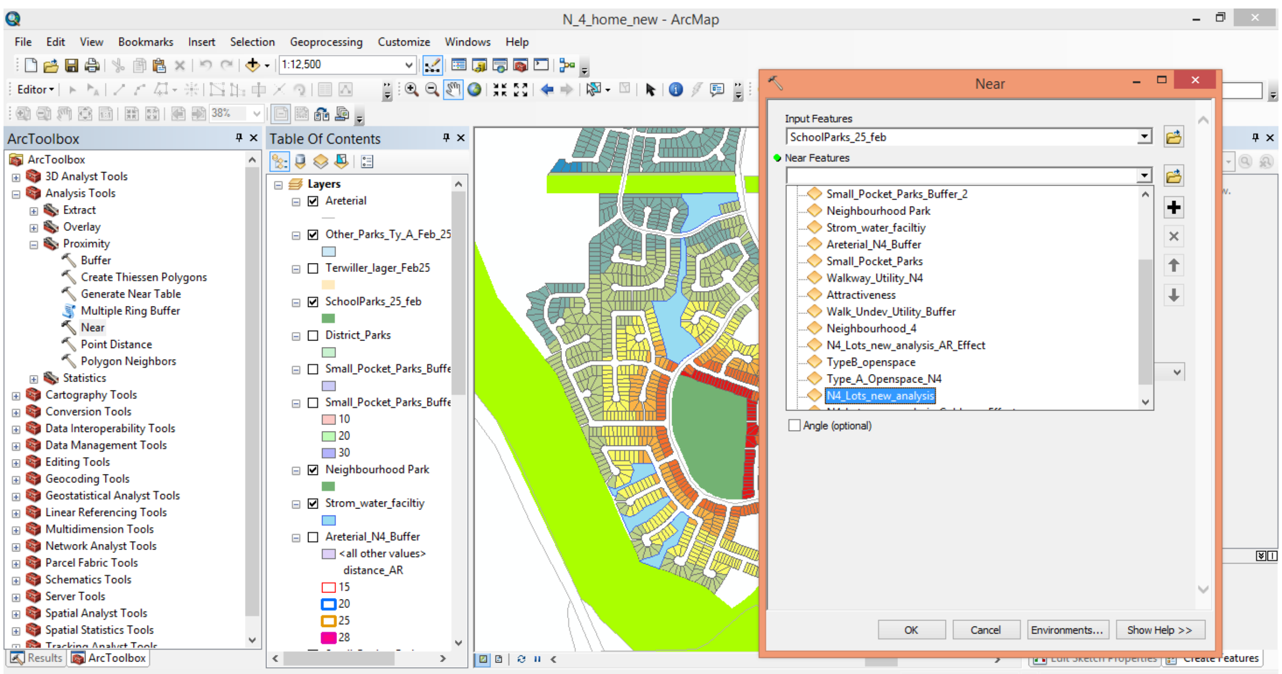


Figure 24: Proximity tool used to calculate the Euclidian distance in ArcGIS

3.4.1 Arterial Roads Proximity Effect and Park Parcel update:

One important parameter for the hedonic pricing model[2] is the proximity effect of arterial roads on houses since traffic volume is higher on these types of roads compared to other transportation

[2] Details of this model are provided in section 3.6

corridors. Incorporating this parameter into the model requires identifying the housing lots adjacent to the arterial roads. The overlay analysis toolset of ArcGIS is applied. A 15 m to 30 m buffer layer is created from the centre line of the roadways in the arterial road network polyline layer (Figure 25), and a spatial joining operation with the neighbourhood parcel layer created the affected parcel layers within different buffer distances. Using python script, a simple binary value assigning code in the field calculator, numerical value *1* is assigned to those parcel fields which are within the buffer zone of arterial roads. The lot parcels with binary value equal to *1* in the arterial data field receive the effect of being proximate to arterial roads in the hedonic pricing model. The assessment dataset is also missing playground and junior park facilities. These missing attributes are identified from an online neighbourhood interactive map service provided by the City of Edmonton, and a new park parcel is created from georeferenced aerial photography images (Figure 26). All the park and open space areas are determined using a calculated geometry toolset in Projection 3TM CM114, UTM Zone 12 (Figure 27).

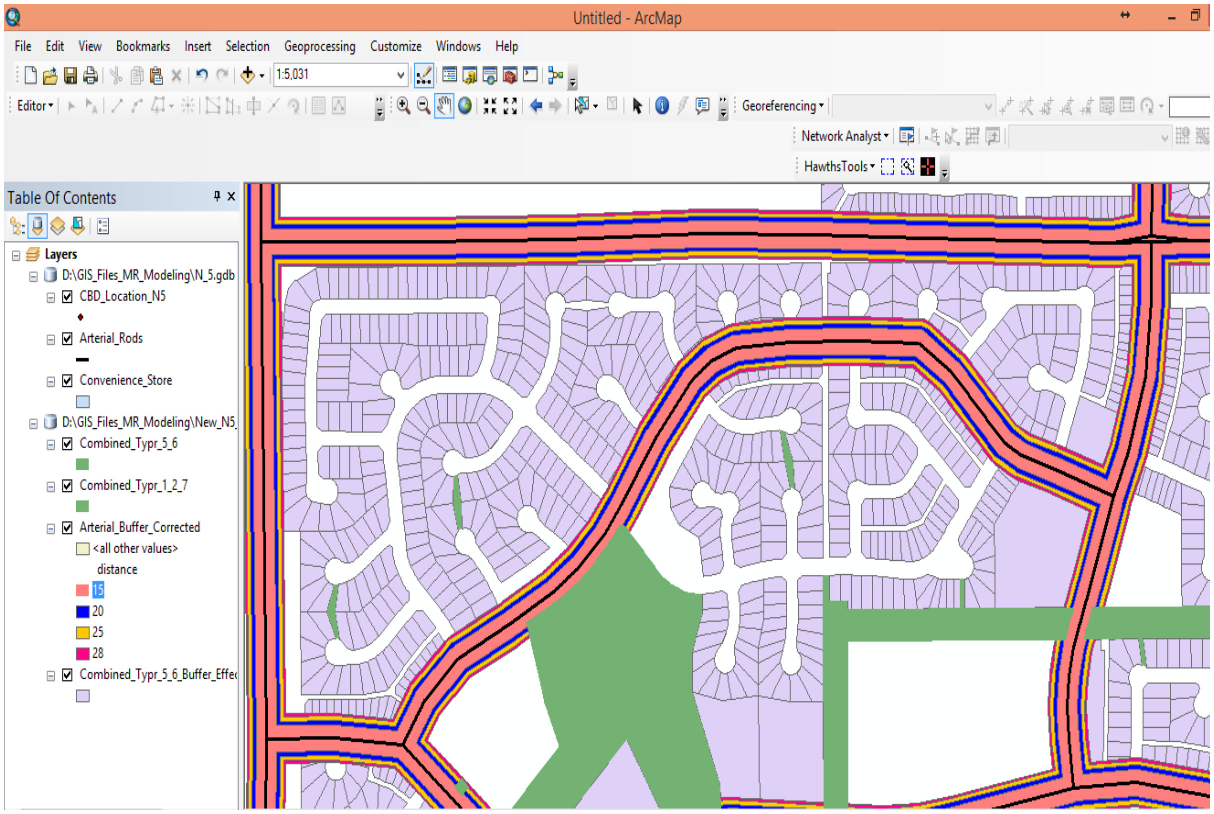


Figure 25: Arterial road buffer overlay analysis

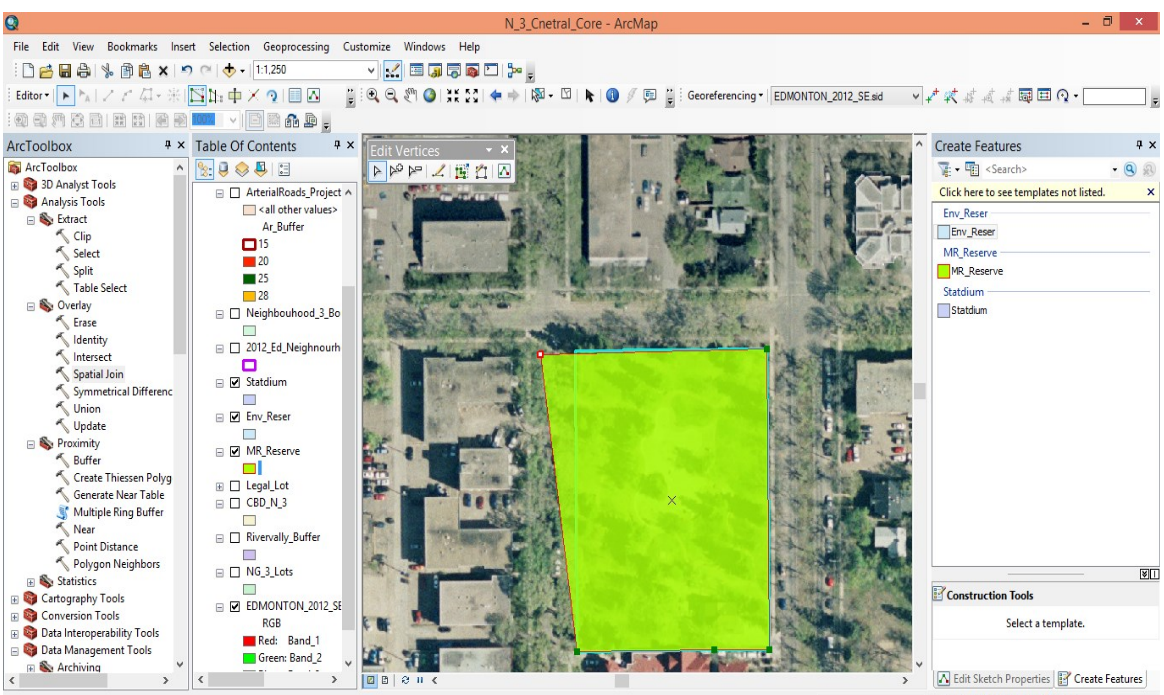


Figure 26: Creating park parcels from raster image

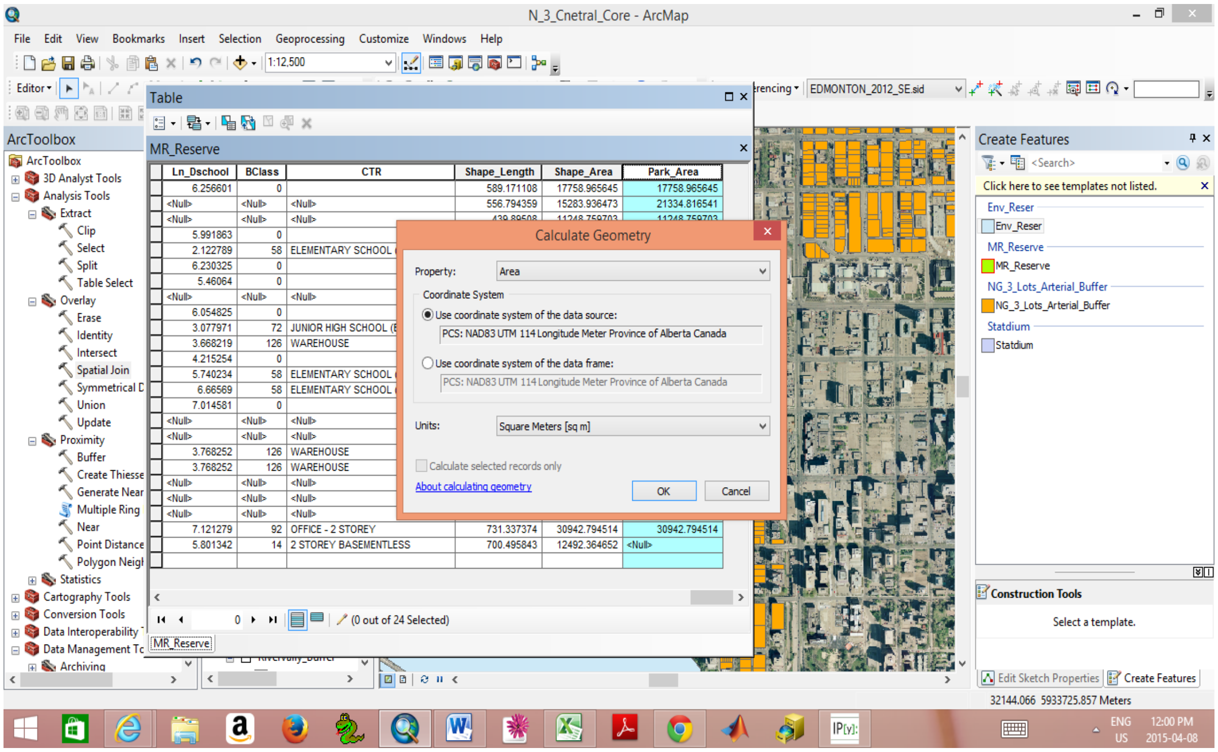


Figure 27: Calculating the corresponding neighbourhood park area

3.5 Spatial Interaction Model of Neighbourhood Parks:

Accessibility is an important metric to quantify the likelihood of effective park space usage. It is defined as the magnitude of spatial distribution of certain actions at points of interest considering the willingness and capacity of users to overcome spatial separation (Hansen, 1959). For example, the accessibility of a neighbourhood park for physical activity from a house location is proportional to its size and inversely proportional to the separated distance between the home and park (Hansen, 1959). In general terms, accessibility is a measurement of the spatial distribution of activities at a specific point, adjusted for the ability and the desire of people to overcome spatial separation (Hansen, 1959). This idealized concept is known as *gravity model*.

Furthermore, Giles-Corti et al. (2005) developed the *accessibility model* to observe the use of public open spaces considering attractiveness, size, and distance as follows:

$$A_i = \sum_j Att_j^{\alpha}\ S_j^{\lambda} / D_{ij}^{\beta} \qquad (1)$$

$$Att = \sum_j A_j * w_j \qquad (2)$$

Where,

A_i = accessibility index at origin *i*

Att_j = attractiveness of the amenity

S_j = size of the amenity

D_{ij} = distance between origin *i* and amenity *j*

α = amenity-specific attractiveness-decay parameter between *i* and *j*

β = amenity-specific distance-decay parameter between *i* and *j*

λ = amenity-specific size decay parameter between *i* and *j*

A_j = a binary indicator (0,1) of the existence of the j^{th} attribute

w_j = weight for the j^{th} attribute

Eventually this modelling approach functions as an alternative form of the gravity model, which hypothesizes that as the distance from origin to destination increases, interaction between public space and residents declines (Zhang et al., 2011). This functional form is termed *spatial interaction model* and is applicable to measure the accessibility of parks using GIS (Zhang et al., 2011).

Giles-Corti and Donovan (2002) used the public survey dataset of the Department of the Arts, Sport, the Environment, Tourism and Territories, Australia, for the period of 1992 to 1998 to measure the use and spatial accessibility of six formal and three informal recreational facilities (Giles-Cortia and Donovan 2002). They created various clusters in their study area, where the lowest class was 500 m and the highest was 20 km or more. This distance variable was cross-tabulated according to the response of survey participants on usage of the facilities. Then it was applied to create a new dataset where they grouped the mid points (e.g., 250 m) of previous clusters with the percentage of chances to use the facilities by survey participants. *Linear regression modelling* on the log of distance versus the log of percentage of opportunities to access the amenity produced the *distance decay parameter* β (Table 4). The same process resulted in the *amenity-specific attractiveness-decay parameter* α (= 0.52 for public open space) and *amenity-specific size decay parameter* λ (= 0.85 for public open space) (Giles-Corti et al., 2005).

Table 5: Distance-decay parameter for different types of recreational amenities (Giles-Cortia and Donovan 2002)

Facility Type	Distance-Decay parameter β^*
Public open space(i.e., parks and ovals)	1.91
River	1.71
Tennis court	1.64
Beach	1.48
Gym/health club/exercise centre	1.39
Swimming pool	1.27
Sporting complex and recreation centre	1.16
Golf course	1.06

Facility Type	Distance-Decay parameter β *
Other facilities	1.03
Overall	1.57

* Value greater than one indicates that as the distance doubles, the use of the facility reduces more than one half

While designing a neighbourhood, the level of accessibility of the open green spaces should be taken into consideration for planning an active residential space. The above mentioned spatial interaction model is applicable to determine the effective accessibility of neighbourhood parks for the case studies in this research. By observing the Neighbourhood Structured Plan (NSP), land use map, raster image, and sports field maintenance standard, it is obvious that case study neighbourhood parks are all facilitated with rectangular sports fields, playing surfaces, baseball diamonds, and playground equipment in Edmonton; these same structures are also employed by the outlying municipalities (Figure 28). These features contribute to the attractiveness of the amenities. Due to the lack of attractiveness survey data, it is reasonable to assume that all neighbourhood parks have the same level of attractiveness according to residents. Consequently for this study, the above mentioned model takes the following form for individual housing lots.

Spatial interaction index (SI_x) of a home for the nearest park as:

$$SI_x = \frac{A_y^{\lambda}}{D_{xy}^{\beta}} \qquad (3)$$

Where, A_y is the area of the neighbourhood park y, and D_{xy} is the Euclidean distance from the home x to the park y; λ represents people's perception effect on the size of the park, whereas β represents the distance decay effect of the amenity y proximate from the point of interest.

The decay parameters calculated by Giles-Cortia and Donovan (2002) are adopted for this research since theirs was the only study found that described a socio-ecological model of recreational physical activity incorporating personal, social, and structural environmental factors. The value of β indicates the sensitivity of using an amenity with respect to change in travel distance. If the distance decay parameter (β) of an amenity is greater than one, then its utilization is reduced by more than 1.5 times when the distance is doubled (Giles-Cortia and Donovan, 2002). In reference to parks, β is 1.91 and α is 0.85 (Giles-Cortia et al., 2005; Giles-Cortia and Donovan, 2002); accordingly, Equation (1) takes the following form:

$$SI_x \approx \frac{A_y^{0.85}}{D_{xy}^{1.91}} \qquad (4)$$

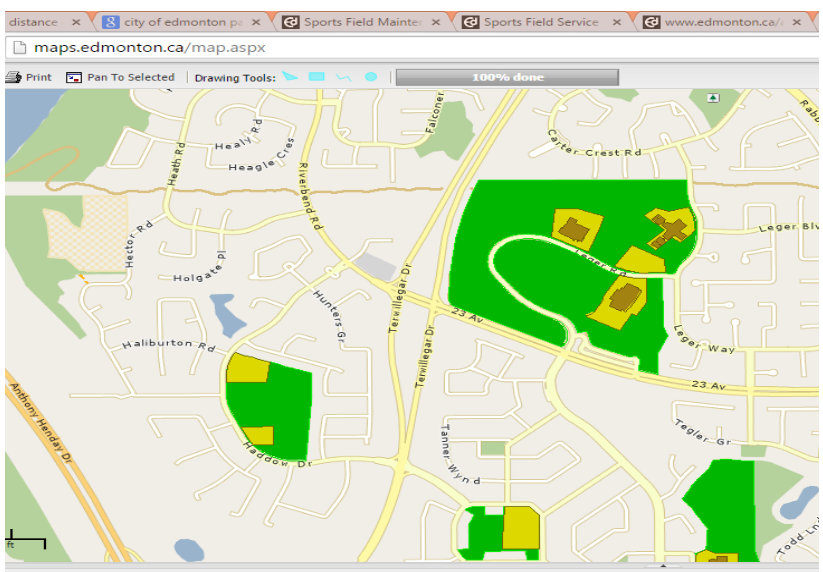


Figure 28: Online neighbourhood interactive map of Edmonton (City of Edmonton, 2015 c)

Applying this spatial interactions model, the SI_x distribution of individual lots with respect to only neighbourhood parks (MR) for the case studies is assessed; (detailed results of this model are explained in Chapter 4). For the purpose of calculating the spatial interaction index of housing lots, the nearest neighbourhood parks inside and outside of the given neighbourhood are incorporated into the spatial analysis (Figure 29).

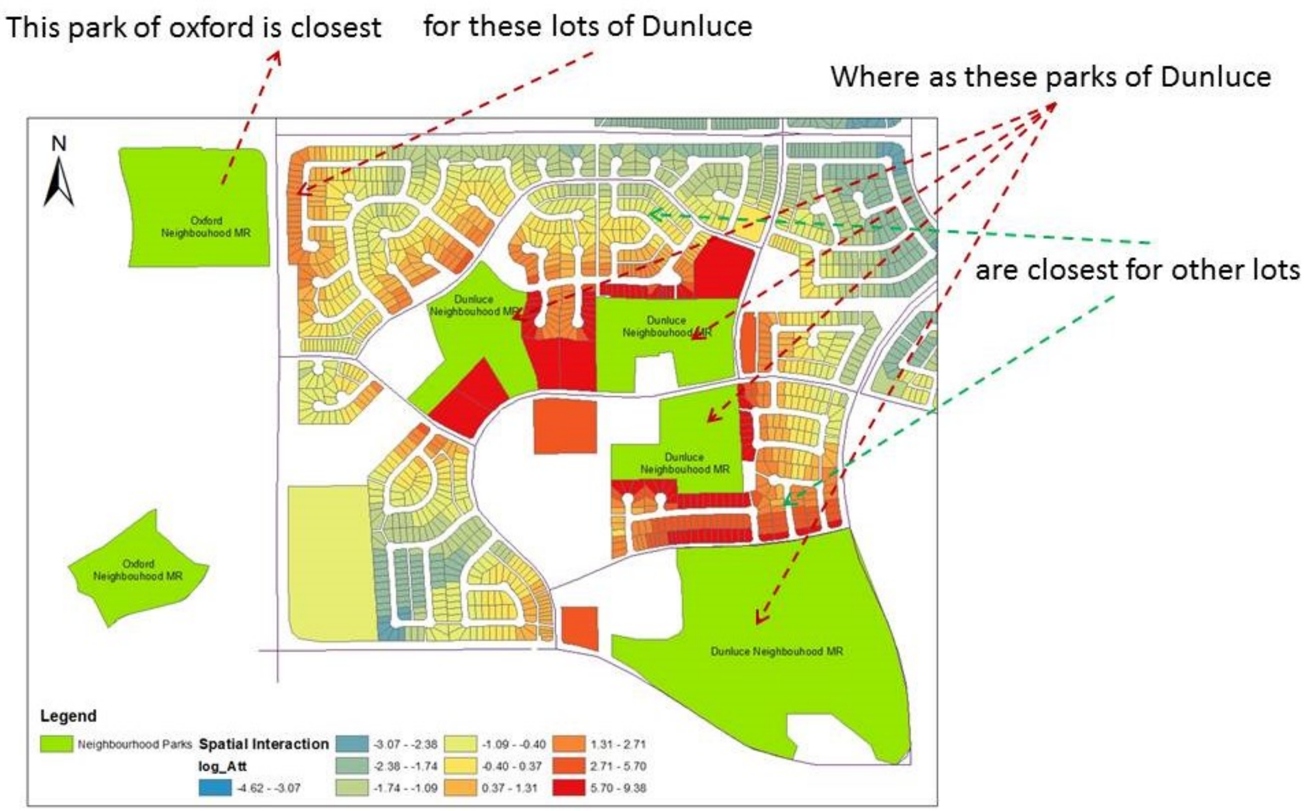


Figure 29: Nearest neighbourhood park selection for SI_x analysis

3.6 Modelling the Financial Effect of Open Spaces on Property Value:

Hedonic pricing model development is required to assess the financial aspect of Municipal Reserve (MR) allocation in NSP. This model considers the price of a home (P_i) as a function of structural property (S_h), any binary characteristics (N_h) (neighbourhood / environmental Characteristics), and distance from neighbourhood/environmental amenities (D_f) as:

$$P_i = f(S_h, N_h, D_f) \tag{5}$$

Differentiation of this function with respect to a given attribute is the marginal value of that attribute, and is referred to as price elasticity or value elasticity (Anderson and West, 2006).

For price prediction the following equation for the linear regression form of the hedonic pricing model is adopted:

$$\ln P_i = \beta_0 + \sum_k \beta_k N_{i,k} + \sum_j \beta_j \ln S_{i,j} + \sum_l \beta_l \ln D_{i,l} + \varepsilon_i \qquad (6)$$

- where $\ln P_i$ is the natural log of real sales price of the $i\ th$ house
- S_{ij} represents the jth structural variable (example: Roofing type, square footage of living area, existence of fire place, etc.), N_{ik} is the measure of the $k\ th$ characteristic binary in nature, and D represents the distance from the lth urban park, Central Business districts, and storm management facility
- $\beta_o, \beta_j, \beta_k, \beta_l$ represent the model parameters which are to be estimated by means of the ordinary least squares (OLS) method
- ε_i is error in the model

Semi-log and log-linear forms of hedonic functions are broadly used because they produce superior fit compared to linear form and interpreting is comparatively easier than Box-Cox model (Li et al., 2006). On the other hand, a flexible semi-log form is capable of handling circumstances when some features take a binary form of zero or one depending upon their existence (Diewert, 2003). Since the datasets exhibit the presence of some binary features in housing structural properties, the flexible semi-log form is chosen for the hedonic model development purpose. The elasticity of property value with respect to distance variable, it should be noted, can be estimated by partial differentiation of home property value with respect to distance variable, and is expressed as:

$$\frac{\partial \ln P_i}{\partial \ln D_{il}} = \beta_l \qquad (7)$$

The estimated coefficient from the OLS method thus represents the elasticity of property value with respect to corresponding variables. If this elasticity with respect to the distance variable has a negative sign, then the property value decreases with an increase in distance from that neighbourhood or environmental amenity.

For the hedonic modelling approach, the following six broad categories and features that affect home prices can be grouped into the following (Figure 30) (Nicholls and Crompton, 2005):

(i) physical or structural features of the individual property;

(ii) neighbourhood conditions;

(iii) community conditions;

(iv) locational factors;

(v) environmental factors; and

(vi) Macroeconomic market conditions at the time of sale.

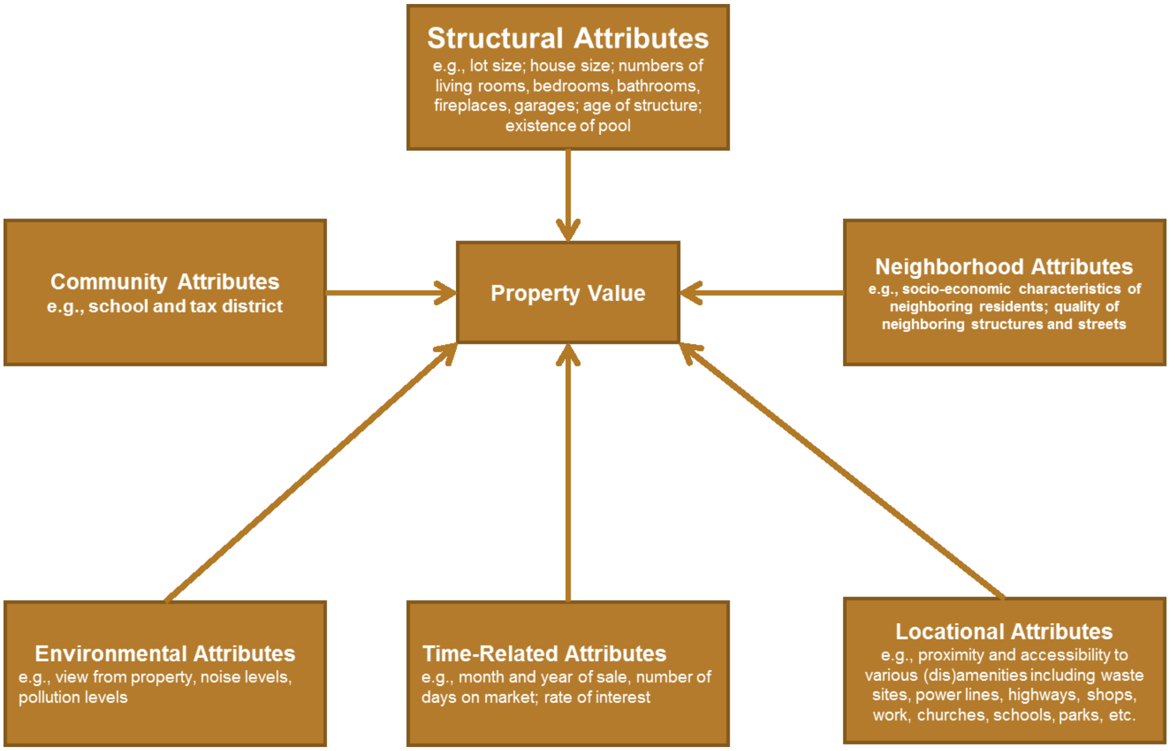
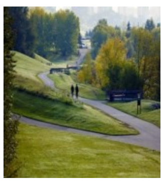


Figure 30: Parameters that determine property value

Incorporating all of the above mentioned factors may create a fairly accurate model for home price prediction purposes, but a limitation in data causes complication in modelling. In this case community, some neighbourhood and locational attributes are missing. However, submarket clustering compensates partially for these missing attributes. For this study, a hedonic price model is developed considering the presence of different housing submarkets in Edmonton. Table 5 explains the broad category variables in more detail that is then integrated into the analysis.

Table 6: Description of independent variables considered in this study

	Variable Name	**Description**	**Type**	**Value**
	Living Area	Total living area (m^2)	Continuous	
	Lot Area	Size of lot (m^2)	Continuous	
	Age	Age of home (years)	Continuous	
	Air Conditioning	Air Conditioning system available (Y/N)	Binary	Yes = 1 No = 0
	Fire Place	Fire place available (Y/N).	Binary	Yes = 1 No = 0
	Walk-out Basement	Walk-out basement (Y/N).	Binary	Yes = 1 No = 0
	Basement Condition	Basement is fully developed (Y/N).	Binary	Yes = 1 No = 0

	Variable Name	Description	Type	Value
	Distance from Type *B* Parks	Euclidian distance from property to closest neighbourhood park	Continuous	
	Distance from District Parks	Euclidian distance from property to closest river valley or district park	Continuous	
	Arterial Road Effect	Property is adjacent to arterial roads (Y/N)	Binary	Yes = 1 No = 0
	Distance from Type *C* Parks	Euclidian distance from property to closest storm management parks/open spaces	Continuous	
	Distance from CBD	Euclidian distance from property to closest central business district	Continuous	

3.7 Housing Submarkets in Edmonton:

Real estate submarkets are defined as the topographical boundaries where the unit price of homes is constant (Goodman and Thibodeau, 1998). For hedonic pricing analysis in the urban housing industry, estimation of residential mortgage backed securities, and property assessment (in order to calculate municipal tax), it is significantly important to categorize the submarkets for the study area (Goodman and Thibodeau, 2003). Within a submarket, it should be noted, all homes have basically the same features such that they can be substituted for one another, while they would make poor replacements for homes in other submarkets (Bourassa et al., 1999; Grisby et al., 1987). The structural attributes of a home thus constitute an important variable for housing submarket clustering. Submarket clustering is also dependent on the sociodemographic and economic characteristics of the households within the submarket, neighbourhood spatial features/characteristics, and locational references (distances to different amenities) (Poudyal et al., 2009).

Since the property dataset is derived from the 2014 property assessment of the City of Edmonton, it is necessary to segment the dataset according to their respective submarket zones. The Canada Mortgage and Housing Corporation (CMHC) (2015) classifies the Edmonton census division into 12 zones (Figure 31). For the hedonic modelling employed in this study, a number of the zones identified by CMHC are adopted. Single-family home property values for CMHC Zones 11, 12, 7, and 1A are used in modelling the property value property value function for each zone.

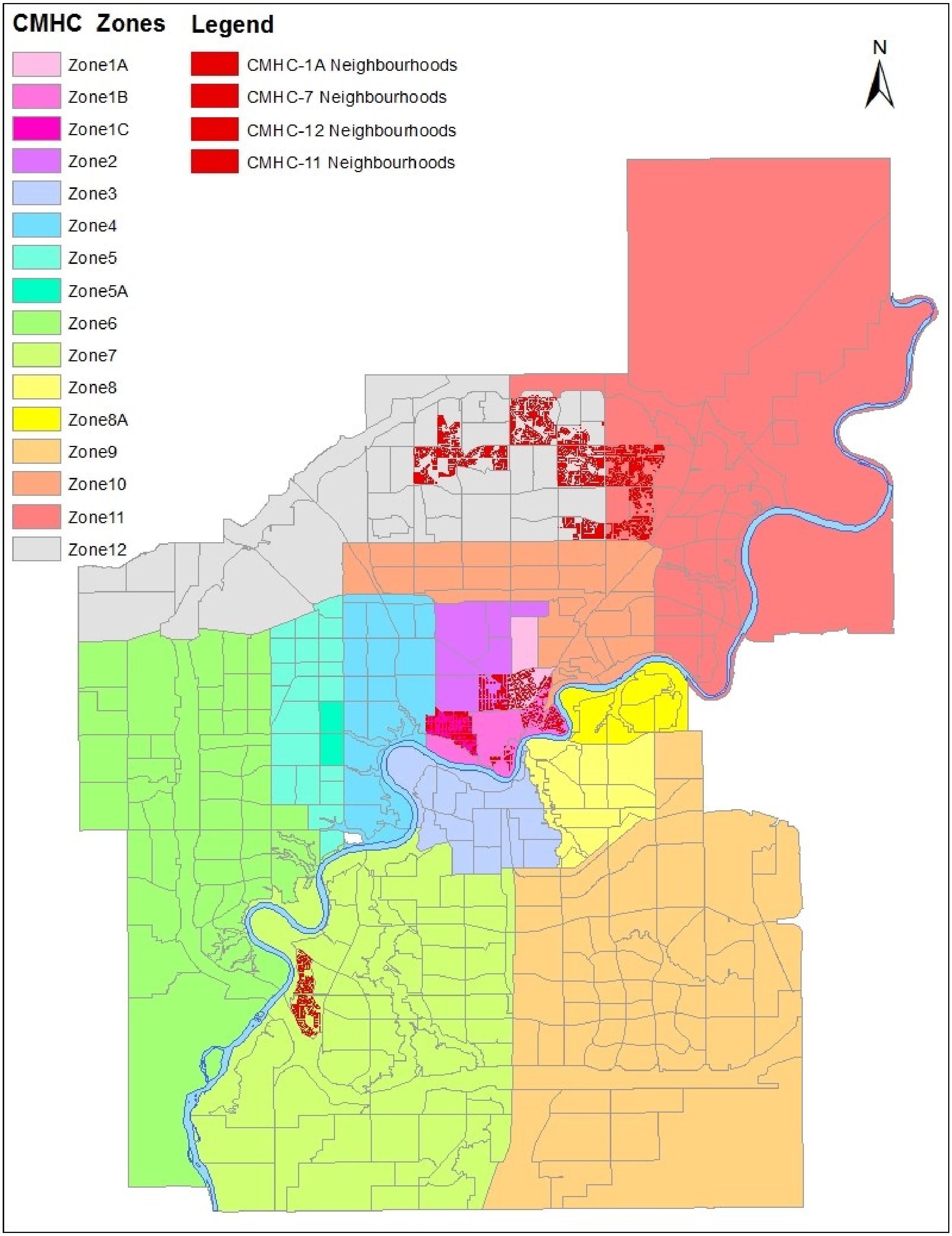


Figure 31: CMHC-defined housing zones for Edmonton, Canada

Chapter Four

Results and Analysis

4.1 Introduction

In this chapter, the results obtained from the implementation of the spatial interaction model and hedonic pricing model for the sample case study are discussed in detail. This chapter also describes the prediction of property value for a hypothetically designed neighbourhood, considering distributed Municipal Reserve (MR), as well as the corresponding change in park management costs and alternative use of mowing machines in maintenance activity for this type of design.

4.2 Spatial Interactions of Neighbourhood Parks for the Selected Case Study

The spatial interaction model discussed in the previous chapter is applied to assess the accessibility of neighbourhood parks (which is denoted as MR in the Neighbourhood Structured Plan) for the selected case study sites. As mentioned, Edmonton is subdivided into 12 zones by the CMHC; 18 sample neighbourhoods representing the south, north, and the central core of Edmonton are assessed in order to calculate a spatial interactions index for neighbourhood parks with respect to individual lots. Using ArcGIS 10.2, Euclidian distances from each single-detached home to the closest neighbourhood parks are estimated, and areas of parks are drawn from the land use map. All the spatial analysis is performed in the NAD83_UTM_114_Longitude_Meter_Province_of_Alberta_Canada projected coordinate system.

Figure 34 and 35 illustrates the variation of SI_x for Haddow and Dunluce Neighbourhood[3]. Since the SI_x value ranges from very low (7×10^{-3}) to very high (1.5×10^{05}), a logarithmic scale is incorporated to represent the map (Figure 33 through 39; Figure 54 through 66). The observation on spatial interaction for the case studies area reveals that Schonsee, Boyle Street, McCauley and Ozerna neighbourhoods have the lowest mean spatial interactions index (SI_x) for their corresponding nearby local parks; however, in the case of Schonsee there are no developed playgrounds or parks within the neighbourhood. The distribution of the spatial interactions index is critically important in judging how well the park or open space has been allocated in the neighbourhood in order to maximize the accessibility with respect to the housing lots. Ideally it is impossible to make an NSP that will benefit all housing lots equally by providing equal spatial accessibility, but the distribution of this parameter could be made (nearly) uniform rather than being excessively skewed to the left or to the right. Distribution histogram plotting of spatial interaction index (SI_x) for the study zones shows that the presence of two or more parks/open spaces within the neighbourhoods has well-distributed spatial interactions benefiting the maximum number of housing lots. For example, Dunluce in CMHC Zone 12 has three well-defined parks with playground facilities which benefit most of the homes in that neighbourhood (Figure 35). The same results are observed in the cases of Lago Lindo, Casselman, and Central McDougall. On the other hand, those having MR concentrated in one location are characterized with left or right skewed distribution, that is, the reserved public space is highly benefiting only some portions of housing lots.

Since the lots adjacent to neighbourhood parks have the highest spatial interaction score, it is reasonable to assume that these lots have maximum probability explicit to usage or visit.

[3] More details available in Appendix-A: Figures 54 to 66

Comparison of the SI_x values for these lots provides the context of park usage possibility for the homes. For the Haddow neighbourhood, the distribution shows 85% of lots have 15% or less spatial interactions index (SI_x) compared to the most accessible lots which indicates that only 15% of homes are receiving sound accessibility to their neighbourhood parks (Figure 32). In the case of Dunluce neighbourhood, the distribution shows that 85% of lots have 29.4% or less spatial interactions index (SI_x) in contrast to those most accessible homes.

Figure 32 and 33 (Box plot of Log of Spatial Interaction Index (SI_x) for all case study neighbourhoods) reveals out of 18 only 4 neighbourhoods have a mean spatial index greater than 1 and shows existence of skewedness in the distribution of this variable. The value of SI_x equal 1 implies the accessibility status to a point where the park size and distance from housing lot have equal influence on the user's decision to visit that park, and thus this state can be considered a minimum level of accessibility. The box plot in Figure 33 shows nine neighbourhoods in which 75% of the lots have SI_x value less than 1. Therefore, 50% of the case study neighbourhood park (MR) designs fail to provide a minimum level of accessibility.

Although NSP is reserving MR for public recreational facilities, a gap in evaluation of the spatial distribution of this open space has resulted in underutilization. Based on these results it may be concluded that in order to maximize utilization of neighbourhood parks, they should be designed in a manner which ensures more uniform distribution of spatial interaction. This hypothesis is validated by designing a hypothetical neighbourhood with the same features and lots as actual design, but with alteration of MR locations and numbers.

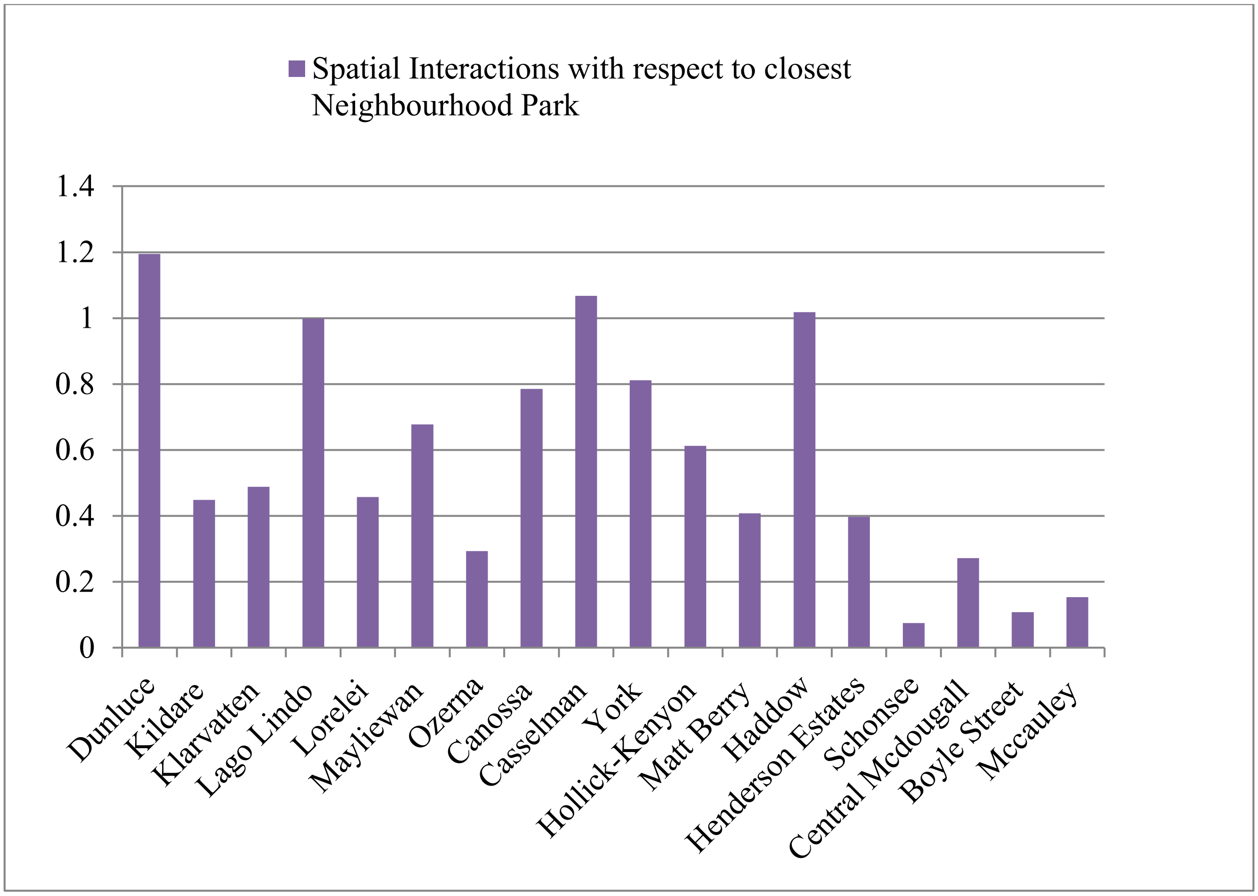


Figure 32: Mean spatial interactions of case study neighbourhoods

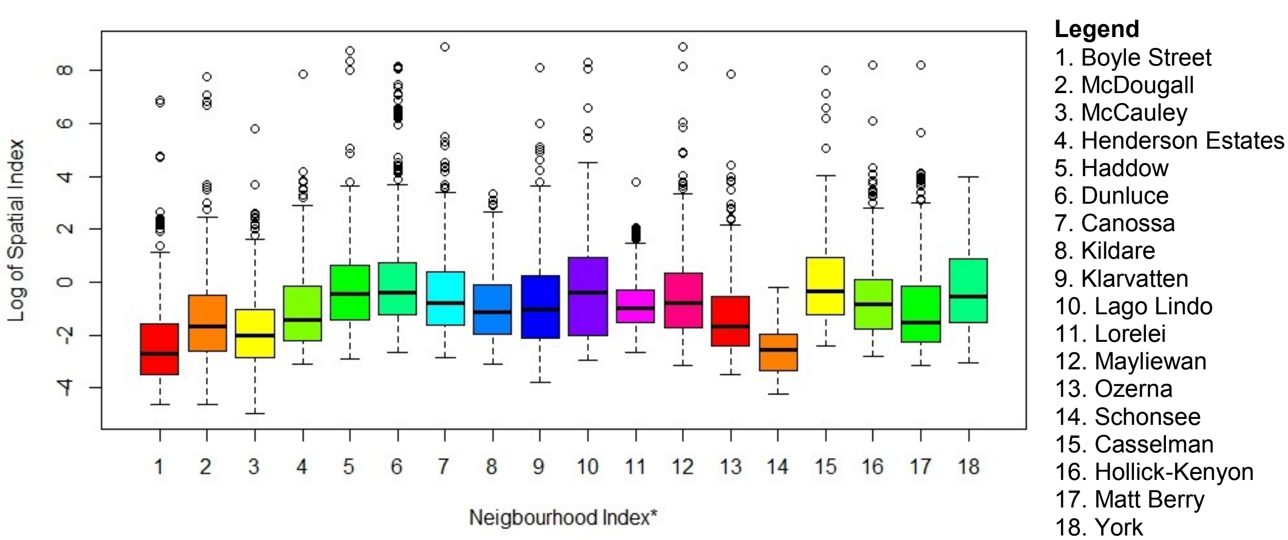


Figure 33: Box plot of Log of Spatial Index for case study neighbourhoods

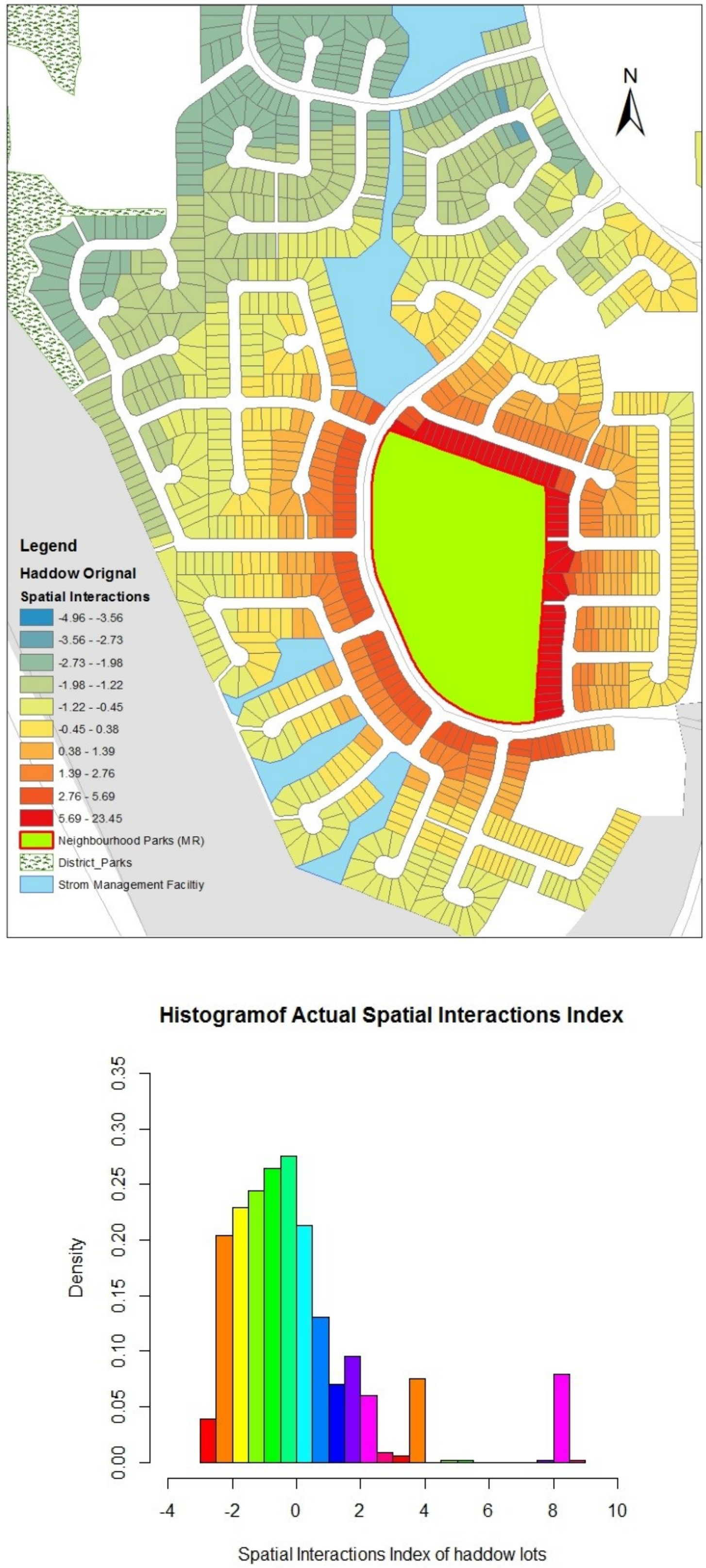
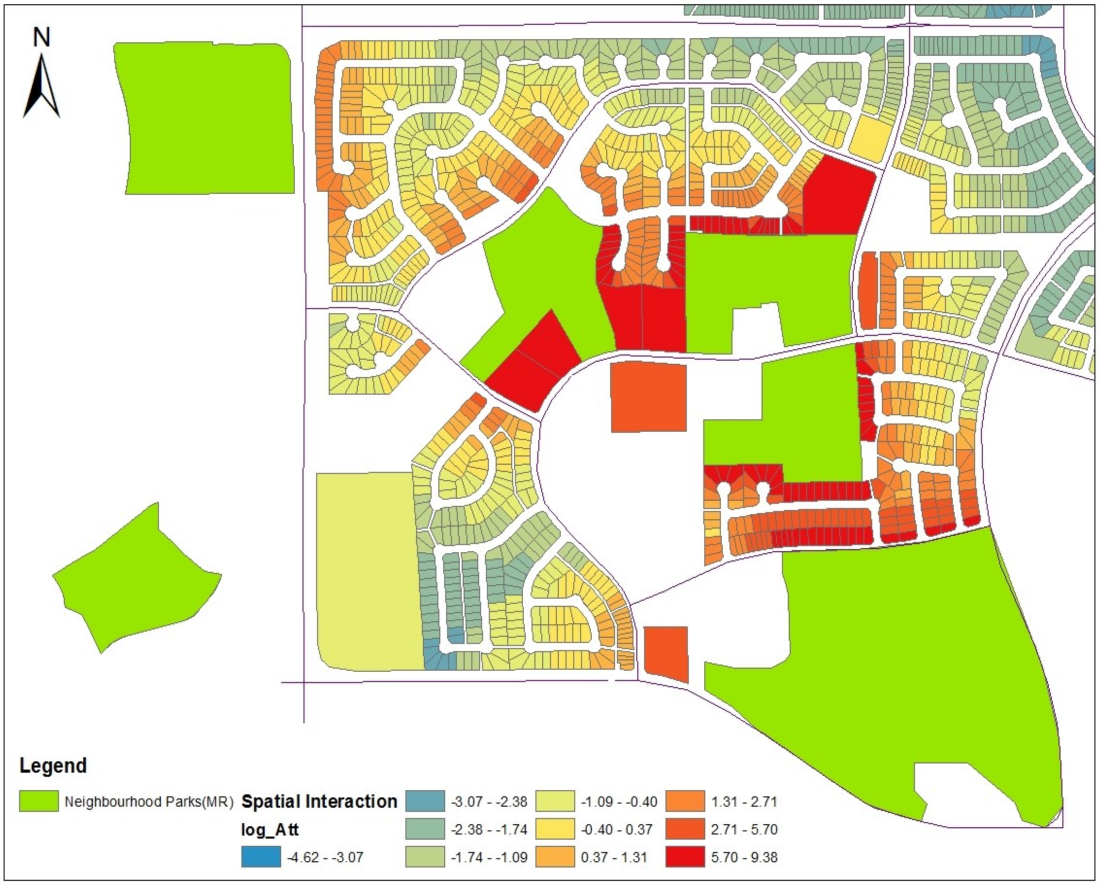


Figure 34: Spatial interactions of Haddow neighbourhood lots



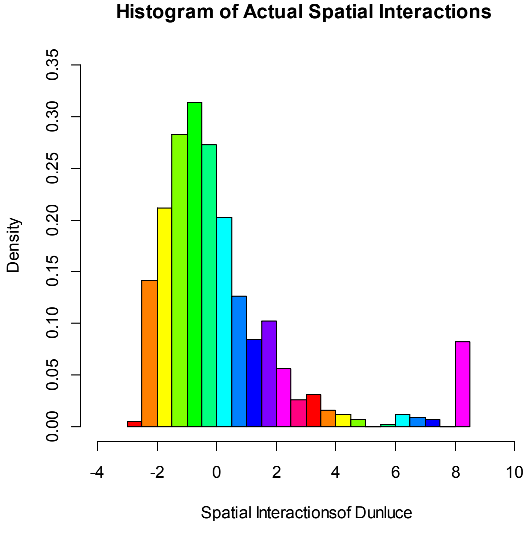


Figure 35: Spatial interactions of Dunluce neighbourhood lots

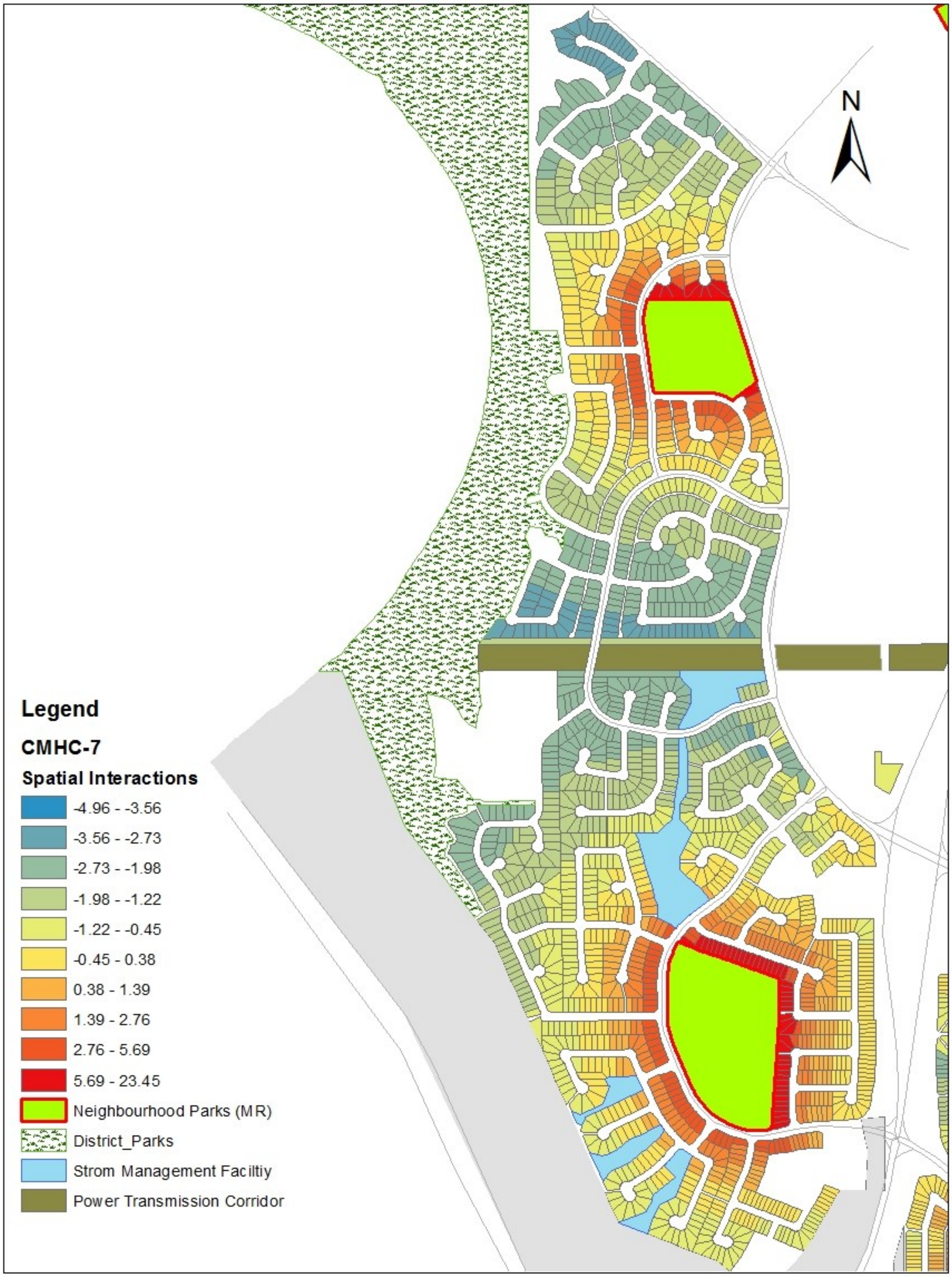


Figure 36: Spatial interactions map of CMHC-7 zone neighbourhoods

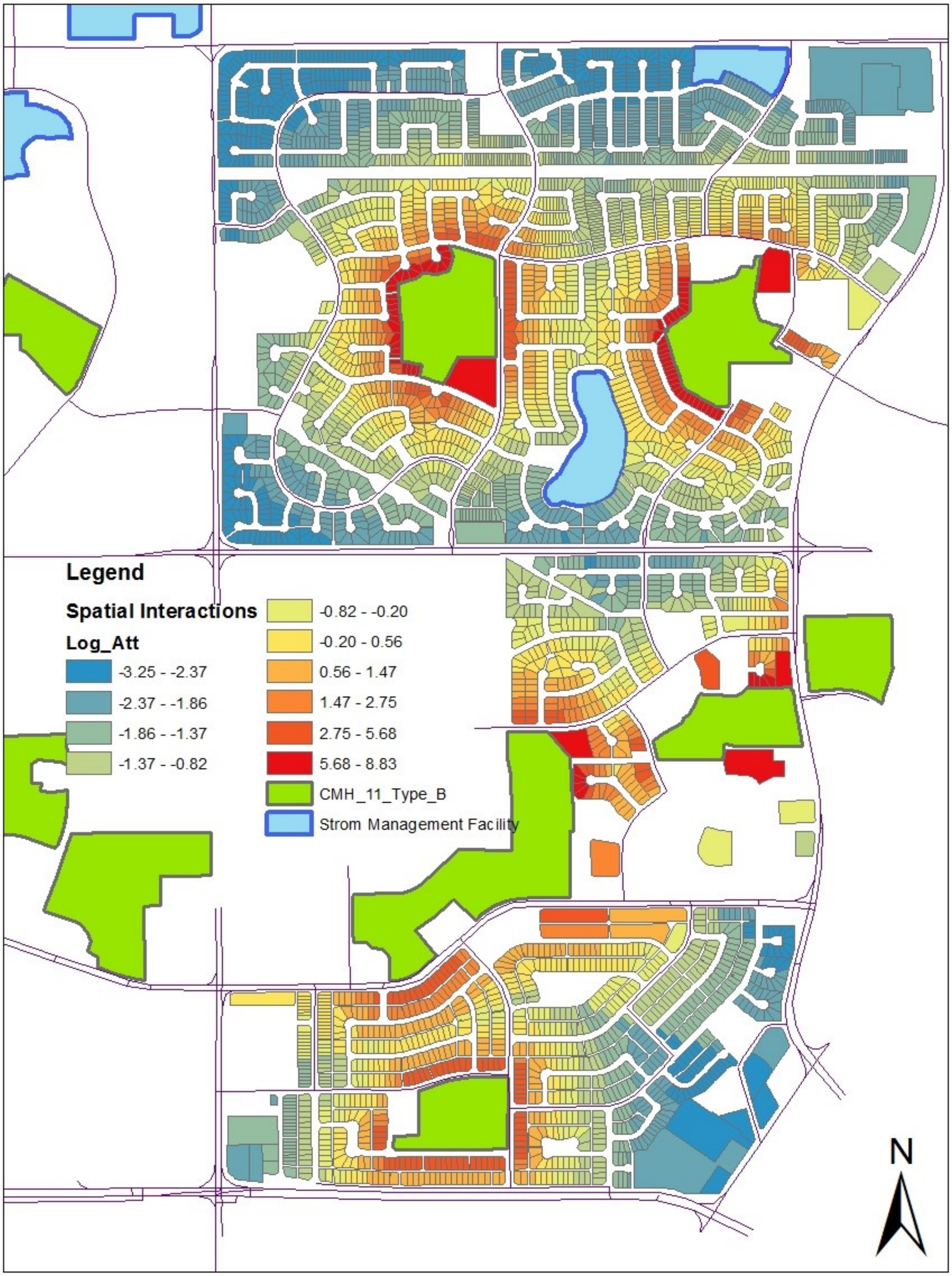


Figure 37: Spatial interactions map of CMHC-11 zone neighbourhoods

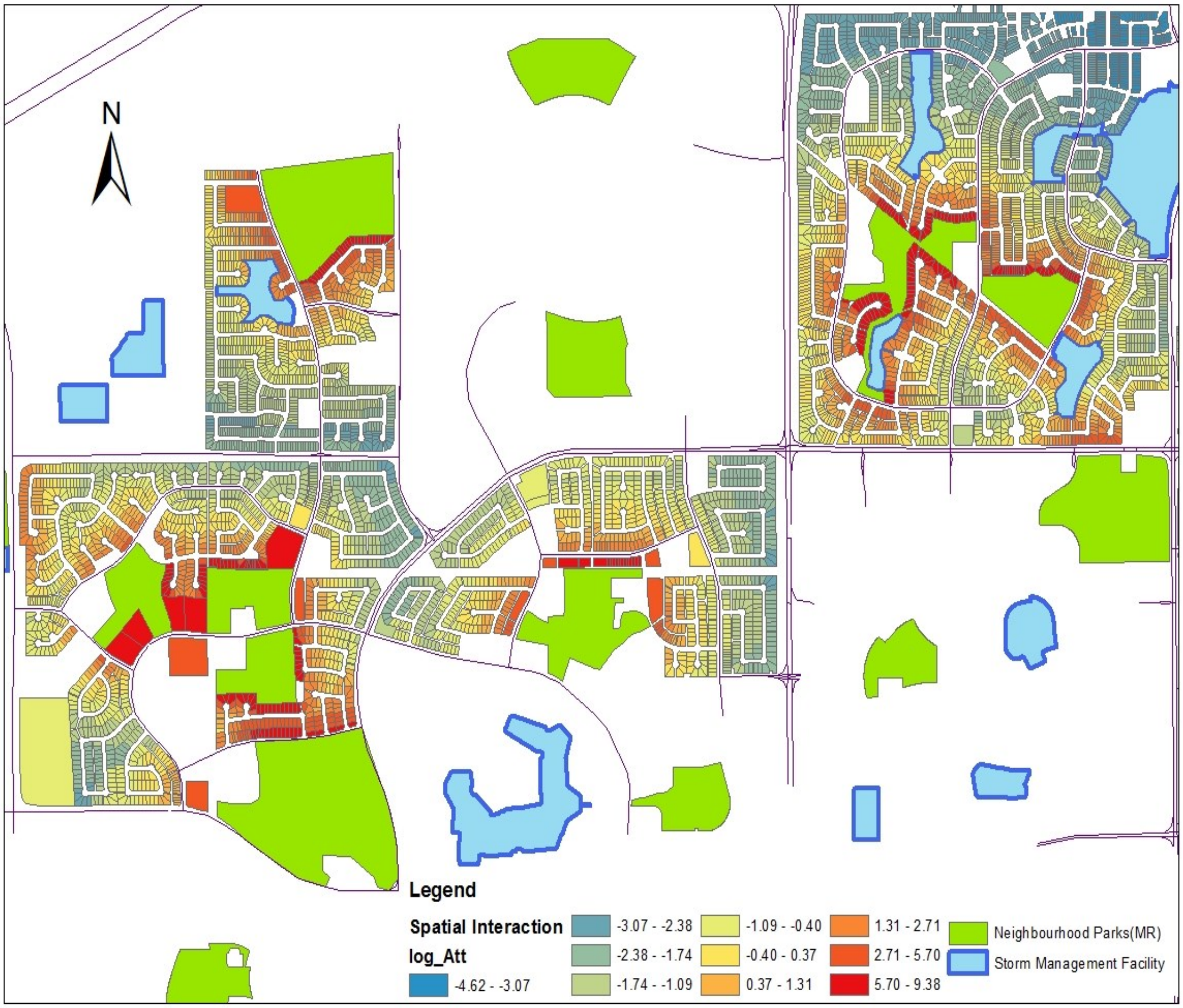


Figure 38: Spatial interactions map of CMHC-12 zone neighbourhoods

Figure 39: Spatial interactions map of CMHC-1A zone neighbourhoods

4.2 Property Value Model:

Using the 2014 property assessment dataset for the case study, a neighbourhood hedonic pricing model is developed considering the mentioned parameters in Chapter 3. Tables 6 through 9 represent the estimated coefficients of individual variable for the case study zones. All the *p*-values of the coefficients in the model are less than 0.05, which indicates that all variables are statistically significant. Also, the *t*-test confirms the rejection of null hypothesis (H_o), which assumes that the coefficient is equal to zero.

Variance Influence Factor (VIF) for the variables is significantly low and confirms the absence of multicollinearity among the dependent variables. The diagnostic plots of the residual errors plotted versus fitted values show a random distribution around the horizontal line, representing a residual error of zero (Figure 67 to 70 in Appendix B); any distinct pattern in this plot implies the existence of heteroscedasticity in the model. The Q-Q plot also suggests that the residual errors are normally distributed. The scale-location plots (square root of the standardized residuals versus fitted value plot) have no distinct pattern. This again confirms that the model satisfies the assumption of homoscedasticity. Finally, residuals versus leverage plot superimposed on contour lines for the Cook′s distance confirm that removing any observation has a diminutive effect on the regression results.

Estimated coefficients indicate the sensitivity of property value with respect to the variables. The coefficients represent the elasticities of dependent variables, i.e., it indicates the percentage variance of the dependent variables with respect to the change in the value of the independent variable. The principal objective of this study is to observe sensitivity of the home values with respect to open space (MR). Coefficient of log(D_Type_B Parks) in the model indicates the effect of the neighbourhood parks for the case study. Although the sensitivity varies throughout the submarkets, positive effect is observed for all cases. For CMHC Zone 7 and 1A, property value decreases by 1.02% and 3.13% respectively when the distance from neighbourhood parks increases by 1%, whereas in the case of storm management facility space this elasticity is 1.5% in CMHC Zone 7. This indicates that a park with a body of water is more attractive than a park without water, which complies with the findings of other studies.

CMHC Zone 1A contains no storm management facility (Figure 39); and, though river valley parks are proximate to this zone, property value is shown to have decreased by 12.5% for every

1% increase in distance from these parks. On the other hand, in CMHC Zones 11 and 12, sensitivity with Type *B* is 0.263% and 0.3475%, respectively. This reduced effect could be explained by the greater influence of open spaces which contain a body of water. Results show in all cases the coefficient for storm management facilities, which can be referred to as a body of water, is greater than neighbourhood parks. Spatial observations on CMHC Zones 11 and 12 identified a more frequent presence of preserved natural water bodies and storm management facilities compared to other zones. It can thus be determined that conserving natural spaces that contain a body of water can financially benefit home owners through an increase in property value, and can benefit the developer through an increased rate of sale for these lot locations.

Table 7: Estimated coefficients for independent variables in CMHC Zone 7

Variable name	**Estimated coefficient**	**Std. error**	***t*-value**	**Pr(>|t|)**	**VIF**
(Intercept)	9.247095	0.087114	106.149	< 2e-16 ***	-
log(Living Area)	0.548892	0.012172	45.094	< 2e-16 ***	1.635
log(Lot Area)	0.304333	0.011581	26.279	< 2e-16 ***	2.088
log(Age)	−0.115702	0.007460	−15.511	< 2e-16 ***	1.635
Fire_Place	0.033356	0.013126	2.541	0.0111 *	1.014
Basement	0.057020	0.005184	10.998	< 2e-16 ***	1.158

Variable name	Estimated coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
Garage_Ex**	NA	NA	NA	NA	NA
WalkAbout	0.098893	0.009282	10.654	< 2e-16 ***	1.556
Air_cond	0.043839	0.009835	4.457	8.86e-06 ***	1.034
log(D_Type_B Parks)	−0.010215	0.002312	−4.418	1.06e-05 ***	1.260
Arterial Road Effect	−0.044363	0.006079	−7.298	4.54e-13 ***	1.145
log(D_District Parks)	−0.063594	0.003054	−20.824	< 2e-16 ***	1.796
log(D_CBD)	−0.007443	0.004720	−1.577	0.1150	1.308
log(D_TypeC Parks)	−0.014934	0.001625	−9.192	< 2e-16 ***	1.203

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.0959 on 1643 degrees of freedom

Multiple R^2: 0.8587, Adjusted R^2: 0.8578

F-statistic: 907.8 on 11 and 1643 DF, p-value < 2.2e-16

** All homes have a garage

Table 8: Estimated coefficients for independent variables in CMHC zone 12

Variable name	Estimated coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
(Intercept)	10.6079376	0.0220432	481.234	< 2e-16 ***	-
log(Living Area)	0.3383547	0.0030165	112.168	< 2e-16 ***	1.781947
log(Lot Area)	0.1353219	0.0033312	40.623	< 2e-16 ***	1.618348
log(Age)	-0.0759680	0.0012697	-59.833	< 2e-16 ***	2.269722
Fire_Place	0.0274772	0.0014368	19.124	< 2e-16 ***	1.241509
Basement	0.0127212	0.0013328	9.545	< 2e-16 ***	1.155832
Garage_Ex	0.1269405	0.0027569	46.045	< 2e-16 ***	1.076879
WalkAbout	0.0936096	0.0042124	22.222	< 2e-16 ***	1.406021
Air_cond	0.0244107	0.0069021	3.537	0.000407 ***	1.010706
log(D_Type_B Parks)	-0.0034750	0.0005761	-6.031	1.69e-09 ***	1.126411
Arterial Road Effect	-0.0008131	0.0015887	-0.512	0.608798	1.040758
log(D_District Parks)	NA	NA	NA	NA	NA
log(D_CBD)	-0.0134800	0.0010565	-12.759	< 2e-16 ***	1.043284
log(D_TypeC Parks)	-0.0165437	0.0005814	-28.454	< 2e-16 ***	1.637364

Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Variable name	Estimated coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
Residual standard error: 0.05556 on 8659 degrees of freedom					
Multiple R^2: 0.8788, Adjusted R^2: 0.8787					
F-statistic: 4831 on 13 and 8659 DF, *p*-value < 2.2e-16					

Table 9: Estimated coefficients for independent variables in CMHC submarket 11

Variable name	Estimated coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
(Intercept)	10.50928	0.030588	343.581	< 2e-16 ***	-
log(Liv_Area)	0.336172	0.004276	78.627	< 2e-16 ***	2.238
log(Lot_Area)	0.15259	0.004848	31.472	< 2e-16 ***	2.007
log(Age_Home)	-0.09481	0.002148	-44.136	< 2e-16 ***	2.756
Garage_Ex	0.100145	0.004674	21.425	< 2e-16 ***	1.096
Bansement	0.006054	0.002122	2.854	0.00435 **	1.423
WalkAbout	0.14956	0.005909	25.311	< 2e-16 ***	1.401
FirePlace_	0.030401	0.002401	12.661	< 2e-16 ***	1.548
Air_cond	0.022335	0.007323	3.05	0.00231 **	1.006

Variable name	Estimated coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
log(D_District Parks)	NA	NA	NA	NA	NA
Arterial Road Effect	-0.01469	0.001922	-7.639	2.8e-14 ***	1.041
log(CBD)	0.000197	0.001085	0.182	0.85572	1.198
log(D_Type_B Parks)	-0.00263	0.000927	-2.843	0.00450 **	1.174
log(D_TypeC Parks)	-0.01359	0.001063	-12.79	< 2e-16 ***	1.818
log(Type_A_Parks)	-0.00083	0.001002	-0.828	0.40745	1.314

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 0.05176 on 3522 degrees of freedom
Multiple R^2: 0.9169, Adjusted R^2: 0.9166
F-statistic: 2989 on 13 and 3522 DF, *p*-value < 2.2e-16

Table 10: Estimated coefficients for independent variables in CMHC submarket 1A

Variable names	Estimated Coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
(Intercept)	10.97906	0.142163	77.229	< 2.00E-16 ***	-
log(Lot_Area)	0.238317	0.015672	15.207	< 2.00E-16 ***	1.401
log(Living_A_1)	0.361064	0.015934	22.66	< 2.00E-16 ***	1.527
log(Age)	-0.12733	0.006096	-20.888	< 2.00E-16 ***	1.605
Air_Con	0.112637	0.031042	3.629	0.000299 ***	1.088

Variable names	Estimated Coefficient	Std. error	*t*-value	Pr(>|t|)	VIF
Fire_Place	0.14156	0.015386	9.201	< 2.00E-16 ***	1.881
Garage_E	0.085836	0.011532	7.443	2.12E-13 ***	1.131
Base_Walko	0.200863	0.067959	2.956	0.003193 **	1.024
Base_Dev	0.045879	0.009716	4.722	2.67E-06 ***	1.062
AR_Effect	-0.07186	0.011741	-6.12	1.34E-09 ***	1.169
log(Type_B_Sch)	-0.0313	0.00572	-5.472	5.61E-08 ***	1.118
log(Type_C)	-0.12503	0.004621	-27.057	< 2.00E-16 ***	1.614
log(CBD)	-0.03604	0.008203	-4.393	1.24E-05 ***	1.127

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 0.1497 on 998 degrees of freedom
Multiple R^2: 0.8901, Adjusted R^2: 0.8888
F-statistic: 673.6 on 12 and 998 DF, *p*-value < 2.2e-16

4.3 Hypothetical Design of the Case Study Neighbourhood:

To investigate how the distribution of MR could affect the lot price as well as the spatial accessibility for the reserved space, a new hypothetical Haddow NSP is designed by distributing the MR throughout the neighbourhood, which is in contrast to the original design of the Haddow neighbourhood. This conceptual area comprises the same type and number of residential lots, but the MR is divided into two segments. Haddow neighbourhood is situated in the southwest region of Edmonton, south of the developed residential neighbourhoods of Henderson Estates and

Falconer Heights, and between Terwillegar Drive and the North Saskatchewan River. According to the Neighbourhood Area Structure Plan (NASP), Haddow has a total of 107.98 ha (266.82 ac) gross developable area, and 8.91 ha (22.02 ac) area is reserved as MR (Figure 34). This portion of MR is located in the center of the neighbourhood. The MR is divided into two segments with areas of 3.32 ha (8.0 ac) and 5.25 ha (13.0 ac), respectively. Analysis of spatial interaction (Table 10) shows 3rd Quantile value of data set is 1.84, and that the distribution is no longer left-skewed, as had been the case previously (Figure 40).

Table 11: Summary logarithm of spatial interaction in modified design of Haddow

Min	1st Quantile	Median	Mean	3rd Quantile	Max
−2.897000	−1.338000	−0.616100	0.001247	0.609900	7.915000

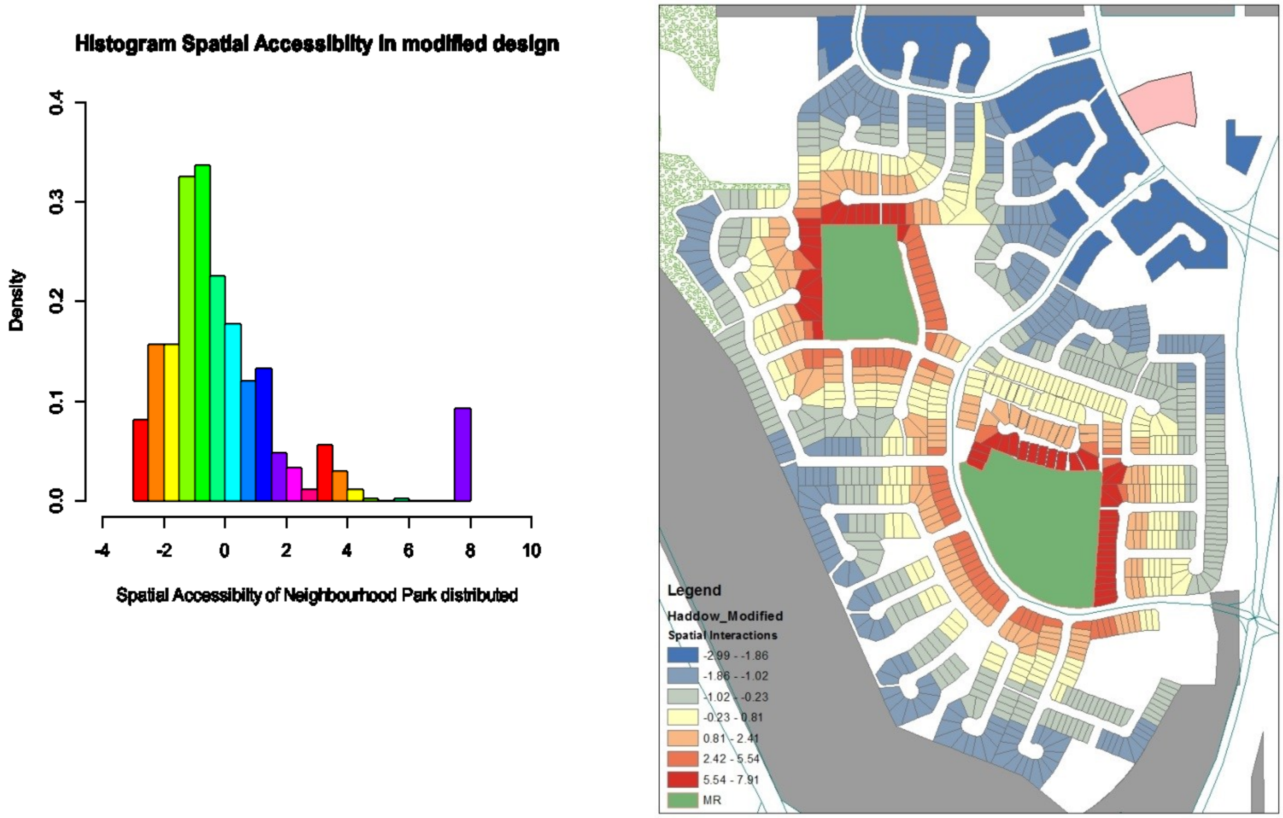


Figure 40: Improved spatial interaction in modified design

4.4 Validation of Hedonic Pricing Model:

One of the primary objectives of this study is to predict property value for the hypothetically designed Haddow neighbourhood, located in CMHC zone 7. Before predicting property value for this case study, it is necessary to validate the hedonic pricing model developed for CMHC zone 7. Although the residual diagnostic plots of the fitted model show acceptability, there is a better statistical validation method, called "Cross Validation", which is effective for evaluating the model performance for a new prediction on cases it has not perceived before. The simplest process of Cross Validation is the holdout method, in which the dataset is divided into two fragments: (a) Training set, and (b) Testing set (Witten et al., 2011). The testing dataset for validation accounts for 24% of the entire CMHC zone 7 dataset in this case. Figure 41 (property value is in log scale) is the plot actual versus predicted property value for the testing dataset, where the estimated and observed points are reasonably close to the 45° reference line and the R^2 value is 0.8, implying that 80% of actual property value has been captured by the model. The model can thus be considered a reasonably good fit for predicting property values for this neighbourhood.

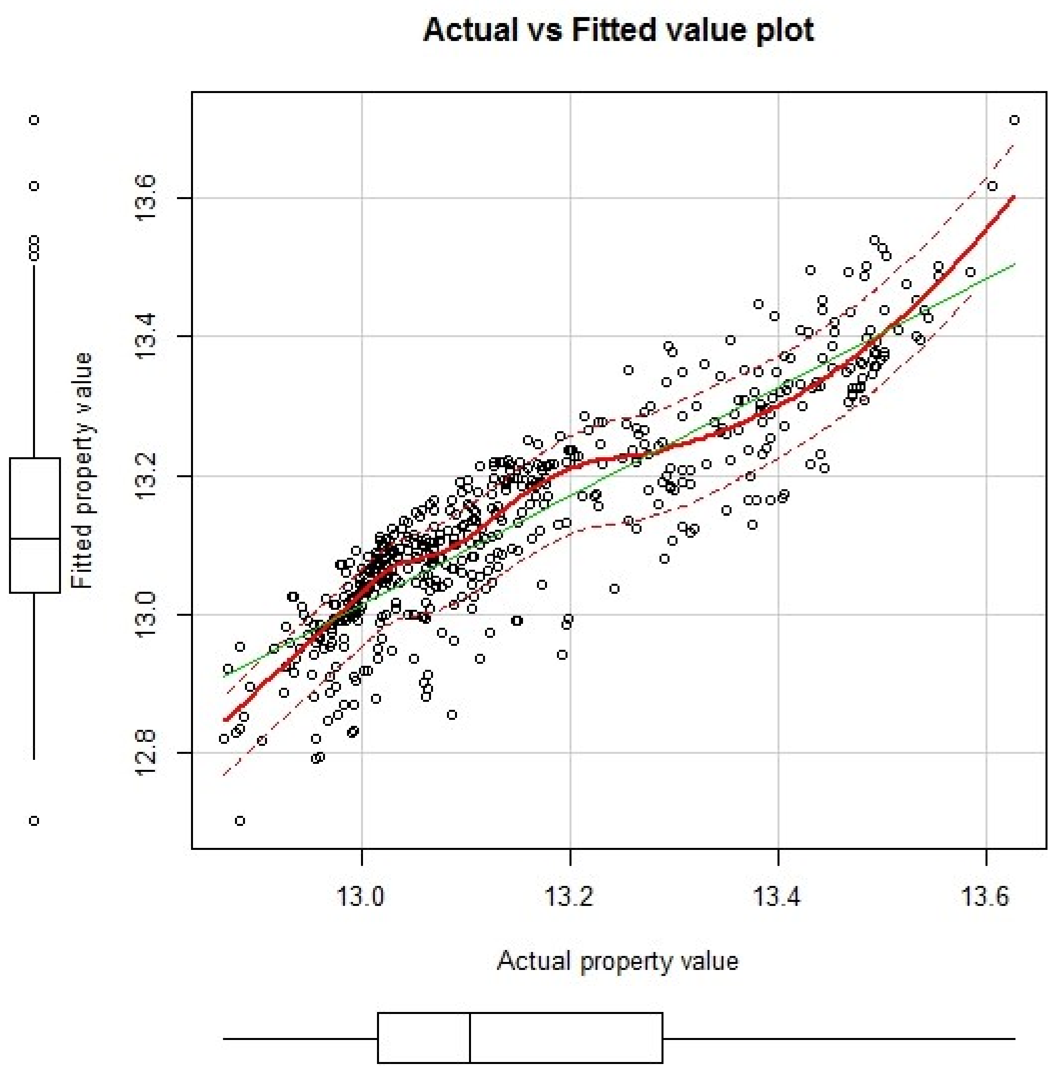


Figure 41: Validation of hedonic pricing model developed for CMHC 7 zone

4.5 Property Value Predicting from the Developed Model:

The hedonic functional form used is:

$$\ln P_i = \beta_0 + \sum_k \beta_k \ N_{i,k} + \sum_j \beta_j \ \ln S_{i,j} + \sum_l \beta_l \ \ln D_{i,l} + \varepsilon_i$$

Using the ordinary least squares (OLS) method $\beta_o, \beta_j, \beta_k$, and β_l coefficients have been estimated in the previous section. Since ε_i is normally distributed for all the fitted models in the case study housing submarkets, the dependent variable price $\ln P_i$ is also normally distributed, assuming that the regressors are non-random which ultimately entails that P_i will follow a *Log-Normal* distribution. For prediction of the price it is required to transform from the logarithmic form using the following function:

$$P_i^* = \exp\{[\log(P_i)]^* + \frac{s^2}{2}\} \qquad (8)$$

Where $[\ln P_i]^* = \beta_0 + \sum_j \beta_j \ \ln S_{i,j} + \sum_k \beta_k \ N_{i,k} + \sum_l \beta_l \ \ln D_{i,l}$ and $\frac{s^2}{2}$ is the correction factor to reduce the bias in transformation (Cowpertwait and Metcalfe, 2009). s^2 is the variance of ε_i. The correction factor derives from the relationship between *Normal* distribution and log-normal distribution. If a *Random* variable price P_i is normally distributed with mean μ and variance σ^2 (the equation form is $x \sim N[\mu, \sigma^2]$) then for lognormal distribution $y = \exp(P_i) \sim \log{-}N[m, v]$, where m and v are the mean and variance of the corresponding log-normal distribution (Giles, 2013). It should be noted the following relationships of mean and variance in case of log-normal distribution is as follows:

$$m = \exp[\mu + \frac{\sigma^2}{2}] \qquad (9)$$

$$v = \exp[\sigma^2 - 1]\exp[2\mu + \sigma^2] \qquad (10)$$

For prediction mean error is equal to the expected value of the error term is zero ($\mu = E[\varepsilon_i] = 0$) and σ^2 would be the variance of standard error ($\sigma^2 = \mathrm{var}[\varepsilon_i]$). Consequently the expected value of prediction is shown as:

$$P_i^* = E[y] = \exp\{[\ln P_i]^* + \sigma^2 / 2\} \qquad (11)$$

For the prediction in this research σ^2 is replaced with s^2, which is an unbiased estimator of σ^2 in OLS estimate of the model.

The coefficients of a previously fitted hedonic pricing model for actual design lots are used to predict the value for lots in the new hypothetical design of Haddow. Predicted mean price for the hypothetical design is $597,300 whereas in the actual design, mean price is $589,400. Each individual predicted value of lots is subtracted from the price in the actual plan in order to track the change in property value. The improvement in spatial accessibility for the hypothetical design serves to enhance the overall property value of the whole neighbourhood to approximately $5,686,924.11, which is determined by summing all property value changes (Figure 42 and 43). Using the City of Edmonton property tax calculator, the estimated corresponding increase in property tax revenue is $43,132.48. It can thus be concluded that distributing the MR into two fragments enhances the spatial interaction of the park, and also generates additional municipal tax revenue from the elevated property value (Figure 40).

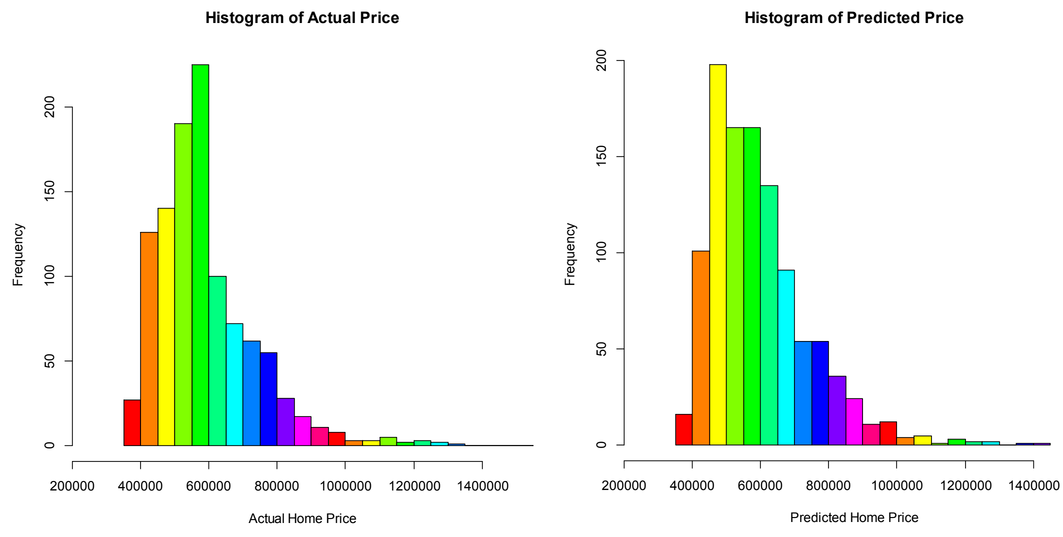


Figure 42: Change in property value.

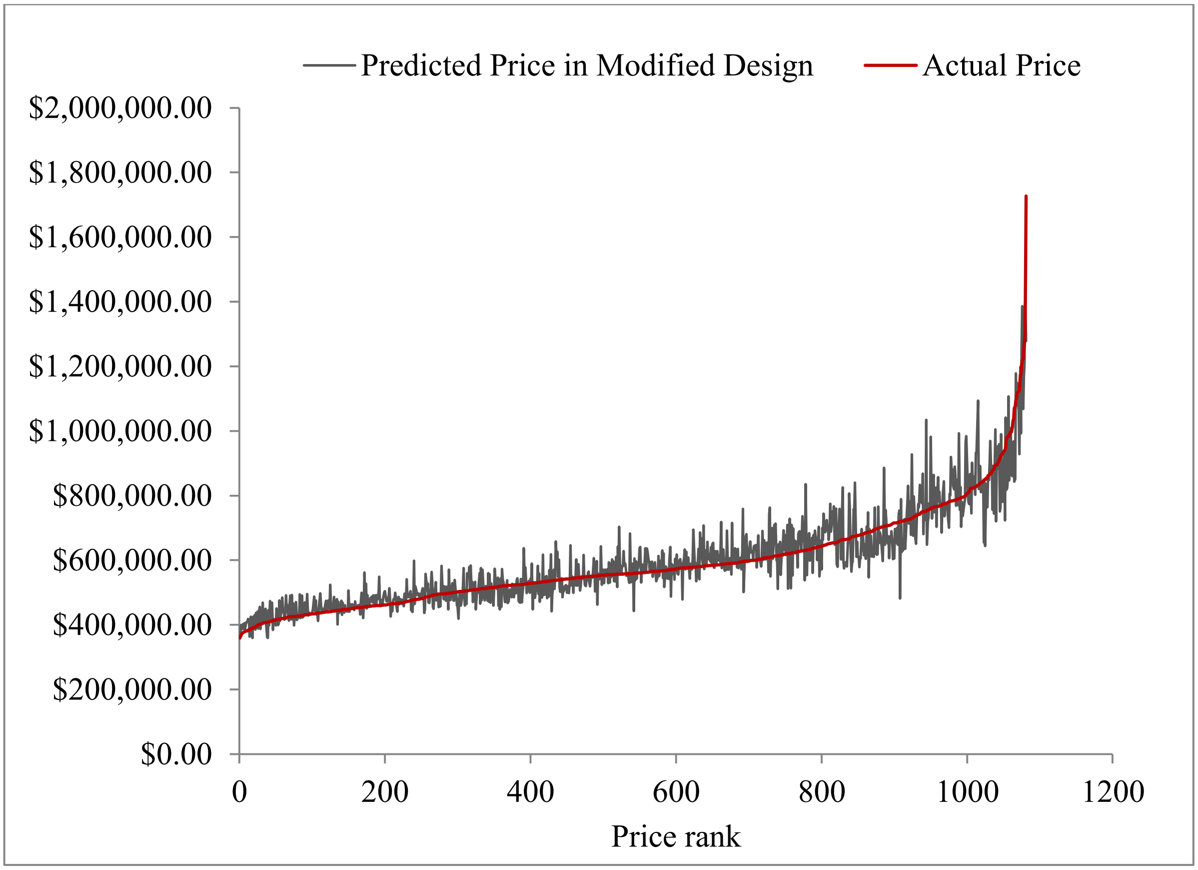


Figure 43: Predicted versus actual price for Haddow

4.6 Neighbourhood Park Maintenance Costs:

Maintenance costs for neighbourhood parks are major concern when distributing the MR in NSP. In the case of the City of Edmonton, this reserved space is initially developed by the land developer and later owned by municipal authority. The Sports Field Operations Team in the Neighbourhood, Parks and Community Recreation Operations branch of the City of Edmonton is responsible for maintaining all the parks, sports fields, diamonds, and race tracks located within the city. In 2013, this branch maintained a total of 1,677 sports fields, 83 tennis courts, more than 400 long jump pits in schoolyards, and 6 staffed class B facilities operating 7 days per week (16 hours per day) mid-April through November. This department follows certain maintenance standards for its provided services (Table 11). To estimate the parks/open space management costs for the case studies in this research, service levels are considered to be similar to those for sports field operations. Cost data is obtained from the Parks and Community Recreation Operations branch, and includes *field unit cost* and *external charge-out rate*. Field unit cost is applicable to parks owned by the city, and an external charge-out rate is relevant to privately owned parks.

Table 12: Sports field service levels followed by City of Edmonton neighbourhood, parks & community recreation operations

Group	Activity	Service Level	Quality Standard
Grass Cutting	Power Mowing	10 cuts/season for neighbourhood/school sites playground	Turf height cut at 5 cm. Maximum heights at 12 cm on average.
	Trimming	4 times/year	Turf height 5 cm. Reduce to 2 times per year.
Turf Quality Management	Fertilizing	Once per year on priority fields (high use fields identified by users).	Apply evenly, uniform and free of burn spots
	Herbiciding	As per standards	Turf height 5 cm.

Group	Activity	Service Level	Quality Standard
		recommended in IPM standard field – 6 weeds m^2	No over spray or drift on non-target area. No spraying on designated herbicide free sites.
	Misc. Turf	Observe current status; provide if needed	Top dressing - uniform application not to exceed 10 mm thickness. Irrigation -thorough soaking to the depth of root zone. De-thatching -uniform throughout, thatch removed. Edging -curbs free of overgrowth. Clippings removed to prevent the killing of grass.
	Aerating	Observe current status; provide if needed	Cover all uniformly
Playground Surface Maintenance	Major Turf Repair – Seed	Observe current status; provide if needed	Apply seed uniformly and evenly Service portions are graded and flush with surrounding turf
	Major Turf Repair – Sod	Observe current status; provide if necessary	
	Line Marking	Provide if existing marks are not well visible; maximum 10 times/year would be applied on premier fields	4 in well visible lines should be created maintaining the standard dimensions
Fixtures Maintenance	Sports Field Furniture and Fixtures	Observe current status; provide if necessary	Ensure safety of all Sports fixtures and free of damage.

Group	Activity	Service Level	Quality Standard
			Goal posts are properly numbered and colored by white paint Bleachers/benches installed on a concrete pad. Backstops are numbered and bottom rail.
	Jump Pit Maintenance	Observe current status; provide if necessary	Debris free sand is provided Maximum 2 jump pits/ per school sites. No installation or maintenance of take-off boards

The following assumptions are made in calculating the cost for hypothetical design in order to meet the City of Edmonton's maintenance standards and provide better physical activity facilities to the community:

- One 300 ft x 180 ft and two 150 ft x 100 ft rectangular sports fields are considered for the small portion space (3.25), whereas the greater portion has two 300 ft x 180 ft and one 240 ft x 140 ft rectangular playground (Figure 45); these three types of standard dimensions of sports fields are chosen to meet the demand of different age groups of residents.
- Each open space has one junior play facility such as a climbing structure or a sand pit.
- Each open space includes six benches for sitting.

- Since the City of Edmonton has a policy to irrigate only the premier sports fields up to 1" of moisture per week depending on rainfall, only the rectangular sports fields are considered for irrigation activity. A premier sports field in Edmonton is defined as a full-size, rectangular field that is irrigated and regularly maintained by municipal authority. The sports fields in the case study park are thus considered premier fields. This postulation will create a more optimistic scenario for cost-benefit analysis.

- The cost dataset obtained from the Neighbourhood, Parks and Community Recreation Operations branch has three group cost components: (a) field unit cost; (b) charge-out rate for inter-department; and (c) charge-out rate for external. If the park is owned by the city, then the field unit cost would be applicable, whereas for a privately owned amenity, maintenance cost calculation would require the charge-out rate for external unit cost.

- Three cost scenarios are considered for the cost analysis: (i) both parks are city owned; (ii) both parks are privately owned; and (iii) one park is privately owned and one is city owned.

- Snow removal for the paths that connect to major roads is performed by the Transportation department, so no snow removal is considered for the parks in winter.

- There are no Class *B* facilities present in this case study park (these facilities in Edmonton have regular staff for maintenance and operate 7 days per week, 16 hours per day, from mid-April to November.)

- No schools exist in the actual design, so, for the hypothetical design, no school building envelope is considered. The entire open space is solely designated for public active recreational facility.

- No landscape design (e.g., trees, bushes, walking trails) is considered; however, the locations of specific features in the space are changed in order to divide the space into two fragments.

Figure 44: Actual sports fields in Haddow park (Source: City of Edmonton, 2015a)

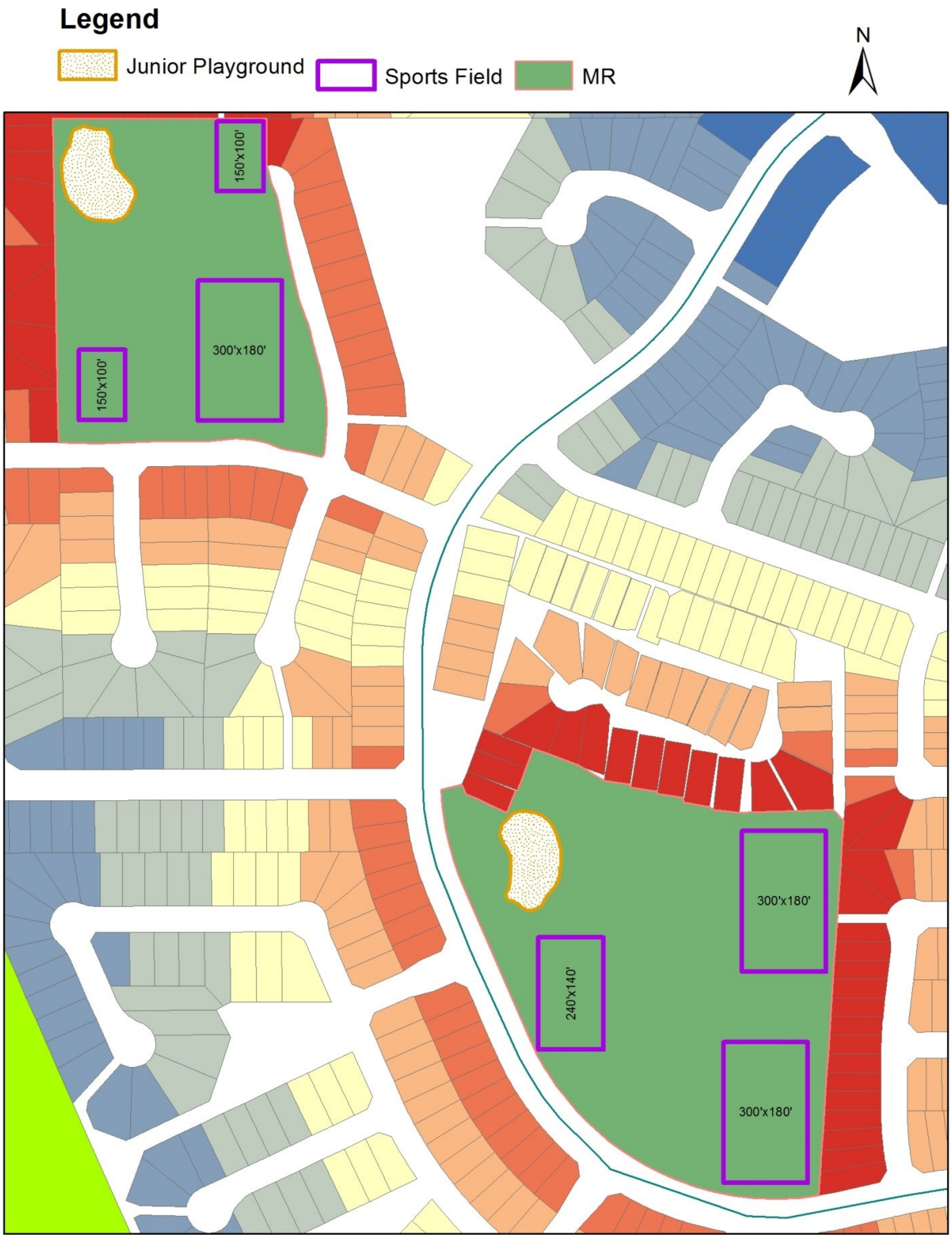


Figure 45: Sports fields and features in hypothetically designed Haddow neighbourhood

The following policy scenarios are in turn simulated for the purpose of maintenance cost analysis:

No	Cost scenarios	Policy index in Figure 46
i	MR is allocated as one large park owned publicly	1
ii	MR is distributed into two smaller parks owned publicly	
iii	MR is allocated as one large park owned privately	2
iv	MR is distributed into two smaller parks owned privately	
v	MR is distributed into two parks, the smaller portion of which is privately owned, whereas the larger portion is owned publicly	3

The first maintenance cost scenario (i) involves consideration of the fact that the park is owned by city officials; the cost figure of the actual design is $21,589 while the hypothetical design (scenario ii) (where MR is divided into two segments) would require $25,193 for annual maintenance. These cost figures are only about 50% and 58%, respectively, of additional municipal tax revenue generated from the hypothetical design in which the MR has been distributed throughout the neighbourhood. Maintenance costs for distributed design are thus 14% higher than the actual design.

Both the third (iii) and fourth (iv) hypothetical maintenance cost scenarios assume that all the parks are privately owned, and the annual park maintenance cost is $41,482 for actual design, which is 96% of additional municipal tax revenue generated in the hypothetical design.

On the other hand, if the distributed design is implemented, the annual park maintenance cost would be close to $47,459; that is only 9% higher than the additional municipal tax revenue generated in the hypothetical design. The maintenance cost for distributing MR is only 13% higher than the actual design.

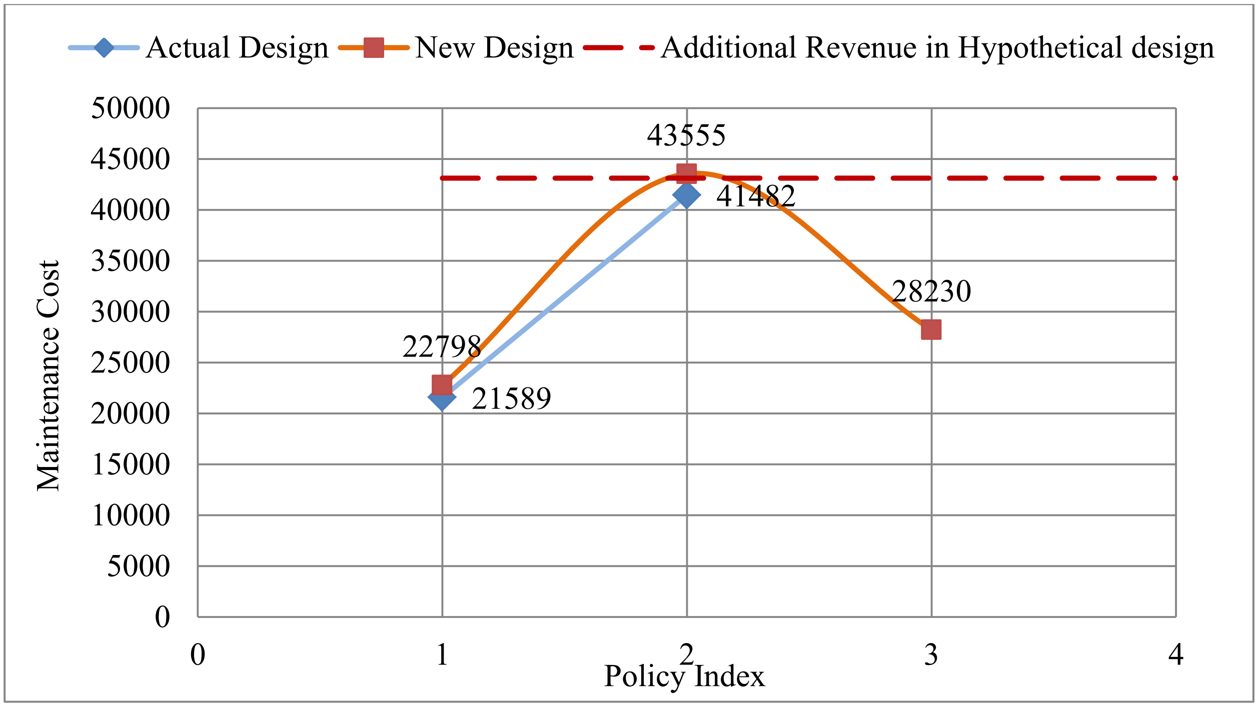


Figure 46: Maintenance costs for different policies

Figure 46 illustrates the cost analysis for the above mentioned policy scenarios. The fifth scenario (v) has a policy index value of 3 in Figure 46. In this case, the maintenance cost is about \$28,230 which is only 65.5% of additional municipal tax revenue generated in the hypothetical design.

Distributing the MR into several locations thus increases the park maintenance cost, but the revenue generated by these open spaces through an increase in property value is sufficient to accommodate maintenance expenses regardless of policies for ownership of the land.

4.7 Mowing Operation Analysis

Scattered patterned design of MR would promote modification in the current maintenance procedure. Mowing operations would be greatly impacted due to changes in the size of the parks. Currently, the city maintenance team uses the following mowing machines:

a) 48 in and 72 in riding rotary mowers

b) 192 in winged rotary riding mowers

c) Tractor mounted 18 ft flail mowers

If MR is segmented and distributed into several locations throughout the neighbourhood, park size will be relatively smaller and as a result mowing machine size could be reduced. In this research, an attempt is made to monitor the changes in duration of mowing time if the machine size is changed for the case study neighbourhood parks. A simulation model (Figure 47) is developed using Simphony.NET 4.0[4] to observe the change in duration of mowing. Mowing productivity information is collected from online sources of different mower machine manufacturers[5]. The mowing productivity rate is considered a triangular fit due to limited information on the production rate (Table 12).

[4] More information available in Appendix D
[5] Details information available in Appendix D

Table 13: Input parameters in simulation model

Machine Size	Mowing Rate (ac/h)	Travel Speed (mph)	Distribution
36 in	1.600	4.0	Triangular
	1.890	5.0	
	2.000	6.5	
42 in	1.400	4.0	Triangular
	2.200	8.0	
	2.800	9.0	
48 in	3.490	9.0	Triangular
	3.695	10.0	
	3.900	16.0	
54 in	4.400	10.0	Triangular for mowing rate Uniform for travel speed
	4.800	10.0	
	6.110	14.0	
60 in	4.900	10.0	Triangular for mowing rate uniform for travel speed
	5.800	10.0	
	6.780	14.0	
72 in	4.980	8.0	Triangular
	7.000	12.0	
	8.140	14.0	
124 in	4.400	7.5	Triangular for mowing rate Uniform for Travel Speed
	6.425	7.5	
	10.900	15.0	
132 in	4.300	7.5	Triangular for Mowing rate Uniform for Travel Speed
	6.500	7.5	
	10.600	15.0	

In the simulation model (Figure 47), it is assumed that the maintenance crew will complete mowing in the largest park first and then move to the second largest park, and so on. The park size parameter limits the maximum size of mowing machines. Table 13 shows the recommended size of mowing machine relevant to use for park size from 0.2 ha (½ ac) to 1.2 ha (3 ac) (Cub Cadet, 2015). The case study area in this research comprises a total 8.9 ha (22 ac) of MR segmented into 5.3 ha (13.0 ac) and 3.2 ha (8.0 ac) parks, respectively, in a hypothetical neighbourhood design. Following the recommended machine size in Table 14, a maximum machine size capacity of 72 in is considered for mowing smaller parks, while a machine size of

132 in (which is presently the maximum available size on the market for riding rotary mowers) is considered for larger park. Table 15 describes different combinations of machine sizes considered in this simulation. Figure 48 depicts the duration of mowing time for the machine combination scenarios mentioned above.

Table 14: Recommended size of riding mower (Cub Cadet, 2015)

Yard Size	**Riding Mower Deck Size**
1/2 - 1 acre	42 in deck would be appropriate
1 - 2 acres	42 in or 46 in deck would be sufficient
2 - 3 acres	46 in, 50 in or 54 in deck would get the task completed more efficiently

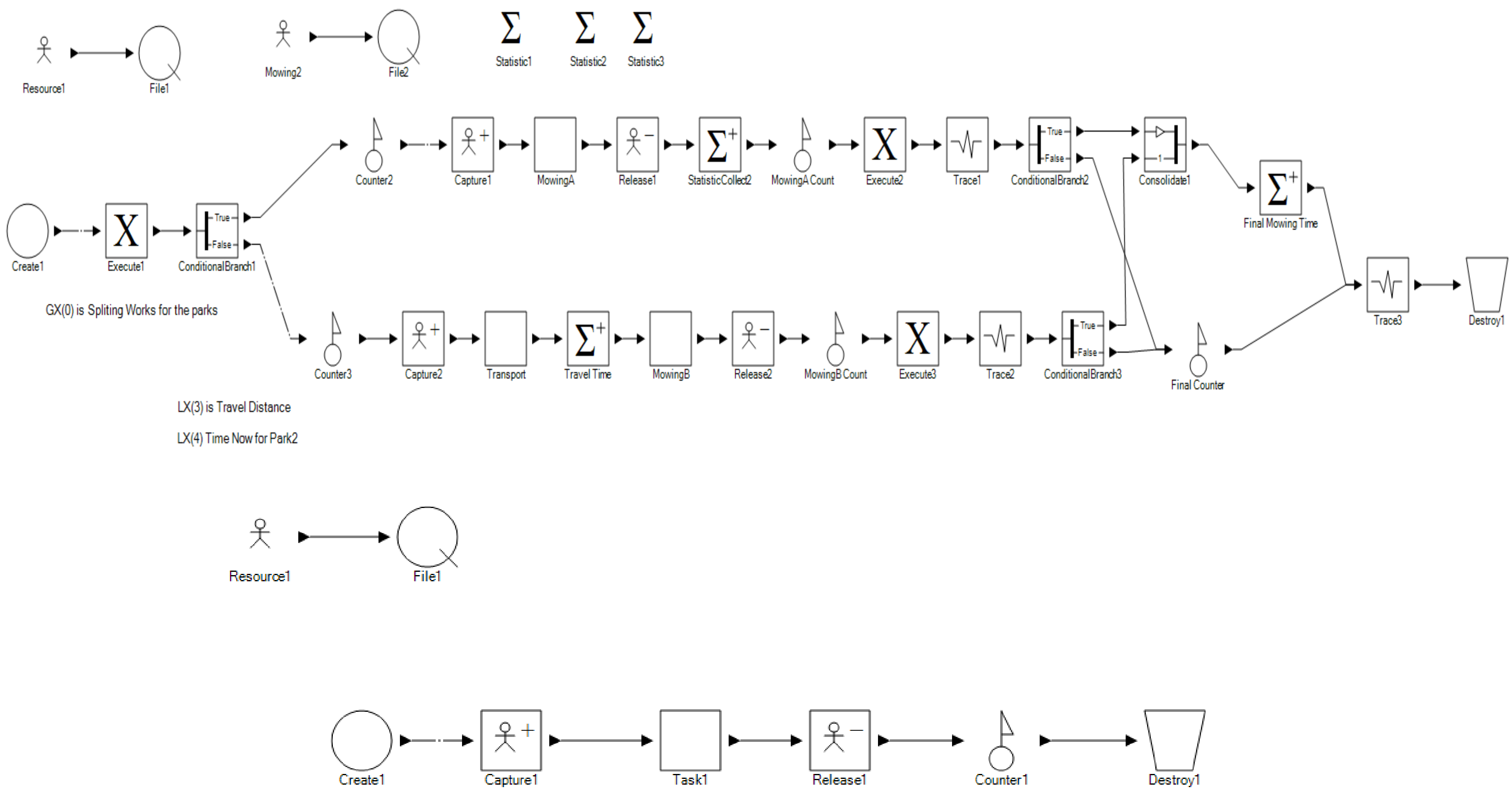


Figure 47: Simulation model in Simphony.NET 4.0

Table 15: Different type of machine size configuration for mowing

Scenario index	**For actual park design**	**For hypothetical MR distributed design**
1	Use only 36 in mowing machine	Use only 36 in mowing machine
2	Use only 42 in mowing machine	Use only 42 in mowing machine
3	Use only 48 in mowing machine	Use only 48 in mowing machine
4	Use only 54 in mowing machine	Use only 54 in mowing machine
5	Use only 60 in mowing machine	Use only 60 in mowing machine
6	Use only 72 in mowing machine	Use only 72 in mowing machine
7	Use only 124 in mowing machine	124 in for larger portion and 72 in for smaller park
8	Use only 132 in mowing machine	132 in for larger portion and 72 in for smaller park

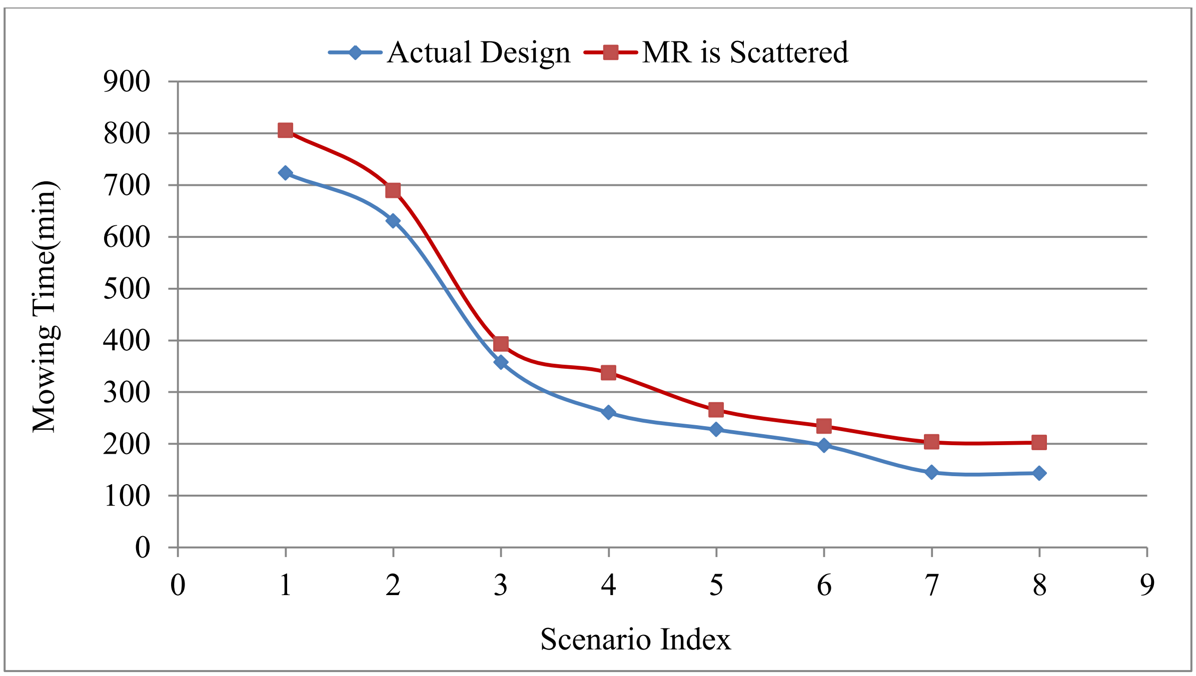


Figure 48: Mowing time for use of different size machine configurations

Simulation results[6] show that through the use of different combinations of machines the duration of mowing time could be optimized. Presently, 48 in and 72 in mowing machines used by the city maintenance team are applicable for the case study area. If only a 48 in machine is used for

[6] See Appendix G

both design an additional 35 minutes time required for distributed design; Whereas 72 in machine 37 minutes additional time compare to actual design. However, there is a variety of machines available on the market that can improve performance. For example, a combination of 124 in and 72 in machines can reduce the duration of mowing time to 203.42 minutes in contrast to the use of a 72 in machine alone that requires 233.92 minutes. Therefore it can be concluded that there are several ways to achieve optimization of these maintenance operations. The objective of this simulation is to illustrate a simple process that reduces mowing time by only changing the machines, but numerous processes such as lean concept and optimization algorithms, which require detailed information on the park maintenance operation performed by the city maintenance crew, may be applicable in this case. However, this simulation explores further demands for research in this context.

Figure 49: Super Z 72 in riding lawn mower by Hustler Turf Equipment (Source: Hustler Turf Equipment, 2015)

Figure 50: Dixon Speed ZTR 42 in riding lawn mower by Dixon (Source: Dixon, 2015)

4.8 Discussion:

As a primary finding of this study, the spatial interaction index (SI_x) analysis shows improper distribution for the majority of the case study neighbourhoods. This analysis approach can identify the percentage of housing lots with sufficient accessibility in a NSP. Planning for MR to be concentrated in the center of neighbourhoods produces a skewed distribution of SI_x, whereas a scattered pattern exhibits better distribution.

Hedonic pricing modelling for the three CMHC zones establishes a concrete relationship between open space planning and property value. Preserving open space for active recreation not only improves public health by improving accessibility to facilities for physical activity, but also enhances overall property value. Predicting the property value for the hypothetically designed

Haddow neighbourhood proves that the generation of additional MR is possible by implementing a scattered pattern of MR in contrast to the traditional design.

Park management cost analysis serves to justify the MR distribution, which creates improved open space planning and at the same time generates sufficient municipal tax to cover the corresponding park maintenance costs. The mowing duration simulation model provides better insight on alternative machine size use for mowing operation to improve productivity, although more comprehensive simulation is preferable to optimization overall maintenance productivity .

The findings of this study not only provide better understanding of the deficiencies in current MR allocation in neighbourhood design, but also improve future planning of open space preservation in urban neighbourhoods.

Chapter Five

Discussion

5.1 Conclusion:

Neighbourhood parks play a critical role in the built environment since they are the primary residential resource for active recreational space. A significant number of studies have demonstrated that the availability of park facilities within close proximity to residences such as soccer fields, walking trails, baseball diamonds, splash parks, fitness stations, and skate parks increases the physical activity level of that population (Kaczynski et al., 2008; Sugiyama et al., 2013; Moody et al., 2004; Kaczynski et al., 2014). Although increased accessibility to parks and recreational facilities enhances physical activity in all age ranges, the younger generations tend to be the most active groups (Kaczynski et al., 2009; Veugelers et al., 2008; Frank et al., 2007). In terms of demographic composition, the case study neighbourhoods have proportions ranging from 9.36% to 30.07% of residents aged 0 to 19 years (Figure 51) compared to a proportion of 22.87% for Edmonton overall. This percentage of population requires greater accessibility to neighbourhood parks if the goal in planning is to increase the level of physical activity in order to achieve the Canadian Society for Exercise Physiology (CSEP) recommended standard. Accessibility could be increased by distributing MR in order to achieve (nearly close) uniformity of the locational beneficiary for housing lots.

Albertans greatly value green space; in fact, 68% of Albertans believe parks and recreation services matter a great deal, and 29% of individuals feel that these amenities are somewhat important in their daily life (Harper et al., 2008). According to a 2007 survey conducted by the Alberta Recreation and Parks Association (ARPA), 38% of individuals and 33% of households responded that they had used parks and recreation services within the corresponding review year (Figure 52) (Harper et al., 2008).

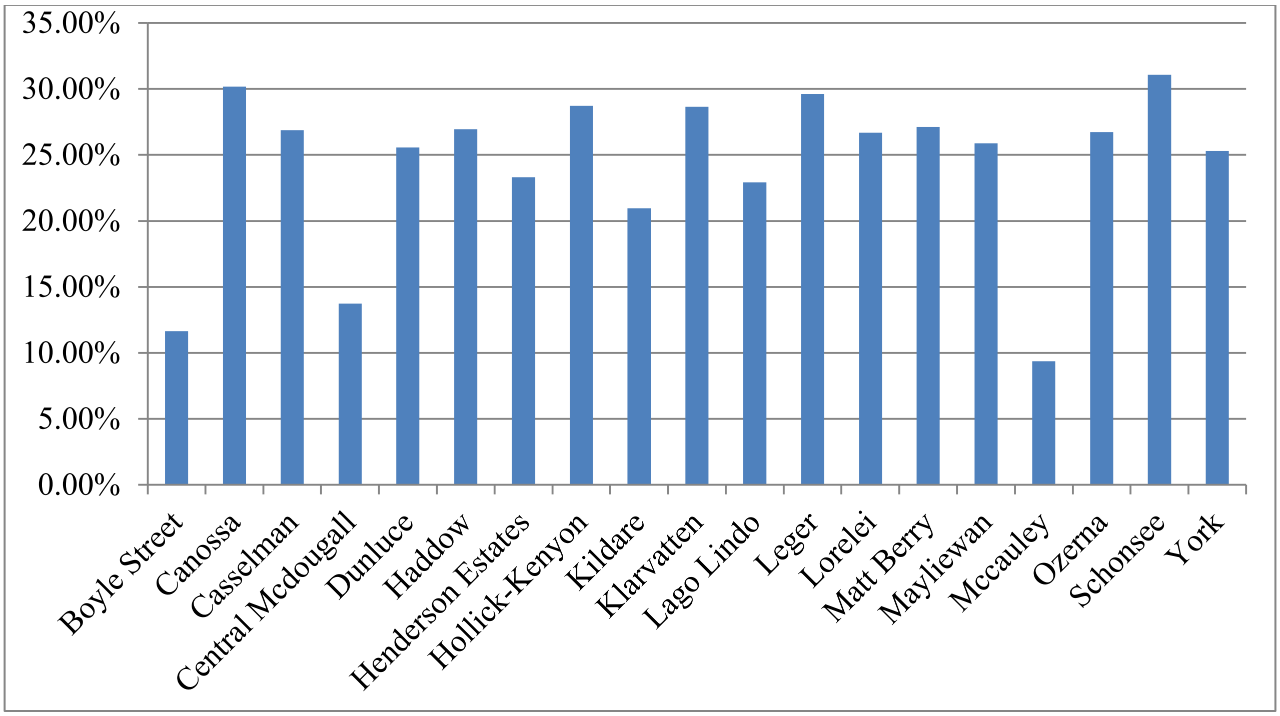


Figure 51: Percentage of population aged between 0 to 19 years of the case study neighbourhoods (Data Source: City of Edmonton, 2015b).

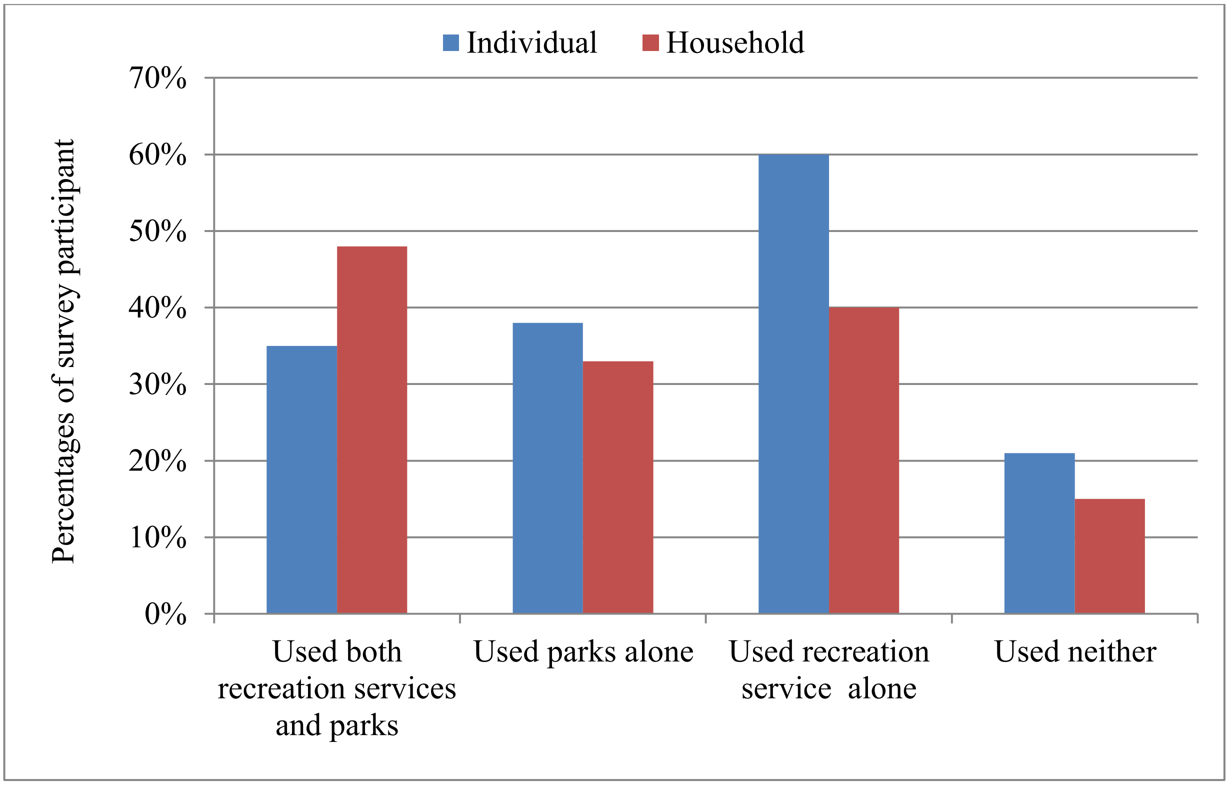


Figure 52: Use of local parks and recreational space in Alberta (Harper et al., 2008)

Moreover, 51% of respondents (families with at least one child) report using available local parks frequently (Figure 53), and 9 out of 10 Albertans believe any type of park contributes to their quality of life (Harper et al., 2008). Moreover, the park facilities that are available to residents of Edmonton, as the major city in Alberta, are a vital metric to evaluate policy for public outdoor and natural recreational facilities of the built environment. Survey data on park usage indicates that increased accessibility would cause a rise in utilization since an already significant percentage of the population is currently using and willing to use these spaces.

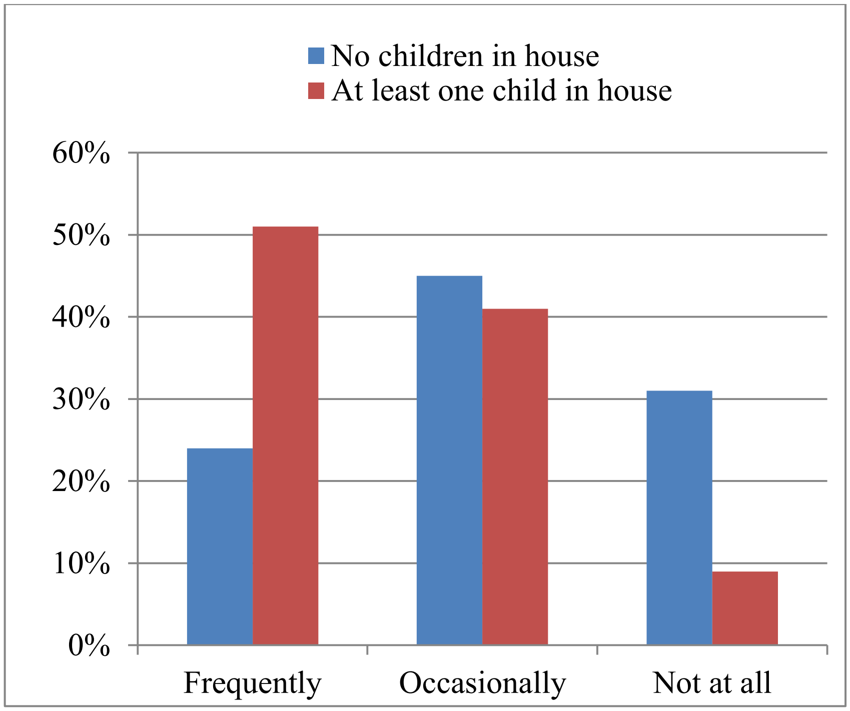


Figure 53: Use of local parks by household members (Harper et al., 2008)

This study focused on how accessibility to neighbourhood parks (MR) could be enhanced by adjusting and improving the distribution of this reserved space, as well as to quantify the change in park maintenance cost. It also aimed to answer the research question, “How does the distribution of MR compensate the developer and municipality through the intangible benefits of parks, open space, and natural areas?” It evaluated health benefits associated with this MR for neighbourhood residents by developing spatial interaction modelling using GIS. A statistical model is also developed to quantify the property value. A hypothetical neighbourhood design is in turn created to simulate the effects of different policy scenarios on neighbourhood design concepts.

The results reveal that a distributed design of MR may increase the utility of the reserved public space, as well as the overall property value and corresponding municipal tax revenue. This extra revenue could be directed toward the management cost of the distributed park spaces.

Presently, the City of Edmonton is facing challenges of building parks with prime landscape design concepts (e.g., creating clock towers, gazebos, bridges, etc.) that are beyond the city's financial capacity for maintenance (City of Edmonton, 2006). Distributing MR into several locations and obtaining partial private ownership of neighbourhood parks (policy index 3, as discussed in Chapter 3) may be a solution for this type of facility. Maintenance cost analysis in this case shows that the financial gain from MR distribution generates sufficient municipal tax to accommodate the increased cost.

Although price is a suitable metric by which to evaluate the value of nonmarket goods, it fails to reflect the actual worth of beneficial attributes of a neighbourhood such as open space, clean air, community, and safety (Edwards, 2007). Other benefits, such as public health and active lifestyle, are equally important to outline the effectiveness of such policies including MR reservation in land development projects.

5.2 Research Contributions

This study may aid the land development industry in designing active neighbourhoods; also, the policy development authority may gain insight into the manner and extent to which current neighbourhood design practice affects revenue.

It is common to measure the accessibility in terms of walking or travelling distance/time between a residential home and the park/amenity, but this approach fails to account for the effect of amenity shape and size; this study employed a spatial interaction modelling approach that includes both distance and size into the assessment of certain features of the built environment. The spatial interaction index could be a useful parameter to evaluate an NSP in the context of creating active neighbourhoods.

This study also establishes fairly accurate proximate value estimations for parks and open space by means of statistical modelling to predict property value. Hypothetical neighbourhood design encourages the present planning practice to be re-evaluated in relation to this process in order to maximize the benefits from MR reservation, distribution, and usage.

5.3 Limitations of the Study

The spatial interaction model could have obtained better results if variations for this geographical region, socio-demographic compositions, climatic conditions, and economic status had been considered. The collective perceptions of residents regarding different types of recreational facilities for this climatic region are still unknown, and a substantial amount of sociological survey data is required to incorporate into future modelling, planning, and design. This limitation may incur a percentage of error in the spatial interaction index (SI_x) value of the housing lots. However, the research concern is the distribution of this parameter throughout the geometrical developable space; therefore, error in value has an insignificant effect on this analysis. Detailed information regarding parks and open space facility trips and corresponding health parameters for such cold climatic regions are also required in order to precisely calibrate the model for this zone.

The accuracy of the Euclidean distance measurement is ±1.5 m due to the aerial image precision, which is found to cause a 1.5% error for the distance variable in the hedonic price modelling. Moreover, some structural attributes of homes are missing (e.g., number of bathrooms, roofing characteristics, floor tiles, and outside deck), which also contributes to error for the hedonic price modelling. Despite the above mentioned limitations, this study gives an overall illustration on the effectiveness of the current planning concepts for MR.

5.4 Future Scope of Study:

Results of this study explore the rationality of the MR allocation policy in monetary terms and public health perspective for a growing city such as Edmonton, where many other primacies exist. The methodology used in this research may contribute to further exploration which may include:

i. More detailed survey data on neighbourhood parks and recreational facility use by Edmontonians may depict actual spatial interaction of parks for this region and produce a correlation between physical activity level and current urban policy in such cold climatic conditions.

ii. New land devolvement projects and annexations of Edmonton can use the data to evaluate planned NSP to determine the benefits and accessibility in regards to physical activity.

iii. To build an active city, these methodologies can insight the effect of various policies on open space reserves prior to actual application.

iv. Municipal authorities may perform sensitivity analysis in maintenance budgeting using the outlined approach.

v. Overall Mowing operation optimization is possible if the present process dataset is made available.

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Appendix-A: Spatial Interactions Index Distribution of Case Study

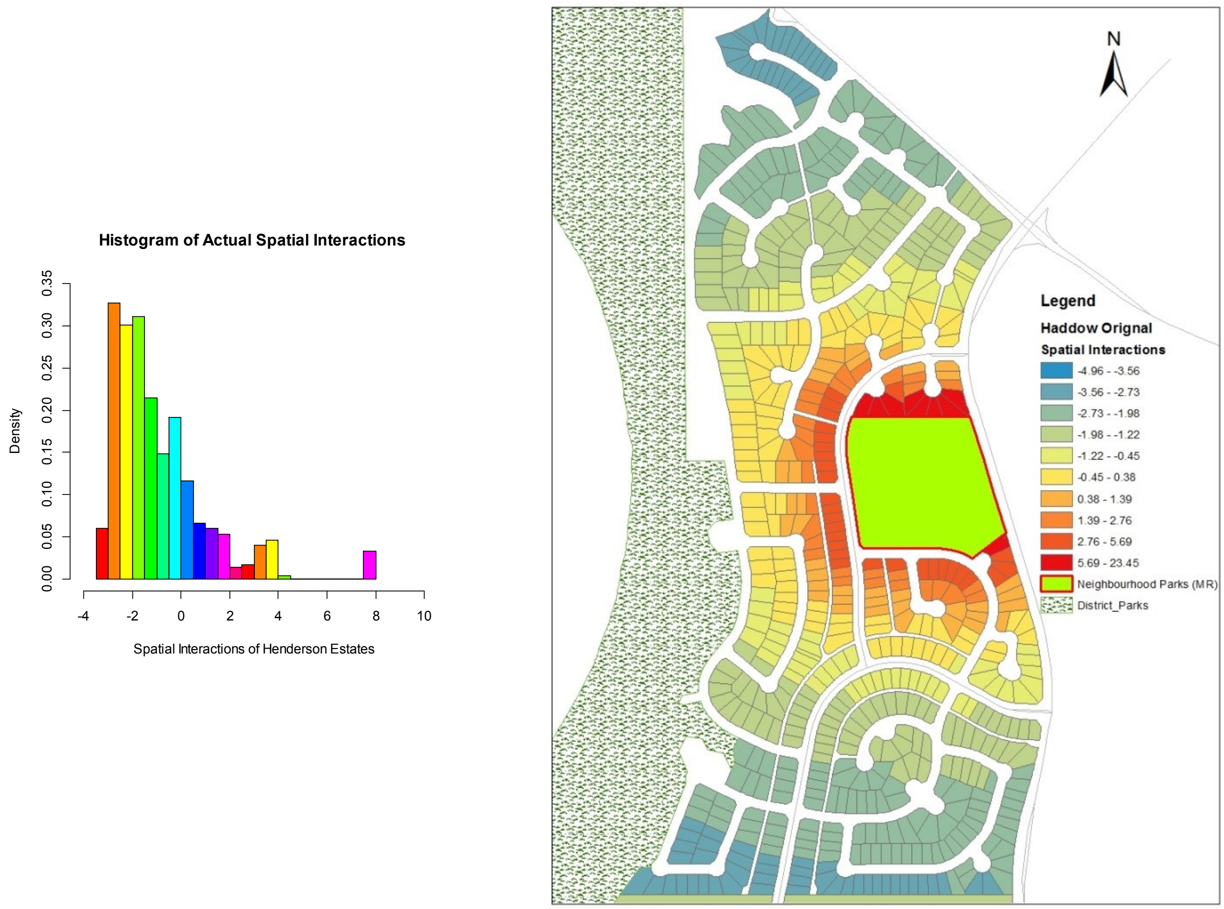


Figure 54: Spatial interactions of Henderson Estates neighbourhood lots

Figure 55: Spatial interactions of Lorelei neighbourhood lots

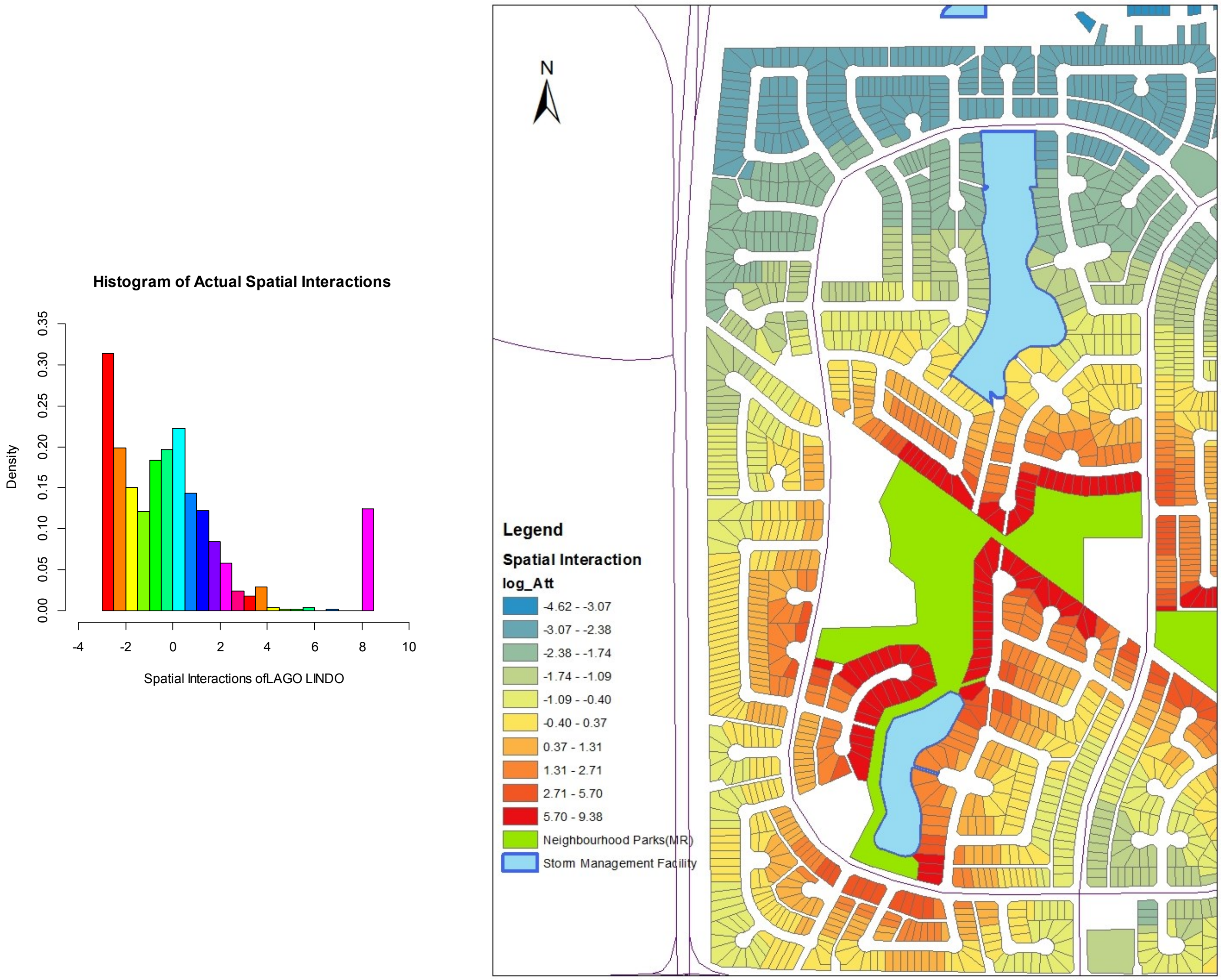


Figure 56: Spatial interactions of Lago Lindo neighbourhood lots

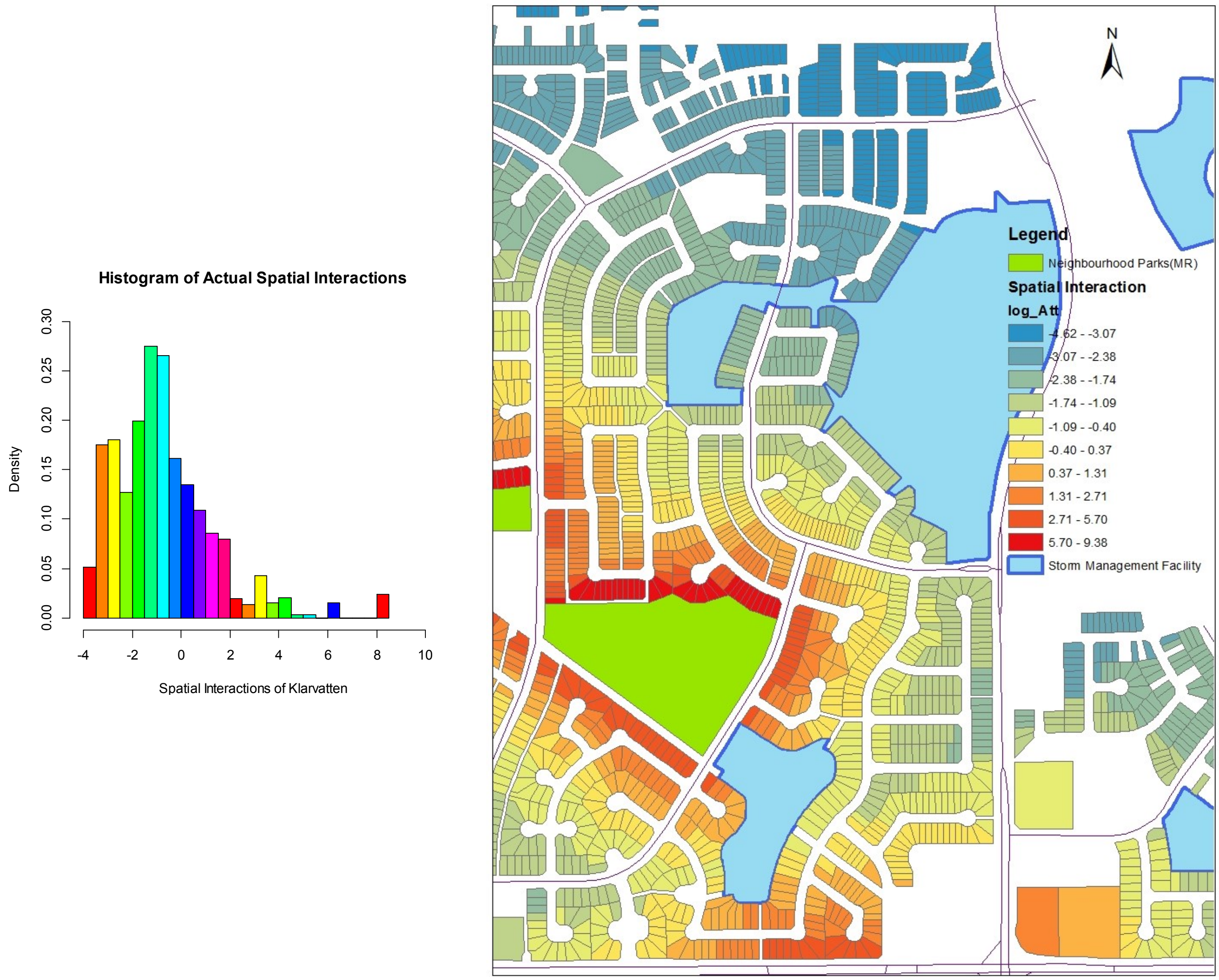


Figure 57: Spatial interactions of Klarvatten neighbourhood lots

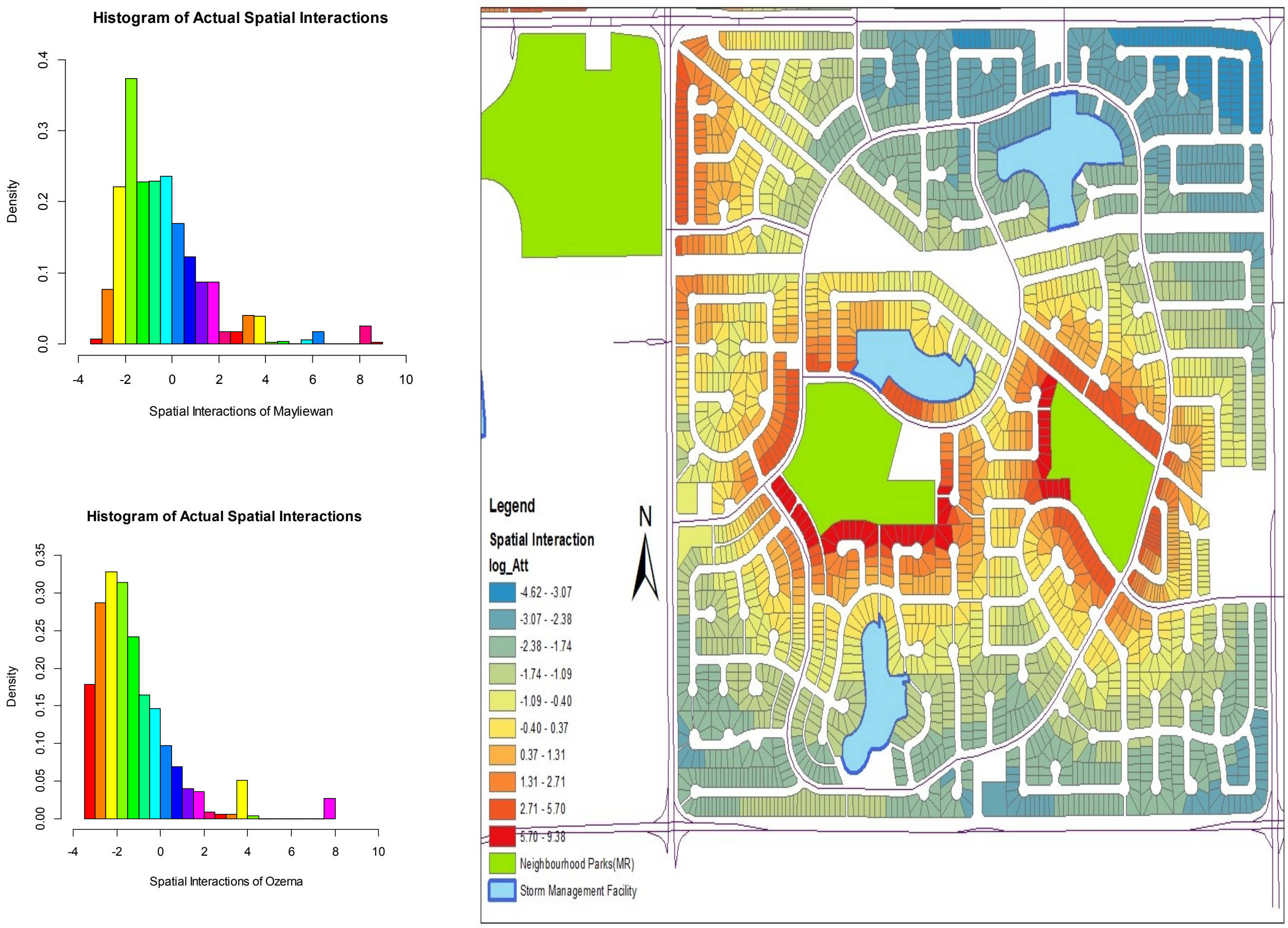


Figure 58: Spatial interactions of Mayliewan and Ozerna neighbourhood lots

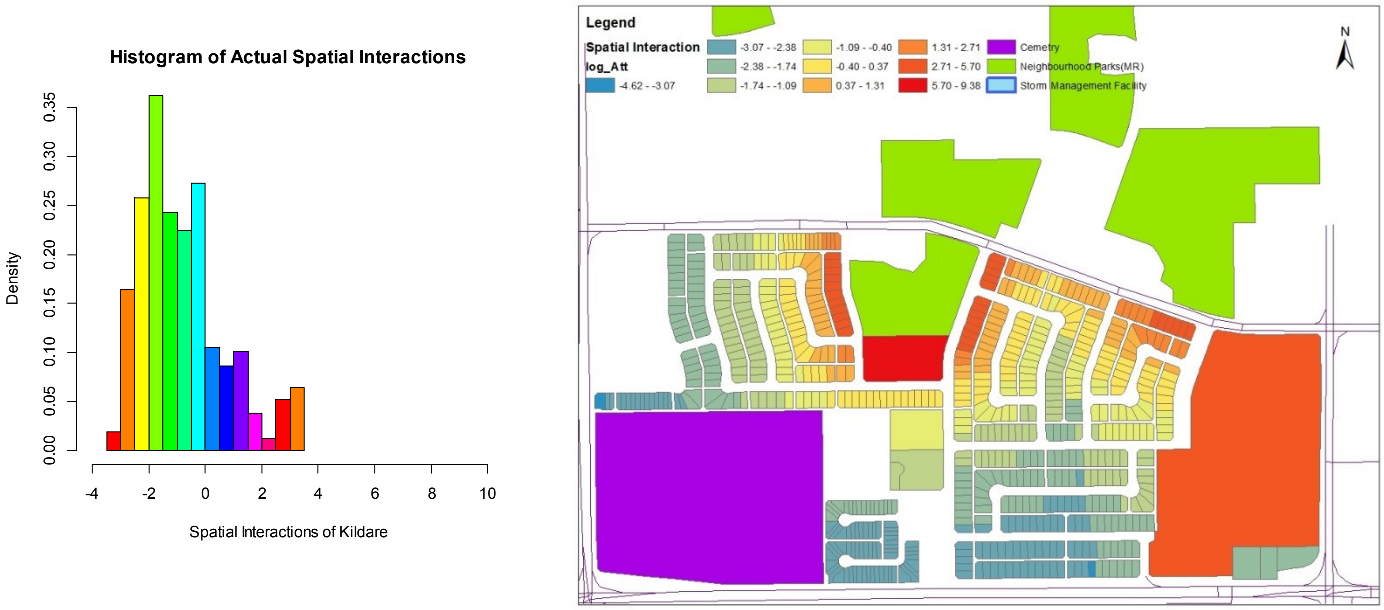


Figure 59: Spatial interactions of Kildare neighbourhood lots

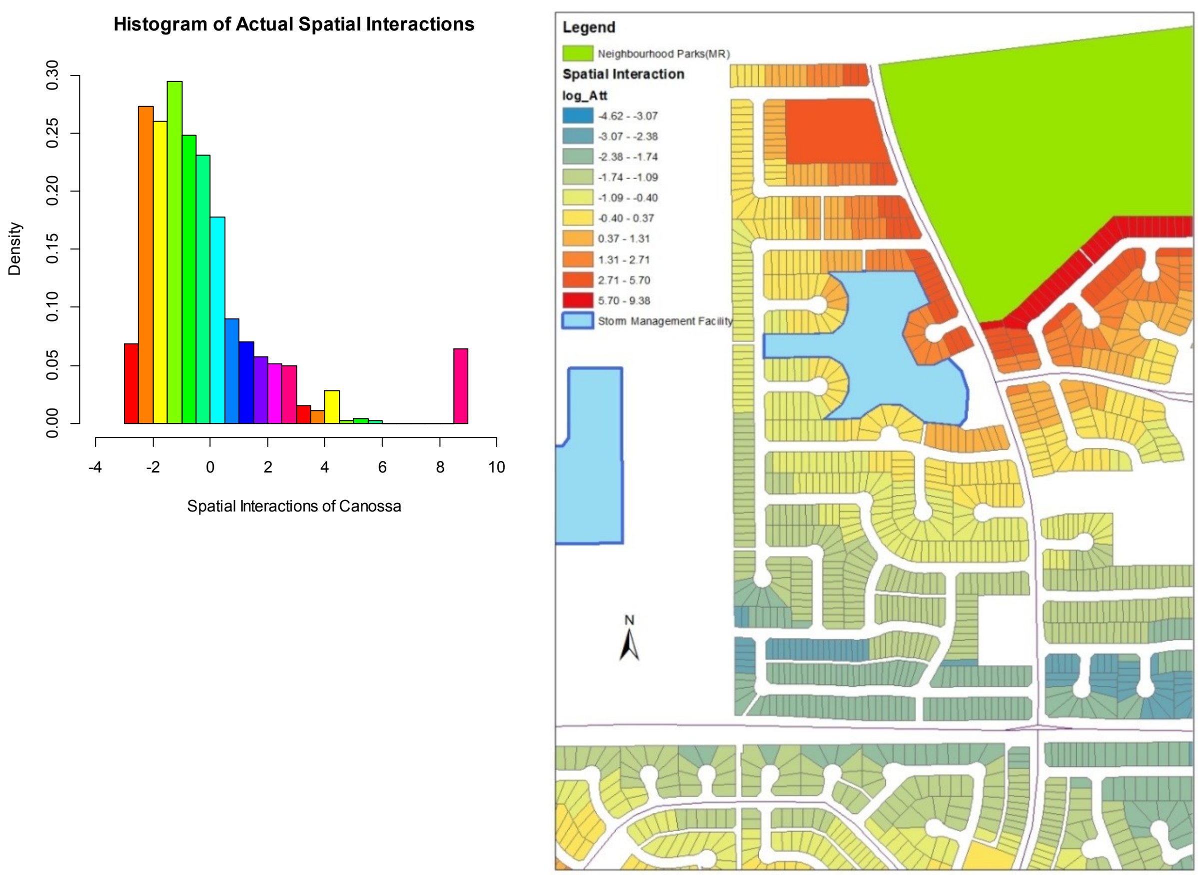


Figure 60: Spatial interactions of Canossa neighbourhood lots

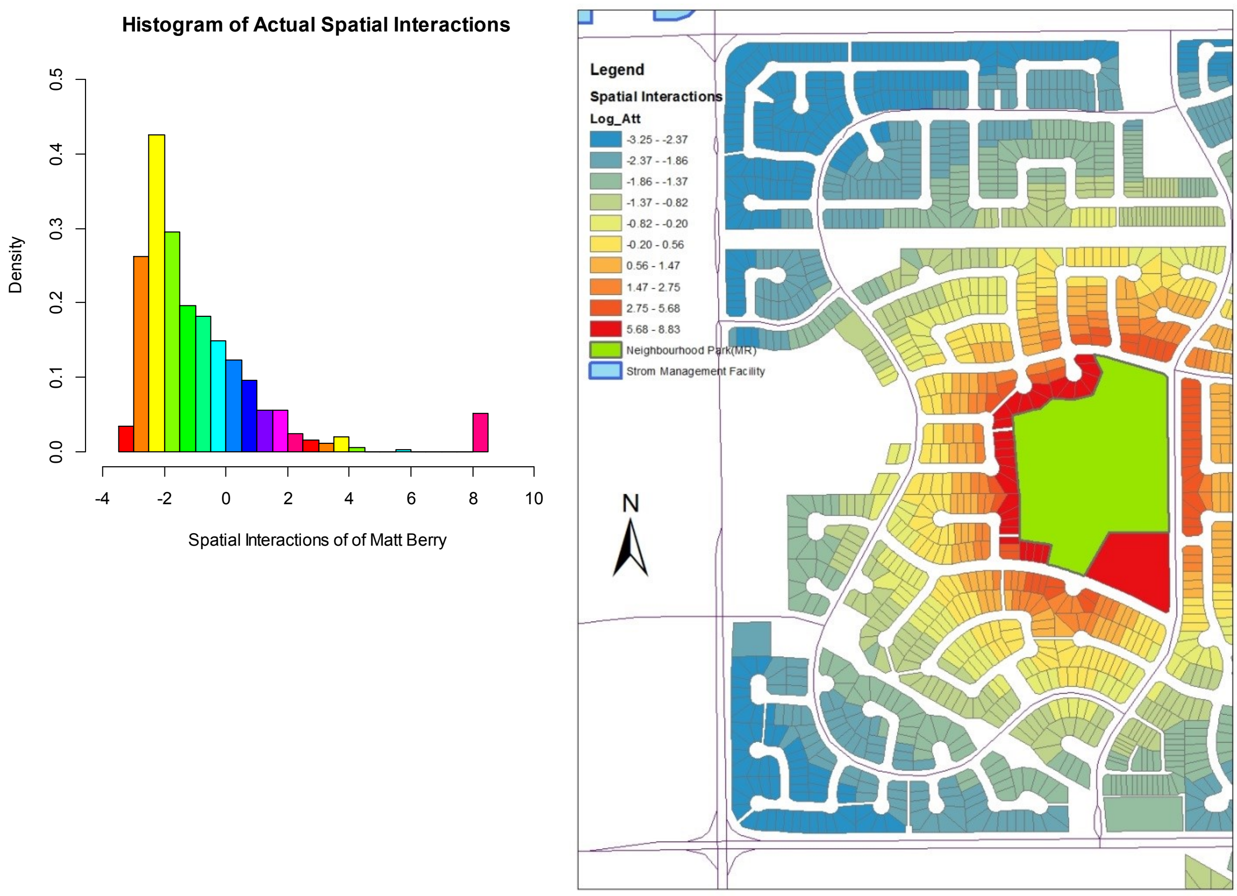


Figure 61: Spatial interactions of Matt Berry neighbourhood lots

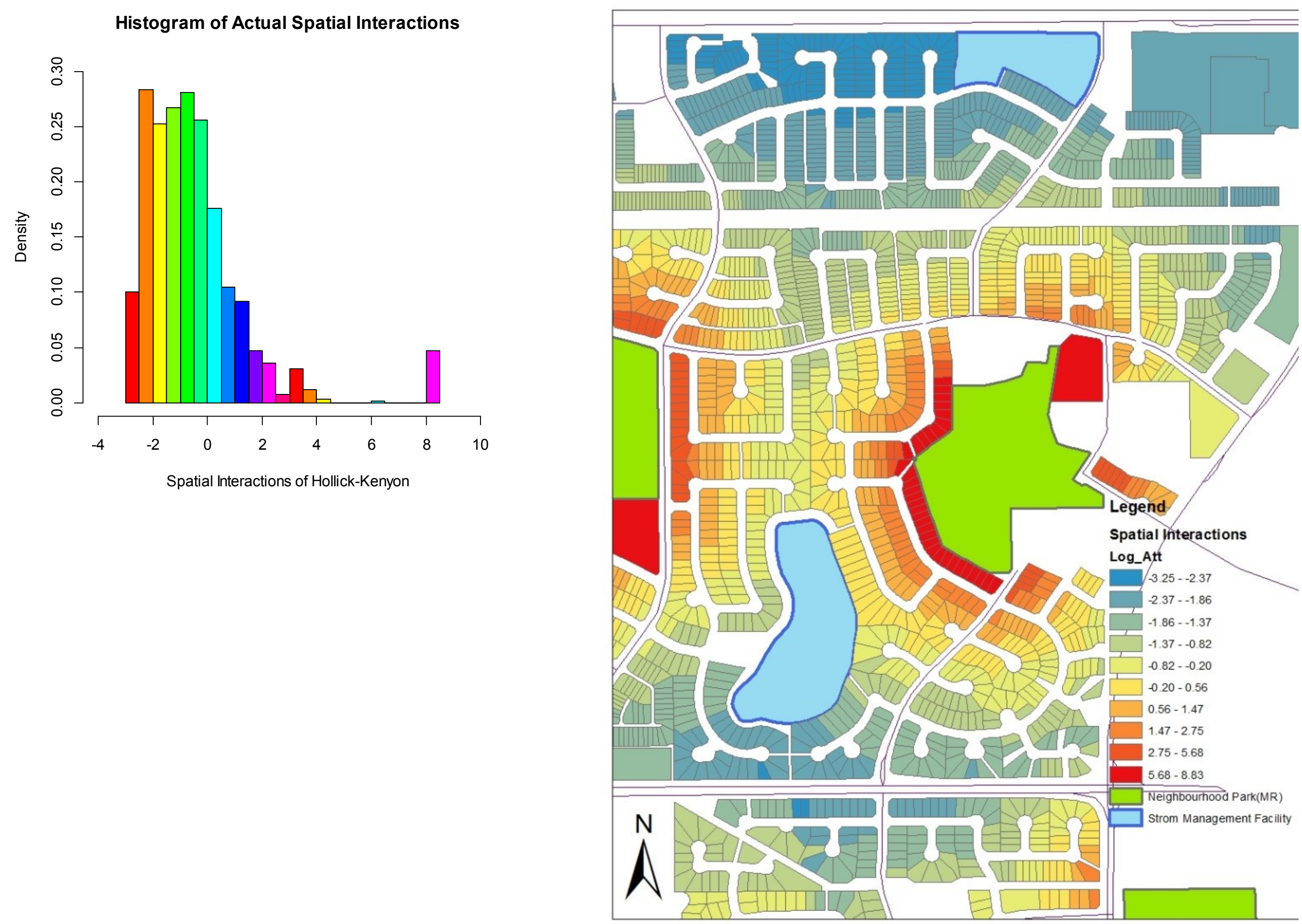


Figure 62: Spatial interactions of Hollick-Kenyon neighbourhood lots

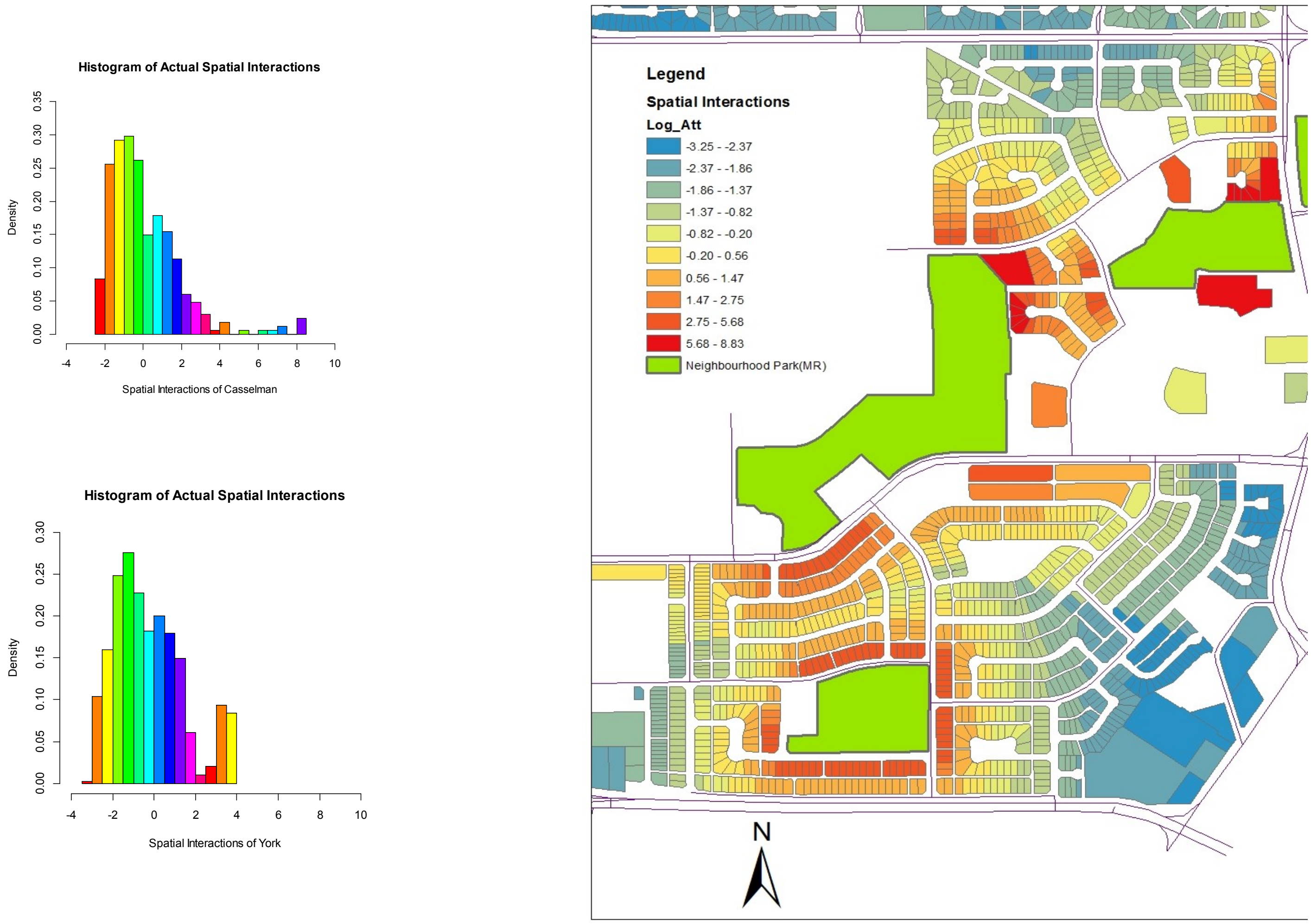
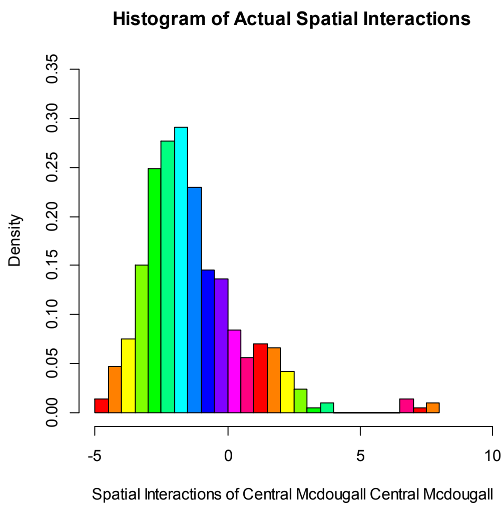


Figure 63: Spatial interactions of Casselman and York neighbourhood lots



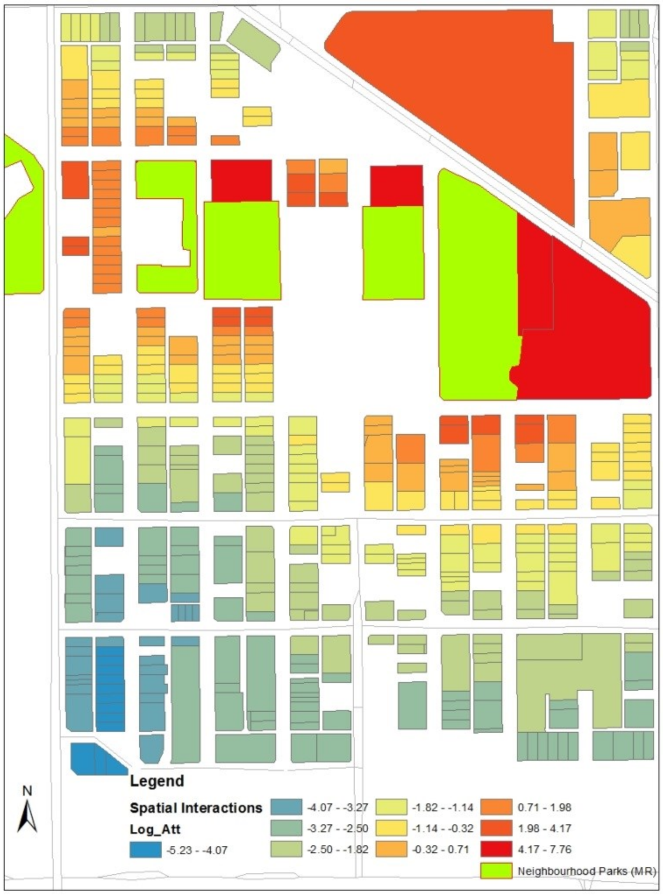


Figure 64: Spatial interactions of Central McDougall neighbourhood lots

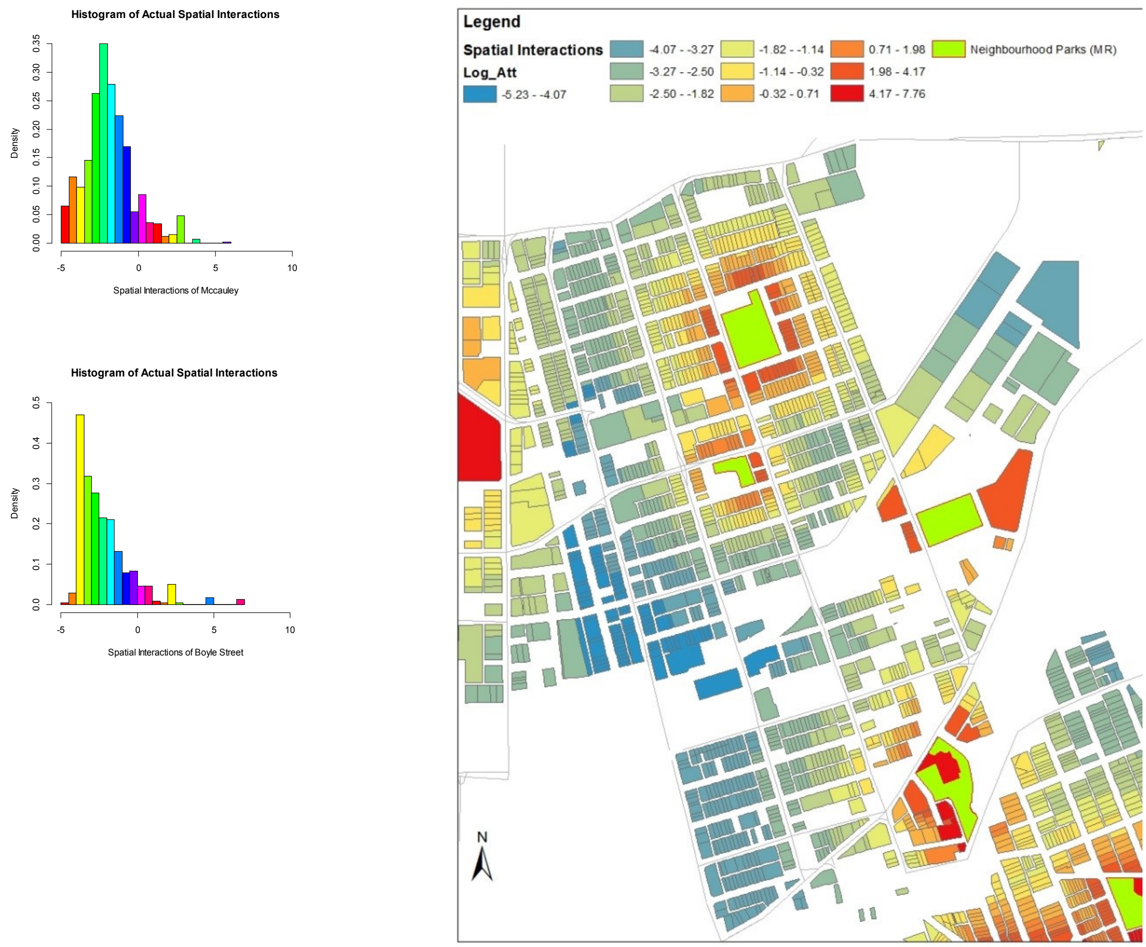


Figure 65: Spatial interactions of McCauley and Boyle Street neighbourhood lots

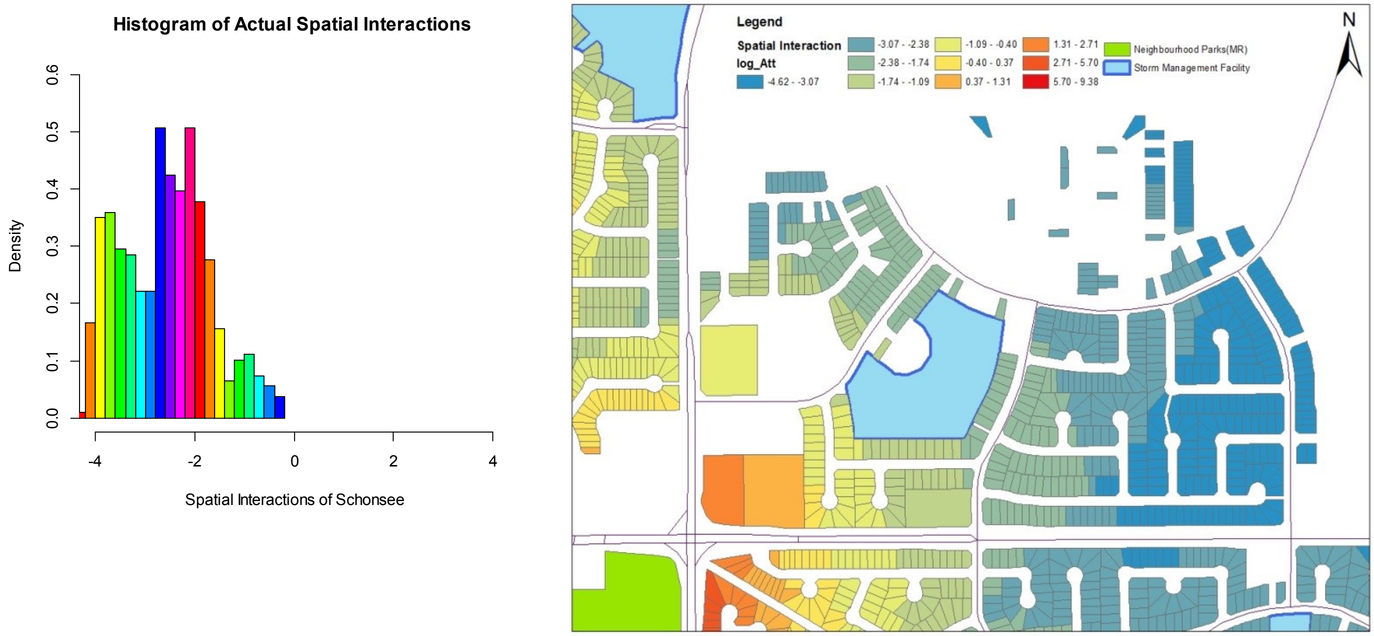


Figure 66: Spatial interactions of Schonsee neighbourhood lots

Table 16: Spatial interactions (logarithmic value) statistics of selected neighbourhoods

Neighbourhood	Min.	1st Quantile	Median	Mean	3rd Quantile	Max
Dunluce	-2.641	-1.224	-0.416	0.178	0.754	8.168
Kildare	-3.088	-1.949	-1.148	-0.802	-0.078	3.342
Klarvatten	-3.788	-2.135	-1.027	-0.717	0.218	8.120
Lago Lindo	-2.977	-2.031	-0.413	-0.002	0.914	8.324
Lorelei	-2.668	-1.522	-0.969	-0.783	-0.3034	3.808
Mayliewan	-3.167	-1.720	-0.804	-0.389	0.3403	8.926
Ozerna	-3.485	-2.437	-1.699	-1.228	-0.5329	7.870
Canossa	-2.840	-1.625	-0.800	-0.241	0.3986	8.930
Casselman	-2.417	-1.217	-0.368	0.066	0.91130	8.006
York	-3.039	-1.529	-0.558	-0.209	0.8854	3.972
Hollick-Kenyon	-2.811	-1.773	-0.821	-0.491	0.1197	8.224
Matt Berry	-3.151	-2.263	-1.551	-0.897	-0.1470	8.228
Haddow	-2.885	-1.429	-0.441	0.018	0.6153	8.747
Henderson Estates	-3.138	-2.303	-1.498	-0.924	-0.2407	7.892
Schonsee	-4.216	-3.359	-2.543	-2.585	-1.996	-0.218
Central McDougall	-4.631	-2.606	-1.656	-1.302	-0.4772	7.759
Boyle Street	-4.618	-3.509	-2.708	-2.221	-1.581	6.879
McCauley	-4.988	-2.845	-2.026	-1.875	-1.046	5.827

Appendix -B: Diagnostic plots of Property Value Model

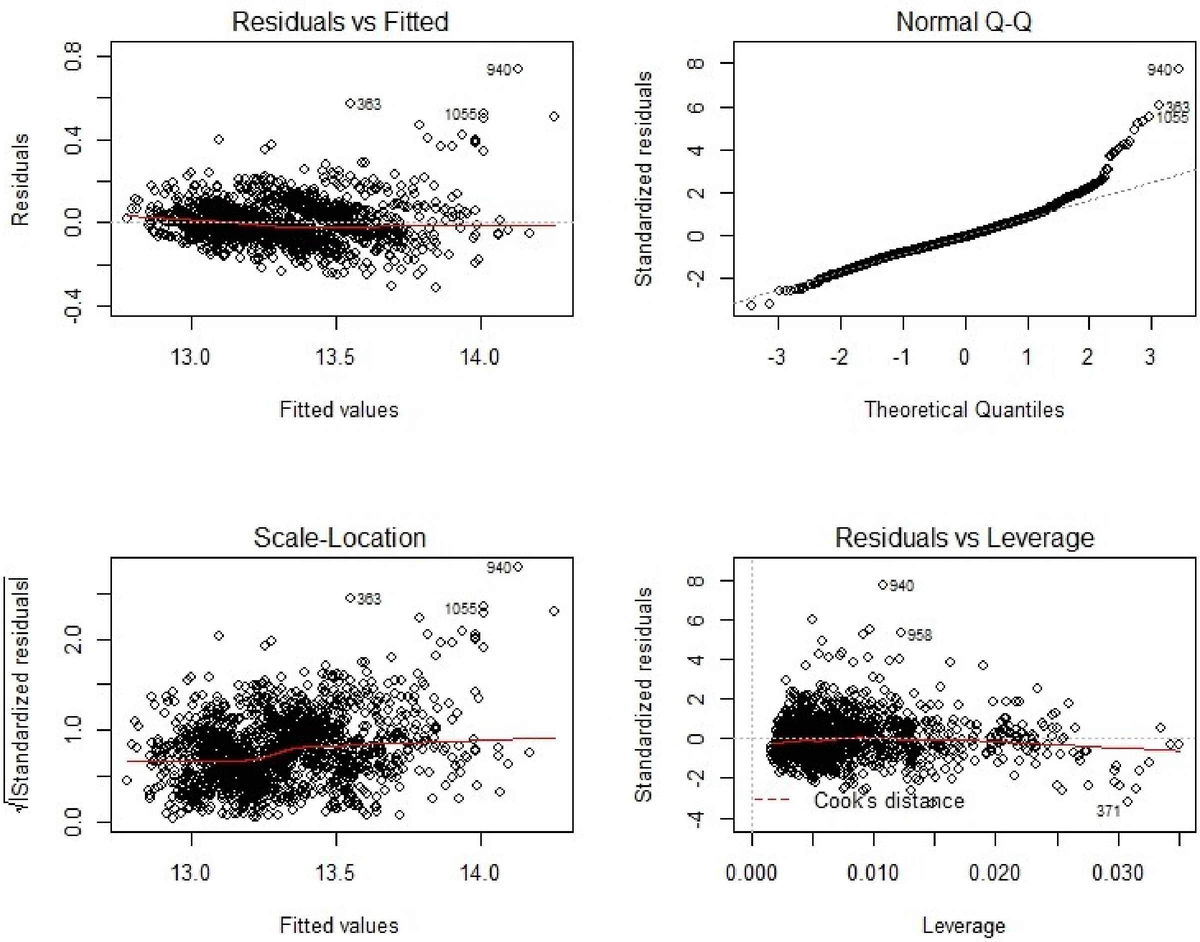


Figure 67: Diagnostic plot for the model in CMHC Zone 7

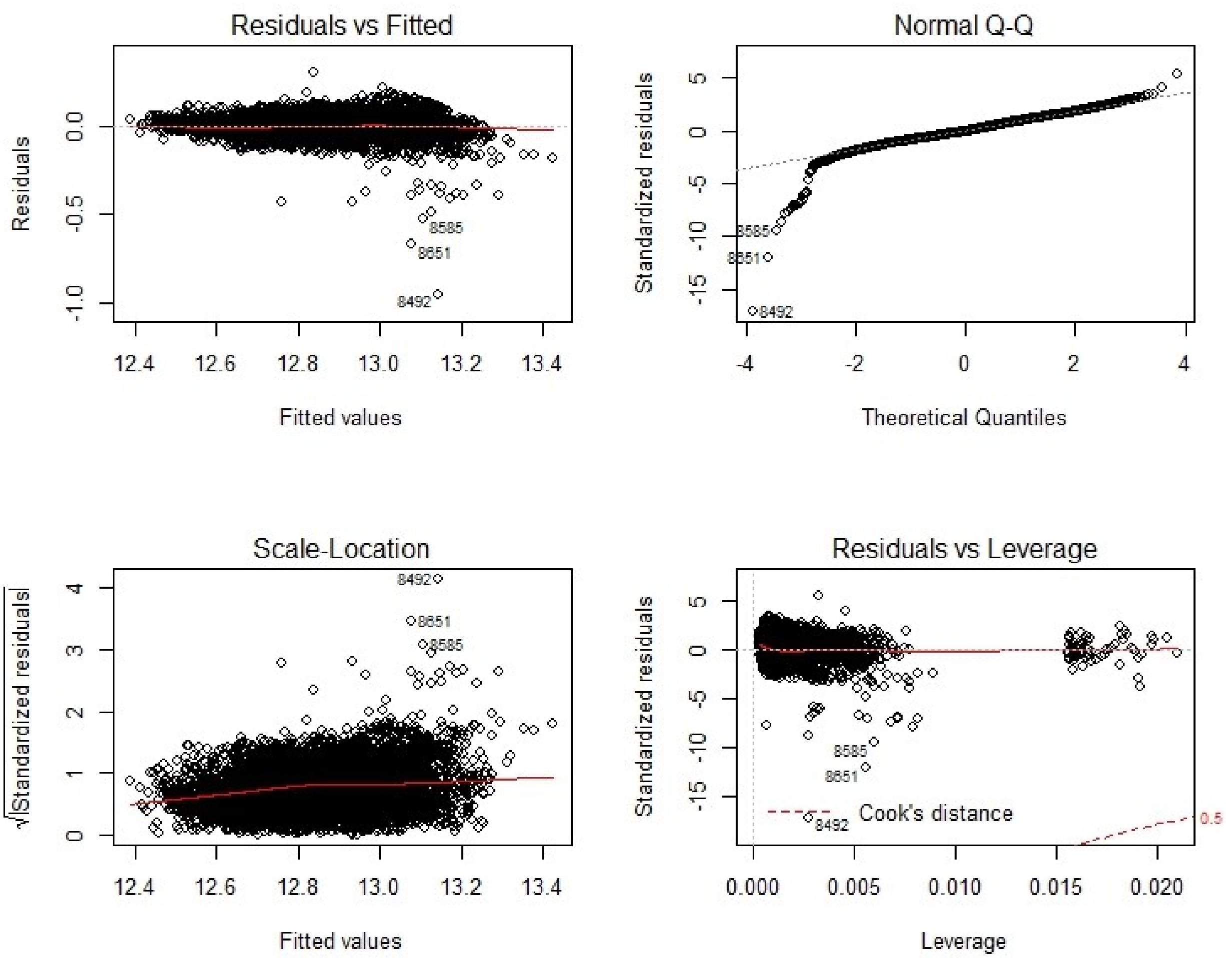


Figure 68: Diagnostic plot for the model in CMHC Zone 12

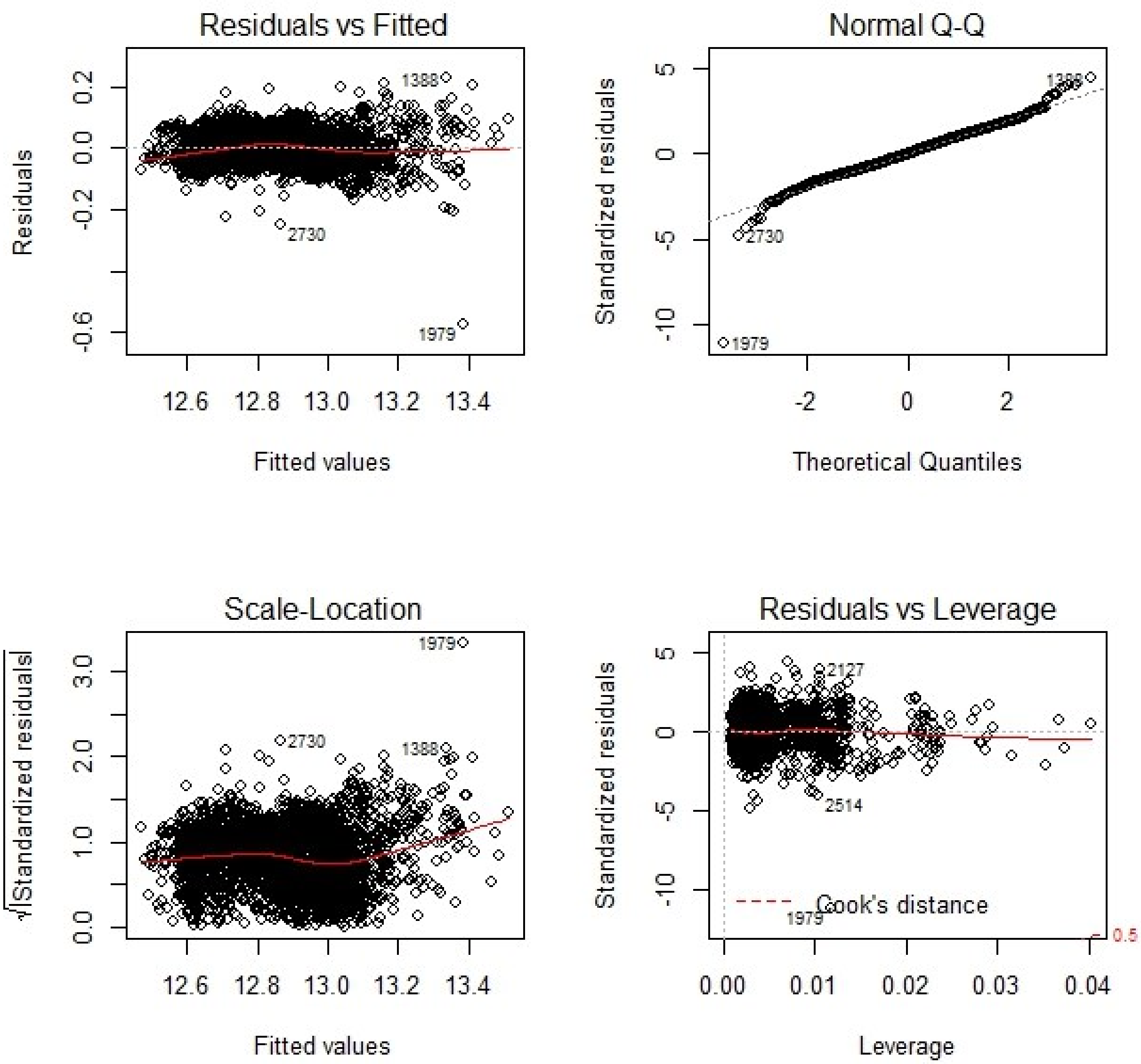


Figure 69: Diagnostic plot for the model in CMHC Zone 11

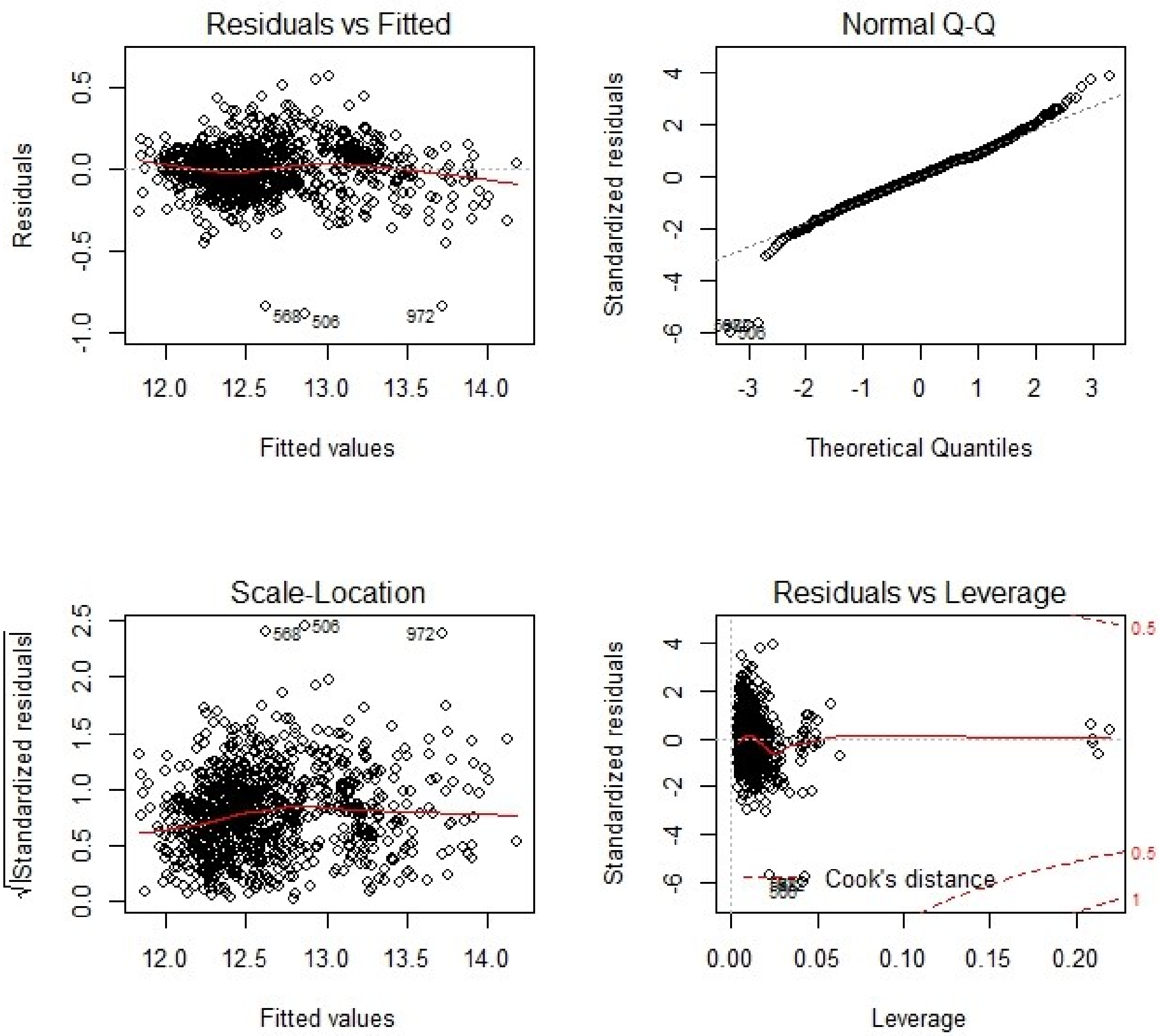


Figure 70: Diagnostic plot for the model in CMHC Zone 1A

Appendix-C: Park Management Cost

Table 17: Park maintenance cost

Task No	Task Description	Unit Measure (SKF)	Field Unit Cost	Charge-out rate (External)	Haddow Actual Design			Haddow Hypothetical Design		
					Haddow Old Design Field Unit Cost	Charge-Out Rate (Inter-Dept)	Charge-Out Rate (External)	Field Unit Cost	Charge-Out Rate (Inter-Dept)	Charge-Out Rate (External)
1	Turf Mowing	Ha	$85.47	$184.80	$7,615	$16,091	$16,466	$7,325	$15,477	$15,837
2	Turf Trimming	Ha	$34.05	$73.62	$1,214	$2,564	$2,624	$1,167	$2,466	$2,524
3	Turf Rehabilitation	Ha	$8.21	$17.76	$73	$155	$158	$70	$149	$152
4	Major Sanitation	Ha	$24.26	$52.46	$216	$457	$467	$208	$439	$450
5	Marking - Rectangular Fields	Fields	$261.71	$678.99	$1,309	$3,318	$3,395	$1,570	$3,981	$4,074
6	Tennis Court Maintenance	Tennis	$26.27	$68.15	-	-	-	-	-	-
7	Diamond Maintenance	Diamnd	$127.96	$331.99	-	-	-	-	-	-
8	Sportsfield Fixtures	Fixtur	$36.75	$95.34	$184	$466	$477	$221	$559	$572
9	400 m TRACK MAINTENANCE	Tracks	$298.63	$774.77	-	-	-	-	-	-
10	Junior Playground / Climb Structure	Each	$310.81	$506.62	$311	$499	$507	$622	$998	$1,013
11	Irrigation Of Fields	Ha	$6,610.41	$10,774.97	$10,538	$16,914	$17,178	$13,855	$22,237	$22,583
12	Benches	Each	$12.95	$21.11	$130	$208	$211	$155	$249	$253
Total Cost					$21,589	$40,672	$41,482	$25,193	$46,556	$47,459

Appendix-D: Mowing Simulation

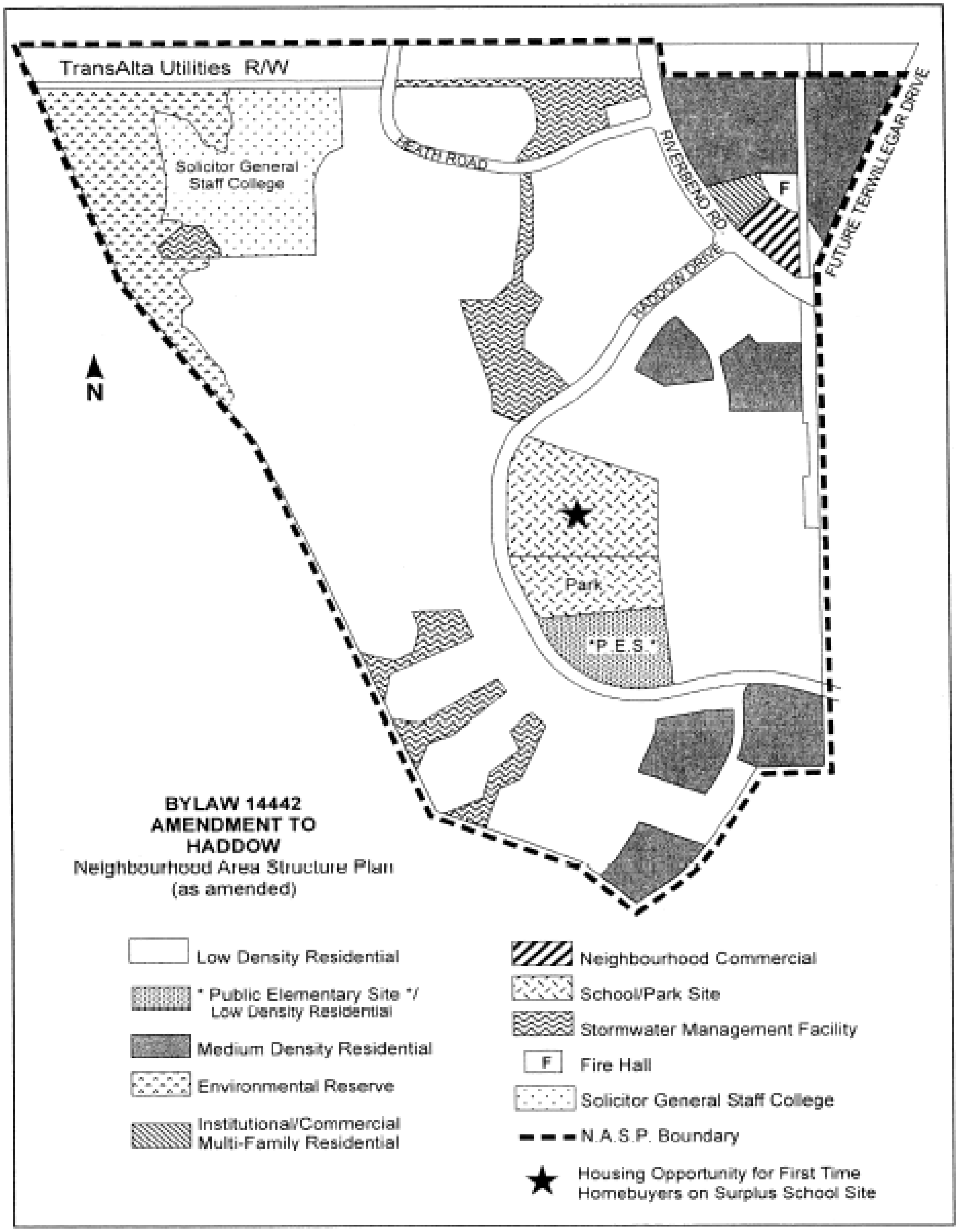
Simphony.NET 4.0: A simulation tool developed by the University of Alberta's Construction Engineering and Management Group.

Visit: http://129.128.253.76/simphony40/ for more information

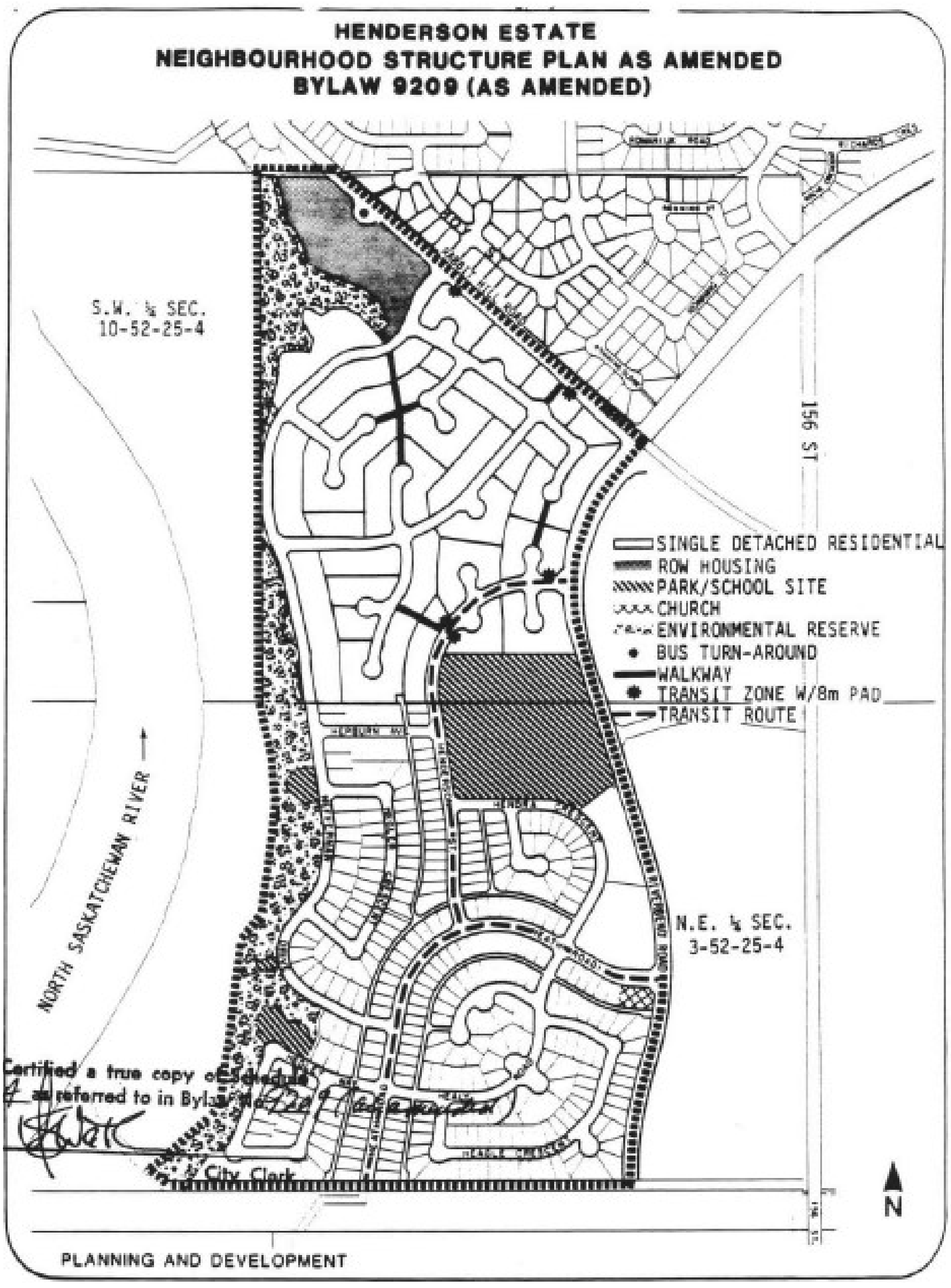
For mowing time simulation, the following website information has been used
http://www.husqvarna.com/ca/en/products/zero-turn-mowers/pz-72/#specifications http://www.toro.com/grounds/4000/pdfs/GM4000_4100_Brochure.pdf http://www.dixon-ztr.com/products/zero-turn-mowers/speedztr-42/#tab-techdata http://www.husqvarna.com/ca/en/products/lawn-mowers/husqvarna-lawn-mowers-for-homeowners/ http://www.hustlerturf.com/products/Super_Z http://products.jacobsen.com/img/products/hr_9016-dsus.pdf http://jacobsen.com/hr9016t http://www.edneyco.com/assets/files/category/Cutters%20and%20Mowers/Schulte%20Rotary%20Cutters.pdf http://grounds-mag.com/equipment/grounds_maintenance_making_big/ http://www.toro.com/en-us/sports-fields-grounds/mowers/large-area-rotaries/pages/series.aspx?sid=groundsmaster-4000-d-4010-d http://www.toro.com/grounds/4000/pdfs/GM4000_4100_Brochure.pdf http://www.ferrismowers.com/us/en/why-choose-ferris/mowing-productivity-chart http://todaysmower.com/press-kit/mower-acreage-chart/ https://www.cubcadet.ca/webapp/wcs/stores/servlet/CubCadetFullPageArticleDisplayView?langId=-1&storeId=10051&catalogId=14101&pageView=Cubcadet_Residential/WHAT_IS_THE_RIGHT_DECK_SIZE.html

Appendix-E: Neighbourhood Structure Plan (NSP)

Haddow NSP



Henderson Estates NSP



Appendix-F: Python Codes for ArcGIS

Assign 0 or 1 to binary variables

```
def binary(t):
   if t=='Y':
      value=1
   else:
      value=0
   return value
```

Spatial Interaction index calculation formula in ArcGIS

```
def att(x,y):
   import math
   if x>0:
      z=math.pow(y,0.85)/math.pow(x,1.91)
   else:
      z=math.pow(y,0.85)/math.pow(2,1.91)
   return z
```

Calculate Park Area and assign to corresponding lot ID

```
def area(i):
   import csv
   myfilename='D:\\UofA_Thesis_Backup_02_Feb\\MR Modelling DataSets\\Area_Parks\\
Type_B_parks_Area_CMH12.csv'
   myfile=open(myfilename)
   mycsv=csv.reader(myfile)
   rownum=0
  for row in mycsv:
```

```
    if rownum==0:
        pass
    elif i==row[0]:
        value=row[1]
    rownum+=1
return value
```

Appendix-G: Mowing activity Model

Out Put validation for 5000 Runs:

A total of 5,000 runs of the simulation model are performed for each machine size combination. The model output is validated by only plotting the Q-Q plot and histogram plot. Absence of actual mowing duration data, it is not possible to validate this model with respect to actual mowing time. However, the output of the Q-Q plot exhibits normality of output results, and the trace element is also a tool that implies the flow of entity in the appropriate manner throughout the model, and thus serves as a validation of the simulation model.

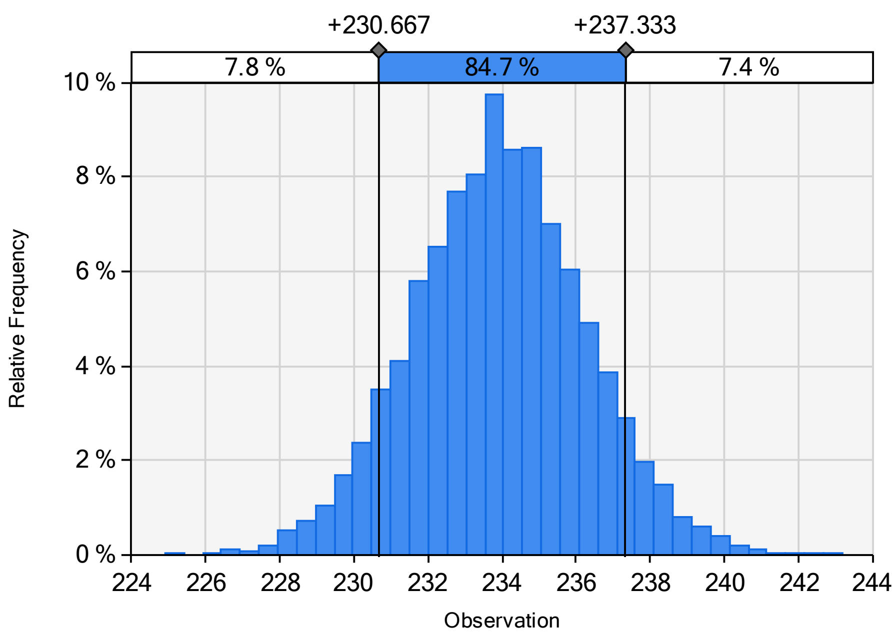


Figure 71: Mowing duration output histogram from simulation model

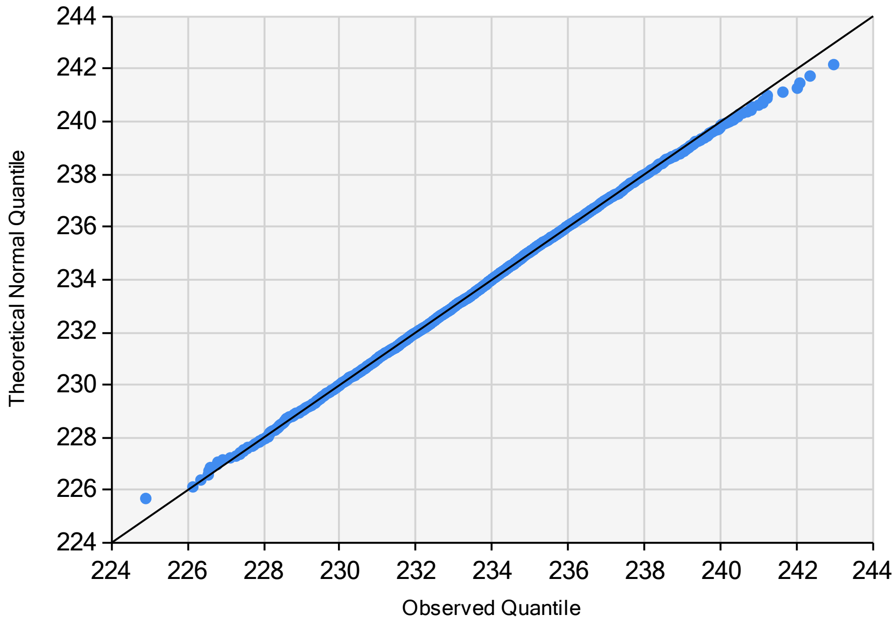


Figure 72: Q-Q plot of output from simulation model