1-1-2003

Identifying the variance in the magnitude of landfill impacts on residential property values using multiple regression analysis

Jong Seok Lim
Ryerson University

"Identifying the variance in the magnitude of landfill impacts on residential property values using multiple regression analysis"

by

Lim, Jong Seok

A thesis

presented to Ryerson University

in partial fulfillment of the

requirement for the degree of

Master of Applied Science

in the Program of

Environmental Applied Science and Management

Toronto, Ontario, Canada, 2003

Your file Votre référence
ISBN: 0-612-85321-7
Our file Notre référence
ISBN: 0-612-85321-7

Author's Declaration

I hereby declare that I am the sole author of this thesis.

I authorize Ryerson University to lend this thesis to other institutions or individuals for the purpose of scholarly research.

•

I further authorize Ryerson University to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

•

Ryerson University requires the signatures of all persons using or photocopying this thesis. Please sign below, and give address and date.

"Identifying the variance in the magnitude of landfill impacts on residential property values using multiple regression analysis."; Lim, Jong Seok; Master of Applied Science in the Program of Environmental Applied Science and Management; Ryerson University; 2003

Abstract

The economic advantage of constructing and operating large-scale landfills over small-scale landfills has been used to justify regional landfills as the solution to the municipal waste management problem. However, the availability of sufficient landfill capacity will have dampening effects on the social efforts to reduce waste and/or divert waste away from landfills, especially when external costs of landfills are not appropriately reflected in the estimation of total costs. In this study, the negative effects of a landfill that are capitalized in property values of houses located in the proximity of two landfill sites ("Britannia" and "Keele" landfill sites representing a small and a large landfill respectively) in the Greater Toronto Area are examined in a single multiple regression equation. The results indicate that the large landfill has greater adverse impacts than the small landfill on property values. This study suggests further analysis in a model to which more independent variables that explain locational characteristics should be added.

Acknowledgement

This work could not be accomplished without a dedicated support from those who I feel greatly indebted to: My advisory faculty, Dr. Ronald Pushchak, not only illuminated me on every front, but took the labour to edit the paper in such a great detail. I want to thank him again for his time and effort invested in making an arrangement with Royal LePage Advisors Inc.; The assistance from Dr. Paul Missios (my secondary advisory faculty) was essential in having the empirical study completed.; I owe a debt of gratitude to Royal LePage Advisors Inc. who provided housing sales records. They are the most key element for the study. A special thanks is given to Mr. Andrew Browning and Mr. Tony Reale in Royal LePage Advisors Inc.; I have also a deep appreciation for Professor Susan Laskin with Geography Dept. at Ryerson University who created maps for the study areas in a professional way.; I would also like to express my thanks for those who have kindly commented on my inquiries either in an e-mail or on a telephone.

Above everything else, I thank my wife, Yoo-Hyun Shin Lim, and my son, Chris Lim, for their patience and endurance shown throughout the years of my graduate study. I have had no time to take them even to the Niagara Falls ever since we landed on Canada three years ago. I promise to my son that I will take him to the Niagara Falls this summer. Thanks again.

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

An integrated waste management approach, an initiative to reduce reliance on landfills, was initiated in Canada in the 1980s. The national objective was to achieve a 50% diversion of waste from landfill by the year 2000 based on the "waste management hierarchy" (source reduction; re-use; recycling; waste combustion; landfilling) (McDougall, 2001; Sawell, Hetherington and Chandler, 1996; Eighmy and Kosson, 1996).

Source reduction that requires waste minimization at the production level and a reduction in the underlying demand for products was thought to be too demanding on society as a whole, as pointed out by Price and Joseph (2000). They said, therefore, that very little consideration or effort has been given to source reduction.

Recycling, including incineration in Canada, accounts for only 14.22% of all wastes generated (Sakai et al., 1996). The development of a recycling market has shown a slow growth pace despite the efforts by municipalities to increase the recycled portion of their waste because the success of recycling depends heavily on three main factors: supply of raw materials, high energy and capital costs of processing materials, and high environmental costs in materials production and disposal (Chandler, 1983). Recycling programs are also influenced by landfill capacity (Highfill and McAsey, 1997 & 2001). Bailey (cited by Highfill and McAsey, 1997, p. 118) said, "... curbside recycling doesn't pay.... And it does so at a time when landfill space turns out to be both plentiful and extremely cheap."

Landfilling is still the dominant waste disposal method especially in North America, with Canada burying 83.9% of all residential and ICI wastes in landfills, while other countries with smaller land areas such as Denmark and Japan have greatly reduced their dependence on landfilling to less than 20% of total wastes generated (Sakai et al., 1996). Landfill disposal is warranted by the continued supply of landfill capacities, which have not reduced notwithstanding that many small-sized, open-and-dump landfills have been closed (US EPA, n.d.). The closing of small open-and-dump landfills has been characterized by the replacement of large-scale engineered landfills designed on a regional scale.

Large-size regional landfills do not come without problems, although they help curb the rising costs of engineered landfill disposal by achieving economies of scale. Not only are large-scale landfills suspected of generating greater externalities (bad odour, litter, noise, more truck traffic, and so on), but they are conducive to the generation of larger waste volumes than small-scale landfills are.

This chapter will critically investigate the cost minimization advantage of large-scale regional landfills considering the environmental costs that are usually not counted as a cost component and provide an analysis of how large-scale regional landfills induce a larger quantity of waste into landfills than small landfills do.

1.1 Large-Size Regional Landfills[1] and Cost Minimization

Construction of large-size regional landfills has been opted for over the past few decades to deal with two challenges associated with provision of new landfill facilities. They include: (1) the increasing difficulty in obtaining governmental approval and public acceptance for any new disposal facilities (Bellingham, 1971), and (2) the increased cost pressure caused by stricter landfill construction and operation regulations[2] (Dooley, Bangsund, Leistritz, and Fischer, 1993).

These two factors combined have pushed up the overall costs of landfill-disposal service. The rising costs have pushed the waste industry to strive to reduce both competition and to control the rising service production costs to a level as low as possible to remain competitive. The ease of competition has been achieved through merging and acquiring small-size operations and the increasing landfill disposal service costs have been curbed to a large extent by constructing large-scale regional landfills.

Studies by Glebs (1988); Walsh (1990a & 1990b); Dooley et al. (1993); and Renkow and Keeler (1996) that analyzed the landfill development costs and studied the least-cost landfill size are reviewed in this section to provide a foundation for understanding the economic advantages of large-size landfills. It is emphasized that there exists a point in the operating costs at which diseconomies of scale appear and that the cost advantages of constructing large landfills are

---

[1] In this paper large-size landfill is interchangeably used with regional landfill. Due to a large waste stream from a multiple of municipalities, regional landfills tend to be large in scale.
[2] Subtitle D in USA or Ontario Regulation 232/98 are those that enforce such requirements.

reversed when consideration is given to externalities and transportation costs. Inconsistencies among the cost estimation results have also been found.

Glebs (1988) presented the historical landfill development costs (in 1986 dollars) per ton that showed costs rose to U$18/ton in 1990 versus U$4/ton in 1975 for a 40-acre landfill with a total capacity of 1 million tons of waste. The pressures for increasing costs, mainly caused by stricter new regulations, have been mitigated by switching to large-scale landfills. According to the survey results by the Ministry of Environment, Ontario (1993), the annualized cost per ton fell from about C$33 per ton for landfills receiving 5,000 to 30,000 tons of waste a year to about C$9 per ton for facilities receiving over 1,000,000 tons of waste per annum. The values were in 1989 dollars.

Both Glebs (1988) and Walsh (1990a & 1990b) developed a cost model for given landfill site conditions and estimated the total site development costs under the assumption that construction was completed in one phase. The projected total development cost by Glebs (1988) was U$16 million dollars for a 50-acre fill area landfill with a total receiving capacity of up to 1,425,000 tons for a 7.3-year site life, while Walsh (1990a & 1990b) estimated the development cost was U$125 million dollars for an 80-acre area landfill with a total capacity of 6 million tons for a 20 year life period. Because Walsh (1990a & 1990b) did not provide per-ton total costs, the author calculated annualized per-ton total costs, applying a 7 percent interest rate per annum, for the Walsh's (large) landfill, which were U$24.28.[3] Glebs' per-ton total costs were U$11.25. Admitting that there was not sufficient information/data provided in the literature that could help

[3] The life-time total costs of predevelopment, construction, and closure/post closure except operating costs were annualized. The per ton operating costs were obtained simply by dividing the annual operation costs by the annual waste quantity as the annual operating costs were simplified to remain constant over life years in the literature.

explain the difference[4], it is obvious that the difference was great enough to raise a question about large landfills being able to capture economies of scale at all times.

Dooley et al. (1993) and Renkow and Keeler (1996) addressed the specific task of determining the landfill size that ensures the lowest development costs per ton. The high level of investment associated with meeting construction and operation requirements has made small landfills unable to compete against large landfills because large capacity landfills have cost advantages over small capacity landfills due to the economies of scale in landfill development and operation costs (Dooley et al., 1993). Both papers found that there exist economies of scale over a certain range of landfill sizes, recognising that consideration of externalities[5] and transportation costs would diminish the advantage of economies of scale in construction and operation costs.

While Dooley et al. (1993) compared the projected annual costs for five different waste streams (W) under a given operating life (T), 20 years, Renkow and Keeler (1996) attempted to find the optimal operating life (T) that minimizes annual costs subject to V (landfill size) = WT. The studies broke down the costs into four main categories—predevelopment (or political costs), construction, operation, and closure/post-closure costs, to estimate the total landfill development cost. Each cost component addressed in these studies is reviewed to help understand how a cost minimization model leads to choosing large size landfills with a long-term operating life.

---

[4] When the costs of each category are compared, the operating costs of large landfill (U$84 million dollars) were much higher than that of small landfill (U$7 million dollars), which was out of proportion in terms of total capacity.
[5] For further discussion about economic measurement of externalities, see "Externalities and Economic Measurement" in Chapter 2.

Walsh (1990a & 1990b) found out that predevelopment activities such as site feasibility analysis and environmental assessment would last five years[6] and that the failure rate appeared to be higher than one-to-two (For each site that succeeds, two site applications fail[7]). The strategy to open one big landfill with a longer operating life sounds much more sensible economically, rather than attempting to open a few small ones, because predevelopment costs do not vary greatly according to landfill size, rather they represent a fixed cost.

The estimation of operating costs was relatively easy as they were assumed to depend on waste volume (W) only. They are largely concerned with daily activities such as compacting, grading, applying daily cover, and so on. It can be maintained intuitively that operating costs per ton go lower as more waste volumes are treated in one batch. Dooley et al. (1993) found out that per-ton operating costs continued to fall from U$11.26, and U$5.92 to U$5.44 for landfills accepting 20 tons per day (TPD), 250 TPD, and 400 TPD respectively.[8]. However, the operating costs per ton were U$5.16 for a landfill of 750 TPD[9] (Glebs, 1988) and U$13.355 for a 1,000 TPD landfill[10] (Walsh, 1990a & 1990b). This indicates that diseconomies of scale can exist over a certain waste volume. Because operating costs account for 50 to 70 percent of the total site development costs (Glebs, 1988; Walsh, 1990a & 1990b), the identification of a waste quantity over which diseconomies in operating costs occur is very important.

---

[6] Anderson et al. (2002, p.47) said that $25 to $100 million might be put at risk only to seek an operating permit that could consume 10 years or more for completion.

[7] The most recent example is the failure of the efforts made by the City of Toronto to site Kirkland Lake as a replacement for Keele Valley landfill that is closing in the year 2002.

[8] The total capacity for each landfill size is 125,000 tons, 1,600,000 tons, and 2,500,000 tons respectively over 20-year life year.

[9] The total capacity of it was 1,425,000 tons for 7.3-year life.

[10] The total capacity of it was 6,000,000 tons for 20-year life.

Construction costs of landfills are basically determined by two considerations—waste quantity (W) and landfill life (T). As was indicated by Renkow and Keeler (1996), lower annual waste streams into a landfill which thereby extend the life of a landfill were consistent with the economies of scale in construction. The construction costs to build a landfill are an investment in an asset, "the landfill," which will be the most cost-effective if it can produce outputs over "longer" life years. When the output level (the annual waste quantity, W) is determined at a point where per-ton operating costs are minimal, the life of a landfill is chosen at a point where per-ton construction costs from annualized construction costs are the lowest. The longer the life of landfills, the lower the annualized construction costs. However, this is true only when "the landfill" asset does not produce any external costs or incur maintenance costs during its life. Renkow and Keeler (1996), considering these reversing factors, found out that the least-cost landfill would have a 48 year life for a waste quantity of 100,000 tons per year.

The study by Dooley et al. (1993) that estimated construction costs for different sizes of landfills with the same design conditions and years of life showed a continued decline in a per-ton costs from U$13[11] for a 20 TPD landfill and U$4.18 for a 250 TPD to U$3.9 for a 400 TPD landfill. However, the construction costs in the studies by Glebs (1988) and Walsh (1990a & 1990b) did not show a consistent declining pattern as landfill size grew. That may be due to differences in locations[12] and design assumptions. At any rate, it is worthwhile to note that the estimate for construction costs by Glebs (1988) was U$411 per ton for a landfill with a total

[11] These per ton construction costs were annualized from life-time construction costs at 7 percent.
[12] Dooley et al. (1993) studied landfills in North Dakota, Walsh (1990a & 1990b) in the State of Michigan, and Glebs (1988) in an upper Midwestern state.

capacity of 1.4 million tons while per ton construction costs for Walsh's (1990a & 1990b) estimation was translated to be U$812 for a landfill with a total capacity of 6 million tons.

1.2 Low-cost Large Landfills Are Not Without Problems.

Data reveal that the number of landfills has been reduced greatly, but the total disposal capacity has not changed at all due to the provision of large size landfills. According to U.S. EPA (n.d.), the number of landfills in the United States decreased—from 8,000 in 1988 to 1,967 in 2000[13]. A report, "The Landfill Capacity in North America" produced by The National Solid Waste Management Association (as cited by Gerrard, 1994), revealed that the number of MSW landfills in USA declined from about 20,000 in the early 1970s to about 7,000 in 1991, but that the 364 new landfills opened between 1986 and 1991 were very large in capacity. The U.S. EPA (n.d.) reports that the capacity, however, has remained relatively constant because new landfills are much larger than in the past[14].

Bob Rae said, "Creating landfills creates an incentive to use them" (Eyles, Boyce, and Hibbert, 1992, p.51). In other words, supply creates demand. The availability of landfill capacity in the USA has been a last-resort option for the Greater Toronto Area (GTA), which otherwise would have devised other waste management programs in a more effective and prompt manner amidst the repeated failures of siting new landfills. The Michigan landfill site has taken wastes from the GTA for $40 per ton compared with $150 per tonne in Toronto (Eyles et al., 1992).

[13] Data presented by O'Leary and Walsh (2002) revealed that since 1989, the number of municipal solid waste landfills in the United States has declined from 7,379 to 2,216 in 1999.

[14] Repa and Sheets (as cited by Gerrard, 1994) maintained that total landfill capacity in USA has actually increased. According to O'Leary and Walsh (2002), since 1989, the average amount of waste received by a landfill has increased from 92 tons per day to 300 tons per day (increased proportionally to the decrease in the number of landfills), which clearly indicates that landfill size has grown and the quantity of landfill-disposed waste has not decreased.

It is, therefore, understood that an increase in the price of landfill-disposal services over the past decades is basically not so much the result of a reduction in the amount of landfill disposal services supplied as the result of operating cost increases and reduced competition. The stable supply of landfill capacity raises the concern that the society will be placed under less pressure to reduce wastes and/or divert wastes away from landfill-disposal. The stable landfill capacity raises a greater concern when the waste generation rate slows down or decreases[15]. The landfill service price will go down as a result of excess supply. The problem associated with this downward pressure on service price is that waste diversion efforts are dampened.

The social demand to reduce our reliance on landfill disposal is weakened by the complacency of having large-size and long-term[16] landfills that are believed to be the least-cost solution. It is even so when a group of municipalities participating in a regional large-size landfill construction agreement are bound to use the landfill as specified in the contract. Long-term large landfills involve a sizeable investment amount. Landfill developers try to avoid investment-related risks by having municipalities sign up for a contract and securing a minimum waste quantity over contracted years. Even private owners or operators offer a specially arranged landfill disposal price to municipalities in return for a minimum quantity of waste to be sent to their landfills. Municipal solid waste landfills sometimes lobby businesses to induce waste contributions from ICI sources to achieve economies of scale[17]. There is no doubt that this type

---

[15] There has been a noticeably small increase in the municipal solid waste generation by only 0.1 pound per person per day from 4.5 pound/person/day to 4.6 pound/person/day in 1990's, compared to 0.4 to 0.8 pound/person/day increase every decade since 1960 (US EPA, n.d.).

[16] Walsh (1990a & 1990b) made a remark that the majority of landfill applications for ultimate development currently entail waste receipts over a 20-year time frame over which a landfill developer could recoup his costs for new site development. Renkow and Keeler (1996) found that the least-cost landfill would have a 48-year life span for an annual waste stream of 100,000 tons.

[17] A good example of this case is Essex-Windsor Regional landfill that is supposed to receive approximately 250,000 tons of waste annually both to raise the money for 3R programs and to keep disposal costs reasonable. The

of arrangement will impede the growth of political, social, and economic initiatives that are required for waste reduction and/or diversion.

It is also legitimate to evaluate the economies of scale of large-size and long-term landfills from the environmental and human health perspectives. Landfill disposal is in the least preferred waste management option from a sustainability point of view. Renkow and Keeler (1996) concluded, taking into account externality costs as a part of the total costs, that disposing of larger volumes of waste reduces per-ton cost, but the cost advantages are exhausted at a certain point because of increasing externality costs, political costs and the capital financing costs.

It is evident, from the literature reviewed above, that the average costs per ton of small-size landfills are higher than those of large-size landfills and the magnitude of externalities[18] in small-size landfills is smaller than that in large-size landfills. The following two sections will indicate graphically how the higher average costs per ton of small landfills and the greater magnitude of externalities of large landfills affect the quantity of waste disposed of at landfills.

landfill has received waste from ICI sources as well. But since the export of ICI waste in the region has been taking place, the waste volume being received has been reduced to approximately 130,000 tons annually. The region amended the approval to expand the Service Area of the landfill to include other Ontario municipalities to make up the short fall, thereby keeping the costs reasonable.

[18] Externalities from large-size landfills are greater than those from small landfills because large-scale landfills are associated with greater negative impacts from larger land area use and larger volumes of waste.

1.2.1 Large-size landfills slow down the incentives to abate landfill-disposed waste

The information presented in the previous section demonstrates that rising disposal costs (per ton) at small landfills have been replaced by relatively low costs (per ton) at large size landfills[19] and that the landfill capacity has not been reduced[20] as a result of a transition to large-size landfills that municipalities have favoured to achieve the least-cost landfill operation.

The observation above is also closely related to two other phenomena in the municipal solid waste management market. First, the price increase of landfill disposal is not directly or completely transferred to waste generators. The current funding system for municipal solid waste management is a flat fee charge system relying on a general tax (property tax). The least-cost landfill must be the most preferred option to municipalities in that municipalities should bear additional costs above the flat fee. Second, the change in the quantity of waste disposed of at landfills in response to a disposal price increase depends as well to a great extent on the availability of other waste disposal alternatives such as reduction and diversion, let alone the price level of virgin materials. Although the recycling market plays a limited role in managing municipal solid waste, recycling and landfill disposal markets are in a direct competitive relationship. Therefore, the lower cost landfill disposal option will undermine the potential growth of recycling market.

---

[19] Dooley et al. (1993), in an analysis that was limited to cost tradeoffs between disposal and transportation (other landfill costs such as externalities, truck traffic, aesthetics, local opinion were ignored), found that if each county was required to develop its own landfill facility, MSW disposal costs would be more than $50 per ton to comply Subtitle D.

[20] Landfill disposal is still the predominant method of waste disposal that accounted for 97 percent of the total waste managed in Ontario (Ontario, 1993) notwithstanding that landfill disposal costs have increased greatly in the past two decades.

Figure 1 and Figure 2 demonstrate how a large landfill can be conducive to the generation of more waste discarded than a small landfill, from both supply and demand perspectives.

Figure 1. Price Effect

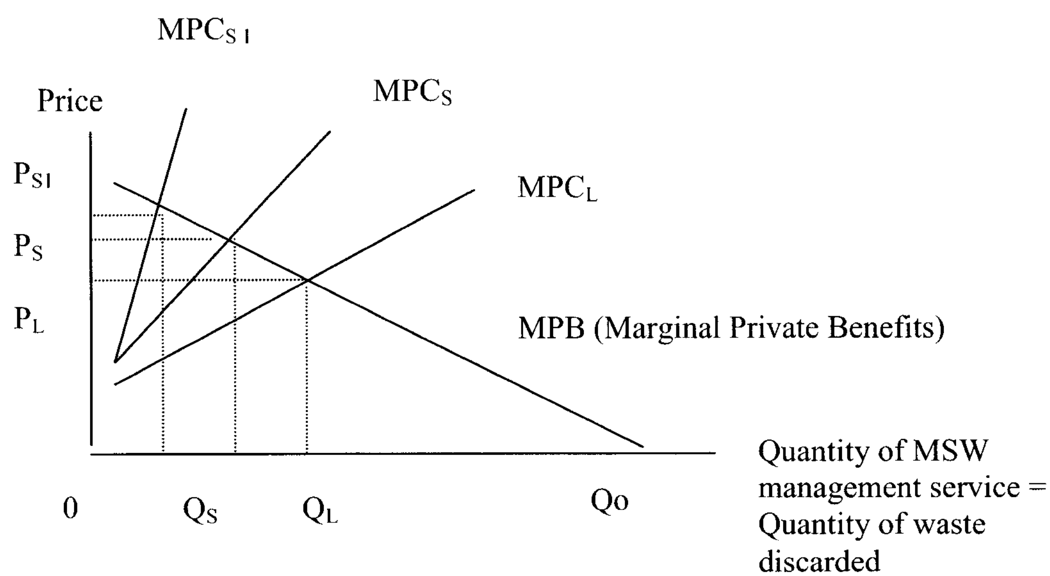


Figure 1 demonstrates the situation in which the lower marginal private costs of a large landfill (MPC_L) impede the reduction in the quantity of waste discarded from Q_L to Q_S that could be obtained from a small landfill. Suppose that MPCL represents the marginal private cost curve of a large landfill and MPC_S represents marginal private cost curve of a small landfill. MPC_S will have a steeper slope than MPC_L because the marginal private costs of small landfills are greater than those of large landfills[21].

If the price increases from P_L to P_S as a result of a change from a large landfill to a small landfill, the demand for waste disposal service is reduced by as much as Q_LQ_S. This holds true for a smaller landfill with a steeper slope, MPC_S 1, which has a lower price elasticity than MPC_S. Waste generators who behave along the curve of MPC_S 1 tend to be highly insensitive to price changes and would rather try to lengthen the lifespan of the small landfill while staying at a high price. The significant initial investments related to planning, political, and construction costs in opening up a new landfill to replace the closing one may encourage longer use of current landfills. This will result in further waste reduction and higher prices.

Because the externalities from disposed waste are not included in the marginal private cost (MPC), the product of Q_L Q_S and the externality cost per ton of waste discarded represent the "additional" welfare loss that results from a transition to a large landfill from a small landfill. This is a "Price Effect."

[21] Marginal cost (MC) = δTC / δQ = (δFC + δVC) / δQ, where Q: output, TC: Total cost, FC: Fixed costs, VC: Variable costs. Since δFC / δQ = 0, MC = δVC / δQ. Dooley et al. (1993) revealed that the variable operating costs of landfills varies inversely with size.

Figure 2. Substitution Effect

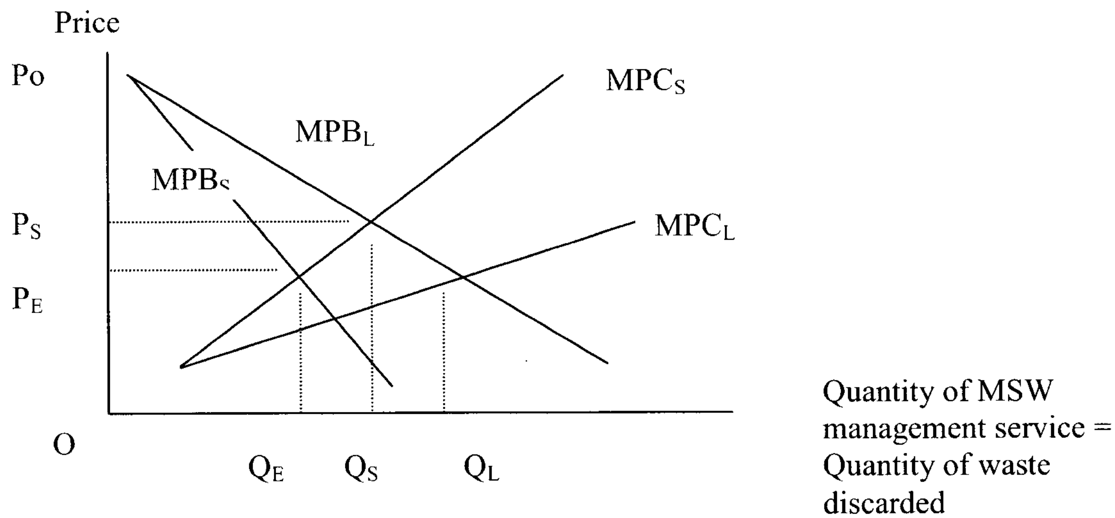


Figure 2 shows the waste reduction that can be achieved by a "substitution effect" that assumes waste generators' rational behaviour. An additional decrease in the quantity of waste discarded is expected if waste generators have correct and complete information about landfill capacity and if they rationally respond to it. When there is no municipal solid waste (MSW) disposal service provided, waste generators would be willingly pay as high price as possible (Po) for the first service provided. As the quantity of MSW disposal service increases in the market, users of the service want to pay less and less for an additional ton of waste disposed. If MPB_L represents the demand curve for a large landfill, the demand curve for small landfill capacities is positioned in the left area of MPB_L because the demand curve elasticity under small landfill capacities is much smaller than that under large landfill capacities. In other words, waste generators realize that they have to respond as little as possible to the price change in order to avoid incurring a prohibitively high price associated with constructing another small landfill. For this reason, the demand curve for a small landfill is drawn as MPB_S.

Suppose that equilibrium is obtained at a price, OPE and at a quantity of service provided, OQ_L. When a large landfill (MPC_L) is replaced by a small landfill (MPC_S), the waste quantity discarded is reduced from OQ_L to OQ_S. However, the final resultant reduction in the quantity of waste can be greater than Q_LQ_S if consumers realize that they can not stay at the same demand curve and react to reduced landfill capacities. Then MPB_L shifts to MPB_S and quantity of waste disposal will be reduced additionally by as much as Q_SQ_E, which is a result of the "Substitution Effect." So the total waste quantity reduced is equal to Q_EQ_L, which is greater than QLQS.

1.2.2 Large-scale landfills and externalities

In the previous section, it was established that a regional approach was consistent with a long-term and large-size landfill because it offers lower operating and construction costs in terms of per-ton cost[22] than a short-term and small-size landfill. As analyzed in Figures 1 and 2, a larger quantity of waste than would be expected to be disposed of in the small landfill situation is discarded into a large landfill, which poses a net welfare loss to a society if the market price is determined by marginal private costs instead of marginal social costs[23]. Jenkins (1993) said that the welfare loss is eliminated when the quantity of waste disposed of is determined at a point where marginal social benefit (MSB) is equal to marginal social cost (MSC).

[22] The cost advantages of large-scale regional landfills over small landfills are focused on cost factors such as predevelopment costs, construction costs, operation costs, closure costs, and post-closure costs (Glebs, 1988; Walsh, 1990a & 1990b; Dooley et al, 1993).

[23] Marginal social cost (MSC) is a sum of marginal private costs (MPC) and marginal externalities costs (MEC). When marginal private cost (MPC) that does not include the externality costs (assuming they are not decreasing) is prevalent in the market, the externalities are paid by the society. The term, "price", used in this paper, usually indicates MPC unless otherwise stated. It is, therefore, assumed that the reduced quantity of waste discarded always decreases the magnitude of social costs.

Due to the enforcement of stringent regulations, externality costs have begun to be included in marginal private costs to some extent: operating costs related to monitoring activities including leakage and methane gas emission check-ups are incurred to reduce externality costs that are associated with groundwater contamination and air pollution. An investment for liner installation, as part of construction costs, is also made to prevent groundwater contamination. Funds to meet post-closure costs are also raised during the lifetime of landfills, which will be spent to reduce the possible externalities that may occur after landfills are closed.

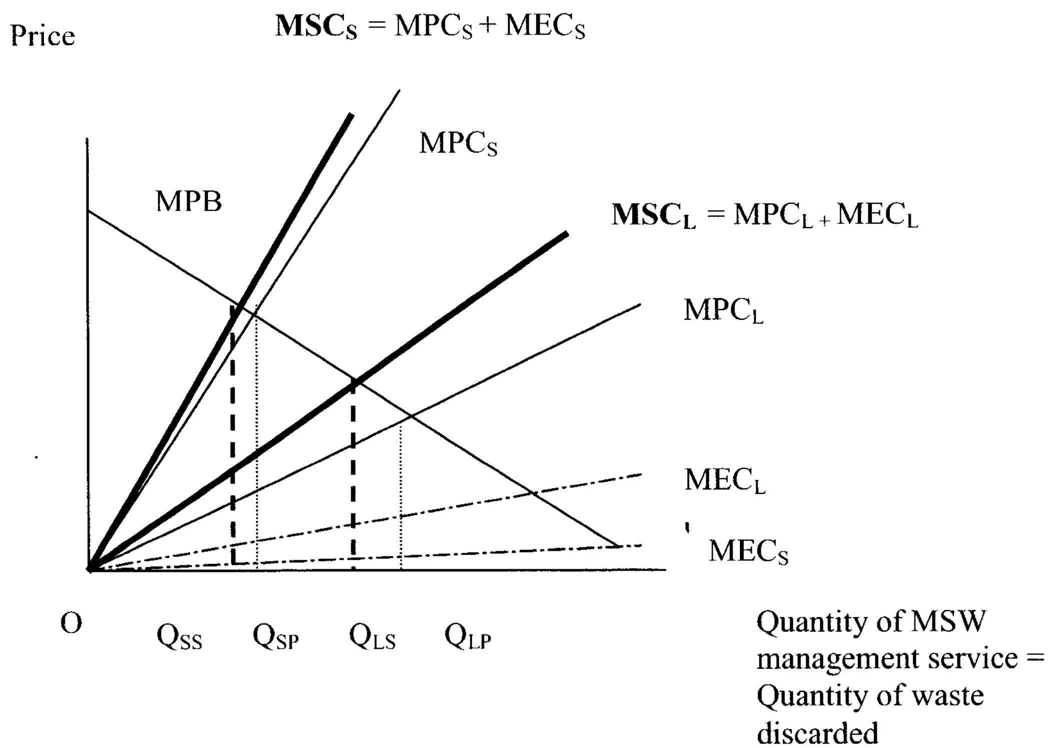
Although those externality-reducing costs are eventually included in marginal private costs, they hardly represent the total external cost because externalities cannot be removed or eliminated by such preventive actions[24]. Dooley et al (1993) made it clear that other landfill costs (externalities, truck traffic, aesthetics, local opinion) were ignored in their analysis because they were difficult to objectively quantify. Glebs (1988) added in his conclusion that the waste disposal costs could double if interest, insurance, contingencies, remediation, and profit were included.

The externalities from large landfills are believed to be worse than those of small landfills because of their bigger land areas (as a landfill) and larger volumes of waste being received. In this section, the effects of externality costs to reduce the quantity of waste discarded and reverse the cost advantages of large landfills are presented graphically in Figure 3, assuming that: 1) the

[24] More about the total external costs of landfills is discussed in section, "Total External Costs of Landfills and Property Value Measurement" in Chapter 2.

externality costs at large landfills are greater than those at small landfills; and 2) the externalities positively increase as the waste quantity increases.

Figure 3. The Effect of Marginal External Costs



As seen earlier, more waste is discarded at large landfills at the same price level because MPC_L are comparatively lower than MPC_S. In a market where externality costs are not reflected in the market price of waste disposal services, more waste in the amount of $Q_{SP}Q_{LP}$ is discarded at large landfills than at small landfills.

Increasing marginal external costs are represented by two lines: MEC_L for a large landfill and MEC_S for a small landfill. They are added vertically to MPC_L and MPC_S respectively to draw marginal social costs, MSC_L and MSCs. The gap in the quantity of waste discarded, $Q_{SP}Q_{LP}$, between a small and a large landfill with private costs will be reduced to $Q_{LS}Q_{SS}$, and decreased by as much as $[(Q_{LP} - Q_{LS}) - (Q_{SP} - Q_{SS})]$ when externalities are appropriately reflected in the marginal private prices. As MEC_L becomes greater and/or MEC_S is smaller (the difference in the magnitude of externalities between small and large landfill becomes greater), the cost advantages of large landfills become less and less.

1.3 Purpose

The objective of this paper is to identify the difference in the magnitude of externalities between a small landfill ("Britannia Landfill") and a large landfill ("Keele Valley Landfill") that can diminish the economic advantages associated with large-scale regional landfills.

Externalities increase because large-size landfills tend to handle greater volumes of waste over a longer period of time. A higher volume of trucks, a larger parcel of land used, and a longer period of post-closure stabilization are consistent with greater negative impacts of landfills on the natural environment and human health. The costs of such externalities are not generally internalized by the total landfill management costs, which may make the economic advantages of large landfills look even greater than they actually are.

Interest in small-sized landfills would logically increase from the perspective of diverting and/or reducing municipal solid waste. Smaller landfills are more apt to reduce the quantity of waste being disposed of at landfills through the "Price Effect"[25] and "Substitution Effect,"[26] as reviewed. Therefore, if the policy goal lies in diverting and/or reducing landfill-disposed waste quantities, smaller size landfills should be chosen over large size landfills.

---

[25] See Figure 1.
[26] See Figure 2.

1.4 Research Method

The study compares the size of impacts on the residential property values of two landfills ("Britannia Landfill," hereinafter referred to as "Britannia," and "Keele Valley Landfill," hereinafter referred to as "Keele") that are different in landfill lot size and in waste volumes handled per day.

Previous studies have found, using multiple regression models, that the externalities (or disamenities) of the landfill are accounted for in the price of homes and the impacts of the externalities dwindle as homes are located farther away from a landfill.

This study uses distance from the landfill as a proxy to measure the negative impacts of the landfill on the values of surrounding properties, and employs a regression analysis model that separates out the relationship between property values and the negative impacts of a landfill, when all other things are held constant. The distance coefficients in the model between "Keele" and "Britannia" are compared to identify the difference in the size of the negative impacts of the landfill capitalized in the property values.

Chapter 2. Review of Literature

This chapter consists of three main components. The first one will review the theoretical background of property value impact studies. The conceptual model and empirical approaches that have been used in property value studies, to establish that negative external impacts are capitalized in property values (establishing an association between negative externalities and property values), are investigated. The second part discusses the limited ability of property value impact studies in explaining the total external costs of a landfill. The total external costs are hardly captured by the property value impact studies in their entirety. The coefficient for the landfill externalities, estimated from the hedonic regression equation, should not be interpreted as fully representing the total external costs of the landfill. The third section reviews the problems associated with the specification of correct hedonic price equation. If the estimation of prices for characteristics of houses is, to a large extent, dependent on the correct specification of a hedonic function, the selection of housing characteristics that predominantly determines the house prices in the market, and the choice of functional form of the equation (linear, quadratic, interactive, and so on) that best explains the relationship between prices and the characteristics of a house, is essential. The last component reviews the previous studies conducted to investigate the adverse impacts of a landfill upon the adjacent residential area in terms of price effects measured by the distance of houses from the landfill. The guidelines on how to select landfill sites to be studied and study impact areas are of primary interest.

2.1 Theory of Property Value Impact Studies

Residential property values are often used to indicate the magnitude of negative external impacts[27] imposed by projects, such as waste disposal facilities (landfills, incinerators), nuclear power plants, highways and airports, on neighbours living near those facilities. The basic argument is that if people generally want to avoid the negative external impacts generated by such facilities, the potential buyers or occupants would not prefer homes in the vicinity of those facilities (and the current owners or occupants would try to move out of such areas) over identical homes,[28] except where there are no such negative external impact sources in the neighbourhood. Even those buyers who have to choose the area near a landfill will want to purchase a house as far away as possible from the adverse source. Current dwellers in the area who cannot bear the impacts and are willing to expend money and time to escape from the source will put up their houses for sale to leave the area. In this way, the people's reluctance to live near a negative external source is capitalized in the market price of housing. The postulation for a property value model is that if negative externalities exist in residential areas, housing prices are under downward pressure, when other things are equal.

There have been two major approaches used to assess the impacts of negative facilities or projects upon the residential property values in adjacent areas: "Simple Comparative Analysis" and a "Hedonic Price Model."

---

[27] The negative externalities are usually related with environmental and health impacts.

[28] This means that houses are exactly the same in terms of characteristics of the property structure (i.e., the number of rooms, lot size, age, and so on) and characteristics of the location (i.e., proximity to parks, shopping centre, and central business district, the quality of school, the presence of unwanted facilities, and so on).

"Simple Comparative Analysis" directly compares the mean sales prices between the "facility area[29]" and "control area.[30]" to show that a difference in housing value trends between the two areas has existed. If the mean sales price is found to be lower in the facility area than in the control area, that difference suggests the presence of negative impacts of the landfill, if everything else is equal. The assumption in this approach is that the housing value trends in the facility area would have developed in a similar fashion to the housing value trends in the control area, if there had been no externality sources in the facility area. This approach employs "Time Series Analysis" approach as it usually compares the property value trends over time periods, "before" and "after" the negative facility opens. The research conducted by Research and Planning Consultants, Inc. (1983), employing this approach, investigated the sanitary landfill impacts on property values. Price (1988) reported a review of studies done about the impacts of waste facilities on the residential property values in areas of West Palm Beach Area (Florida), Westchester County (New York), and the City of Winnipeg (Manitoba). Only a few studies using this approach have been found while the papers employing the "hedonic price approach" are abundant.

The problem with the comparative analysis approach is that it is not practically easy to find a control area that is the same as the facility area in terms of housing structure and location conditions so that the control area can be considered a close comparator. If the control area fails to simulate the facility area.in terms of characteristics affecting the property values, except the presence of the landfill, the variations between the two areas in the housing values cannot be interpreted as being attributable to the negative impacts of the landfill. The variations could have

[29] It is also referred as "study area," indicating the single-home residential area near the landfills.
[30] This refers to an area that is very similar to facility area in terms of housing characteristics and other neighbourhood characteristics. It must be located outside of any possible influence of the landfills.

been caused by the differences of other factors affecting the housing values. It is, therefore, important to select the control area that is identical or at least very similar to the facility area for the results of this approach to be meaningful. Another problem is that, as this method compares the average housing prices between the two areas, the quantification of the negative external impacts of the landfill on individual houses and an examination of the differences in the impact levels over distances from the landfill is not possible[31].

The "Hedonic Price Model," developed by Rosen (1974) based on Lancastrian's new consumer theory (1966), allowed the price of negative externalities, or disamenities that are implicit in property values, to be estimated. The basic premise is that housing is not a homogeneous good for which demand is largely determined by the level of price and income. The house buyer tends to pay a higher price for the house located near his or her workplace than for the identical house farther away. The house located near the workplace provides higher utility in terms of commuting time and expenses. The three major questions households are faced with when purchasing a house include, according to King (1976), the characteristics of the dwelling, its location, and the price.

As such, demand for housing by consumers is determined by the composite attributes of housing embodied in its property and location characteristics. As Rosen (1974) puts it, goods are valued for their utility-bearing attributes or characteristics. Rosen (1974) combined a theoretical analysis of the impact of negative externalities on property values with a hedonic price model in which the hedonic or implicit prices of attributes of differentiated goods can be estimated by regressing the explicit prices or observed prices of differentiated products on the specific values

[31] The nuisance pollution from the landfill has been found diminishing with distance away from the source, the landfill, by the research papers reviewed in the following section.

of characteristics associated with them. The hedonic pricing model is based on the Lancastrian view, developed in the new consumer theory (1966), which argues that it is the properties or characteristics of the goods from which consumers derive utility, not the goods themselves. It assumes that goods are inputs in a consumption activity and a collection of characteristics is produced as outputs. The assumption that goods have multiple characteristics, that influence consumer behaviour, enables us to explain and predict consumer reactions to variations in the attributes of goods, which traditional theory was unable to explain[32].

Many property value studies have been conducted using the theory of hedonic price to find the contribution of environmental amenities or disamenities to housing values. Empirical applications of the hedonic pricing model include studies of the effect of air pollution on property values by Ridker and Henning (1967), Harrison and Rubinfeld (1978), Nelson (1978), and Graves, Murdoch, Thayer and Waldman (1988) and the effect of solid waste disposal sites on property values by Havlicek, Richardson, and Davies (1985), Nelson, Gebereaux, and Genereaux (1992), Hite, Chern, Hitzusen, and Randall (2001), and Gamble, Downing, Shortle, and Epp (1982).

Estimating the prices of environmental attributes in a house service bundle is one of the economic tools that is used to indirectly assess the external costs of environmental disamenities. The underlying question with respect to these indirect assessment methods is whether they capture the external costs less or more than they actually are. While it is recognized that the actual external costs are also subject to a large number of variations depending on the probability

[32] The weakness of traditional consumer theory, which implies utility is derived from goods and services purchased in the market place, according to Becker and Michael (1973), is the extent to which it relies on differences in tastes to explain consumer behaviour where income and prices do not explain observed behaviour, when it can neither explain how tastes are formed nor predict their effects.

of occurrence (of externalities) and on the size of investments spent to avoid them, an attempt is made in the following section to explore the extent to which the total external costs of the landfill are explained by property value impact studies.

2.2 Total External Costs of Landfills and Property Value Impact

A review of the two previous studies (Hwang and Rudzitis, 1977-1978; Renkow and Keeler,1996), which estimated total external costs of landfills using the results of property value studies, leads to the conclusion that the property value impact model captures only part of the total external costs; it captures the costs of human risks only; it captures neither the costs of system (capital and operating costs of landfill system) nor environmental risks[33].

Hwang and Rudzitis (1977-78) estimated the external costs of landfills in the Chicago Metropolitan Area by incorporating into their analysis the two regression coefficients for prevailing downwind location and distance from a landfill site, that were produced by Havlicek, Richardson, and Davies (1985). They assumed that the changes in property values could capture all of the external costs produced by the landfill activity. However, the results of their study showed small or even insignificant values, therefore, they were compelled to conclude that the total social cost of landfills, defined as the sum of private and external costs, did not show a significant variance from private costs.

Renkow and Keeler (1996)[34] classified significant externalities of landfills into four categories: 1) reduced property values, 2) groundwater contamination and aesthetic diminution of the environment, 3) nuisances such as the noise, litter, and traffic congestion, and 4) negative externalities after closure.

---

[33] Total external costs consist of system costs (of landfill, environmental costs and human costs.

[34] Renkow and Keeler viewed that the externalities vary depending on the annual volume of waste and the size of the facility, for which the author extends a credit.

The sources of externalities were extensively covered, however, the same assumption made by Hwang and Rudzitis that all of the externalities could be captured by the impacts on property values was also employed in estimating external costs. The authors devised a simple linear function that was drawn from the study on property value impacts of landfills conducted by Nelson et al. (1992)[35] in order to select landfill sizes presenting minimum externality costs, admitting that the specification of externality costs was more arbitrary than that of other cost factors in their study, such as construction, operating and political costs.

The findings of the two papers above have led me to raise two questions: The first one is the appropriateness of using the results of property value impact studies for the estimation of the total external costs.[36] The key concern is underestimation of the true total external costs. The second question is whether state-of-the-art engineered landfills eliminate potential risks in the future. If the investment to build the landfill system and expenses to operate the landfill system do not produce perfect safety for the environment and human health, those landfill system costs cannot be interpreted as the total external costs.

2.2.1 Human risks and Environmental risks

It is unclear whether all types of landfill externalities are perceived by the people and reflected in property values. If not, the property value impact assessment underestimates the total external costs or cannot be used as a tool to estimate the total external costs.

[35] Nelson et al. clearly defined externalities of landfills, for the purpose of their study, to the forms of nuisance such as noise, flies and other insects, hours of operation, traffic, odours, debris, and appearance.
[36] The limitations and/or scope of the property value model will be covered later in this chapter.

Different types of landfill externalities may require different approaches to estimate their costs[37]. Landfill externalities can be classified into two types of risks depending on whether they are identifiable and measurable—Environmental Risks and Human Risks. The identification and measurement of risks poses analytical problems because of their complexities and the difficulties associated with their interaction and interconnectedness in time and space. To put it simply, those risks that cannot be identified and measured now are still perceived by human beings as risks being present.

Therefore the perception of risks is a good criterion to classify risks. Risks that are perceived as high are classified as human risks. They are related to either human health issues or nuisance issues. Environment risks are not perceived to be as high as human risks unless they are revealed to be a form of human health risk. However, environmental risks can pose much greater impacts than human risks on property values, once people perceive them. The news of groundwater contamination by leachate from a landfill in a town where residents rely on underground water for their drinking water will have a depressing effect on the real estate market there.

Environmental risks include groundwater or surface water contamination, explosions and fires, vegetation damage, air pollution, or global warming arising from landfill leachate and gases. Human risks include those from increased traffic, noise, unpleasant odours[38], aesthetic

---

[37] Discussion of various economic valuation methods of the environment is beyond the scope of this study.
[38] Hirshfeld et al. (1992) classified odour as a "physical impacts," but the author followed the observation in the paper produced by El-Fadel et al (1997) which stated "Although many odorous trace compounds may be toxic, they

degradation and limited land utility (Hirshfeld, Vesilind, and Pas, 1992; El-Fadel, Findikakis, and Leckie, 1997)[39]. O'Hare, Baron, and Sanderson (1984) and Zeiss (1984) noted the human health effects and stigma effects attached to landfills. Health effects comprise all effects, risks and uncertainties that may affect human health. The stigma effects relate to "unfair" losses imposed on the host-community by the decreased prestige caused by the landfill.

Landfills located away from human habitation—or, away from urban centres—will be more of a concern to the environment rather than to human health. Property value impacts may not be observed in some landfills where no human settlements are established in their vicinity. The question of how people perceive the environmental risks and how the perceived environmental risks are revealed in the change of property values is not applicable in this case. Different methods other than the use of a property value model must be considered.

Property value can begin to decline even when the siting process starts (at a time when a landfill is not actually operating), or the actual groundwater contamination by the leachate from a landfill may not be detected and thus not perceived as a potential risk to residents. Therefore, the actual impacts from groundwater contamination may not be reflected in the property value until the ground water contamination is reported and publicly known. The property value may not be impacted at all when the groundwater is not a drinking water source for the residents in the neighbourhood. Howard, Eyles, and Livingstone (1992) pointed out that groundwater was rarely

---

have historically been perceived more as an environmental nuisance than a direct heath hazard." Please refer to Young and Parker (1984) and Young and Heasman (1985) for original sources.

[39] Hirshfeld et al. (1992) termed these two types as "physical impacts" and "social impacts." The author replaces them as "environment impacts" and "human impacts" respectively as were termed in the landfill classification system designed by Ontario Ministry of The Environment (1991). The landfill inventory classified by the MOE will be used as a primary source for selecting landfills for the empirical study of this paper.

regarded as a priority issue by the GTA population as they relied on water from Lake Ontario for potable use.

The methane gas emitted from landfills that contributes to the accumulation of greenhouse gases has farther and wider effects than the property value impact study can cover. The property value model usually focuses on the impacts on the residential houses adjacent to landfills because the impacts generally dissipate and disappear with distance away from landfills. Therefore, the property value model cannot capture the externalities occurring in other areas that are not included in the study.

Therefore, it is reasonable to assume that property value studies capture the external costs associated with human risks only. The actual damage that might have been done to the environment, but not noticed or recognised, or that may happen in the future is not captured by the property value impact studies.

2.2.2 Landfill system costs

Landfill owners or operators are forced to spend more money than before in designing, construction, and operation of landfills to minimize the pollution risks by containing contaminants such as leachate and gas within landfills, and by collecting emissions for further treatment. To the extent that the investments and expenditures made in connection with the engineered landfill system diminish the environmental and human impacts, the human and environmental costs will be decreased. Where this is so, the investments and expenditures spent for the systems must be included in the calculation of the total external costs.

Landfills continue to generate contaminants for many years even after closing. Ontario Regulation 232 under the Environmental Protection Act requires the contaminant sources of landfills to be managed and monitored even after landfills are closed, for up to 25 years after closure.

Then the next question is the reliability of the system. Where the reliability of the system is uncertain, the magnitude of environmental and human risks is not reduced inasmuch as the amount of money invested and/or spent for the system. Even when an engineered landfill system manages to safely prevent the contaminants from leaving the landfill boundary for good (after closure), some additional expenditures that are associated with soil clean-up or land stabilization may still be required to enable use of the site for any other uses. Limited land utility may persist after closing. During its lifetime, a landfill system will continue to generate some negative impacts such as increased air pollution and noise from garbage trucks, regardless of the performance of the landfill system.

Eyles, Boyce, and Hibbert (1992) said that significant deterioration in the performance of an engineered containment system can be revealed after 50 years since the life of the system is estimated to be about 50 years. However, there is no actual experience of operating a system to establish its reliability. Hirshfeld, Vesilind, and Pas (1992) provided many reasons from many sources for the failure of a containment system.

2.2.3 Summary

The discussions above are necessary and useful in better understanding the limitations of the property value model in terms of estimating total external costs. The understanding of the scope of damages that a landfill causes is related to what the property value impact study can capture.

First, the human risks comprising nuisances and stigma effects are easily perceived by the residents living near landfills. Therefore, people tend to reflect human risks in the housing price. However, environmental risks have a tendency not to be perceived as high risks or tend to be ignored until found to be hazardous to human health. In this way, the property value model is likely to capture the externalities of the landfill partially because residents in the neighbourhood are more sensitive to human risks than they are to environmental risks.

Second, containment landfill systems designed to collect and treat landfill leachate and gases tend to contribute to a reduction in the environmental risks while contributing only slightly to a decrease in the human risks. Therefore, the human risks of landfills are not supposed to be significantly different in their sizes between containment and non-containment landfills except the case wherein the latter is not covered daily. It would more likely be landfill size, and the daily volume of waste disposed of in the landfill, that affect the human risks. In this regard, both types of landfills can be treated equally by the property value model as human risks are not significantly affected by the types of landfills.

Third, landfills posing different levels or different kinds of risks to their neighbouring environment are discouraged from being selected for the study. Suppose there are two landfills and residents in the vicinity of one of the two depend on groundwater that is susceptible to contamination by landfill leachate for drinking water, whereas residents in an area of the other landfill rely on lake water (very far from the landfill site) for drinking. Those two landfill sites do not make the best candidates for this study because they have risk environment differences that are presumed to be significant enough to affect the real estate markets differently. In this case, it may not be easy to isolate the effects of landfill size (or waste volume) for comparison between two regions.

Fourth, the total external costs are composed of three primary components: the costs of constructing and operating the engineered containment system (or system costs), the human impact costs, and the environmental impact costs. The sum of human and environmental costs is the "perceived cost (or external cost)." System costs are internalized costs. Therefore, it can be said, generally, that perceived costs have an inverse relationship with system costs.[40] The reliability of this inverse relationship depends on the reliability of the system. That is, when the system fails to be trustworthy to the residents with respect to its preventive capacity[41], the level of perceived risks will tend to be greater. Therefore, the estimation of the total external costs must consider system costs, and the costs of environmental risks and human risks at the same time. But this is a very challenging task because of the difficulty in identifying and measuring

[40] Human risks are much less dependable on the system variable (i.e., the inverse relationship between human costs and system costs is weaker than that between environment costs and system costs), but they are combined with environmental risks for easy illustration.
[41] It is assumed here that better performing landfill system is consistent with higher system costs.

the environmental risks, bearing in mind that a property value study estimates human risks in an accurate way.

2.3 Measurement of Prices for Various Attributes of Housing Using a Hedonic Price Model

Correct estimation of economic prices of housing characteristics depends on correct specification of the price and characteristics relationship (Butler, 1982). There are numerous studies that have dealt with, partially or exclusively, the correct specification of the price-characteristic relationship (Butler, 1982; Kain and Quigley, 1970; Graves et al., 1988; Straszheim, 1974; Cropper, Deck, and McConnell, 1988; Li and Brown, 1980). The empirical studies, mentioned in previous section, that investigated the effects of air pollution and a landfill on property values also paid a great deal of attention to the question of specification. The purpose of this section is to establish the foundation on which the most appropriate specification that best contributes to the goal of this study can be formulated.

2.3.1 Determination of Independent Variables

Specification involves determination of which explanatory variables to include and to exclude in and from a regression equation and the functional form of the equation (Butler, 1982). Exclusion of relevant variables leads to *biased* estimates of the true coefficients. Inclusion of the irrelevant variables that are *correlated* with the included relevant variables is likely to reduce the significance of estimated coefficients, leading to less precision in estimated coefficients (Schroeder, Sjoquist, & Stephan, 1986). Therefore, the correlation among the independent variables (called multicollinearity) needs attention when the study focuses on the explanatory power of the regression coefficients. The predictability of the regression model, usually defined by the goodness-to-fit[42], is not much affected by the presence of multicollinearity.

The key variable in this study is the coefficient for distance away from the landfill. The distance coefficients will be compared between small and large size landfills. Therefore, the significance of the distance variable is critically important for the purpose this study, as comparison of unstable coefficients are meaningless. When the standard error of the coefficient is large[43], the significance of the estimation of the coefficient is suspicious. Other things being equal, an independent variable that is highly correlated with one or more other independent variables will have a relatively large standard error. Ridker and Henning (1967)[44], in estimating the effect of variations in air pollution levels on property values, included more and wider variables than were generally included in property value studies in order to avoid the situation in which the primary variable, the impact of air pollution on property value, appeared to be significant because some important correlated variables were left out of the equation.

Specification bias[45] due to the exclusion of relevant characteristics was tested by Butler (1982). He tried to find the magnitude of the specification bias by comparing the restricted model and the benchmark model. The former one employed only a few explanatory variables available

---

[42] Statistical results to indicate the goodness-to-fit are R^2 (the Coefficient of Determination) or R_a^2 (Adjusted Coefficient of Determination).
[43] Multicollinearity is suspected if t-values for the coefficients are insignificant (while the model is useful) or variation inflation factors(VIF) is greater than 10.
[44] To deal with multicollinearity, Ridker and Henning (1967) used stepwise procedure that observes the effect on the partial regression coefficients of existing independent variables when new variables are added to the regression equation.
[45] Specification bias is that the estimated coefficients of the included variables are influenced by the excluded variables when the excluded variables do really constitute the factors of the true model (Butler, 1982).

from SMSA-level census data[46] (owner's estimate of market value; Gross rent, number of rooms; age of the structure; and the condition and plumbing facilities of the dwelling unit represented by the dummy variable SNDNPL & POORCOND) whereas the latter one used a relatively extensive set of housing characteristics from more than 100 characteristics identified from surveys of approximately 1,500 individual households in the city of St. Louis. Those include distance to the central business districts, lot size, density (estimated population per acre), county (dummy variable), percentage of the structures on the same blockface (as the units that are in deteriorated-obsolete-neglected-poor condition, a direct measurement of the structural dimensions of neighbourhood quality), and Median arithmetic achievement test score for sixth-grade students (a proxy for both school quality and the quality of public service).

The differences in the values of coefficients between the restricted specification and the benchmark model were found to be negligible; leading to a conclusion that inclusion of all relevant characteristics may not be economical, with a caveat that a fairly complete variable list should be used in estimating non-structural characteristics (such as the effect of race on rents) because they are more intercorrelated than structure attributes[47] and thus the specification biases are very likely to occur. The presence of a difference in the collinearity between structural attributes and neighbourhood attributes was confirmed by Atkinson and Crocker (1987). They stated that the specification uncertainty caused by collinearity is small for structural attributes (floor space, age, and lot size) but substantial for neighbourhood attributes (air pollution, school quality, and crime).

---

[46] The variable set lacks of representation of location, lot size, and neighbourhood quality.
[47] Butler(1982) noted that structure coefficients are insensitive to specification changes.

Graves et al. (1988) also conducted a study to examine the influence of alternative variable selection upon the coefficients of key (or "focus") variables[48] in order to test the robustness of the benchmark hedonic equation. The bias in the estimated coefficients of the focus variables was identified by regressing housing price on the focus variables, the free variables[49], and every permutation of the doubtful variables[50]—i.e. including/excluding the doubtful variables in possible combinations. The focus was on the influence of "doubtful" variables such as mean census tract income, crime rate, a school quality measure, and a set of county dummy variables on the "focus" variables, recognising that the "free" variables, such as structural and access variables, present less specification uncertainty than doubtful variables. The result was that only the coefficients of visibility changed significantly, responding sensitively to the county dummies. Exclusion of a relevant variable, in this case the county dummy, has biased the economic price of the focus variable.

In addition to the exclusion/inclusion problems, the importance of adequate measurement of housing attributes was noted by Kain and Quigley (1970). They suggested that the previous property value studies were deficient because they used aggregate (published census tract) data[51] and the explanatory variables from the aggregate data did not correctly specify the model. An attempt was made to correct the deficiencies by rigorously identifying 39 variables indicating the physical or visual quality of the bundle of residential services from three separate surveys of approximately 1,500 individual households in the city of St. Louis.

[48] Visibility and Total Suspended Particulate Concentrations were the focal variables in the study.
[49] Physical qualities are examples of free variables. They are highly contributory to house value.
[50] Doubtful variables such as neighbourhood income are uncertain in their economic relationship with house value.
[51] Ridker and Henning (1967) used data aggregated across census tracts.

The 39 variables were based on the judgment of the interviewers about the interior and external quality of the house, plus the neighbourhood quality. The 39 variables were then aggregated into five factors consolidated by factor analysis to provide more consistent and meaningful quality measures. The five-factor aggregation of variables, explaining 60 percent of the variance among the 39 original variables, included: (1) Basic Residential Quality (the overall quality of the exterior physical environment such as structure, landscaping, cleanliness of the parcel and block face, condition of the streets, walks and driveways). (2) Dwelling Unit Quality (the interior of the dwelling unit), (3) Quality of Proximate Properties (the cleanliness, landscaping, and condition of nearby properties), (4) Non-residential Use (the effects of commercial and industrial land uses in the immediate vicinity such as noise, smoke, and traffic), and (5) Average Structure Quality on the block face

17 variables describing the overall quality of the exterior physical environment accounted for 39 percent of the total variance, followed by 8 percent accounted for by dwelling unit quality. The importance of housing quality variables that explained the majority of the total variance was highlighted in this study. The multicollinearity problem in association with aggregating was recognised by the authors, but a method how to deal with it was not given. This may be partly the reason why structural conditions were found to be significant compared to non-structural attributes. The inclusion of other types of variables might have reduced the significance of quality variables.

Li and Brown (1980), pointed out that few studies have included location-specific attributes of the micro-neighbourhood[52] for housing in the specification of a hedonic pricing function. They attempted to estimate the influence of these variables on housing values and to investigate if exclusion of these factors biased the estimates of housing values.

1971 sales records of 781 single-family houses in 15 suburban towns in the Boston area were obtained from multi-listing agencies. Attributes of a house were grouped into five: (1) structural and site characteristics, (2) neighbourhood characteristics (such as neighbourhood median income, residential density, the percentage of persons between 16 and 21 years old who are high school dropouts, and air pollution levels), (3) local public services and costs (the quality of a school system and property taxes), (4) macro-accessibility to CBD, and (5) micro-neighbourhood characteristics (aesthetic characteristics, noise levels, and proximity)

A key test in this paper was an investigation of a trade-off effect between neighbourhood attributes and micro-neighbourhood characteristics. In addition, an interaction between the number of rooms and lot size was also examined. Three models were specified and run; model 1 used micro-neighbourhood characteristics and model 2 lacked micro-neighbourhood characteristics, while model 3 was a modified specification of model 2 that replaced the number of rooms and land area in model 2 with an interaction term of lot size and number of rooms.

[52] Li and Brown (1980) classified the micro-neighbourhood attributes into three types: aesthetic attributes, pollution levels and proximity. Proximity was classified into two other attributes: accessibility (proximity to a grocery store, a park, a school, a river, or a conservation land) and proximity to external diseconomies (congestion, noise and air pollution).

The introduction of micro-neighbourhood characteristics did affect the structural attributes least, however, the coefficient of census tract median income (a proxy for the neighbourhood) that was significant without micro-neighbourhood variables in the specification turned out to be insignificant when they were included. The coefficient for median income was reduced from U$605 in Mode l 1 to U$180 in Model 2.

Interesting findings were made with respect to the micro-neighbourhood characteristics. The authors split them into two subgroups: one with the benefits of accessibility only and the other group with both the benefits of accessibility and the costs of externality[53]. People attributed a positive value to being close to the former group including the ocean, rivers, and express interchanges. However, for the latter group (industry, commercial area and thruway), the net effect of proximity (the sum of the benefit from being close and the externality of being close) was not linear. The net effect for proximity to industry showed a benefit up to about 550 meters (housing prices increased up to 550 meters because the benefits of accessibility continued to exceed the costs of externality). After that point housing prices began to decrease as the net effect was regarded as negative. The net effect of the commercial area was a rather consistent amenity over distance, so housing prices continued to drop as distance increased from commercial centre. The positive net effect of proximity to thruways increased with distance after showing a slight decline up to 300 meters.

There was a multicollinearity in which the value of lot size was not independent of the number of rooms. There were no significant differences in sales prices among small houses (5

---

[53] For example, housing prices increase with distance from industry because the external costs are reduced with distance, but housing prices decrease with distance from industry because the accessibility benefits are reduced with distance. However, the accessibility benefit at zero distance from industry was never positive.

rooms) on small lots (1/4 acre), small houses on large lots (2 acres) and large houses (8+ rooms) on small lots. There was only a $3,329 difference between an eight-room house and a five-room house on a ¼ lot size. The authors attributed this to "our inability to completely specify the quality of houses."

2.3.2 Functional Forms

There are many different functional model types such as linear, log-linear, semilog, quadratic, translog, Box-Cox linear, and Box-Cox quadratic. It is, to a great extent, up to the empirical test results to tell one from the other. As Butler (1982) and Cropper et al. (1988) put it, little guidance is provided in hedonic theory with respect to formulating the hedonic equation form. Papers that have dealt with the choice of a functional form are limited. The empirical studies that have been reviewed, including those to be reviewed in the next section, have not provided a basis for choosing the model to be employed.

Kain and Quigley (1970) estimated the implicit prices of the attributes of a housing service bundle based on linear or semi-logarithmic models, after investigation of more complex models involving quality-quantity interactions. But little analysis was done to compare them.

Butler (1982) suggested that functional forms that are approximate to the correct form have been empirically found to be close substitutes, adding that there seemed to exist some sort of interactive relationship among housing characteristics as they are clustered around over a limited range. In the Li and Brown (1980) paper, the individual variables, lot size and number of rooms, were replaced with the interaction term between lot size and number of rooms (in 11 dummy variables based on three room-size and four lot-size categories). By doing this, the interdependence of the two individual variables could be analyzed; large houses (with large a number of rooms) on a large lot sell for much higher prices than small houses on large lot or large houses on small lot.

The research paper by Cropper et al. (1988) seemed to be the one that most exclusively addressed the question of choosing a hedonic functional form. The study compared, in a simulation of a housing market equilibrium in which the marginal price paid for each attribute by consumers is estimated, the marginal price attributes with the gradient of the hedonic price function. The findings were that when all attributes are observed, linear and quadratic Box-Cox forms provide the most accurate estimates of marginal attribute prices, but when certain variables are not observed, a simple linear function consistently outperforms the quadratic Box-Cox function.

More guidance for the choice of most appropriate functional forms is explored in the following section.

2.4 Empirical Studies of Landfill Impacts

The impacts of the presence of a landfill on adjacent residential areas usually come in two forms: the impacts on property values and n development in the neighbouring area[54]. Two methods[55] to estimate the impacts were used by the studies reviewed; "simple comparative analysis," and "hedonic pricing model."[56] This section focuses on the studies that investigated the landfill impacts on property values using a hedonic model.

Research and Planning Consultants, Inc. (1983) and Price (1988) employed "simple comparative analysis" in their research. Research and Planning Consultants, Inc. (1983) conducted four case studies to assess the effects of the landfill to be constructed on the property values of adjacent neighbourhoods. Average property values were compared between each facility area and an each control area for five years before and for five years after the initial development of the landfill. In addition, the study also focused on the change in patterns of development since the landfill was opened. The results were that no changes in either nominal value or in the direction or rate of change in property value in facility areas were found.

Price (1988) reviewed the studies in the areas of West Palm Beach Area (Florida), Westchester County (New York), and the City of Winnipeg (Manitoba). Those studies also employed the simple comparative analysis approach. The studies compared the difference in the appreciation rates between residential neighbourhoods within close proximity to the landfill and

[54] Gamble and Downing (1982) examined the two effects of sanitary landfills.
[55] The details of the two approaches and comparisons were made in the section, "Theory of Property Value Impact Studies," of this chapter.
[56] For a comparison, see page 23 – 27.

those located some distance away. The conclusion was that there was no significant difference in the appreciation rates, meaning that landfill proximity had no negative effects on the property values. However, there was one interesting finding in the Florida case. The higher priced properties experienced a lower rate of increase if located within about 2 km from an active landfill than the low to mid-priced homes.

Studies that employed a hedonic pricing approach to analyse the implicit price of the impacts of the landfill on property values include Havlicek et al. (1985), Gamble et al. (1982), Nelson et al. (1992), and Hite et al. (2001). All used hedonic regression methods.

The first attempt to measure external effects of solid waste disposal sites on residential property values in proximity was made by Havlicek et al. in 1971.[57] The key hypothesis was that the properties would be more adversely affected by the negative effects of the landfill as they were located closer to the landfill and in prevailing downwind areas of the site. A simple linear regression model was hypothesized to estimate the prices of key variables, the distance of property from the nearest landfill and the absolute angle in degrees that identifies a property in the prevailing downwind area of the site.

The sample included was 182 single house sales between 1962 and 1980 in each of five disposal sites in the Fort Wayne area. Eight other variables relevant to physical attributes of properties were obtained from the Multiple Listing Service. Zero-one variables were used to represent the differences among landfills. Two more variables ("distance to the nearest industry"

[57] Their research done in 1971 under title, "Measuring the Impacts of Solid Waste Disposal Site Location on Property Values," was unpublished. However, the summary of it was printed in *American Journal of Agricultural Economics, 53, p. 869 in 1971.* The information cited in this paper for their work is based on the book as referenced.

and "distance to the nearest shopping mall") were added to the conventional model separately. Three models (the conventional model, the conventional model plus "distance to the nearest industry," and the conventional model plus "distance to the nearest shopping mall") were run.

The coefficients for the two key variables were found to be positive: the value of a residential property increased by U$0.61 per foot of distance away from the site and by U$10.30 per degree of angle from the downwind area of the site. The coefficients for distance to industry and shopping mall were estimated as negative, indicating that the proximity of a residential property to industry and shopping mall was regarded as an amenity.

Model 2 and Model 3 produced substantial changes in the coefficients of zero-one variables while the coefficients of physical attributes remained unaffected. Therefore, the authors pointed out the need for further research on the disaggregation of neighbourhood attributes, which is consistent with the findings from the reviews of literatures on the general determinants of housing values[58]. The authors also stressed that the difference in the quality of operation of the disposal sites would result in a significantly different estimation result. However, this would not bear much significance on the current sanitary landfill system.

There were two problems found here. First, there was no boundary limit given for which coefficients of the two key variables were valid, as pointed out by Hwang and Rudzitis (1978). Based on the diffusion effect of the externalities with distance, it should be reasonable to assume that the negative effects of externalities stop influencing property values beyond a certain

---

[58] Straszheim (1974) emphasized that neighbourhood (or "submarket") differences must be incorporated in the equation to reduce some of the "across-submarket" variation in prices.

distance. Second, the number of observations, 182 sales records, was too small compared to other studies that followed. The hedonic price model is a statistical framework in which the observed prices of houses are regressed to find the implicit prices for housing and location services. The amount paid, as measured by the regression function for a certain attribute, may not be equal to what the buyer wanted to pay for that particular attribute. Therefore, it is a reasonable assumption that the estimation might be more accurate statistically when there are more observed cases, on condition that that there is no wide and deep variance in the choice of housing each individual makes[59].

The problem of not having enough observations in a regression model was clearly emphasized by Gamble et al. (1982), who examined the two effects of the landfill: the change in the amount or rate of residential development, and the change in property values. The effect on property values was analyzed by two methods: the simple comparison between impact areas and control areas, and the hedonic price function.

The sample for simple comparison included all valid sales of single family houses within the impact zones and control areas between 1977 and 1981 at 10 sanitary landfills in Pennsylvania. The mean sales values, after adjustments for inflationary effects using quarterly price deflators, were grouped into large and small landfills.[60] Property values near the landfills (in the impact zones) were not lower than in the control areas regardless of whether they were near large or small landfills. However, it was indicated that the rate of new residential construction and the number of sales of houses within one-half mile of the landfills were

---

[59] Suppose there are two identical houses in a location with the same neighbourhood environment. House A with five rooms must not be extraordinarily higher in price than house B with four rooms.
[60] This research paper was the only empirical study, among reviewed, that tried comparing the impacts of the landfill between large and small landfills. Large landfill meant sites receiving more than 300 tons of waste per day.

substantially less in those areas with landfills handling waste in excess of 500 tons daily compared to the rates for landfills handling 300 tons or less per day.

The hedonic model used a linear regression function. The key variable of interest was "distance to the landfill" whose coefficient was hypothesized to be positive. The regression model was run for only one site, the Boyertown (Montgomery County) area, for two reasons[61]. The equation was estimated for three years, 1977, 1978, and 1979. The coefficients for 1977 and 1979 were not significant, suggesting that property values were not noticeably affected by the landfill. Only the 1978 result for "the distance to the landfill" was significant. In addition, in 1979 a negative relationship was observed between property values and distance to the landfill.

Although the results showed that the landfill had no significant negative impacts on property values, the authors concluded that they could not determine the relationship between property values and distance to landfill based on the Montgomery County study, suggesting that the small number of available observations caused the unavoidable problem of misspecification.

Nelson et al. (1992) conducted the most comprehensive study on price impacts of landfill distance on 708 single-family houses located within 2 miles of the landfill[62] in Ramsey, Minnesota, sold during the 1980s.

An ordinary least squares regression was used. Twelve independent variables[63] were considered. Nelson found that there was little price effect on property values beyond 2 miles

[61] The first reason was that no specification could handle the market variations across ten sites simultaneously, implying that functions should be estimated separately for each area. The second reason was that Montgomery County area had the largest number of observations among the ten sites—137 sales.
[62] It receives up to and sometimes more than 500 tons of waste per day.
[63] They were age, number of bedrooms, number of bathrooms, distance of the centre of property to the nearest interchange with Interstate, the square feet of the house foundation, number of fireplaces, lot sizes, year of

away from the landfill. The coefficient for the distance of property to the landfill was almost U$5,000, indicating that the house price increases by U$5,000 for each mile away from the landfill[64].

There are two fundamental problems with this study. The observed data were collected in the years 1979 through 1989. Housing prices must have been affected by the changes in other price levels. To isolate the changes in the housing prices caused by the supply and demand of housing in the market, the observed prices should have been adjusted by a deflation factor. The second problem is that no neighbourhood variables but "distance to the landfill" and "trees" were considered in the model. It is possible that exclusion of relevant neighbourhood variables led to biased estimates of the true coefficients of the key variable. Inclusion of more neighbourhood-related variables could have yielded different results. The third one is that the coefficient of determination (R^2) in this study was only 57 percent, meaning that 57 percent of the variation in housing prices was explained by the model, compared to about 77 percent in Model 1 from the work of Havlicek et al. (1985)[65] and 72 percent in the study of Gamble et al. (1982). Though no guidelines have been found in the literature with respect to the optimum R^2 level, a lower R^2 level suggests that additional independent variables be included in the model to increase its explanatory ability.

Hite et al. (2001) estimated the impact of four landfills[66] in Franklin County, Ohio on housing prices within 3.25 miles. The data set included sales of 2,913 single-family homes and

---

transaction, two full floors, three or more full floors, tree cover status, and distance of the centre of property to the centre of the landfill to the nearest one-twentieth of a mile.

[64] On a percentage basis, house price rises 6.2 percent per mile away from the landfill.

[65] In Havlicek et al. (1985), both "distance to industry" and "distance to shopping mall" were included. In Gamble et al. (1982), "distance to employer " was considered as a neighbourhood attribute.

[66] They are two sanitary landfills in operation and two demolition landfills closed already at the time of study.

condominiums in 1990. A mixed log-linear specification, incorporated with a certain degree of market segmentation, was used in the analysis to capture the effects of distance to a landfill.

What made this distinguishable from other studies was the consideration of housing market segmentation and inclusion of a property tax component. The four landfills are located in distinctly different areas. Therefore, parks that might be viewed as disamenities in one area may be amenities in other areas. This was confirmed by the results of the estimated coefficients of the variables. The implicit prices for the same characteristics were observed to be different according to location. However, as it was believed that Franklin County represented a single employment market, a dummy variable representing each landfill was applied only to a selected set of variables including all of the structural attributes.

If the willingness-to-pay for local public services is well measured by the levels of property tax, combining this factor into an equation is appropriate. It is particularly so when considering that property values are generally based on physical aspects of a house.

Contrary to the previous studies, this study included many neighbourhood attributes including proximity to the airport and to railroads, freeways, parks, and country clubs, crime rate, and competitiveness of local school districts in addition to distance to the CBD, the landfills and a trash-burning power plant. The difficulty to measure distances to airport, railroads, and freeways was overcome by.giving dummy variables to properties falling within a certain mileage[67].

[67] Houses within 1.5 km from the airport were assigned a dummy variable and within one-half mile of railways and freeways were assign a dummy variable.

The findings suggested that both open and closed landfills negatively affected property values located in proximity to the landfills and property taxes were relatively less sensitive to the presence of landfills than were property values. However, the negatively impacted house prices would in the long run undermine the tax base.

2.4.1 Problems or Constraints

It has been found that there are problems and/or constraints in empirical studies that used have hedonic regression models as below:

First, there must be sufficient number of observations for the model to be more predictive and/or explanatory; in a non-experimental environment, it is practically impossible to increase the number of observations. Adding new observation data that may contribute to the explanation of the model is difficult due to time, cost and data constraints. Therefore, resolving biased regression coefficients or high multicollinearity is very challenging.

Second, a large urban area may comprise “sub-markets” for housing. It is not easy to separate the urban area into distinct “sub-markets” and thus it becomes even more difficult to create a viable specification model for an urban area. Therefore, the regression estimators represent no more than an approximate estimation of the true prices for each individual housing attribute.

Third, the independent variables are not really independent, but are correlated. As reviewed, the neighbourhood attributes are more likely to correlate with each other. The presence of multicollinearity among the variables causes the interpretation of the estimation results to be ambiguous (Chatterjee & Price, 1991, p.173). The problem is that there are few effective ways to deal with multicollinearity.

2.5 Summary

Butler (1982) concluded that estimating the implicit prices of housing characteristics must be "approximate" or "deficient" because of the complex relationships among housing characteristics. Maler (1977, p.355 & 368) said, "The problem of solving the critical problems of specification of both the regression and the database are far from being solved. ...it is not even possible to determine the direction of the bias sign of the regression coefficients."

However, the outstanding advantage of a hedonic price model that enables researchers to estimate the implicit prices for attributes in the bundle of housing services has made it the most extensively used econometric tool in empirical property value studies.

The studies of landfill impacts on property values generally recognise, by isolating the capitalized amount of negative landfill impacts upon property values over distance, that landfills impose adverse externalities on the neighbourhoods and the impacts dwindle as the neighbourhoods are located farther away from the landfills.

Findings that are largely relevant to the specification of the regression model are summarized here.

2.5.1 Variables

Dependent variables were obtained through two different sources: sales records and census data. Li and Brown (1980) and Graves et al. (1988) used actual sales records from multiple-listing services. Ridker and Henning (1967), Kain and Quigley (1970), and Butler (1982) employed median census data based on owners' estimates[68].

The accuracy of estimates by owners is suspected, but that does not mean that the actual sale prices are correct because they usually fail to reflect the true willingness-to-pay by buyers and willingness-to-accept by sellers[69] (Freeman, 1993) due to a lack of information with respect to variables. However, there is no better information for an independent variable than actual sales prices in terms of representing market equilibrium.

The independent variables that were employed in the literature reviewed can be grouped into two classifications: physical and neighbourhood characteristics. Sources for these two characteristics are usually different because physical attributes are part of the individual nature of each house and are available from markets, however, neighbourhood attributes are not always available from markets.[70] They are usually calculated by census tract in median or mean values. A census tract is assumed to be a homogeneous neighbourhood in terms of the socio-economic conditions.

---

[68] Kish and Lansing (as cited in Ridker and Henning, 1967) claimed, however, that the response errors became smaller for averages based on their study result that showed the difference between the means of appraisers' and owners' estimates for 568 homes was only U$360.

[69] In this case the housing market is not in an equilibrium so estimated implicit prices do not reflect the true values of housing attributes.

[70] Income and distance to work must be obtained directly from the owners or occupants. Graves et al. (1988) utilized information from 1980 census for neighbourhood attributes.

Physical (also referred to as "structural," or "house,") attributes usually include features relevant to the size and quality conditions of housing such as number of rooms, number of bathrooms, number of garage spaces, age, and the like. The literature revealed that physical attributes had more direct and explicit qualities than neighbourhood attributes to the utility of housing consumers, so their coefficients were rather consistent and were least affected by the reformation of equation.

Neighbourhood qualities that involve both location and environmental qualities are relatively broad in their scope because they are basically associated with social (crime rate, school quality, distance to park, and so on) or economic (distance to central business district, distance to work, lot size, population density, and so on) aspects.

Location-specific amenities/disamenities felt by the residents in a neighbourhood are capitalized in housing value. Houses located near the CBD earn higher rent incomes for the owner. Being closer to work brings down the costs associated with commuting to work. However, being too close to CBD may cost the owner or occupant the benefit of living in a larger house space in a suburban area. The presence of an obvious source of disamenities like a landfill establishes only a negative relationship with sales prices. But many of the location-specific attributes such as the presence of industries and commercial centres have both positive and negative effects on house prices simultaneously. Li and Brown (1980) provided a detailed analysis of these effects.

2.5.2 The house and neighbourhood characteristics

Specification issues involve not only inclusion/exclusion of variables but the multicollinear nature of variables, particularly between house and neighbourhood attributes. They appear different, but are statistically inter-correlated.

The structural variables are less intercorrelated with each other and more consistently explain the hedonic regression equation than neighbourhood variables. If prices for neighbourhood characteristics are to be measured, a very complete list of neighbourhood variables must be used to prevent excluded variables from affecting the estimation of included variables (Butler, 1982; Atkinson & Crocker, 1987).

The complexities of measuring socio-economic conditions in a neighbourhood were addressed by using census tract median incomes (Ridker and Henning, 1967) as a proxy. This involves the problem of aggregating the characteristics of an individual household (individual income) into a neighbourhood attribute. The assumption that high income people possess a greater ability to escape from the sources of externalities and higher willingness to pay for property with a low level of externalities (higher income, higher prices of housing) seems plausible. However, the effectiveness of an income variable as a proxy for neighbourhood attributes is doubtful. The Li and Brown (1980), and Ridker and Henning (1967) studies showed that the significance of median income proxy changed when the equation was appropriately specified.

Lot size was also used as a proxy to represent neighbourhood quality because larger lot sizes provide higher aesthetic value to the neighbourhood than small lot sizes. The interaction effect between living space area and lot size, and between the number of rooms and lot size were analyzed by Schmalensee, Ramanathan, Ramm, and Smallwood (1975) and Li and Brown (1980) respectively. A complete separation of the effects between these two variables was not feasible, as long as the data showed that larger lot sizes had larger houses and more rooms.

Chapter 3. Method

The key interest of this study is in comparing the size of the negative landfill impacts upon house prices between two landfill sites—small and large landfills. The theory is that house is a composite product with many different attributes for which market prices are not established. Consumers of houses obtain utility from each individual characteristic of a house, but they are not asked to pay prices for each of them. One component of the housing service bundle is environmental amenity or disamenity. The presence of a landfill is considered as a disamenity to its neighbouring residents. As the environmental attributes are determined by the location of the house, they are called neighbourhood characteristics.

A regression equation in which the sales prices of houses are regressed on the bundle of housing characteristics including neighbourhood characteristics is used to isolate the implicit price of the landfill disamenity capitalized in housing price.

The environmental disamenity of the landfill for neighbourhood residents is thought to dissipate as their house is located farther away from the landfill. Therefore, "distance from the landfill" of a house is used as a proxy variable in the regression equation to represent the people's willingness to pay more for being away from the landfill.

3.1 Selection of Study Areas

The uncompromising condition—the existence of residential development in the vicinity of landfills—for landfills to be appropriate candidates for this study has not left many landfills for consideration in southern Ontario area. Two landfills located in the Greater Toronto Area (GTA) have been selected for the study: “Britannia Landfill” (in the City of Mississauga, hereinafter referred to as “Britannia”) and “Keele Valley Landfill” (in the community of Maple in the City of Vaughan, hereinafter referred to as “Keele”).

Figure 4 shows where "Britannia" and “Keele Valley” landfills are located. “Britannia,” which is about 25 km west of Toronto's downtown, is located at 5700 Terry Fox Way, south of Britannia Road in the City of Mississauga. "Keele," which is about also 25 km north of Toronto's downtown, is located at the intersection of Dufferin St. and Major Mackenzie Dr. in the community of Maple in the City of Vaughan—west of Dufferin St. and north of Major Mackenzie Dr.

Figure 4. Location of Landfill Sites

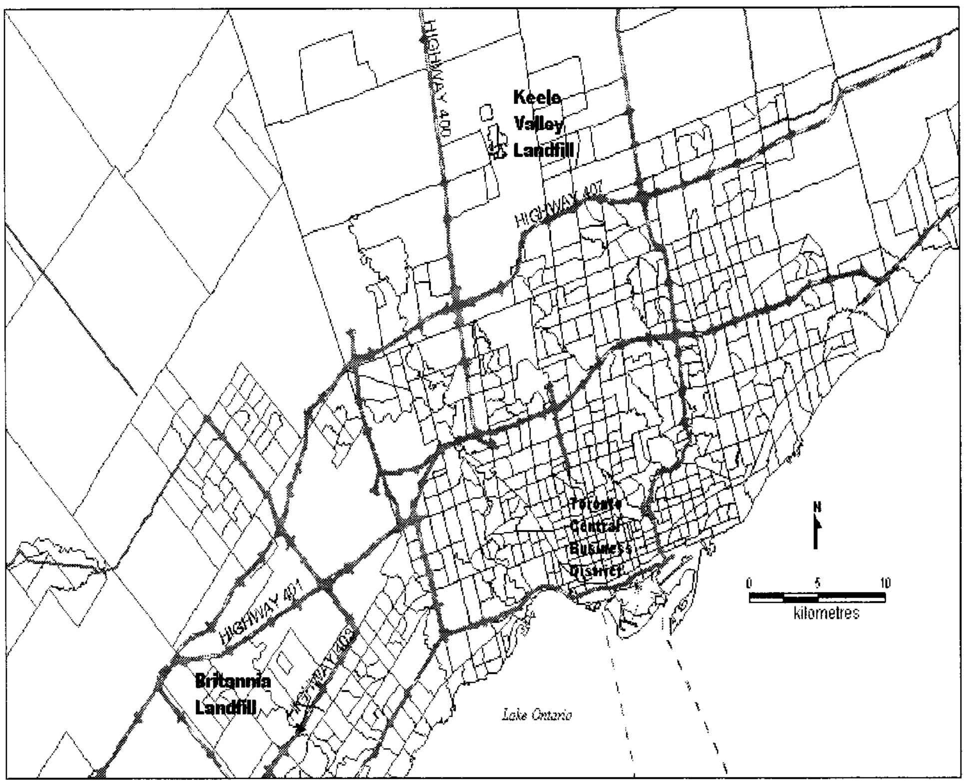


Figure 5. Britannia Landfill

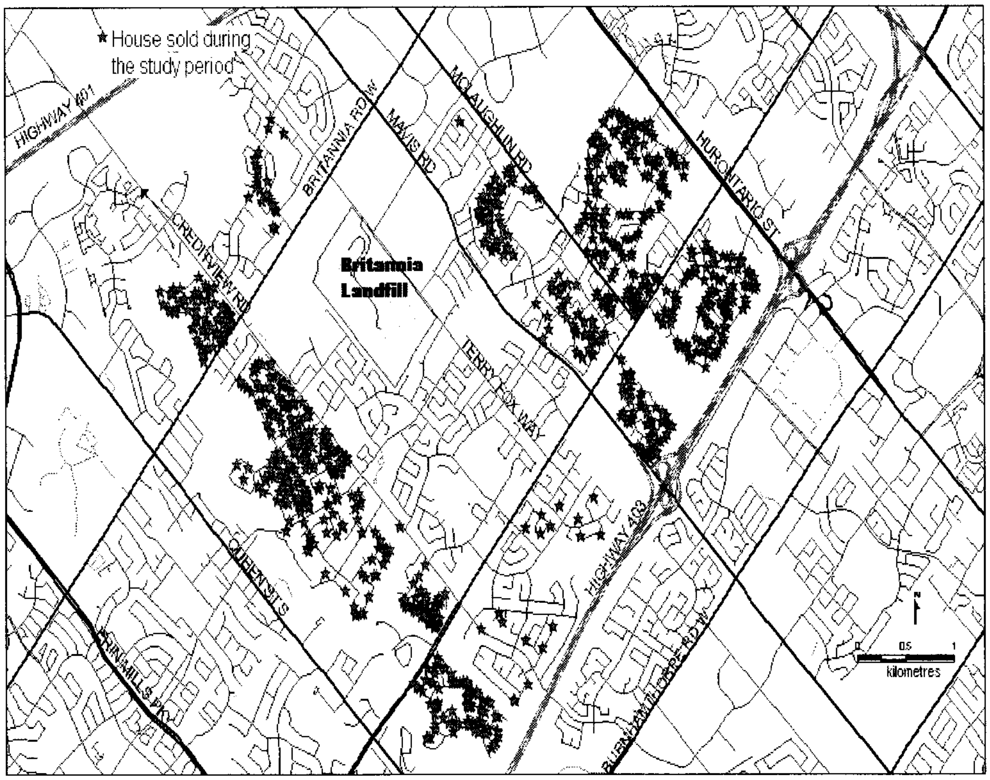


Figure 6. Keele Valley Landfill

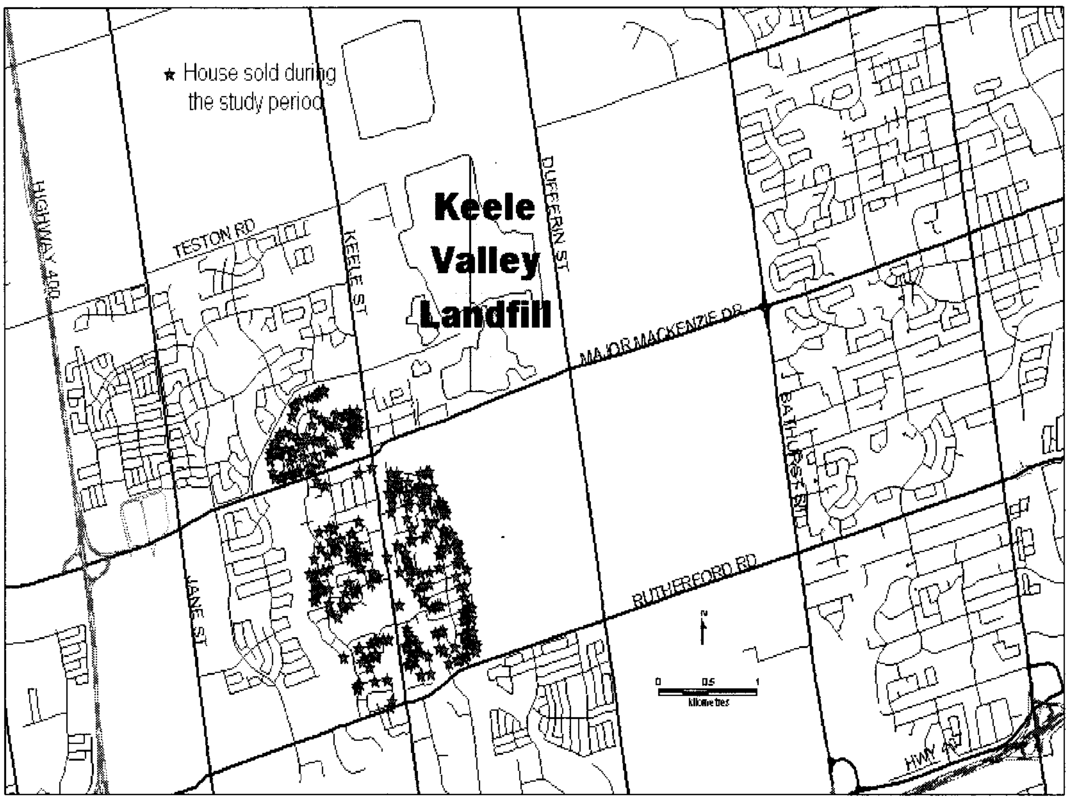


Figure 5 shows the study area of Britannia landfill. The houses symbolized by a star (* in red) indicate the houses sold during the study period. The property of Britannia is 83 hectares (206 acres) in size. It opened in 1978 and received about 4 million tons of waste before closing. In 1998, approximately 200,000 tons of municipal waste was disposed of at this site. It was closed in 2001. The housing sales records for the "Britannia" site have been taken from two Residential Districts: Hurontario and East Credit. The Secondary Plan for both districts was created in 1981 to meet the expanding pressure of the City Centre. The population of Mississauga was about 612,000 in 2001 which was an increase by 12.6 percent compared to 1996, according to the 2001 Census Report.

Figure 6 shows the study area of Keele Valley landfill. The houses symbolized by a star (* in red) indicate the houses sold during the study period. The property of Keele is about 376 hectares (929 acres) in size. It opened in the year 1983 and received more than 26 million tonnes as of Nov. 2001 (1,500,000 tons every year in recent years). It closed on Dec. 31, 2002. The residential district from which the housing sales were obtained for "Keele" site has a very similar development history as the "Britannia" area. The population in the City of Vaughan is about 182,000 in 2001 which has increased by 37 percent compared to 1996, according to Canada's 2001 Census Report.

Both cities are part of Greater Toronto Area (GTA) that is the most rapidly growing region in Canada in terms of population and economic performance. The cities of Mississauga and Vaughan have seen a rapid expansion in the past two decades in line with GTA growth. The houses selected for the study are distant from central business centre in Metro Toronto, ranging from 23 km to 28 km. Though this is far exceeding the median commuting distance in Toronto area, it is still within commuting distance from the business centre in Toronto.

There is a remarkable difference in the pattern of residential development between the two regions. As can be seen from the number of housing sales that were obtained in a 3-km boundary from the edges of the landfills (1139 from "Britannia", and 339 from "Keele"), the residential development in "Britannia" area has been much denser than "Keele." It can be presumed that housing development near "Keele" has been more deterred by the presence of an intimidating-looking large landfill.

3.2 Statement of Hypothesis

Residential property values are adversely affected by the presence of a landfill. However, the negative impacts of a landfill tend to decrease with distance from the landfill. So it is hypothesized that property values will increase, all other things held constant, as the properties are located farther from the landfill. There is a positive relationship between property value and the distance variable. Therefore, the partial regression coefficient of the distance variable in a regression model must be positive.

It is an unrealistic assumption, however, that the property value-distance relationship should remain unchanged for different landfill sizes or for different waste volumes being handled. It is, therefore, hypothesized that properties located near a large landfill ("Keele") site gain a higher premium on their values than the properties in a small landfill ("Britannia") do as they are removed away from the landfill.

The influence of landfill size on the property value-distance relationship can be captured by a dummy variable interactive model using a single-equation model. In this model, a dummy variables for LOCATION (*dichotomous*, 0 or 1) are included as independent variables; zero (0) represents "Britannia" landfill area, and one (1) represents "Keele" area. When LOCATION is assigned zero (0) dummy variable (in case of "Britannia" landfill), zero values are assigned to DIST-LF variable for "Keele" observations. In the same manner, when LOCATION is assigned one (1) dummy variable (in case of "Keele" landfill), zero values are assigned to DIST-LF variable for "Britannia" observations. In this way, the two estimations are permitted to be different on neighbourhood variables.

Dummy interactive terms are applied to all neighbourhood independent variables (lot size and other distance variables) as they appear to be distinctly different depending on location. For example, the average lot size of houses in Keele Valley landfill area is about 800 square feet larger than that of Britannia landfill area. Accessibility to highway in both study areas is different so as to create price discrepancy in housing market.

The dummy interactive term for DIST-LF is exemplified as below:

$Y = \beta_0 + \beta_1$ (LOCATION-DUMMY VARIABLE) + β_2 (DISTANCE FROM LANDFILL-"Britannia") + β_3 (DISTANCE FROM LANDFILL-"Keele") + ε.

However, the physical properties of a house are pooled for observations of both locations[71] so that the two estimations are constrained to have the same coefficients on those independent variables.

Therefore, the estimation equation for "Britannia" observations becomes as following:

$Y = \beta_0 + \beta_1$ (#ROOM) + β_2 (#PCS-BATHRM) + β_3 (#GARAGE) + β_4 (BSMTP) + β_5 (BSMTF) + β_6 (CAC) + β_7 (FIREPLACE) + β_8 (GARAGE TYPE) + β_9 (STYLE1) + β_{10} (STYLE2) + β_{11} (HOUSE TYPE) + β_{12} (RERUN) + β_{14} (LOTSIZE-"Britannia") + β_{16} (DIST-LF-"Britannia") + β_{18} (DIST-HWY-"Britannia") + β_{20} (DIST-CBD-"Britannia") + ε.

---

[71] Read page 71 for explanations.

The estimation equation for "Keele" observations is as following:

Y = β_0 + β_1 (#ROOM) + β_2 (#PCS-BATHRM) + β_3 (#GARAGE) + β_4 (BSMTP) + β_5 (BSMTF) + β_6 (CAC) + β_7 (FIREPLACE) + β_8 (GARAGE TYPE) + β_9 (STYLE1) + β_{10} (STYLE2) + β_{11} (HOUSE TYPE) + β_{12} (RERUN) + β_{13} (LOCATION) + β_{15} (LOTSIZE-"Keele") + β_{17} (DIST-LF-"Keele") + β_{19} (DIST-HWY-"Keele") + β_{21} (DIST-CBD-"Keele") + ε.

The null hypotheses to be tested for the relationship between DIST-LF variable and property value being positively linear for both observations, and for the coefficient of DIST-LF being influenced by the LOCATION dummy variable are established as following:

1) H_0: $\beta_{16} <= 0$ and $\beta_{17} <= 0$ (The relationship between DIST-LF variable and property value is negative or non-existent for both landfill sites);

2) H_0: $\beta_{16} = \beta_{17}$ (The distance-property value relationship is the same for both landfill sites).

3.3 The regression Model

The property prices in the model are hypothesized to be linearly related to 17 independent variables—twelve in the physical attribute category, and one dummy variable representing the differences in location between the two areas, and four neighbourhood characteristics (lot size and distance variables).

The empirical model developed for the analysis in this study is as below:

$Y = \beta_0 + \beta_1$ (#ROOM) + β_2 (#PCS-BATHRM) + β_3 (#GARAGE) + β_4 (BSMTP) + β_5 (BSMTF) + β_6 (CAC) + β_7 (FIREPLACE) + β_8 (GARAGE TYPE) + β_9 (STYLE1) + β_{10} (STYLE2) + β_{11} (HOUSE TYPE) + β_{12} (RERUN) + β_{13} (LOCATION) + β_{14} (LOTSIZE-"Britannia") + β_{15} (LOTSIZE-"Keele") + β_{16} (DIST-LF-"Britannia") + β_{17} (DIST-LF-"Keele") + β_{18} (DIST-HWY-"Britannia") + β_{19} (DIST-HWY-"Keele") + β_{20} (DIST-CBD-"Britannia") + β_{21} (DIST-CBD-"Keele") + ε

where

Y = the price of a house, in unit dollars, sold as reported in the MLS records, adjusted by NHPI[72];

#ROOM = the total number of rooms (inclusive of living room, family room, and the like.), as recorded in the MLS records;

[72] New Housing Price Index

#PCS-BTHRM = number of total pieces in bathrooms, as recorded in the MLS records;

#GARAGE = number of garage spaces available, as recorded in the MLS records;

BSMTP = the status of the basement of a house, as reported in MLS records, a dummy variable, 1, is used if a basement is partially finished;

BSMTF = the status of the basement of a house, as reported in MLS records, a dummy variable, 1, is used if a basement is fully finished;

CAC = Central Air Conditioning, as reported in MLS records, a dummy variable, 1, is used if present;

FIREPLACE = Fireplace, as reported in MLS records, a dummy variable, 1, is used if present;

GARAGE TYPE = a garage type, as recorded in the MLS Records, a dummy variable, 1, is used if garage is attached to a house;

STYLE1 = style of house, as reported in the MLS records, a dummy variable, 1 if the house is sidesplit, or backsplit, or 1 ½ storey;

STYLE2 = style of house, as reported in the MLS records, a dummy variable, 1, is used if the house is 2-storey or 2 ½ storey, 0 if not;

HOUSE TYPE = a house type, as reported in MLS records, a dummy variable, 1, is used if fully detached;

RERUN = a dummy variable, 1, is used if a house was rerun in 90 days;

LOCATION = a dummy variable, 1, is used if "Keele", 0 is used if "Britannia";

LOTSIZE = lot size in square feet, as reported in MLS records;

DIST-LF = the closest distance from an edge of the landfill to a house in meters, as measured by a geo-coding system;

DIST-HWY = the distance of a house from the closest highway junction, as measure in meters by a geo-coding system; and

DIST-CBD = the distance of a house from a central business district in Metro Toronto, as measured in meters by a geo-coding system;

ε = a random error

Three models are established and estimated sequentially in a way that the models aptly serve to explain both the division between "Keele" and "Britannia" markets, if any, and isolate the difference in the effects of the neighbourhood characteristics—lot size and distance from landfill—on the property value depending on locations denoted by the dummy variables.

The physical attributes are pooled in a regression equation (Model 1), assuming that the two areas are homogeneous in terms of house buyers' preferences for the specific physical attributes of houses. According to census profiles (compiled by the two cities based on 1991 and 1996 Census of Canada[73], Statistics Canada), age group composition is very similar. The age group, 25 to 44 years old, accounts for 38% in both areas. The median household income is $65,252 for the East Credit District and 61,777 for the Maple Community. These census data are consistent with the descriptive statistics (Table 1) that show there are no significant variances in the structural qualities of houses for both areas.

The LOCATION-independent variable is the dummy variable interaction term that influences the physical attributes and neighbourhood properties as well. In this model, it is

[73] The census data are for the East Credit District (in the City of Mississauga) and the Maple Community (in the City of Vaughan). 1996 data are for population in both areas and for income in East Credit District. The income data for Maple Community is based on 1991 Census Report.

assumed that the coefficients of the explanatory variables of physical attributes do not depend on LOCATION. The way in which the LOCATION variable influences them is through the y-intercept (Model 2). The value of the y-intercept for dummy variable, 1, becomes ($\beta_1 + \beta_{13}$) instead of β_1. The positive β_{13} indicates that the house in "Keele" that has properties identical to the house in "Britannia," in terms of physical attributes, is sold at a higher price than the equivalent house in "Britannia," due to locational factors.

The multiplicative interaction terms between the LOCATION dummy variable and all the physical attribute variables in the model will reveal that the partial regression coefficients for the physical attribute variables differ depending on locations[74]. However, the multiplicative interaction terms between the LOCATION variable and physical attribute variables are not included in the model due to high multicollinearity. The inclusion of multiplicative interaction terms did not improve the predictive power of the model in a significant way. Rather they introduced high multicollinearity in the model, which makes the individual coefficients insignificant.

In Model 3 and Model 4, neighbourhood characteristics (lot size and distance factors) are added to Model 2. Attention is given to examine if inclusion of neighbourhood properties to Model 2 may introduce multicollinearity. Instead of applying dummy variable interaction terms to all independent variables, only neighbourhood characteristics are estimated using a dummy variable interaction model. The complete segmentation of two locations has been given up for

[74] One single multiplicative model using a LOCATION dummy variable produces the same statistical results as the results from separate estimations for the two locations, as long as the dummy variable, 1, is dummied to all other independent variables.

the sake of selecting a parsimonious model. The separate estimations will be compared with the statistical results of pooled data.

There are twelve independent variables representing the physical attributes of a house. The number of rooms and the number of bathrooms are positive indicators of house quality and are hypothesized to be positively related to the price of property. The number of rooms includes the bedroom, living room, family room, study room, and the like. The total pieces in all bathrooms were used instead of the number of bathrooms because the former is likely to better represent the luxuries of each bathroom. Dummy variables for the basement count the differences between unfinished and part-finished and between unfinished and finished. As finished basement always adds a premium to the value of a house, ceteris paribus, the coefficient for a fully finished basement should be greater than that for a partially finished basement. Dummy variables for house style indicate the number of floors in the house. A higher number of floors generally means a larger size of living space. The coefficients for these dummy variables are hypothesized to be positive. The variable, rerun, is a proxy to indicate the general condition of a house. Other things being equal, a house with a better interior or one that is well maintained will sell in a shorter time than a house in poorer condition would take. The relationship of rerun is expected to be negative to property value.

There are five neighbourhood factors included in the model: a dummy variable for location, lot size, and three distance variables. A larger lot size will provide not only an extended area for living space but also an aesthetic value to the neighbourhood. Other things being equal, the lot size of a house is hypothesized to be positively related to the price of property. The locational convenience of a house is usually determined by the time taken to travel downtown, especially in a suburban location that is highly dependent on its larger urban centre. However, this is arguable. For those who have to commute downtown everyday, the distance and transportation availability (such as subway system, highway access, and time taken) will be critically important factors in home-purchase decision making. Those who want to escape a crowded urban centre to seek a quieter place will tend to prefer a house distant from highway access or public transportation points.

3.4 Data Source and Variable Measurement

The study area boundary was drawn in a 3 kilo meter from the edges of the landfill, using the city map. 1,471 single house sales records for both study areas (1,139 records for "Britannia" and 332 for "Keele") delineated as above were obtained for the periodJuly 01, 1987 to June 30, 1991 from the database of the Multiple Listing Service (MLS). All the variable information except distance measurements in the regression model was obtained from the MLS.

The impacts of negative externalities of a landfill that is planned to shut down in the near future can be significantly mitigated by expectations of positive future use of the landfill site. Most existing studies have found that the values of properties are least affected adversely after the landfill is closed (Havlicek et al., 1985; Gamble et al., 1984; Nelson et al., 1992). As the two landfills were already closed ("Britannia" in 2001, "Keele" on the last day of 2002), obtaining house sales that occurred many years ago such that the buyers and sellers of the houses acknowledged the presence of the landfill was necessary. The time period selected for the sales was July 01, 1987 to June 30, 1991.

The year 1989 and the early part of 1990 were the peak years in the real estate market in the past 20 years, except for the recent years' price resurgence. There were rising, peak, and falling trends in the four-year period in terms of house prices. The presence of multiple trends in housing prices necessitates that any effects associated with the vitality of the housing market on the variance in housing prices should be ruled out.

The New Housing Price Index (NHPI)[75] was used to remove the inflationary effect from property prices, a dependent variable. NHPI is a monthly series that measures changes over time in the contractors' selling prices of new residential houses, where detailed specifications pertaining to each house remain the same between two consecutive periods. The base period was 1992 (1992=100)[76].

The distance of a house from the landfill was measured by geo-coding the addresses of homes in the study area, using GIS software. Because the distance was not measured from the centre of the landfill, but from the edges of the landfill, measuring the shortest distance was the biggest concern. Each house was measured from a multitude of points along the edges of the landfill and the shortest distance among them was taken for the analysis.

In a similar way, distances from central business district (CBD) in Metro Toronto and from the closest highway junction were measured. The intersection of King St. and Bay St. was used as the reference point of the CBD. Highway 400 runs South to North at the west side of the "Keele" area, and Highway 401 and 403 runs East to West at the north and south of the "Britannia" area respectively.

[75] The information was obtained from Statistics Canada.
[76] For information, the index for 2002 is in the range of 120 to 124.

Chapter 4. Empirical Results

Least squares regression was applied to 1,471 sales of houses, using four alternative models. The descriptive statistics are reported in Table 1. Table 2 exhibits all the statistical results of three models. The estimated parameters plus statistical results specified in the model are reported in Table 3 (Model 1), Table 4 (Model 2), Table 5 (Model 3), and Table 6 (Model 4).

For Model 3 (Table 5), the presence of heteroscedasticity was tested by drawing residual plots for the three sets of data (all areas, Britannia, and Keele). The result indicated that there is no systematic pattern in the error variances, suggesting homogeneous variances in the random errors. The homogeneity of variances not only confirms that the least squares estimators of the model parameters are not biased, but also indicates that the two separate observations can be aggregated into one regression equation sharing the same random error. This means that the use of a dummy interaction variable term is possible in one single equation for aggregated data.

Table One presents the mean values of all individual independent variables plus a dependent variable. It is noted that most of the physical attributes are very similar between the two areas in terms of quantities expressed in mean values. There is a significant difference in mean values in lot size.

Table 1

Descriptive Statistics

Variables	All areas (N=1417)	Britannia (N=1139)	Keele (N=332)
Price (adjusted)	230,786(44303)	228,647(47845)	238,125(27876)
#ROOM	8.01(1.111)	8.15(1.101)	7.53(1.006)
#PCS-BATHRM	7.55(2.395)	7.69(2.430)	7.05(2.203)
#GARAGE	1.84(.464)	1.89(.403)	1.69(.606)
BSMTP	.11(.312)	.10(.298)	.15(.355)
BSMTF	.12(.324)	.10(.305)	.17(.378)
CAC	.52(.500)	.50(.500)	.58(.494)
FIREPLACE	.91(.284)	.93(.260)	.86(.349)
GARAGE TYPE	.97(.178)	.98(.155)	.94(.238)
STYLE1	.01(.100)	.00(.042)	.04(.194)
STYLE2	.96(.190)	.99(.089)	.86(.346)
HOUSE TYPE	1.00(.052)	1.00(.051)	1.00(.055)
RERUN	.58(.494)	.59(.492)	.55(.499)

LOCATION	.23(.418)	.00(.000)	1.00(.000)
LOTSIZE	5,068(1423)	4,892(1305)	5,674(1634)
DIST-LF	1,676(655)	1,724(688)	1,509(491)
DIST-HWY	2,342(904)	2,139(889)	3,040(529)
DIST-CBD	25,089(1591)	25,232(1734)	24,600(766)

- Numbers in parenthesis represent standard deviation.
- A dummy variable 1 was assigned to a detached house in House Type variable. Only four houses were not detached.

Table Two exhibits the statistical results of pooled data that were run under Model 1, Model 2, and Model 3. The addition of neighbourhood variables increased the coefficient of determination (R^2) from .477 to .602, without affecting the significance of the coefficients of physical attributes.

Table 2

Statistical Results of Three Models

Independent Variables	Model 1		Model 2		Model 3	
	Coefficients	Standard errors	Coefficients	Standard errors	Coefficients	Standard errors
Constant	35019	17916*	10676	17479	-23263	16399
#ROOM	18063	953***	19277	929***	16140	867***
#PCS-BATHRM	4907	381***	5065	369***	4071	339***
#GARAGE	4440	2377*	5372	2299**	3746	2088*
BSMTP	9566	2744***	8250	2655***	7557	2406***
BSMTF	4365	2798	4497	2704*	7082	2465***
CAC	19512	1725***	17821	1676***	13753	1545***
FIREPLACE	18263	3435***	16153	3326***	14837	3015***
GARAGE TYPE	-15604	5484***	-14876	5301***	-12366	4797***

STYLE1	-10600	9826	-11956	9497	-11226	8617
STYLE2	-35382	5636***	-24431	5552***	-4964	5996
HOUSE TYPE	29142	16293*	27402	15747*	14477	14287
RERUN	-3793	1710**	-3155	1654*	-4325	1498**
LOCATION			21137	2073***	54631	9115***
LOTSIZE-Britannia					12.141	.708***
LOTSIZE-Keele					3.296	1.238***
DIST-LF-Britannia					3.286	1.223***
DIST-LF-Keele					8.379	3.250***
DIST-HWY-Britannia						
DIST-HWY-Keele						
DIST-CBD-Britannia						
DIST-CBD-Keele						

# of Observation	1471	1471	1471
R^2	.477	.512	.602
R_a^2	.472	.507	.597
F-value	110.685***	117.377***	129.219***

* Significant at 10 % level

** Significant at 5 % level

*** Significant at 1 % level

Table Three displays the results of pooled data and of separate data under Model 1 that includes only physical attributes. No coefficients have different signs across pooled and separate data except for the GARAGE TYPE and House Type.

Table 3

Model 1, Regression Results

Independent Variables	All areas		Submarkets			
			Britannia		Keele	
	Coefficients	Standard errors	Coefficients	Standard errors	Coefficients	Standard errors
Constant	35019	17916*	-4973	24204	134709	23209***
#ROOM	18063	953***	19660	1096***	13034	1520***
#PCS-BATHRM	4907	381***	5693	436***	2300	571***
#GARAGE	4440	2377*	5239	2960*	7061	2767**
BSMTP	9566	2744***	11531	3347***	1754	3257
BSMTF	4365	2798	6774	3331**	3467	3849
CAC	19512	1725***	18566	2037***	13064	2392***
FIREPLACE	18263	3435***	20990	4362***	6810	3871*
GARAGE TYPE	-15604	5484***	-11587	7105	-11611	5854**
STYLE1	-10600	9826	-42855	26651	-2660	6852

STYLE2	-35382	5636***	-40672	12633***	-2491	5269
HOUSE TYPE	29142	16293*	42663	19312**	-21763	21509
RERUN	-3793	1710**	-2699	2007	-4294	2255*
# of Observation	1471		1139		332	
R^2	.477		.528		.488	
R_a^2	.472		.523		.469	
F-value	110.685***		105.163***		25.368***	

* Significant at 10 % level

** Significant at 5 % level

*** Significant at 1 % level

Table Four displays the results of pooled data and of separate data under Model 2 that added the LOCATION variable to Model 1. The addition of LOCATION dummy variable identified that there is a distinction between the two areas, but resulted in little impacts in the coefficients of the existing independent variables.

Table 4

Model 2, Regression Results

			Submarkets			
Independent	All areas		Britannia		Keele	
Variables		Standard		Standard		Standard
	Coefficients	errors	Coefficients	errors	Coefficients	errors
Constant	10676	17479				
#ROOM	19277	929***				
#PCS-BATHRM	5065	369***				
#GARAGE	5372	2299**				
BSMTP	8250	2655***				
BSMTF	4497	2704*				
CAC	17821	1676***				
FIREPLACE	16153	3326***				
GARAGE TYPE	-14876	5301***				

STYLE1	-11956	9497
STYLE2	-24431	5552***
HOUSE TYPE	27402	15747*
RERUN	-3155	1654*
LOCATION	21137	2073***
# of Observation	1471	
R^2	.512	
R_a^2	.507	
F-value	117.377***	

* Significant at 10 % level

** Significant at 5 % level

*** Significant at 1 % level

Table Five displays the results of pooled data and of separate data under Model 3 which added Lot Size and DIST-LF variables to Model 2. The two hypotheses of this study are tested with the results of Model 3.

Table 5

Model 3, Regression Results

Independent Variables	All areas		Submarkets: Britannia		Submarkets: Keele	
	Coefficients	Standard errors	Coefficients	Standard errors	Coefficients	Standard errors
Constant	-23263	16399	-12176	22144	71221	25024***
#ROOM	16140	867***	16461	1020***	12539	1511***
#PCS-BATHRM	4071	339***	4483	403***	2450	544***
#GARAGE	3746	2088*	2515	2697	4845	2667*
BSMTP	7557	2406***	9606	3041***	3159	3115
BSMTF	7082	2465***	8796	3024***	6314	3735*
CAC	13753	1545***	14291	1868***	11467	2382***
FIREPLACE	14837	3015***	17709	3961***	7801	3717**
GARAGE TYPE	-12366	4797***	-11013	6445*	-9624	5591*

STYLE1	-11226	8617	-26188	24194	-6425	6552
STYLE2	-4964	5996	-30494	11486***	17626	6309***
HOUSE TYPE	14477	14287	22897	17590	-8950	20657
RERUN	-4325	1498**	-4338	1823**	-3819	2148*
LOCATION	54631	9115***				
LOTSIZE-Britannia	12.141	.708***	11.647	.770***		
LOTSIZE-Keele	3.296	1.238***			5.116	.963***
DIST-LF-Britannia	3.286	1.223***	3.406	1.306***		
DIST-LF-Keele	8.379	3.250***			5.000	2.493**
# of Observation	1471		1139		332	
R^2	.602		.613		.540	
R_a^2	.597		.608		.519	
F-value	129.219***		127.105***		26.537***	

* Significant at 10 % level

** Significant at 5 % level

*** Significant at 1 % level

Table Six displays the results of pooled data and of separate data under Model 4 which added DIST-HWY and DIST-CBD variables to Model 3. Due to high multicollinearity introduced by the addition, Model 4 did not generate statistically significant results.

Table 6

Model 4, Regression Results

Independent Variables	All areas		Submarkets			
			Britannia		Keele	
	Coefficients	Stadandard errors	Coefficients	Standard errors	Coefficients	Standard errors
Constant	-152833	26671***	-147171	31359***	953611	184836***
#ROOM	15992	855***	16265	1001***	11604	1479***
#PCS-BATHRM	3935	335***	4316	396***	2551	528***
#GARAGE	3475	2064*	2034	2655	4584	2594*
BSMTP	7274	2376***	9224	2986***	5035	3078
BSMTF	7448	2442***	9285	2970***	8285	3712**
CAC	12377	1542***	12543	1860***	12156	2310***
FIREPLACE	15043	2984***	18189	3906***	10481	3642***
GARAGE TYPE	-11346	4737**	-9260	6339	-8023	5443

STYLE1	-11439	8493	-28333	23759	-7641	6347
STYLE2	-4808	6038	-30672	11273***	22263	6230***
HOUSE TYPE	17037	14090	25146	17270	-15733	20128
RERUN	-4544	1477***	-4567	1790**	-3399	2087
LOCATION	N/A					
LOTSIZE-Britannia	11.084	.731***	10.600	.790***		
LOTSIZE-Keele	3.624	1.212***			4.280	.956***
DIST-LF-Britannia	5.831	1.876***	6.422	1.999***		
DIST-LF-Keele	15.409	3.198***			-27.354	7.182***
DIST-HWY-Britannia	-8.713	1.633***	-8.649	1.736***		
DIST-HWY-Keele	7.094	2.873**			-30.010	6.289***
DIST-CBD-Britannia	5.892	.876***	6.102	.936***		
DIST-CBD-Keele	6.087	.830***			-29.773	6.217***

# of Observation	1471	1139	332
R^2	.614	.628	.572
R_a^2	.609	.622	.550
F-value	115.554***	118.267***	26.275***

* Significant at 10 % level

** Significant at 5 % level

*** Significant at 1 % level

4.1 Interpretation of Regression Results

Model 1 (Table 3) was estimated under the assumption that the two study areas are to a great extent parts of a homogeneous market. The relationship signs for most of the independent variables (such as the number of rooms, the number of total pieces in bathroom, basement condition, central air conditioning, and fireplace) were as hypothesized except for GARAGE TYPE, STYLE 1, and STYLE 2.

The studies of Havlicek(1985) and Nelson(1992), however, produced a negative sign for bedroom variable. Hite et al. (2001) study also generated a negative sign for a bedroom variable at two sites out of the four study areas. Havlicek (1985) explained this as a result of a reduced living quality service caused by smaller rooms that are inversely related with the number of bedrooms. A more persuasive answer could be that demands for houses with greater number of bedroom had weakened in rural areas (possibly as a result of population migration into urban centres). The signs of the coefficients of variables such as bathroom, fireplace, and central air conditioning were found to be the same as those found by these studies.

The negative sign of GARAGE TYPE means that a house with an attached garage is less valued than a house with a detached garage, when all other things are held constant. There are 48 observations with a garage other than the attached type. Many of them were specified as "Other." This is a measurement error and interpretation is not appropriate. Most of the houses in the study areas were of the 2-storey style with about 10 percent bungalow style in Keele, and less than 1 %

are bungalow in Britannia. The negative sign means that the bungalow houses in theses areas are valued higher than 2-storey houses, other thing being equal. The information with respect to HOUSE TYPE is hardly meaningful as there is only one house in Keele and three in Britannia that are not detached. The RERUN proxy variable has a negative relationship with property value—that is, houses that had not been sold within 90 days after the first listing were sold at lower prices than the houses sold within 90 days, other thins being equal.

All the linear relationship signs across markets show consistent directions except HOUSE TYPE. The calculation of variation inflation factors (VIF) for the coefficients of individual variables indicated little multicolliearity among physical attribute variables.

Model 2 (Table 4) adds the LOCATION dummy variable to Model 1 to test if there exists a constant difference in the relationship between the property value and a set of variables representing physical attributes of houses depending on location, assuming that the partial regression coefficients of the physical attributes do not depend on locations. When all other things being equal, house value in Keele is higher by $21,137 than the identical house in Britannia, in terms of the physical attributes specified in the model. An F-test[77] for comparing nested models—the ratio of a reduction in the sum of squared errors (from the reduced model to the complete model) to the mean square error for the complete model—indicated that the LOCATION independent variable helped improve the predictive power of the model significantly. The usefulness of the LOCATION dummy variable in Model 2 is that it introduces the dummy interactive model to Model 3 and Model 4.

[77] F-value calculated was 104.

As were confirmed by the studies of Butler (1982), Atkinson & Crocker (1987), and Graves et al. (1981), the addition of LOCATION variable did not present any significant specification bias to the coefficients of physical variables. The study of Havlicek et al. (1985) showed differences in the estimated coefficients of dummy variables among the five sites, but structural variables were unaffected.

The signs of the coefficients of LOTSIZE and DIST-LF produced in Model 3 (Table5) are found to be as hypothesized. They are also significant at 1 percent level. The denser development pattern in Britannia area is consistent with the result of having a higher coefficient ($12.141) which is greater by $8.845 than the LOTSIZE coefficient in Keele area ($3.296). This means that, when all other things held equal, the value of land in terms of square feet is lower by $8.845 in Keele area than in Britannia area.

As hypothesized, the coefficient of DIST-LF for houses in Keele is found to be greater than that in Britannia by $5.093 per one meter. This means that, when all other things held constant, the value of house that is located in one mile from Keele landfill is higher by approximately $8,000 than the identical house one mile from Britannia landfill. It is interesting to note that the size of coefficient of DIST-LF variable found in this study, C$3.286 (for Britannia; equivalent to approximately U$2.12 at current exchange rate) per one meter, is a quite close figure to those obtained by other studies. They were found to be U$1.8 per meter in Havlicek et al. (1985) and U$3 per meter in Nelson et al. (1992).

In Model 3 (Table 5) the hypothesis of this study—the distance variable is positively related to property value, and the coefficients of distance variables depend on the dummy variable values—can be tested. The null hypotheses are expressed as below:

1) H_0: β_{16} (for DIST-LF-Britannia) < = 0 and β_{17} (DIST –LF-Keele) < = 0; and
2) H_0: $\beta_{16} = \beta_{17}$.

The significance of the two distance independent variables being positively related to the property values can be tested by a one-tailed t-test. All the values of distance coefficients are significant at 1 percent level except the one in the estimation of Keele data only. It is significant at 5 percent level. Therefore, the null hypothesis that β_{16} and β_{17} are not positively related to property value is rejected at 5 percent significance level. The house values in Britannia increases by $3.286 for every meter removed from the landfill, when all other things are equal. The distance premium in Keele is much higher than that in Britannia. Houses in Keele gain a premium of $8.379 for every meter from the landfill. This result is consistent with the hypothesis that the residents near a large-size landfill are willing to pay more for the reduction of disamenities (of the landfill), measured in distance from the landfill, than the residents near a small landfill because disamenities of a large landfill are greater than that of a small landfill.

The second hypothesis to be tested is that the dummy LOCATION interaction effect on the distance-property value relationship is significant such that β_{16} does not equal β_{17}. The null hypothesis that the two are equal in size can be checked by the F-test. For the test purpose, the two separate distance terms are combined into one distance independent variable, which will serve as the reduced model[78]. The F-test (F-value: 3.65) indicates that the null hypothesis is rejected at the 10 percent significance level. The result implies that the separation of distance variable into two separate independent variables (applying the LOCATION dummy variable to a distance variable) contributes to the model at a ten percent significance level.

Model 4[79] (Table 6) added extra neighbourhood independent variables such as "distance to downtown" and "distance to highway" to Model 3. Though their coefficients appear very significant (the estimation of them were unbiased), the VIF values are far greater than 10 for DIST-CBD-Britannia, DIST-CBD-Keele, and DIST-HWY-Keele due to their high multicollinearity. The interpretation of the statistical results is meaningless, as their regression coefficients will vary greatly from sample to sample. The LOCATION variable was excluded by the inclusion of the highly correlated neighbourhood independent variables. The addition of DIST-CBD variables in Model 3 without DIST-HWY variables made the coefficient of DIST-LF-Keele become an insignificant parameter because there is a high correlation between the two variables. The DIST-CBD-Keele variable was also found to be insignificant due to the inflated standard error. There is a very consistent pattern observed that a larger distance from the Keel landfill means a smaller distance to the CBD. This means that the effect of DIST-LF variable change cannot be observed when DIST-CBD is held constant, suggesting that the regression coefficient of DIST-LF can not be interpreted as a marginal effect.

Since the purpose of this study is to investigate the effects of key independent variables on property values, the explanatory power of the regression is more important than the power of

[78] The F-test method was obtained from a monograph by Berry and Feldman (1985, p.67).
[79] Model 4 is provided for explanation purpose only. Model 3 is the final regression for this study.

prediction (Berry and Feldman, 1985, p.41). Therefore, the DIST-CBD and DIST-HWY independent variables were dropped from the regression equation.

4.2 Summary

As have been reviewed earlier, the physical attributes of a house have remained least affected by the specification. The partial regression coefficients of the attributes are relatively stable indicators of their implicit prices. However, the neighbourhood variables have shown a high collinearity with each other, especially for the observations in the Keele area (such as DIS-LF-Keele and DIST-CBD-Keele, DIST-LF-Keele and DIST-HWY-Keele). Therefore, these variables were also highly correlated with the LOCATION factor.

As shown in the results of Model 4, the LOCATION factor has been excluded due to its extremely high collinearity with distance variables. This is an evident indication that the LOCATION factor is a good proxy variable for neighbourhood attributes that were included in the model (distance variables in this study). To deal with the multicollinearity problem, the DIST-CBD and DIST-HWY variables were dropped from the analysis until more relevant neighbourhood variable, but not highly correlated with each other, that can explain the difference embodied in LOCATION factor are found for inclusion.

To supplement this study, the following three suggestions are made.

First, there is a possibility that those neighbourhood variables that are not included in the analysis, and are highly relevant factors in determining property values in these areas, can affect the results of this study. Inclusion of a larger number of relevant neighbourhood variables would allow the model to identify the direction of their impacts.

Second, the number of sales records in Keele area was relatively small. Expanding the study period would increase the number of observations, which would enhance the statistical significance for Keele data.

Third, it is necessary that as many landfills of different sizes as possible be applied to this comparative analysis to verify that the findings in this study are consistent from sample to sample.

Chapter 5. Conclusion

The empirical study results have shown that the partial regression coefficients for the "distance from landfill" independent variable vary depending on a landfill size (or the volume of waste a landfill handles per day). This suggests that people perceive the nuisances or disamenities from a large landfill as being far greater than those from a small landfill. The variation between the negative impacts of a large and a small landfill is based on the impacts reflected in property values only. If a large landfill inhibits the development of a host community in a far more prohibitive fashion than a small landfill, in terms of reducing the growth of residences or commercial centres, the negative impacts of a large landfill must be much greater than the result of this study indicates.

The implication of a greater impact of a large landfill on property values is that a smaller landfill is less costly in terms of total social costs associated with waste disposal, suggesting that the economic advantages a large landfill possesses over a small landfill should be diminished. The study result is consistent with the waste management principle, unanimously adopted by waste authorities at various levels for a long time, that reducing, reusing, and recycling wastes is preferred because small landfills will without a doubt contribute to reducing the quantity of waste being disposed of at landfills, as reviewed in the Introduction.

The author argues that the negative costs of a landfill, evaluated by the property value impact study, capture only a certain portion of the total external costs of a landfill. The accurate and complete estimation of the external costs of a landfill does not appear possible at the present moment. However, it is hoped that the results of this study will be taken into account when costs are estimated to choose the optimal landfill size. One may argue that a larger landfill is always better in areas where no residential development is present because the landfill will bring in tipping fee revenues to that host community. Given that a large-scale landfill will be operational for a longer period, the result of this study suggests that residential development can be hindered more significantly by a large landfill area than a small landfill.

References

Anderson et al. (2002). The Impact of Waste Industry Consolidation on Recycling. *MSW Management*. Elements 2002, Vol. 11, No. 4. 46–49.

Atkinson, S. E. and Crocker, T. D. (1987). A Bayesian Approach to Assessing the Robustness of Hedonic Property Value Studies. *Journal of Applied Econometrics 1,* 27-45.

Becker, G. S. and Michael, R. T. (1973). On The Theory Of Consumer Behaviour. *Swedish Journal of Economics 75,* 378-396.

Bellingham, A. (1971). *Solid Waste Management - A Regional Approach.* Toronto: York University.

Berry, W. D. and Feldman, Stanley., (1985). *Multiple regression in practice*. Beverly Hills: Sage Publications.

Butler, R. (1982). *The Specification of Hedonic Indexes for Urban Housing.* Land Economics Vol.58, No.1, *96-108.*

Chandler, W. U. (1983). *Materials Recycling: The Virtue of Necessity.* Worldwatch Paper 56. Worldwatch Institute.

Chatterjee, Samprit., Price, Bertram. (1991). *Regression Analysis by Example*. New York, Wiley, p. 173.

Cropper, Maureen L., Deck, Leland B., and McConnell Kenneth E. (1988). On the Choice of Functional Form for Hedonic Price Functions. *The Review of Economics and Statistics, Vol. 70, Issue 4,* 668-675.

Dooley, F., Bangsund, D., Leistritz, F. & Fischer, W. (1993). *Estimating Optimal Landfill Sizes and Locations in North Dakoda.*. Department of Agricultural Economics, North Dakoda State University, Fargo, North Dakoda, U.S.A.

Eighmy, T. T. and Kosson, D. S. (1996). U.S.A. National Overview On Waste Management. *Waste Management , Vol. 16, Nos 5/6*, 361-366.

El-Fadel, M., Findikakis, A. N., and Leckie, J. O. (1997). Environmental Impacts of Solid Waste Landfilling. *Journal of Environmental Management, 50*, 1-25.

Eyles, N., Boyce, J. I. and Hibbert, J. W. (1992). The Geology of Garbage in Southern Ontario. *Geoscience Canada, Vol. 19, No. 2*, 50-62.

Freeman, A. M. (1993). *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, D.C.: Resources for the Future (367-420).

Gamble, H. B., Downing, R. H., Shortle, J. S., and Epp, D. J. (1982). *Effects of Solid Waste Disposal Sites on Community Development and Residential Property Values*. Final Report for

The Bureau of Solid Waste Management Department of Environmental Resources Commonwealth of Pennsylvania.

Gerrad, M. B.(1994). *Whose Backyard, Whose Risk: Fear and Fairness in Toxic and Nuclear Waste Siting,* London, The MIT Press, p22-23.

Glebs, Robert T. (1988). Landfill costs continue to rise. *Waste Age, March*, 84-93.

Graves, P., Murdoch, J. C., Thayer, M. A., and Waldman, D. (1988). The Robustness of Hedonic Price Estimation: Urban Air Quality. *Land Economics Vol. 64, No. 3,* 220-232.

Harrison, D., Jr. and Rubinfeld, D. L. (1978). Hedonic Housing Prices and the Demand for Clean Air. *Journal of Environmental Economics and Management 5*, 81-102.

Havlicek, J., Richardson, R., and Davies, L. (1985). Impacts of Solid Waste Disposal Sites on Property Values. In G. S. Tolley, J. Havlicek, Jr., and R. Favian (Ed.), Environmental Policy: *Solid Waste, Vol. IV* (pp. 157 – 166). Cambridge, MA: Ballinger.

Highfill, J. and McAsey, M. (1997). Municipal Waste Management: Recycling and Landfill Space Constraints. *Journal of Urban Economics 46*, 118-136.

Highfill, J. and McAsey, M. (2001). Landfilling Versus “Backstop” Recycling when Income Is Growing. *Environmental and Resource Economics 19*, 37-52.

Hirshfeld, S., Vesilind, P. A., and Pas, E. I. (1992). Assessing the true cost of landfills. *Waste Management & Research, 10*, 471-484.

Hite, D., Chern, W., Hitzusen, F., and Randall, A. (2001). Property-Value Impacts of an Environmental Disamenity: The Case of Landfills. *Journal of Real Estate Finance and Economics, 22:2/3,* 185-202.

Howard, Ken W. F., Eyles, N., and Livingstone, S. (1992). Municipal Landfill Practice and its Impacts on Groundwater Resources In and Around Urban Toronto, Canada. *Hydrogeology Journal, V.4, no. 1*, 64-79.

Hwang, E. G. and Rudzitis, G. (1977-78). The External Costs of Sanitary Landfills. *J. Environmental Sytems, Vol 7(4),* 301-308.

Jenkins, Robin R. (1993) *The Economics of Solid Waste Reduction*. Brookfield, Vermont: Edward Elgar Publishing.

Kain, J. F. and Quigley, J. M. (1970). Measuring & Value of Housing Quality. *Journal of the American Statistical Association 65 (June),* 532-548.

King, T. A. (1976). The Demand for Housing : Integrating the Roles of Journey-to-Work, Neighborhood Quality, and Prices. In Nestor E. Terleckyj (Ed.), *Household production and consumption*. New York : National Bureau of Economic Research.

Lancaster, Kelvin J. (1966). A New Approach to Consumer Theory. *The Journal of Political Economy, Vol. 74, Issue 2,* 132–157.

Li, M. M. and Brown, H. J. (1980). Micro-Neighbourhood Externalities and Hedonic Housing Prices. *Land Economic, Vol. 56, No. 2*, 125-141.

McDougall, F. R. (2001). *Life Cycle Inventory Tools: Supporting the Development of Sustainable Solid Waste Management Systems*. Corporate Environmental Strategy, Vol. 8, No. 2, 142-147.

Maler, Karl-Goran. (1977). A Note on the Use of Property Values in Estimating Marginal Willingness to pay for Environmental Quality. *Journal of Environmental Economics and Management 4,* 355-369.

Nelson, A., Gebereaux, J. and Genereaux, M. (1992). Price effects of landfills on house values. *Land economics, 68(4),* 359-365.

Nelson, J. P. (1978). Residential Choice, Hedonic Prices, and the Demand for Urban Air Quality. *Journal of Urban Economics 5*, 357-369.

O'Hare, M., Baron, L., and Sanderson, D. (1984). *Facility Siting and Public Opposition*. New York: Van Nostrand Reinhold Co.

O'Leary, P., Walsh, P. (2002) Landfilling as the cornerstone of an integrated waste system. *Waste Age, Vol. 33, Issue 1*. 38-46.

Ontario. Fiscal Planning and Economic Analysis Branch. (1993) *A Socio-economic assessment of Ontario waste management initiatives* : report / prepared for the Ontario Ministry of the Environment, Fiscal Planning and Economic Analysis Branch ; report prepared by VHB Research and Consulting Inc. in association with Econometrics Research Limited. Toronto: The Branch.

Ontario Ministry of The Environment. (1991). *Waste Disposal Site Inventory.* Queen's Printer for Ontario.

Price, Joe R. (1988). The Impact of Waste Facilities On Real Estate Values. *Waste Management & Research 6(4), 393-400.*

Price, J. L. and Joseph, J. B. (2000). Demand Management – A Basis for Waste Policy: A Critical Review of The Applicability of The Waste Hierarchy In Terms Of Achieving Sustainable Waste Management. *Sustainable Development 8,* 96-105.

Renkow, Mitch & Keeler, Andrew G. (1996). Determining the Optimal Landfill Size: Is Bigger Always Better? *Journal of Environmental Management, 36,* 67-75

Research and Planning Consultants, Inc. (1983). *Effects of Sanitary Landfills On The Value of Residential Property.* Austin, TX.: Planning Research Associates, Inc.

Ridker, R. G. and Henning, J. A. (1967). The Determinants of Residential Property Values With Special Reference To Air Pollution. *Review of Economics and Statistics, 49,* 246-256.

Rosen, Sherwin, (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy, 82,* 34 –55.

Sakai, S., Sawell, S. E., Chandler, A. J., Eighmy, T. T., Kosson, D. S., Vehlow, J., van der Sloot, H. A., et al., (1996). World Trends in Municipal Solid Waste Management. *Waste Management , Vol. 16, Nos 5/6,* 341-350.

Sawell, S. E., Hetherington, S. A., and Chandler, A. J. (1996). An Overview of Municipal Solid Waste Management in Canada. *Waste Management , Vol. 16, Nos 5/6,* 351-359.

Schmalensee, R., Ramanathan, R., Ramm, W., and Smallwood, D. (1975). *Measuring External Effects of Solid Waste Management.* Prepared for Office of Research and Development U. S. EPA Washington, D. C. (EPA-600/5-75-010).

Schroeder, L. D., Sjoquist, D. L., and Stephan, P. E., (1986). *Understanding regression analysis : an introductory guide.* Beverly Hills : Sage Publications.

Statistics Canada. (n.d.) *Population and Dwelling Counts, for Canada, Census Metropolitan Areas, Census Agglomerations and Census Subdivisions (Municipalities), 2001 and 1996 Censuses.* Retrieved Jan. 03, 2003, from http://www12.statcan.ca/english/census01/products/standard/popdwell/Table-CMA-C.cfm?CMA=535

Straszheim, M. (1974). Hedonic Estimation of Housing Market Prices: A Further Comment. *Review of Economics and Statistics, 56*, 404-405.

U. S. Environmental Protection Agency (n.d.). *Municipal Solid Waste*. Retrieved on Aug. 17, 2002, from http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm.

Walsh, James. (1990a). Sanitary Landfill Costs, Estimated. *Waste Age, March*, 50-54.

Walsh, James. (1990b). More On Sanitary Landfill Costs. *Waste Age, April,* 289-292.

Young, P. J. and Heasman, L. A., (1985). An assessment of the odor and toxicity of the trace components of landfill gas. In Landfill Gas, *Proceedings of the 8th International Landfill Gas Symposium,* GRCDA, San Antonio, Texas, pp23.

Young, P. and Parker, A. (1984). Origin and control of landfill odors. SCI London, *Chem. Ind. London, 9*, 329-334.

Zeiss, C. (1984). *The Financial and Social Costs of Waste Disposal.* M.Sc Thesis, School of Community and Regional Planning, University of B.C., Vancouver.