RESEARCH REPORT

COSTING MECHANISM TO FACILITATE SUSTAINABLE COMMUNITY PLANNING

PHASE 1 - BACKGROUND RESEARCH AND COSTING FRAMEWORK

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COSTING MECHANISM TO FACILITATE SUSTAINABLE COMMUNITY PLANNING

PHASE 1 – BACKGROUND RESEARCH AND COSTING FRAMEWORK

May, 2005

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

J:\0235\10.0 Reports\Final Report\CHMC Costing Model-Phase1-Final-May 2005.doc

RESEARCH HIGHLIGHT

September 2005 Socio-economic Series 05-023

COSTING MECHANISM TO FACILITATE SUSTAINABLE COMMUNITY PLANNING—

BACKGROUND RESEARCH AND COSTING FRAMEWORK

INTRODUCTION

There has been much debate in recent years about the costs of development, both in terms of the true costs of different development forms as well how the costs of development are shared between the various public and private sectors. There is mounting evidence that more compact, mixed use development is a more cost-efficient and environmentally sustainable form of development than low density suburban development. However, there are very few readily available tools to demonstrate the degree to which this is true, or to effectively compare different types of development.

As documented in this report, there is also a lack of data to develop a full picture of neighbourhood development costs and revenues, specifically costs related to green infrastructure items, which are now gaining prominence in the development industry.

OBJECTIVES

The ultimate intent of this project is to develop a tool that is available to anyone wanting to explore the costs of sustainable community development.

This project is being undertaken in two Phases. The purpose of Phase 1, which is the subject of this report, was to conduct background research on the key costs for development, in particular those that can be influenced by sustainable community planning. The Phase 1 component of this project also conducted a review of available tools for sustainable community planning, and based on this research, it outlined a framework for the development of a costing tool.

Phase 2 of the project will involve the development of the costing tool itself. Phase 2 will also involve extensive testing and validation of the costing tool and underlying costing assumptions.

The purpose of this Phase 1 report is to provide interim findings on the project, specifically the results of the background research and recommendations for development of a costing tool. ***Although the report also includes some preliminary costing results, these are intended to simply inform the development of the costing tool, as opposed to providing definitive answers on the costs of various development scenarios. All costing results should therefore be considered preliminary and for discussion purposes only.***

RESEARCH APPROACH

In addition to the literature review of community planning cost/revenue indicators and available costing models, the Phase 1 research also involved an extensive effort to collect representative values for key cost components. In most cases, these costs were drawn from available sources for representative cities across Canada. The intent was to establish the range of potential costs and how they vary by development form, as the basis for developing a preliminary model.

The Phase 1 research also developed six representative scenarios for the purposes of guiding and testing the costing framework. These scenarios embody a wide range of contrasting locational and neighbourhood design characteristics.

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The final step was to develop preliminary costs and revenues for each of these scenarios in order to explore the sensitivities of these costs and revenues to differing community planning parameters.

FINDINGS

Factors Affecting Community Development Costs and Revenues

As documented in this report, numerous studies have been carried out in an attempt to identify and quantify factors that influence the "cost" of development. One of the challenges in interpreting the results of these studies is that the conclusions often differ by the scale of analyses (neighbourhood vs. urban area), the type of study (retrospective or revealed results vs. simulated projections), the range of costs considered (hard infrastructure vs. total costs), the time period for analyses (initial development costs vs. lifecycle costs) and finally assumptions about who bears the costs (private developers, municipalities or the public).

Despite these differences in approaches, there are some common conclusions about the key factors influencing the cost of development. Almost exclusively, development density emerges as the main influence on the cost of urban growth. This is not surprising as most municipal infrastructure is linear (e.g. roads, water, sewers, transit) and the more densely developed communities are, the more people, employees, etc. can use a particular piece of infrastructure. On the other hand, there are many other municipal costs such as fire, police, schools and water/wastewater treatment facilities that are more directly proportional to population as opposed to density of development.

Another key determinant of the costs for new development is distance from existing infrastructure, and related to that, excess capacity within existing infrastructure to accommodate growth. It is generally more cost efficient to locate new development adjacent to existing plants, roads, etc. to minimize the cost of new infrastructure. Research has also shown that location within an urban area is also a significant determinant of user costs such as transportation costs, which are often underestimated or excluded in comparing development scenarios[1].

Scope or Costs and Revenues

A comprehensive literature review was undertaken to identify the key categories that should be considered in order to fully account for sustainable development costs. Based on this review, a full range of cost categories was identified for consideration in the costing tool. These can generally be grouped into four major categories:

- Hard Infrastructure, including: road, sewers, stormwater facilities, schools and recreation centres;
- Municipal Services, including: transit services, school transit, fire services, police services and waste management services;
- Private User Costs, including driving costs and home heating costs;
- External Costs, including: air pollution, climate change, motor vehicle collisions.

Most of the studies reviewed in the literature did not consider the costs and benefits of non-traditional or green infrastructure alternatives; however, these costs were considered to be of interest for this particular project. Green infrastructure alternatives considered in the initial costing framework included: bike lanes/paths, district heating/cooling systems, traffic calming, pervious pavement, solar orientation, distributed power generation, xeriscape landscaping, alternative road standards. Although these features were researched, their actual costs will not be quantified explicitly in the background research for the costing model due to the fact that the costs vary significantly by individual neighbourhood circumstances, degree of implementation, etc. For example, traffic calming options may range from simple speed humps to elaborate measures such as traffic circles and curb extensions. To accommodate these differences, it is recommended that the costing tool will provide some basic information on each measure and a range of potential costs.

Revenues from development were also quantified and included in the initial costing framework. The main revenues include property taxes and development charges. User fees such as water usage and transit fares were also considered and netted out from municipal operating costs. In the actual costing tool, it is recommended that user costs be detailed.

1 See for example, *Greenhouse Gas Emissions from Urban Travel, A Tool for Evaluating Neighbourhood Sustainability*, Canadian Mortgage and Housing Corporation, 2000.

Availability of Costing Tools

As part of the Phase 1 project, the range of tools potentially available and their key advantages and disadvantages were documented. Tools or models reviewed included:

- Greenhouse Gas Emissions from Urban Travel: Tool for Evaluating Neighbourhood Sustainability
- SCALDS Model
- STEAM 2.0
- QUEST Model
- PLACES3
- Sierra Club Density Calculator
- SFLCV - This View of Density
- City Green
- Infra-Cycle

The review of existing models/tools indicates that there is no readily available model that meets all of the objectives of this study. The majority of studies, models and tools reviewed are focused on regional-level development decisions and are not applicable at the community or neighbourhood levels. The review also identified models that address specific elements of community planning/development, but cannot be extended to a more comprehensive costing approach. However, there are components of existing tools and reports that can be used as building blocks in the development of a new comprehensive tool. Specifically, the CMHC Tool for Evaluating Neighbourhood Sustainability, while not a costing tool per se, can provide useful input on the scenario development and establishment of relationships between urban form and performance measures such as vehicle use. The two reports conducted for CMHC in 1997 on conventional and alternative development patterns also provide a benchmark for the development of costs and revenues.

Directions for a New Costing Tool

One of the key findings of the Phase 1 project is that quantifying the costs and benefits of sustainable community development is not a straightforward exercise. Many challenges exist in identifying what costs and revenues are to be included. For example, if the costs of schools are included in the development costs, these tend to over-shadow other costs. The range of potential costs found in the literature for specific items such as water treatment facilities and storm water management facilities also varies due to both differences in operating practices and potentially the way costs and revenues are reported. Finally, the issue of "who pays" is one that is conceptually challenging. For example, a developer may pay for the initial construction cost of a street, but the municipality would pay for on-going maintenance and replacement.

Another key consideration in the estimation of development costs is the amount of residual capacity that is available for use by new development. Where there is residual capacity in the transportation, water/waste water or even educational facilities, for example in a brownfield area, this may lower the actual costs of development.

For all of the above reasons, it is considered important to have a costing tool that is flexible and can be tailored to a specific community or development scenario. Individual users may also be interested in different aspects of sustainable community planning costs or revenues.

Representative Scenarios and Preliminary Costs

In the Phase 1 work, a total of six distinct scenarios were developed to inform the costing framework and to present the range of potential costs and revenues from different development types. These scenarios were based on different combinations of neighbourhood characteristics and location within the urban area and included the following:

- A **High Density** Mixed Use Neighbourhood in the **Inner Area**
- A **Medium Density** Neighbourhood in the **Inner Area**
- A **Medium Density** Neighbourhood in **Inner Suburbs**
- A **Low Density** neighbourhood in **Inner Suburbs**
- A **Medium Density** Neighbourhood in **Outer Suburbs**
- A **Low Density** neighbourhood in **Outer Suburbs**

For the purpose of testing initial scenarios, all socio-economic variables (e.g. average household size, number of children and average incomes) were held constant. This was intentionally done so as not to bias the costs for any particular location or type of housing. In the actual model to be developed in Phase 2, users will have the option of varying socio-economic values by scenario.

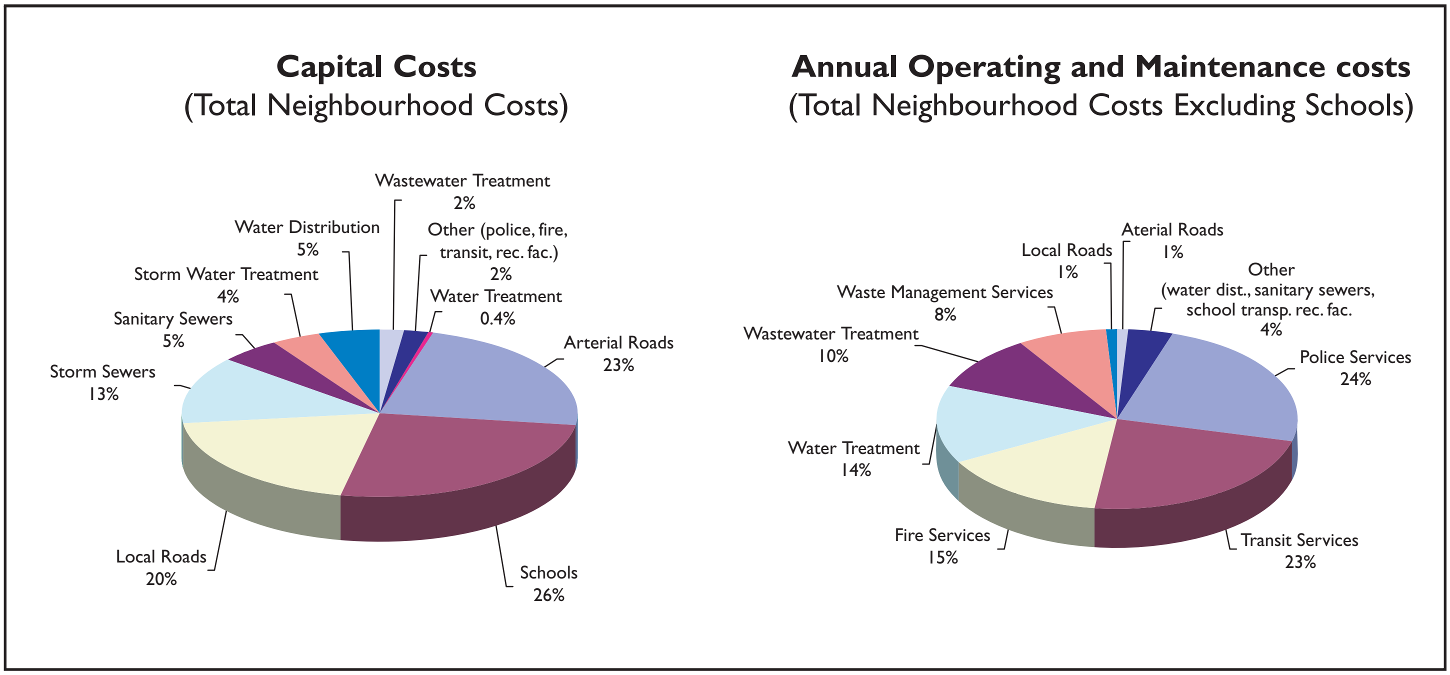

Exhibit ES.1: Distribution of Costs for an Average Neighbourhood

As mentioned previously, the intent of Phase 1 was not to provide definitive costs for specific development scenarios. However, it is illustrative to compare the relative magnitudes of different development cost components in order to validate the costing assumptions.

Exhibit ES.1 provides a summary of the distribution of costs for an average of the six neighbourhood scenarios (weighted by number of units). These percentages are based on the total neighbourhood costs, including both residential and non-residential development. Aside from road costs, school costs represent the highest single capital expenditure for a residential-oriented development.

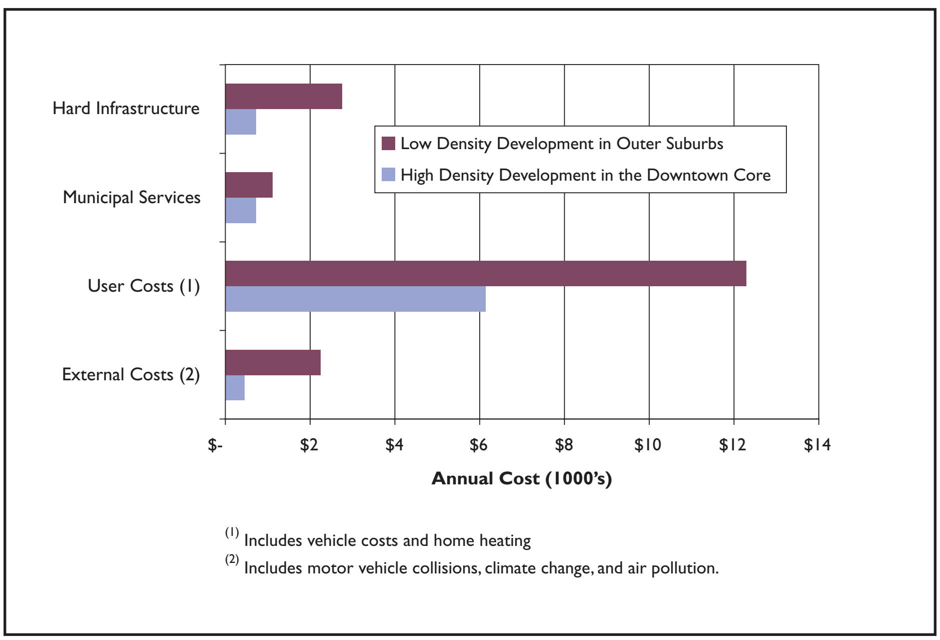

Exhibit ES.2: Annualized Costs by Development Scenario ($/household)

(1) Includes vehicle costs and home heating

(2) Includes motor vehicle collisions, climate change and air pollution.

In terms of operating costs, police services, transit services and fire services account for the majority of costs. Excluded in figure ES.1 are the operating costs for schools, which are estimated to be more than 60 per cent of the operating costs for an average neighbourhood. The capital or operating costs of health care facilities have not been included in any of the comparisons as these are generally regional costs and do not vary by development form.

Exhibit ES.2 provides a summary of preliminary costs, expressed on a per household basis, for two of the six scenarios examined; the high density inner area development and the low density outer suburban development. These two scenarios bracket the costs and revenues for all six scenarios.

The following generalized conclusions on the cost of community development are as follows:

- Cost efficiency is a function of density – more compact neighbourhoods have lower costs per household;
- Capital costs vary more by scenario than operating costs;
- On a lifecycle cost basis (excluding revenues from property taxes and development charges), high density neighbourhoods in inner areas are as much as 50 per cent more cost efficient than low density outer suburbs neighbourhoods;
- External costs such as accidents and air pollution are significantly greater for low-density outer suburbs neighbourhoods.

Another important conclusion from the analysis is that user costs, of which the majority are related to vehicle ownership and operation, are higher than all other cost categories combined. Even more noteworthy is the fact that these costs vary significantly by type of development and location of development. Consumers often over look the cost of owning and operating vehicles in housing purchases.

In terms of revenues, using assessment values and housing prices for Ottawa (as a representative case example), it was found that property taxes do not vary significantly by development scenario and range from $3,000 – $4,000 per year. On the other hand, development charges do vary considerably by scenario with a high density unit in the inner area costing about $5,200 (initial costs) and a typical suburban home costing about $18,600. When annualized over the life of a development, the costs of development charges are fairly low compared to annual property taxes and the differences between scenarios are not as apparent. It is also noted that the amount and implementation of development charges vary significantly between different municipalities.

CONCLUSIONS

The Phase 1 component of the *Costing Mechanism to Facilitate Sustainable Community Planning Project* provides a strong foundation for moving ahead with the development of a user-friendly costing tool. There has been very strong interest in such a tool from the planning community, which is confirmation that comprehensive tools to inform sustainable community planning are not readily available, or require such a substantial effort to adapt them to specific areas/user needs that they are not widely pursued.

A costing mechanism that provides a full range of user flexibility combined with accurate and realistic costing assumptions will help contribute to more informed community planning decisions.

CMHC Project Manager: Douglas Pollard

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Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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LE POINT EN RECHERCHE

Septembre 2005 Série socio-économique 05-023

MÉCANISMES D'ÉTABLISSEMENT DES COÛTS VISANT À FACILITER LA PLANIFICATION DE COLLECTIVITÉS DURABLES — RECHERCHES PRÉLIMINAIRES ET CADRE D'ÉTABLISSEMENT DES COÛTS

INTRODUCTION

On a beaucoup débattu des coûts d'aménagement au cours des dernières années, à la fois en ce qui concerne les coûts réels des différentes formes d'aménagement et en ce qui a trait à la façon dont les coûts sont partagés entre le secteur public, le secteur privé et l'environnement. Il ressort que l'aménagement plus compact à usage mixte est une forme d'aménagement plus rentable et plus respectueuse de l'environnement que l'aménagement suburbain de faible densité. Nous avons toutefois très peu d'outil faciles d'accès pour montrer dans quelle mesure cette constatation s'avère exacte ou pour comparer efficacement les différents types d'aménagement.

Comme le présent rapport l'indique, on manque également de données pour bien se représenter l'ensemble de la situation des coûts et des revenus associés à l'aménagement d'un quartier, particulièrement en ce qui concerne le coût des éléments des infrastructures vertes, qui prennent de plus en plus d'importance dans l'industrie de l'aménagement.

OBJECTIFS

Le but ultime de cette recherche est de mettre au point un outil accessible à tous ceux qui veulent examiner les coûts du développement communautaire durable.

Ce projet est réalisé en deux phases. La phase 1, qui fait l'objet de ce rapport, avait pour but d'effectuer des recherches de base sur les principaux coûts de l'aménagement, plus particulièrement ceux pouvant être touchés par la planification communautaire durable. La phase 1 des travaux a également donné lieu à l'examen des outils offerts en matière de planification communautaire durable. C'est en fonction des résultats de cet examen qu'on a ensuite élaboré une ébauche de cadre de conception d'un outil de calcul des coûts.

La phase 2 de l'étude donnera lieu à l'élaboration de l'outil de calcul des coûts lui-même. La phase 2 prévoit aussi la mise à l'essai et la validation complète de l'outil de calcul des coûts et des hypothèses sous-jacentes d'établissement des coûts.

Le rapport de la phase 1 dont il est question ici présente les constatations provisoires, plus particulièrement les résultats des recherches de base et des recommandations pour l'élaboration d'un outil de calcul des coûts. ***Même si le rapport comprend également des résultats préliminaires de calcul des coûts, ceux-ci visent simplement à renseigner au sujet de l'élaboration d'un outil de calcul des coûts, et non à fournir des réponses définitives sur les coûts des divers scénarios d'aménagement. Tous les résultats d'établissement des coûts devraient donc être considérés comme préliminaires et servir aux fins de discussion seulement.***

MÉTHODE

En plus de l'examen de la documentation sur les indicateurs de coût et de revenu de la planification communautaire et des modèles de calcul de coûts disponibles, la recherche effectuée lors de la phase 1a aussi misé considérablement sur la collecte de valeurs représentatives pour les composantes clés des coûts. Dans la plupart des cas, ces coûts ont été tirés de sources disponibles de villes représentatives partout au Canada. On voulait ainsi établir un éventail de coûts potentiels et déterminer dans quelle mesure ils peuvent varier en fonction de la forme d'aménagement, afin de l'utiliser comme base de conception d'un modèle préliminaire.

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La recherche de la phase 1 a aussi permis d'élaborer six scénarios représentatifs dans le but de guider et de mettre à l'essai la structure d'établissement des coûts. Ces scénarios comprennent un large éventail de caractéristiques de conception différentes selon l'emplacement et le quartier.

L'étape finale consistait à élaborer les revenus et les coûts préliminaires pour chacun de ces scénarios afin d'examiner l'incidence des différents paramètres de planification communautaire sur ces coûts et revenus.

CONSTATATIONS

Facteurs qui influent sur les coûts et les revenus du développement communautaire

Comme l'indique le rapport, de nombreuses études ont été effectuées pour tenter de déterminer et de quantifier les facteurs qui influent sur le « coût » des aménagements. L'une des difficultés de l'interprétation des résultats de ces études tient au fait que les conclusions diffèrent souvent en fonction de l'échelle de l'analyse (le quartier par opposition à un secteur urbain), du type d'étude (résultats rétrospectifs ou réels par rapport à des prévisions), de l'éventail des coûts pris en compte (coût des infrastructures comparativement au coût total), du délai prévu pour l'analyse (coûts d'aménagement initiaux par opposition aux coûts du cycle de vie) et enfin, des hypothèses formulées au sujet de qui en assume les coûts (entrepreneurs privés, municipalités ou le public).

Malgré ces différences, on trouve tout de même des conclusions communes à propos des facteurs clés pouvant influer sur les coûts d'aménagement. Presque exclusivement, la densité de l'aménagement ressort comme facteur déterminant du coût de la croissance urbaine. C'est l'évidence même. Compte tenu du fait que la plupart des infrastructures municipales sont linéaires (par ex. routes, conduites d'eau, égouts, transport en commun), et plus l'aménagement des collectivités est dense, plus il y a de personnes, d'employés, etc. qui peuvent utiliser un élément particulier de l'infrastructure. En revanche, il y a de nombreux autres coûts municipaux à considérer, tels les services d'incendie et de police, les écoles, les usines de traitement de l'eau et des eaux usées qui sont plutôt proportionnels à la taille de la population qu'à la densité de l'aménagement.

La distance par rapport aux infrastructures existantes constitue un autre facteur déterminant important du coût des nouveaux aménagements et il en est de même pour la capacité excédentaire des infrastructures existantes à s'adapter à la croissance. Il est généralement plus économique de situer un projet de nouvel aménagement près de centrales ou de routes existantes pour réduire au minimum le coût des nouvelles infrastructures. La recherche a aussi révélé qu'un emplacement situé à l'intérieur d'une zone urbaine est également un facteur déterminant important du coût pour l'utilisateur, comme les frais de transport, qui sont souvent sous-évalués ou exclus des scénarios comparatifs d'aménagement[1].

Portée ou coûts et revenus

Une revue complète de la documentation a été entreprise pour définir les catégories principales devant être utilisées pour tenir compte de tous les coûts du développement durable. À partir de cette revue, des catégories de coûts ont été déterminées afin d'être considérées dans l'élaboration de l'outil de calcul des coûts. Celles-ci sont généralement regroupées en quatre catégories principales :

- Infrastructures : routes, égouts, égouts pluviaux, écoles et centres récréatifs.
- Services municipaux : services de transport en commun, transport scolaire, services d'incendie, de police et services de gestion des déchets.
- Coûts pour l'utilisateur individuel, y compris les coûts liés à l'utilisation d'un véhicule et de chauffage de la résidence.
- Coûts découlant de facteurs externes, dont la pollution de l'air, les changements climatiques et les collisions automobiles.

La majorité des études examinées dans la documentation ne tenaient pas compte des coûts ni des avantages des infrastructures non traditionnelles ou vertes; cependant, pour cette initiative particulière, ces coûts se sont avérés

1 Consulter par exemple, *Émissions de gaz à effet de serre du transport urbain: Instrument d'évaluation de la durabilité des quartiers*, Société canadienne d'hypothèques et de logement, 2000.

d'intérêt. Les autres éléments des infrastructures vertes considérés dans le cadre initial de l'établissement des coûts comprenaient : voies et pistes cyclables, systèmes de chauffage et de climatisation urbains, éléments de modération de la circulation, recouvrement perméable, orientation solaire, production d'énergie distribuée, xéropaysagisme, normes routières de rechange. Bien que ces recherches aient été effectuées à l'égard de ces caractéristiques, leurs coûts réels ne seront pas quantifiés explicitement dans la recherche de fond pour le modèle de calcul des coûts, car les coûts varient considérablement selon les circonstances particulières du quartier, le degré de mise en oeuvre, etc. Par exemple, les choix pour modérer la circulation peuvent varier depuis de simples ralentisseurs à des mesures élaborées telles que des carrefours giratoires et des avancées de bordure du trottoir. Pour tenir compte de ces différences, on recommande que l'outil de calcul des coûts fournisse des renseignements de base pour chaque mesure ainsi qu'un éventail de coûts possibles.

Les revenus engendrés par les aménagements ont également été quantifiés et sont compris dans le cadre initial de calcul des coûts. Les revenus principaux comprennent les impôts fonciers et les droits d'aménagement. Les frais d'utilisation comme la taxe d'eau ou les frais de transport en commun ont aussi été pris en compte et soustraits des coûts d'exploitation municipaux. Pour l'outil de calcul des coûts, on recommande que les coûts pour l'utilisateur soient ventilés.

Outils de calcul des coûts

Comme partie intégrante de la phase 1, l'éventail d'outils potentiellement disponibles et leurs avantages et inconvénients principaux ont été documentés. Voici les outils et les modèles qui ont été examinés :

- Outil pour évaluer la durabilité des quartiers : émissions de gaz à effet de serre du transport urbain
- Modèle SCALDS (coûts sociaux de scénarios d'aménagement des terres)
- STEAM 2.0 (modèle d'analyse de l'efficacité du transport terrestre)
- Modèle QUEST
- PLACES3
- Calculateur de densité du club Sierra
- SFLCV – This View of Density
- City Green
- Infra-Cycle

L'examen des modèles et des outils existants indique qu'aucun modèle ne satisfait à tous les objectifs de l'étude. La majorité des études, des modèles et des outils examinés sont axés sur les décisions prises à l'échelle régionale et ne s'appliquent pas localement ou à l'échelon du quartier. L'examen a également permis de repérer des modèles qui traitent de certains éléments précis d'urbanisme et d'aménagement communautaire, mais qui ne peuvent servir à mener une étude plus complète de calcul des coûts. On peut toutefois utiliser certains éléments des outils et des rapports pour élaborer un nouvel outil plus complet. Par exemple, bien qu'il ne constitue pas un outil de calcul des coûts proprement dit, l'outil SCHL pour évaluer la durabilité des quartiers pourrait fournir des données utiles sur l'élaboration de scénarios d'aménagement et l'établissement des relations entre la forme urbaine et les mesures de rendement telle que l'utilisation des véhicules. Les deux rapports produits pour la SCHL en 1997 sur les modèles d'aménagement conventionnels et de rechange fournissent également un élément repère pour l'élaboration des coûts et des revenus.

Conseils pour un nouvel outil de calcul des coûts

L'une des conclusions principales de la phase 1, a trait au fait que la quantification des coûts et des avantages de l'aménagement de collectivités durables ne s'est pas avérée un exercice simple et direct. Il faut surmonter nombre de difficultés pour déterminer les coûts et les revenus à inclure. Par exemple, si le coût des écoles est compris dans les coûts d'aménagement, les premiers ont tendance à éclipser les autres coûts. L'éventail de coûts potentiels trouvés dans la documentation pour les éléments particuliers comme les installations de traitement de l'eau et les installations de gestion des eaux pluviales varient également en raison des différentes pratiques d'exploitation et possiblement aussi de la façon dont les coûts et les revenus sont indiqués. Enfin, la question de savoir « à qui incombe le coût » n'est pas facile à trancher. Par exemple, un promoteur peut acquitter les coûts de construction initiaux d'une rue, mais la municipalité se chargerait de l'entretien courant et de la réfection.

Une autre considération clé en matière d'évaluation des coûts d'aménagement concerne la portion de la capacité résiduelle pouvant être utilisée pour desservir un nouvel aménagement. Lorsqu'il y a une capacité résiduelle dans le transport, l'alimentation en eau ou le réseau d'égouts, ou même les établissements d'enseignement, par exemple dans le cas d'un terrain industriel, une diminution des coûts réels d'aménagement peut en résulter.

Pour toutes les raisons énumérées ci-dessus, il importe que l'outil de calcul des coûts soit souple et qu'il puisse s'adapter à une collectivité ou à un scénario d'aménagement particulier. Les utilisateurs individuels pourraient aussi être intéressés par différents aspects des coûts ou des revenus d'aménagement de collectivités durables.

Scénarios représentatifs et coûts préliminaires

Dans la phase 1 des travaux, six scénarios distincts au total ont été élaborés pour alimenter le cadre de calcul des coûts et pour présenter un éventail de coûts et de revenus potentiels selon différents types d'aménagement. Ces scénarios ont été établis à partir de différents regroupements de caractéristiques de quartier et d'endroit dans le milieu urbain :

- Un quartier à usage mixte à **haute densité** dans une **zone centrale**
- Un quartier à **densité moyenne** dans une **zone centrale**
- Un quartier à **densité moyenne** dans une **banlieue centrale**
- Un quartier à **densité faible** dans une **banlieue centrale**
- Un quartier à **densité moyenne** dans une **banlieue extérieure**
- Un quartier à **densité faible** dans une **banlieue extérieure**

Dans le but de faire l'essai des scénarios initiaux, toutes les variables socio-économiques (par ex. taille du ménage moyen, nombre d'enfants et revenus moyens) ont été tenues constantes. On a procédé ainsi de manière intentionnelle afin de limiter l'incidence sur les coûts selon qu'il s'agisse d'un endroit ou un type de logement particulier. Dans le modèle à concevoir ou au cours de la phase 2, les utilisateurs auront le choix de faire varier les valeurs socio-économiques en fonction du scénario choisi.

Est-il besoin de le répéter, la phase 1 avait pour objectif d'arriver à des coûts définitifs en fonction de scénarios d'aménagement précis. Il est toutefois avantageux de comparer l'ampleur relative de différents éléments de coûts d'aménagement afin de valider les hypothèses d'établissement des coûts.

Le tableau ES.1 présente un résumé de la répartition des coûts pour une moyenne de six scénarios de quartier (pondéré par nombre de logements). Ces pourcentages sont établis selon les coûts totaux d'aménagement du

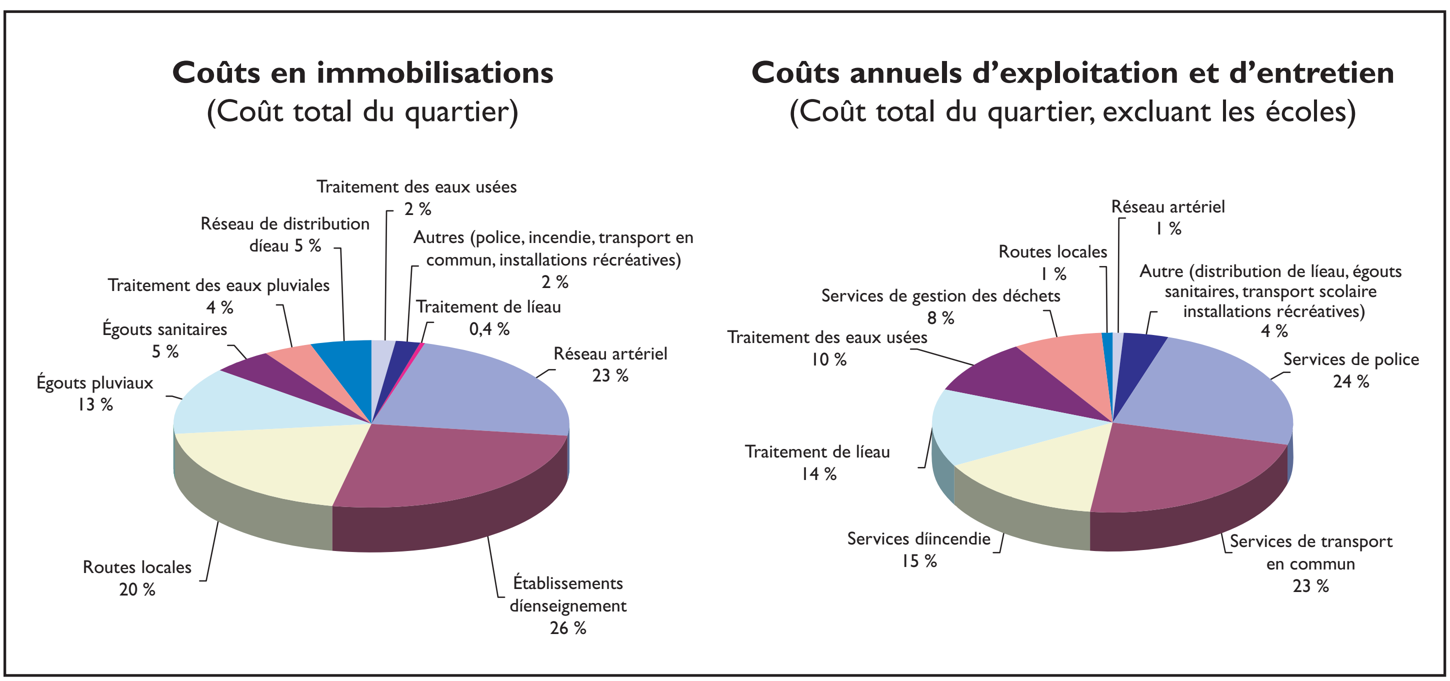

Tableau ES.1: Répartition des coûts pour un quartier moyen

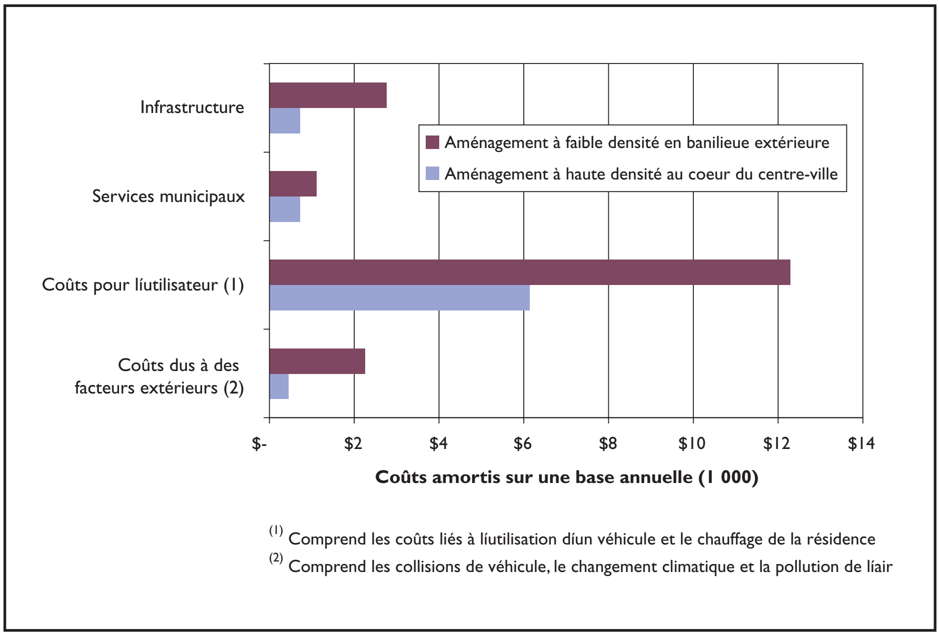

Tableau ES.2 : Coûts amortis sur une base annuelle par scénario d'aménagement ($/ménage)

(1) Comprend les coûts liés à l'utilisation d'un véhicule et le chauffage de la résidence
(2) Comprend les collisions de véhicule, le changement climatique et la pollution de l'air

quartier, y compris les aménagements résidentiels et non résidentiels. Mis à part le coût des routes, le coût des écoles représente la dépense en immobilisations la plus élevée dans le cas d'un aménagement résidentiel.

Au chapitre des coûts d'exploitation, les services de police, les services de transport en commun et les services d'incendie représentent la majorité des coûts. Les coûts d'exploitation des écoles, évalués à plus de 60 % des coûts d'exploitation d'un quartier moyen, sont exclus dans la figure ES.1. Les coûts en immobilisations ou les coûts d'exploitation des établissements de santé ne sont pas compris dans les comparaisons, puisqu'il s'agit généralement de coûts régionaux qui ne varient pas avec la forme d'aménagement.

Le tableau ES.2 montre un résumé des coûts préliminaires, indiqués par ménage, pour deux des six scénarios examinés; l'aménagement d'une zone centrale à haute densité et l'aménagement de banlieue extérieure à faible densité. Ces deux scénarios englobent les coûts et les revenus des six scénarios.

Voici les conclusions générales à l'égard du coût d'aménagement communautaire :

- L'efficacité est fonction de la densité – les quartiers plus compacts affichent des coûts plus faibles par ménage.
- Les coûts en immobilisations varient plutôt par scénario que par coûts d'exploitation.
- Selon la méthode du coût complet sur le cycle de vie (excluant les revenus provenant des impôts fonciers et des droits d'aménagement), les quartiers à haute densité dans les zones centrales sont jusqu'à 50 % plus efficients que les quartiers de banlieue extérieure à faible densité.
- Les coûts externes tels que les accidents et la pollution de l'air sont significativement plus élevés dans les quartiers de banlieue extérieure à faible densité.

Selon une autre conclusion importante tirée de l'analyse, les coûts pour l'utilisateur, dont l'essentiel a trait à la possession et à l'utilisation d'un véhicule, sont supérieurs à toutes les autres catégories de coûts combinées. Le fait que ces coûts varient considérablement suivant le type d'aménagement et son emplacement est d'autant plus remarquable. Les consommateurs négligent souvent de tenir compte du coût de possession et d'utilisation des véhicules automobiles lors de l'achats d'une habitation.

Au chapitre des revenus, en utilisant les valeurs d'évaluation et le prix des logements à Ottawa (à titre d'exemple représentatif), on a montré que les impôts fonciers ne variaient pas de façon considérable par scénario. En revanche, les droits d'aménagement varient considérablement selon le scénario : dans le cas d'un logement dans une zone centrale à haute densité, ils sont d'environ 5 200 $ (coût initial) et pour une résidence typique de banlieue, ils atteignent environ 18 600 $. Lorsque les coûts sont amortis sur une base annuelle pour la durée de vie de l'aménagement, le coût des droits d'aménagement est relativement bas si on le compare aux impôts fonciers annuels, et les différences entre les scénarios deviennent moins évidentes. On remarque aussi que le montant des droits d'aménagement et leur mise en oeuvre varient de façon considérable entre les différentes municipalités.

CONCLUSIONS

La phase 1 du *Projet sur les mécanismes d'établissement des coûts visant à faciliter la planification de collectivités durables* offre une base solide pour aller de l'avant avec la conception d'un outil convivial de calcul des coûts.

Les urbanistes se sont montrés très intéressés envers un tel outil, ce qui confirme que les outils complets en matière de planification de collectivités durables ne sont pas aisément accessibles ou qu'ils requièrent tellement d'efforts pour être adaptés à des lieux particuliers ou aux besoins des utilisateurs qu'ils ne font pas l'objet de recherches plus poussées à une grande échelle.

Un mécanisme d'établissement de coûts qui offre la plus grande souplesse à l'utilisateur, jumelé à des hypothèses de coûts précises et réalistes, permettra de prendre des décisions plus éclairées en matière de planification de collectivités.

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1 INTRODUCTION

1.1 Background

In recent years and months there has been increasing evidence that planners, municipal councils and developers are engaging in serious exploration of sustainable development. Municipalities across Canada are taking on the "smart growth agenda" through strategic growth management studies and in the way they tackle strategic plan updates and in the development of community plans. Most planners are anxious to support this movement towards more sustainable urban form. One question that inevitably arises is "what is the cost differential between conventional urban development forms and more sustainable and compact urban forms"? Of interest are both direct and indirect/external costs of hard infrastructure, municipal services and non-traditional infrastructure. Who pays and alternatives for cost recovery are associated issues of concern.

CMHC has undertaken this study of "costing mechanisms to facilitate sustainable community planning" with the aim of providing a tool to municipal staff, politicians and stakeholders to fairly compare key costs of sustainable urban forms and conventional development. The study is intended to be applicable to municipalities across Canada.

The tool is intended to provide relevant, meaningful, usable, easy to understand information to inform land use planning decisions, not to set development or construction budgets. It is intended to identify and compare the linear cost of infrastructure for new developments and the full cost implications of planning decisions over time so that the cumulative impacts of planning and other key decisions can be determined during the planning phase. The information generated is intended for community planners, community organizations and municipal departments who normally do not have ready access to costing information to determine whether a chosen strategic direction is appropriate from a cost perspective. The tool is not intended to establish firm development budgets, but rather allow for the scoping of scenarios, following which more detailed costing would be undertaken for the preferred scenario(s).

The project is structured in two distinct Phases. The objectives of the first phase (which is the focus of this report) are to investigate the state of existing costing models and consider how they can contribute to the overall full costing model needed for this project. An associated literature review of key cost variables and comparable research is also part of this Phase. Phase 1 develops a framework methodology for a conceptual costing model including testing representative development costs for six different urban form scenarios (reflecting conventional and sustainable development). The purpose of the testing initial scenario costs and revenues is to validate the proposed methodology. At the conclusion of Phase I, the intent is to review the feasibility of developing the "tool" and proceeding with Phase 2. The second Phase will consist of enhancement of the methodology and development of the analytical tool.

It is proposed that the tool be developed as a spreadsheet model with a user-friendly interface. The model will provide a menu of cost items and scenario descriptors to be entered by a user (or the user may default to optional representative settings). Many of these cost items and descriptors have been identified in Phase 1, in this report. This report also identifies additional cost items that could be added to the tool in Phase 2. Six generic urban form scenarios are explored in Phase 1 and it is proposed that they will also be applied in the model (as default settings) so that the client user may make comparisons. Phase 2 will explore opportunities for the client user to define other scenarios for analysis. The objective is for the tool to provide flexibility to meet client user needs and to accommodate available useful data.

1.2 Purpose and Organization of the Report

This report summarizes the results of Phase 1. In particular this report,

- Provides the results of the review of costing models and mechanisms;
- Summarizes the literature review and research results on key costs for sustainable community planning as well as the key finding of these studies;
- Summarizes an initial conceptual framework for costing;
- Describes the process for selection and characterization of development scenarios to be tested in the model;
- Reports the initial scenario costs and revenues as a validity test of the proposed methodology; and
- Proposes a framework for further developing the planning tool in Phase 2 and recommendations for future steps.

1.3 Interpreting the Results of this Report

This report presents an initial set of values for the purpose of costing neighbourhood development. The report also presents a quantitative summary of the costs and revenues for some representative development scenarios. The main purpose of presenting and discussing these quantitative results is to inform the development of the costing framework and to provide a basis for building the Costing Tool, which is to be carried out in the next Phase of this study. This report was not written with the objective of providing conclusive comparisons on the efficiency of alternative development patterns or community designs. All costing results should be considered preliminary and for discussion purposes only.

2 LITERATURE REVIEW

2.1 Purpose

A literature review was undertaken to investigate conceptual modelling frameworks, strengths and weaknesses to provide guidance to this project. The literature review identifies recent and relevant research performed on the costs of urban growth. The history and types of studies and costs of relevancy are first summarized, then the most prominent variables found to influence the cost of growth are examined and presented in detail in Sections 2.4 to 2.6. And finally, two sections are devoted to a discussion of alternative and emerging conceptual frameworks that have been employed in the past and that help predict the costs of infrastructure. Chapter 3.0 provides a targeted review of available models/tools and how they might contribute to this project.

2.2 History of "Cost of Growth" Studies

Starting in the 1920s but gaining importance with the return of soldiers from World War II, North American cities changed dramatically. With the advent of affordable automobiles, the construction of divided highways and subsidies to new housing in the suburbs, millions of middle-class households moved to the suburbs.

It was not until the late nineteen-fifties that some started to question the economic efficiency of this massive resettlement to single-use, low-density and automobile-dependent areas. In 1955, the Wheaton and Schussheim study examined the impact of density, urban size, location and development pattern in three hypothetical Massachusetts locations. It was followed two years later by the Isard and Coughlin study which looked at similar issues but in one hypothetical community of 25,000. In 1956, William White published *Suburban Sprawl*, describing some of the changes taking place in American cities[1].

In the next decade, the Urban Land Institute's study entitled *Innovation versus Tradition in Community Development* continued addressing some of the issues related to the cost of suburban development. In 1974, the Real Estate Research Group (RERC) released its seminal report, *The Costs of Sprawl*, which concluded that sprawl was in many cases the most costly development model, not only financially, but for individuals and the environment as well. Despite its strong admonishments, *The Costs of Sprawl* failed to elicit much response and conventional development patterns continued unabated.

The 1980s saw an explosion in the number of studies and person-hours spent studying the matter. In 1989 in Florida, James Duncan published *The Search for Efficient Growth Patterns,* and revealed that changing development patterns (i.e. to more compact and mixed use urban structures) could lead to 70% savings in infrastructure costs (roads and utilities). Another major report, *Costs of Alternative Development Patterns: A Review of the Literature,* was prepared by

[1] Frank, White, Peng, Harris and Sanders. (2000)

James Frank for the Urban Land Institute and reached similar conclusions. These two reports continue to be extensively quoted in studies of the costs of development.

In the last decade, one of the most prominent researchers in the field to emerge has been Dr. Robert Burchell of Rutgers University. Starting in 1992, he has authored and co-authored a number of studies for various jurisdictions in the United States on the costs of growth. His most prominent endeavour is *Costs of Sprawl*, a series of reports on the costs of urban growth at the national level completed in 2002 and prepared under the auspices of the federally-funded Transit Cooperative Research Program. His studies have tended to expose smaller savings from compact development patterns over sprawl than preceding studies.

In Canada, Pamela Blais wrote in her much-referenced study, *The Economics of Urban Form,* that up to 29% of hard infrastructure costs could be saved through the adoption of more compact models of development and that the inclusion of indirect and external costs (such as impacts of air pollution on health, traffic accidents) would lead to even greater savings.

In 1995, CMHC commissioned a study on the costs of development that examined the initial and long-term costs attached to alternative development patterns in comparison to conventional patterns[2]. The study concluded that the compact model cost 7.5% less than the conventional model over 75 years but did not include regional costs in its analysis.

2.3 Types of Studies and Focus

Because of the complexity of the issue and wide ranges of estimates for the various costs, several studies exclusively focus on examining and synthesising the conclusions of existing studies. They provide decision makers with an overview of existing local and foreign research without reporting on original research. Such a report is the *Review of the Economic and Financial Costs of Urban Form* by ERM (2000). Government entities and other groups have also developed models and tools to practically evaluate the impacts of urban development, for example by allowing planners or members of the general public to enter individual data and receive an individualized response. These tools are reviewed later.

Studies based on primary research can be broken into two broad types:

2.3.1 Retrospective Studies

The focus of such studies is the analysis of one or several existing areas, often as a comparison between actual costs attached to neighbourhoods that exhibit different development patterns but similar demographic and other contextual characteristics. Researchers compare various indicators and historical cost data related to these existing neighbourhoods. Governments in

[2] Essiambre Phillips Desjardins Associates Ltd. et al. (1995)

Australia have commissioned several studies to assess past and existing policies and these serve as background research to develop new planning policies[3].

Statistical approaches are also used in retrospective studies to attempt to uncover relationships between patterns and costs[4]. It must be stressed that techniques like multiple regression tend to establish relationship, not cause, and are therefore not discussed extensively in this document.

2.3.2 Forward-Looking Studies

Positioned between retrospective and forward-looking studies are studies based on pure economic approaches. Because they use simplified assumptions and essentially ask "what urban form is generated under market equilibrium conditions", they tend to build a certain development pattern, or urban form, into the model[5]. Because of this shortfall, this type of study will not be examined further.

Next, forward-looking studies rely on scenarios to predict the future impacts of planning choices at the local, regional or even national level. Their focus is on estimating costs attached to various development patterns or scenarios.

- At the local level: the object of the study is a specific site. Several development options are considered, and the cost of each analysed. The site can be specific and the study designed to help decision-making[6] , or generic and the conclusions used to constitute an example that the researchers hope can be applied to other locales[7].

- At the regional level: a regional government commissions a study to determine the potential long-term effects of several development scenarios. Under a set of different scenarios, the study examines the potential direct and indirect costs attached to each[8].

- At the national level: at least one study[9] developed national scenarios and estimated the impacts of these on a variety of costs. Here, the focus is not on individual choices made at the neighbourhood, local or even regional level, but the cumulative effect of these choices at the national level over the next two or three decades.

2.3.3 Sprawl and Smart Growth

It should be noted that most studies, especially American, typically use the much-publicized lens of "sprawl" and "smart growth". Because these issues are so prominent in the political debate in America these days, one must acknowledge that studies have been prepared under this intense

[3] Examples include State of Victoria (1993), Esseks et al. (1998).
[4] Ladd (1992), Surface Transportation Policy Project & Center for Neighbourhood Technology (2000) and Ewing, Pendall and Chen (2002)
[5] Brueckner and Fansler (1983), Rodriguez-Bachiller (1986), Ohls and Pines (1975), Ottensman (1977) – ore 1997 – see reference in bibliography and Peiser (1989)
[6] Birrell (1991)
[7] Essiambre Phillips Desjardins Associates Ltd. et al. (1995)
[8] Envision Utah and the Quality Growth Efficiency Tools (QRET) Technical Committee (1999)
[9] Burchell, Shad, Listokin, Phillips, Downs, Seskin, Davis, Moore, Helton and Gall (2002)

spotlight and can thus be politicised. Often, the revenue impact on municipal budgets forms a large part of the discussion as well, expanding on the net cost of providing infrastructure and services with an estimate of revenue attached to each type of development or scenario. Extrapolation can be problematic as the cost or even cost-revenue ratio to only one entity, for example a local municipality, is considered, as opposed to the full societal cost. For example, road cost differentials may be dismissed by the authors of a study paid for by a municipal government as being relatively minor since major highways are primarily a state or provincial responsibility. This may make the conclusions of some studies less transportable, since intended audiences differ with each study and realms of responsibility for program investment and spending vary among different jurisdictions.

Finally, of note is an over-emphasis on the residential sector in many – but not all – of the studies considered. The focus is generally on the development of residential, rather than employment sites. Not only do non-residential uses play a major role in the efficiency of transportation systems but they are often characterized by space-consuming development patterns such as large parcels, low-rise construction, large surface lots, loading docks and the like. Meanwhile, net residential densities have increased in many regions over the last decade.

2.4 Types of Costs Identified

The following list encompasses most of the costs discussed in the other studies reviewed[10]. ***Appendix A*** contains Tables A-1 to A-3 indicating the variables addressed by each study considered.

2.4.1 Direct Costs

Direct costs are those incurred directly as a result of urban growth, priced by the market and paid for through taxation or other levies. Direct costs are further broken down into capital, operating, maintenance and replacement costs. They include the costs of:

- Roads
- Water and sewage facilities and treatment, including stormwater management
- Power and telecommunications
- Schools
- Hospitals
- Libraries and community centres
- Police, fire and ambulance stations
- Parks, open space and recreation centres
- Public transit
- Private transport
- Real estate (land costs)

[10] Adapted from Environmental Resources Management Australia (ERM) (2001) and Blais (1995)

2.4.2 Indirect Costs

Indirect costs are incurred indirectly as a result of urban growth, priced and paid through the market, but not directly by those responsible for the development activity. Note that indirect costs can sometimes be considered external costs and include:

- Emergency services, including fire and police.
- Municipal services, including solid waste collection and disposal, snow clearing and street cleaning.
- Social services including education and health.

2.4.3 External Costs

External costs are incurred directly and indirectly as a result of urban growth but neither priced nor paid through market mechanisms and include:

- Road accidents
- Air pollution
- Noise pollution
- Travel time costs
- Loss of natural habitats

2.4.4 Capital vs. Operating, Maintenance and Replacement Costs

For hard infrastructure, initial costs are the most visible, the most studied and the object of the most controversy. These represent all the costs initially related to development, not only streets, sewer and water pipes, but also water and sewage treatment plants, schools, hospitals, fire halls and police stations. These are the costs that triggered many jurisdictions to impose development charges[11]. All studies reviewed consider at least some initial – or capital - costs.

Operating costs are tied to initial costs as they involve the long-term maintenance and day-to-day operation of infrastructure. Finally, replacement costs capture the cost of entirely replacing a piece of infrastructure at the end of its useful life.

2.4.5 Public vs. Private Costs (or "who bears the costs")

Most of the costs have a public and a private component. For example, local government pays for building and maintaining highways, but developers generally pay for the initial construction of local streets. Local government then pays to maintain them. Private citizens pay the cost of purchasing and running private vehicles, but governments pay to treat asthma cases related to air pollution. To various extents, studies specify who bears the costs of urban growth.

[11] Also called lot levies and impact fees in some jurisdictions.

2.4.6 Local vs. Community and Regional Infrastructure

All studies explore the local costs of development, for example local streets and local pipes. But many studies ignore or underemphasize community and especially regional infrastructure, including water treatment plants, universities, regional roads and expressways as they assume that these are not influenced by urban form.

2.4.7 Key Cost Study Limitations

Synthetic reviews of other studies[12] stress the importance of acknowledging the methodology used when comparing the various studies. When scenarios are used, they typically embody a series of assumptions, which makes direct comparison arduous.

Some further limitations of the studies reviewed were identified[13]:

- Costs beyond the local realm are routinely under-estimated or ignored although the relationship between development patterns and metropolitan infrastructure costs is significant.

- Non-residential infrastructure is often neglected, although it may occupy 30% of the regional land area.

- Capital cost differentials have been extensively studied but the literature tends to underemphasize lifecycle costs – including operating, maintaining and replacing infrastructure. This may favour existing urban areas where less new infrastructure is necessary since the focus is on the cost of new infrastructure instead of the true lifecycle costs – including replacement and maintenance. Existing urban areas may already have the necessary infrastructure, but it continually requires maintenance and replacement as infrastructure ages.

- In general, direct costs are better understood and documented than indirect costs and especially external costs.

- Differences in land and water consumption and kilometres travelled, among others, are open to interpretation and depend on the methodology used. In addition, large cost differentials can be observed between scenarios and studies depending on the specific costs assigned to each activity. For example, each study may assign a different cost to constructing a school or a foot of street. Assumptions have a great influence on these costs, as does geography.

[12] Blais (1995), ERM (2001)
[13] Blais (1995), ERM (2001)

2.5 Key Predictors of Costs[14]

Most of the studies reviewed include a discussion of some of the factors that can potentially have a substantial effect on the capital and lifecycle costs of development pattern choices. The following reflects the most commonly discussed predictors.

2.5.1 Net and Gross Density

Net density refers to the number of dwelling units over an area and is essentially dependent on lot size net of all public infrastructure, e.g. roads, schools, parks, etc. Gross density is the ratio of units over an entire area, typically including roads, parks and other public uses and depends on net density and several factors usually controlled by governments, such as road widths, parkland dedications and stormwater management infrastructure.

The density of a development has a myriad of effects on costs. For example, keeping the number of dwelling units constant, the area to service is larger if density is lower. At the onset, longer pipes, cables, roads and sidewalks must be built. And because the area covered is larger, facilities limited by their catchment areas like schools, police and fire stations must be built in larger numbers. And every time one piece of the infrastructure must be replaced or maintained, higher costs are incurred. On a day-to-day basis, distances driven by commuters and service vehicles belonging to all service providers are longer. Water pumping costs also grow with distance.

2.5.2 Distance from Existing Infrastructure

The further from existing infrastructure development takes place, the more costly it will be to extend it. And if existing infrastructure is too distant for an extension, new facilities will have to be built altogether. The total size of the urban area in question is also a contributing factor, as a larger metropolitan area will tend to have longer networks – e.g. water and sewer. The shape of the metropolitan area – determined by geographic features and history – plays a role as well (e.g. star-shaped, circular, rectangular or linear). For example, cities such as Vancouver are constrained by water and mountains while cities like Regina are not constrained and have developed in a more circular, albeit fairly compact manner. Other urban areas, including the Greater Toronto Area initially developed along rail lines, but are now developing along highway corridors. As discussed in Section 2.7 below, there is a general consensus that there is cost savings between spread development and compact development, and to some extent nodal development (e.g. see IBI 1990 and 1995a)

2.5.3 Contiguity / Dispersion

Contiguity and its flipside, dispersion – or “scattered” growth – refer to the extent to which clusters of development are located nearby one another. It is common for subdivisions, office

[14] Speir and Stephenson (2002), ERM (2001)

parks and other tracts of single-use development to be organized in ”pods”, separated from other uses and each other by vacant land or swaths of farmland, for example. Contiguity reduces the need for roadways to link the various isolated “pods” and reduces the length of linear infrastructure necessary. Also, scattered development can increase the cost of farming as farmers must move from swath to swath[15] and weaken the effectiveness of natural areas by blocking migration paths, shrinking habitats and hunting grounds and shortening distances between habitats and developed areas.

2.5.4 Mix of Uses

Mixing uses can affect the distance travelled and mode used and will thus have a direct impact on transportation costs. In areas with a high diversity of uses, residents will tend to make shorter trips and thus will be more likely to opt for walking, cycling and transit as modes of transportation instead of the private automobile.

2.6 Other Factors that Influence Costs

Beyond the four basic factors reviewed above, additional factors exist that can dramatically alter cost estimates include the following.

2.6.1 Demographics

Demographics bear a heavy influence on all “soft” services, like health and education. Speir & Stephenson warn against keeping demographics constant as they stress that certain types of urban form are more likely to attract individuals with certain demographic profiles and should therefore be associated with these types, as opposed to being kept constant. However, while this may be a consideration for individual governments and school boards, it is not the case at the metropolitan, regional or national level.

2.6.2 Planning and Service Standards

In their study of existing neighbourhoods with different physical characteristics, Esseks et al. stress that comparing historical cost data can lead to misleading conclusions unless varying service standards among different communities are taken into account. The layout and infrastructure choices of one neighbourhood may appear more costly than another, but maintenance standards and practices may simply be different because of local idiosyncrasies. Climate is obviously a factor as well.

2.7 Regional and National Level of Analysis

This section and the next describe and summarize the results of regional, national and local analyses undertaken to investigate the costs of various forms of development. These are useful

[15] Esseks, Schmidt and Sullivan (1998)

both to identify conceptual approaches to structuring the project model, as well to provide an indication of possible outcomes for model design and testing.

The focus of the following studies is on the regional or national realm. They estimate the costs attached to new growth by developing alternative scenarios, typically one reflecting the current situation, "business as usual" or "recent trends" and one or more involving one or more alternatives, typically revolving around development that is denser, closer to existing infrastructure and contiguous. The following are key studies that were identified:

- Burchell (2002) considered two different scenarios for future growth in the entire United States: In the "controlled" scenario, two complementary methods are used: a redirection of growth to already-urbanised counties and a concentration of new development to urban areas within counties. Development is denser, with a higher proportion of attached and multi-family dwellings. In the urban fringe, it is more often arranged in clusters. The "uncontrolled" scenario is the continuation of current practices. The authors found that for every type of hard cost, the "uncontrolled" scenario was more costly than the "controlled" scenario, although the savings were not always consequential with the methods and variables used.

- Ewing, Pendall and Chen (2002) developed a sprawl index for 83 US metropolitan areas based on the following criteria: residential density, neighbourhood mix of homes, jobs and services, strength of activity centres and downtowns, and accessibility of the street network. The authors then assembled a number of indicators, such as kilometres travelled, air pollution and others, which they compared to each area's position in the sprawl index rankings. In high-sprawl areas, authors found higher rates of driving and vehicle ownership; increased levels of ozone pollution; higher road accident rates; lower incidence walking and cycling, but no significant difference in delays due to congestion. Based on multiple regression analysis, this report's findings are relevant because of the extensiveness of the data analysed and strong methodology employed.

- ERM (2001) performed an extensive literature review of existing studies and considered three types of areas: inner, middle and outer areas. It found that costs varied significantly with urban form, with costs in inner and middle areas generally lower than in outer areas. However, it also found that quantifying and extrapolating the gap is made difficult by the presence of location-specific factors. It also found that while direct costs had been the object of much research, much less was known about indirect costs. Direct costs were found to vary with urban form more than indirect costs, since the latter are more dependent on demographic variables. Also, ERM found that information on operating, maintenance and replacement costs to be insufficient to derive clear conclusions. Finally, ERM found that travel time was the most significant external cost and that travel costs were much higher under non-contiguous development than contiguous development although wide variations were found among studies. No major variation caused by urban form was found to affect air and noise pollution but the authors again stressed the paucity of data available.

- Envision Utah (1999) studied the cost impacts of four growth scenarios for The Wasatch Front region of Utah. Interestingly, this study explored one baseline scenario, which is defined as a continuation of development patterns observed over the last 20 years. Another scenario (A) represents the "Business as Usual" scenario, reflecting more recent trends towards larger lots and more scattered development. The more compact scenarios, C and D, resulted in savings in most, but not all, categories. Although more compact, Scenario D actually resulted in smaller savings than Scenario C in the areas of roads and transit. The air quality index for D was worse as well. It should be noted that the costs of transportation at the regional level in this study refer to projections attached to actual projects in various stages of planning, not merely the costs resulting from estimates of miles of road required to accommodate the expected number of commuters under each scenario.

- SEMCOG (1997) framed a discussion of the costs of sprawl in Michigan in a discussion of the definition of sprawl, a review of recent growth and socio-economic trends and recommendations based on its findings. The authors found significant savings attached to their Compact Growth Scenario compared to current growth patterns.

- IBI (1990 and 1995a). IBI prepared an extensive study of the costs of growth in 1990 under three scenarios: "spread" (continuation of current development patterns), "nodal" (most of the population increase distributed outside the central urbanised area and concentrated in nodes with higher overall densities, and "central" (most of the growth is accommodated within the existing urbanised area). In her review of the 1990 study, Blais points out that even more differences among scenarios might be found if the number of vehicle trips had been allowed to vary. Indeed, a mixed urban form required fewer trips as activities are consolidated and other modes become more attractive. The findings were updated in 1995 and appended with a more extensive examination of external costs attached to the various scenarios. As in the Envision Utah study, the regional transportation costs in this study refer to location-specific projects under consideration. IBI's major findings as published in the 1995 revisions are as follows:

  - Operating costs of transportation were found to vary dramatically between scenarios;
  - Substantial savings were calculated between the spread and central scenarios, and to a lesser extent between the spread and nodal scenario;
  - The areas with the largest potential for capital savings are transportation and hard services. Savings in human services were negligible or even negative, but mostly result from assumptions made about higher land costs in central locations;
  - External cost savings were found to be substantial as well under both alternative scenarios.

- IBI Group (2002). On behalf of the Neptis Foundation, IBI Group is undertaking an analysis of various urban form concepts, similar in nature to and more recent than the Urban Structure Concepts Study above. Here, land use patterns, transportation and water/waste water systems for the Greater Toronto Area and environs are projected to 2031 under a "business-as-usual" scenario and then for three alternative scenarios involving policies aimed at achieving "Smart Growth":

- The consolidated scenario with more growth in existing built-up areas;
- The Multi-centred scenario with more growth in the outlying sub-centres; and,
- The Dispersed scenario with more exurban growth.

These scenarios assume constant employment and population numbers with varying distributions as well as differing transportation (highway/road, transit and commuter rail) and water/waste water system infrastructure appropriate to each alternative. The scenarios are compared in terms of infrastructure costs and quality-of-life measures relating to the economy, the environment and liveable communities. Examples of these measures include:

- Land consumption, loss of agricultural lands;
- Transportation demand (e.g. trips, vehicle kilometres, transit mode share);
- Transportation supply (e.g. auto ownership, highway/road kilometres);
- Transportation performance (e.g. average trip length and travel speed);
- Environmental impact (e.g. emissions and fuel consumption); and
- Public expenditures on transportation and water/waste water infrastructure.

Interestingly, the report concluded that the Business-as-usual scenario actually resulted in the lowest expenditure level for the operation and maintenance of the transportation system. But once private costs of transportation are added, the consolidated scenario is the least cost alternative. In general, the consolidated scenario is the scenario with the lowest infrastructure costs, environmental impact and time delays. The next-most favourable scenario was found to be the multi-centred scenario. Overall, while the direction of the changes between more compact and more dispersed scenarios corresponds to that described in other studies, the magnitude of the change described in this study tends to be smaller for many cost categories.

2.8 Local Level of Analysis

Unlike the studies reviewed above, other researchers focused strictly on the local realm, some considering only changes in density. Savings found in different studies examined by Blais (1996) ranged between 9 and 63%, reflecting the different methodologies used and the definition of scenarios. The lowest variation was found in the 1995 study for CMHC and the highest in Stone (1987). Blais also examined savings related to "frontage costs" only, which include:

- Local and collector roads, including sidewalks and street lighting;
- Sewer pipes;
- Stormwater drainage and conveyance systems (e.g. pipes, swales or ditches);
- Water pipes.

The range of savings observed in the studies reviewed ranged from 14 to 51%. In addition to the potential savings above – which are primarily density-driven – Blais points out that keeping density equal, clustering can save up to $2,000 per lot in servicing costs (1987 US$) or 15%[16].

Researchers at the University of British Columbia compared a proposed alternative community – East Clayton – to an actual conventional subdivision of a similar size. On sites of 4.23 and 4.27 acres, respectively, the conventional site is subdivided into 41 parcels and as many dwelling units while East Clayton fits 111 units onto 74 lots. While the average unit size in east Clayton (1,661 s.f.) is smaller than that in the conventional subdivision (2,300 s.f.), it is interesting to note that East Clayton includes more large detached houses (average size 2,266 s.f.) than its conventional counterpart. Its lower average unit size is due to a greater mix of housing.

Aggregate infrastructure costs in East Clayton are 27% higher than in the conventional subdivision but once apportioned to dwelling units and prorated by constructed square foot, East Clayton's infrastructure costs are 42% and 19% lower, respectively. Worth noting is that the savings are achieved while maintaining the parking ratio per dwelling constant and lot coverage almost identical.

2.9 Key Findings From the Literature Review

The following highlights the key findings from the literature review and the corresponding implications for model development:

- The literature review identifies the key cost categories that must be considered in order to fully account for sustainable development costs.

  Chapter 4.0 applies this information in identification of key costs as part of development of the conceptual framework for the costing model.

- Studies are close to unanimous in stating that development models that are denser, direct growth close to existing infrastructure and follow contiguous patterns, result in lower capital, operating, maintenance and replacement costs. However, it is very important to stress that they do not agree on the magnitude of these variations. Assumptions and varying local circumstances are mainly responsible for these discrepancies. Regional-scale infrastructure, such as highways is currently deemed to serve a region's entire population evenly, although in really it does not. Inclusion of such items could further magnify these cost differences.

  These conclusions about community form and costs are used in identifying sample scenarios for model testing in Chapter 7.0. The scenarios test a range of density and form of development pattern. The literature review also indicates that the model must

[16] Also in Frank (1989) as quoted in SEMCOG p. I19.

be flexible to respond to local circumstances such as the existence of underutilized infrastructure.

- The relationship between urban form variables and cost may not be linear. At least one study (Envision Utah, 1999) found that between two "compact" scenarios, the most compact does not in fact result in increased savings as more complex roads and transit systems are necessary and result in declining rates of return. Air pollution follows the same pattern, but the authors point out that the unique geography under study is the cause of this finding. This further reinforces the importance raised by several authors of local circumstances and idiosyncrasies.

  These conclusions indicate that the model must have some flexibility to respond to local characteristics.

- There is no consensus on the impact of development patterns at the neighbourhood level on travel time, perhaps because travel times vary by person depending on where they choose to live and work. While some studies found significant differences among scenarios in the costs related to time spent travelling, Ewing, Pendall and Chen – who studied actual conditions in metropolitan areas – found no significant differences in delay, perhaps indicating that as employment decentralisation takes place, commuters manage to keep their travel time, and thus costs, fairly constant.

  The fact that some researchers found that there is limited variation in travelling times by community type, combined with the challenge credibly quantifying travel times by development type, lead to the decision to exclude the value of time from the modelling framework. This issue is discussed further in Section 5.5.2. The model does, however, include other direct vehicle costs as listed in Section 5.3.2.

- There is general consensus on the importance of considering the external, non-monetary costs in addition to the conventional monetary costs so as to develop a full cost accounting framework. There is much less consensus on how to quantify and compare these external costs to the internal ones on a level that is fair and equal. However, it appears that urban development patterns do in fact influence items such as congestion levels, air pollution, noise pollution, traffic-related accidents, and possibly travel time, as well as loss of agricultural, recreational and environmentally fragile lands.

  The need to include some external non-monetary items (including air pollution, climate change and vehicle costs and collisions) is considered in Chapter 4.0 in identification of key cost to be considered in the model.

- Infrastructure and service provision related to Human Services was often found to vary less with urban form, but Blais stresses that as with all regional-scale infrastructure, the models often fail to adapt their assumptions to the possibilities afforded by alternative scenarios. For example, in a more compact scenario that focuses development on the already urbanised areas and specifies mixed use, existing infrastructure can be used more efficiently. The construction of many new schools is required in large homogeneous areas with many young families while other schools are decommissioned in similar neighbourhoods built a generation earlier. ERM explains that since large infrastructure projects are “lumpy”, each marginal unit built in an already urbanised area can be served by spare capacity in existing infrastructure – resulting in economies of scale and no need to build anew – while a marginal unit at the fringe may require the provision of entirely new facilities.

This information indicates that the model must have flexibility to account for opportunities afforded in already urbanised areas and to respond to local circumstances.

3 REVIEW OF AVAILABLE TOOLS

3.1 Introduction

This section provides a review of some of the costing model tools that have been designed by others. These are tools, with or without web interfacing, that allow users to enter data specific to their situation and obtain customized results. The targeted public for these tools ranges from decision-makers to members of the general public.

These tools were reviewed for a number of purposes:

- to identify whether any tools exist that accomplish the objectives of this project;
- to identify if tools exist with components that can be linked together to contribute to the CMHC tool;
- to identify direct or indirect information to inform the CMHC tool and conceptual framework for the tool.

3.1.1 Greenhouse Gas Emissions from Urban Travel: Tool for Estimating Neighbourhood Sustainability[17]

On behalf of CMHC, IBI Group developed a user-friendly tool to evaluate differences in neighbourhood greenhouse gas (GHG) emissions based upon community planning and design variables such as density, land use mix, street layout and housing types. Each of three distinctly different neighbourhood concepts (transit/pedestrian supportive, automobile-dependent and an intermediate scenario) were analysed in each of three locations within a major metropolitan area (in the central area, inner suburbs or outer suburbs). For nine alternative scenarios, estimates of GHG emissions per neighbourhood resident were produced, based on data from the Greater Toronto Area. Examples of inputs to the model, defining location, socio-demographic and neighbourhood design characteristics, include:

- Length of roads and bicycle routes;
- Number of intersections;
- Gross land area;
- Number of housing units;
- Number of jobs;
- Distance to the central business district; and
- Average household income.

[17] IBI Group (2000)

From these, the model employs auto-ownership and vehicle/transit kilometres of travel sub-models to determine GHG emissions. The tool is a user-friendly spreadsheet intended for use by planners and developers.

3.1.2 SCALDS Model[18]

The USDOT Federal Highway Administration investigated full land use pattern costs in *The Cost of Alternative Land Use Patterns*. They describe a prototype full-cost model called *The Full Social Cost of Alternative Land Development Scenarios* (SCALDS) model. The operating assumption of the model framework is that the "main effects of a change in [urban] form should be captured through changes in the costs of providing infrastructure services". Using projected demographic characteristics of the area, different land use scenarios may be defined from the base year and the future year costs of each compared.

The model is intended as an accounting framework that can be altered and/or calibrated by Metropolitan Planning Organisations (MPOs) to meet the specific needs of their area at the regional level. It exists as 18 interconnected spreadsheets that build on three components considered essential to a full cost framework, those being infrastructure costs, public and private costs and internal and external costs. These components are captured as:

- Physical development cost, which includes land consumption, construction costs, local infrastructure cost and operation cost of water and wastewater services;
- Travel cost; which captures operation of peak and off-peak travel as passenger miles travelled (PMT); and
- Air pollution and energy consumption of transportation and residential land use, as non-pecuniary costs.

These costs are then summarised for ease of comparison.

3.1.3 Surface Transportation Efficiency Analysis Model (STEAM 2.0)[19]

The USDOT Federal Highway Administration's *Surface Transportation Efficiency Analysis Model (STEAM 2.0): User Manual* describes a model that "was developed in order to provide an analytical tool for estimating impacts of multi-modal transportation alternatives in a system planning context". Using input directly from the traditional four-step travel demand modelling process and based on economic principles, it estimates monetary costs for a range of transportation investments and policies, such as major capital projects, pricing and travel demand management initiatives. Where benefits/costs cannot be quantified in dollars (such as for

[18] Parsons Brinckerhoff Quade & Douglas Inc. (1998)
[19] Cambridge Systematics, (2000)

environmental impacts), other measures are provided to enable a full cost comparison. The model is flexible in terms of transport mode, trip purpose and time period definition, providing default parameters for seven modes. The results of the analysis include:

- Benefits and costs to transportation system users;
- Annualized costs to public agencies;
- Effect on total transportation cost;
- Revenue transfers from tolls/fares; and
- Changes in job accessibility, emissions, energy use, noise, accidents and other external costs.

Risk analyses are also performed.

3.1.4 QUEST Model[20]

Quest is a web-based application developed by the Sustainable Development Research Institute (SDRI) of the University of British Columbia. It is intended as a visioning exercise to encourage thinking about sustainability in a game-like, interactive interface. The model is not intended for planning purposes but is customized by the developers for a given region using local data. Users choose various future trends, consisting of economic, social and physical attitudes, to define an overall scenario. As the trends are presented as attitudes, none of the inputs are numeric. The results of the impact of these choices on the area are then projected from the area base year (2000) data and presented as various grouped performance measures, including public and private costs. Examples of the groups of measures output include:

- Government (e.g. deficit, debt and spending);
- Transportation (e.g. trips by mode, distance, accidents);
- Energy (e.g. residential and industry usage, GHG emissions);
- Solid waste (e.g. amounts generated and recycled); and
- Cost of living (e.g. based on housing type and auto ownership).

To date, the tool has been customized for a number of Canadian and international communities.

[20] University of British Columbia (2002)

3.1.5 PLACES 3 [21]

The USDOE Centre of Excellence for Sustainable Development describes its urban planning model in ***The Energy Yardstick: Using PLACES^3 to Create More Sustainable Communities***. "PLACE^{3}S, an acronym for Planning for Community Energy, Economic and Environmental Sustainability, is a land use and urban design method created specifically to help communities understand how their growth and development decisions can contribute to improved sustainability." Quantification is based on energy use rather than dollars. Community energy needs, as defined by those of transportation, residential/commercial/industrial, infrastructure and energy production, are planned for by comparing energy use under existing conditions to a range of future planning scenarios. This process is comprised of three main components, consisting of public participation, planning and design, and measurement of the energy, economic and environmental effects of each plan. Using a GIS-based framework, the model produces an energy database and tool that can spatially display energy demand and be used to forecast energy needs, monitor the region's energy efficiency and evaluate its sustainability. Inputs to the model are:

- Land use (e.g. housing and job density);
- Transportation (e.g. vehicle miles travelled);
- Infrastructure (e.g. street network, water/sewer capacities);
- Energy use (e.g. vehicle fuel efficiency, electricity/natural gas use);
- Energy supply (e.g. grid locations, capacities and types); and
- Climate data (e.g. solar radiation, wind speeds).

Based on these data, a variety of measures are determined for each development scenario, including:

- Auto dependency (e.g. vehicle miles travelled, mode shares);
- Housing proximity to transit;
- Air pollution;
- Redevelopment readiness (i.e. the difference between the value of the area and the improvements);
- Recreational land supply (e.g. acres per population);
- Solar friendliness (i.e. as orientation of street to the east-west axis); and
- Global warming contribution (i.e. as carbon dioxide emissions).

3.1.6 Sierra Club Density Calculator[22]

The Density Calculator is another web-based application that relates density to the efficiency of an urban area. The user simply inputs a neighbourhood average density (in households per

[21] Criterion Inc. (1996)
[22] Sierra Club (2001)

residential acre), their vehicle's fuel efficiency, and the price of gasoline. From this information, the application determines a number of efficiency measures, including:

- Daily water use;
- Shopping opportunities;
- Auto ownership;
- Annual vehicle miles travelled;
- Fuel consumption; and
- Various pollutant emissions.

Note: the Density Calculator has been fine-tuned a number of times and as of December 2002, was "under construction". Critics claimed that the densities calculated were unrealistic.

3.1.7 SFLCV View of Density Calculator[23]

The San Francisco League of Conservation Voters (SFLCV) has developed an interesting website to explore density. The website provides several different examples of density together with the associated impacts on land use, water use, auto costs and air pollution from driving. All of these variables are assumed to be a direct function of density. The website also allows the user to input their own density and vehicle fuel mileage. This website appears to be developed as an information or advocacy tool, rather than a formal research tool.

Although simplistic, this website provides a good overview of density and potential costs associated with different density levels. No consideration is given to location within an urban area.

3.1.8 City Green

The Sheltair Group has developed a number of tools related to sustainable community planning, including City Green. City Green is an integrated MS Access and ArcView GIS application that models the interrelationships of population growth and the production of wastewater and solid waste for the Fraser Valley region of British Columbia, Canada. Most of these tools are designed to examine issues at the entire urban or regional level, as opposed to the individual neighbourhood level.

3.1.9 InfraCycle

Infracycle Software Limited has developed a software product for the purpose of calculating fiscal and community impact generated by land use plans, proposals and development applications. The software is scalable as follows:

[23] San Francisco League of Conservation Voters

- The software may be modified by the user to create all and any categories of expenditures and revenues. Typically users capture the cost of administration, hard linear infrastructure, community services and programs such as:
  - Water, sewers, solid waste disposal, roads, traffic signals, streetlights, sidewalks, stormwater, libraries, police and fire protection, schools, transit, the judicial system, parkland, recreation facilities, city hall, recreation programs.
- The software may be used to capture costs and revenue at local municipal, regional and provincial levels.
- The software may be used to cost alternative development scenarios.

The software calculates the capital, replacement, operating and maintenance costs and revenues generated from land use. It produces several reports including the bottom-line "net loss or net gain" resulting from a land use plan, land use policy or change in revenue source. The software also calculates the change in the level of service resulting from a development or land use scenario.

The user may use all of the functional capability or part of the software capability. Although the software may be used to calculate some indirect external costs, most municipal clients focus on a comprehensive analysis of the impact of development on internal municipal costs.

The software is used to complete analysis on sites and study areas ranging in size from 1 hectare to 2000 hectares. The size of municipalities that use the software range from populations of 5,000 to 900,000. The majority of users are from municipalities of 5,000 to 200,000 people.

Based on the description of this software found on the company's website (www.infracycle.com), it is highly applicable to this current project. However, due to the fact that this is a privately developed and propriety software, a model was not available for detailed review. It is understood that the software was used to assess the development costs of alternative community designs in Barhaven (Ottawa) as part of or as follow-up to the studies completed by CMHC in 1997.

According to the software developer, the software is available to any user for any purpose. The primary issue or limitation for the user is access to accurate local data. InfraCycle has a database of costs for elements of infrastructure and community services that is available to users.

InfraCycle is primarily a software company with a mission to provide software to any user. Training and professional support is offered to enable the user to be self-sufficient in the use of the software and methodology. InfraCycle provides consulting services and professional as part of the maintenance program. The cost of the software is scalable to the size of the client.

3.2 Key Findings from the Review of Available Tools

There are a number of tools available in Canada and abroad that help to analyze various aspects of community planning and the associated costs. Most of the tools reviewed found fall under two categories:

- Tools that analyze a specific issue such as wastewater production; or,
- Tools that analyze broad urban development patterns and the associated impacts.

Table 3.1 summarizes some of the main characteristics of the tools. The criteria used in the table highlight characteristics needed to meet the objectives of this project. The summary shows that there is no single tool that provides all of the functions intended for the current project, which is to estimate the total costs of development at the community or neighbourhood level. Most of the tools that do estimate the costs of alternative development patterns do so at the urban or regional level, and would not be applicable to the neighbourhood level. Furthermore, there is no single tool that:

- Addresses a wide range of costs including costs of social services and infrastructure;
- Addresses sustainable infrastructure options;
- Is specifically designed for application across Canada, is user-friendly and flexible enough to be adapted to local circumstances.

On the other hand, there are some useful elements of these tools to carry forward to Phase 2. For example, the tool developed for CMHC to estimate GHG emissions from neighbourhood developments has many components that can be carried forward to a more comprehensive costing tool, including the relationships that were established to relate development patterns to vehicle use. The Infra-cycle model, and specifically its precursor studies (CMHC, 1997) also provides background research on costs and revenues for different hard and soft services.

In summary, the review of available tools indicates that a new tool is needed to support the objectives of the project building on the work completed to date. This conclusion is supported by the fact that there is widespread interest across Canada for the development of the proposed costing tool. Throughout the Phase 1 study, there was no indication from any members of the Steering Committee that an applicable tool was already in existence or under development.

Table 3.1: Comparison of Costing Models

	CRITERIA											
	Estimates capital and operating cost variables for hard infrastructure	Estimates full lifecycle costs	Addresses local/neighbourhood scenarios	Allows users to input specific costs for all or some variables	Allows user to input community form scenario or scenario parameters	Addresses air pollution and climate change costs	Easily available to public at no or nominal cost	Tested and ground truthed	Applicable across Canada	Directed to multiple stakeholders (incl. Municipalities)	Easy to use and flexible	Addresses sustainable infrastructure elements
CMHC GHG Tool			✓		✓	✓	✓	✓	✓	✓	✓	
SCALDS Model	✓				✓	✓				✓		
STEAM 2.0	✓	✓				✓						
QUEST Model				✓	✓	✓	✓	✓		✓		
PLACES[3]					✓	✓				✓		
Sierra Club Density Calculator			✓		✓	✓	✓			✓		
SFLCV - View of Density	✓		✓			✓	✓				✓	
City Green									✓			
Infra-cycle	✓	✓	✓	✓	✓				✓			

Note: Blank indicates where model does not satisfy criteria or where functionality is unknown.

4 CONCEPTUAL FRAMEWORK FOR COSTING

Chapters 2 and 3 have provided essential building blocks for development of the model. Specifically the review of literature and available models has provided information on:

- Key costs to be included in the model;
- Key development characteristics affecting infrastructure costs to help to identify the sample development scenarios to be tested;
- Guidance on model characteristics including the need for flexibility to respond to local circumstances;
- Confirmation that a model that achieves the project's objectives does not exist, although existing models will provide useful input to the proposed model.

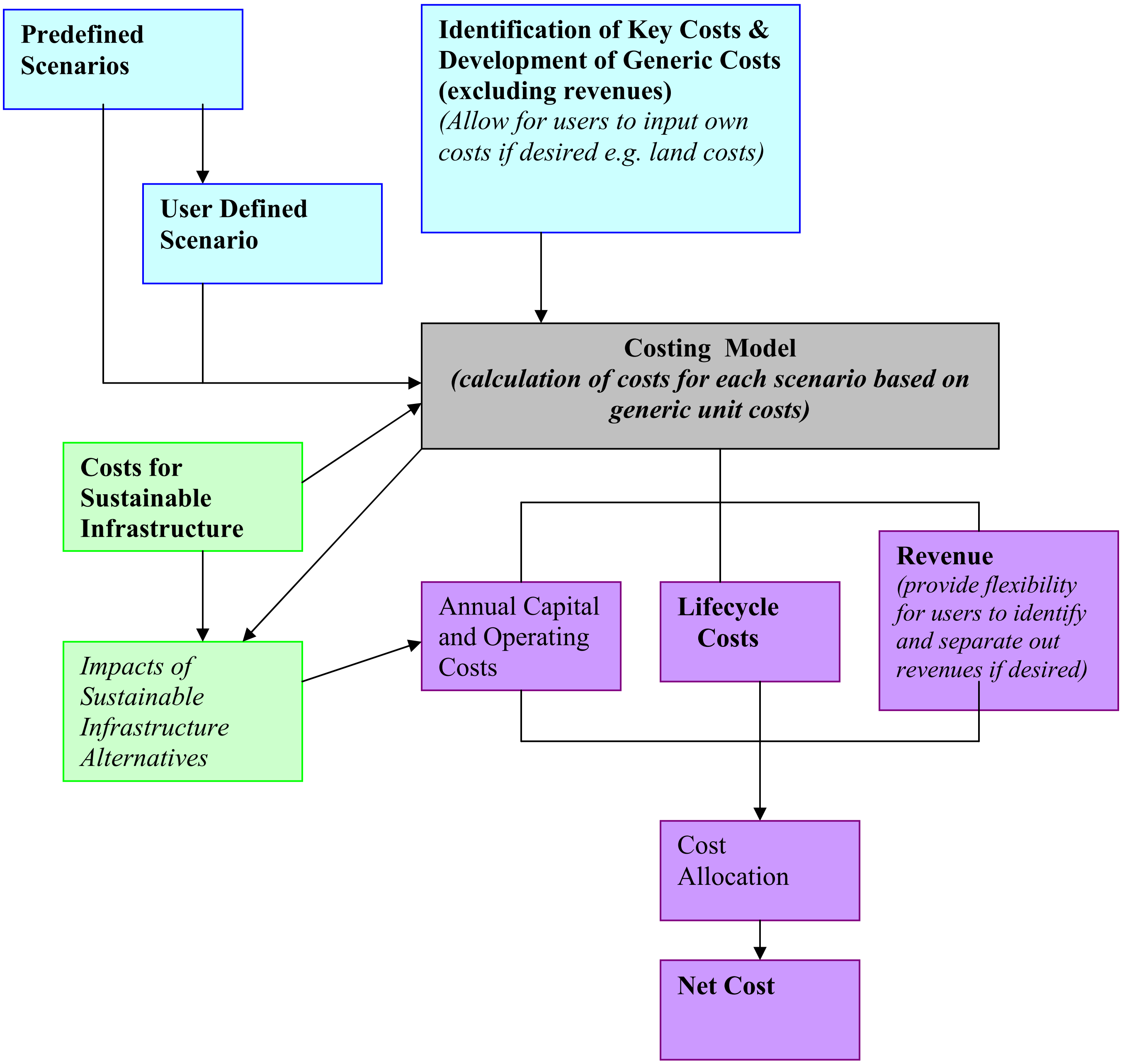
The objective of the conceptual framework for costing is to provide a starting point for the development of the costing model in Phase 2 of the study. This Chapter, and Chapters 5.0 to 7.0 describe core elements of the proposed costing model. This chapter describes the proposed approach to costing for the model. Key unit costs to be considered in the model are also identified. Chapter 5.0 provides details on each of the unit cost categories. Chapter 6.0 provides ideas for addressing sustainable infrastructure costing alternatives and Chapter 7.0 describes the sample development scenarios to be tested in the model and to provide a validity check on the cost estimates.

The development of the conceptual cost model consisted of several integrated steps as follows:

1. Identification of key costs to be considered in the model including sustainable infrastructure alternatives and the level of detail at which they would be assessed.
2. Development of generic costs for each category on a per unit basis, which take into account differences in costs by location and type of development, where applicable.
3. Selection of development scenarios to be tested in the model and provide a validity check on the cost estimates.
4. Calculation of costs for each scenario based on generic unit costs and feedback/corrections to generic costs.
5. Calculation of lifecycle costs for each scenario.
6. Calculation of revenues and net costs.
7. Overlay costs/benefits of sustainable infrastructure alternatives.

Figure 4.1 provides an overview of the proposed framework for the costing tool.

Figure 4.1: Proposed Framework for Costing Tool (Preliminary)



The remainder of this chapter provides a discussion of six of the stages in the costing framework as well as key issues that influenced it. Chapter 7.0 describes the selection of sample development scenarios.

4.1 Identification of Key Costs to Be Considered in the Model

The literature review identified the key cost categories that must be considered in order to fully account for sustainable development costs. These were described in general in Chapter 2 and are summarized by study author in ***Table 4.1***. In addition, a number of other cost categories were suggested in the Terms of Reference for the Project. These costs reflect local and regional infrastructure costs (both capital and operating), private costs, and external costs. This section highlights key costs considered in the preliminary work described in this report as well as the costs proposed to be addressed in the actual tool as options for user input.

Table 4.1: Variables Covered in Selected Studies

Study Author	Roads	Water & Sewage	Utilities	Private Transport	Public Transport	Development costs	Emergency Services	Municipal Services	Education	Health	Road Accidents	Air Pollution	Noise Pollution	Land	Travel Time Costs	Net Fiscal Impact
Burchell	✓	✓		✓	✓	✓		✓						✓	✓	✓
Condon and Gonyea	✓	✓	✓			✓										
Duncan	✓		✓						✓							
Essiambre	✓	✓	✓		✓	✓	✓	✓	✓	✓						
Frank	✓		✓						✓							
IBI	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	
SEMCOG	✓	✓				✓		✓						✓		✓
Envision Utah	✓	✓		✓	✓	✓						✓			✓	

The summary of local and regional cost savings highlighted in the literature review indicate that the key costs that vary with a movement towards sustainable community planning are:

- Local and regional capital, operating and maintenance costs for hard services including water supply and transmission, wastewater treatment and transmission, roads and transit, stormwater servicing.
- External/indirect costs including air emissions, healthcare costs, auto accidents, congestion, parking, travel time.
- Land area/consumption of land.

Some research also suggests that the cost of hospitals and education facilities also vary by neighbourhood; however, the study team found that the majority of these costs are driven purely by population and the cost per person is relatively constant by neighbourhood scenario, unless there is a situation where there is spare capacity. For the purpose of this study, school costs were quantified and included in the costing framework. Healthcare costs however, were not considered. The complex nature of healthcare costs, together with the uncertainty of the link between urban form and costs, did not warrant their inclusion in the costing model.

Land consumption, and its costs, also deserves careful consideration. Land costs are generally passed on directly from the developer to the consumer. There are costs associated with the consumption of land for development (i.e. making it unavailable for other uses), but these vary considerably by location and require significant value judgements. As discussed further in Section 5.5.1, land costs will not be estimated explicitly as part of the primary costing model, but allowances may be made for the user to incorporate land costs if desired and available. The feasibility and mechanisms for doing this will be explored further in Phase 2 of this study.

There is general consensus in the literature on the importance of considering the external, non-monetary costs in addition to the conventional monetary costs so as to develop a full cost accounting framework. It appears that urban development patterns do in fact influence items such as air pollution and traffic accidents. In this study, motor vehicle accidents, air pollution, vehicle costs and climate change are addressed in detail.

This study primarily focuses on public costs and as a result, these are discussed in more detail. However, the study also discusses the issue of who pays broadly and identifies both the primary/first financing body and associated cost recovery mechanisms for one or more of the three sample municipalities. The tool itself will use refined costs which allow the client to separate out user fees, where possible.

Table 4.2 lists the cost categories selected for consideration in this preliminary work to test the feasibility and utility of a model. It also lists costs that have been identified for further consideration in Phase 2 based on the stakeholder comments on Phase 1 results. The Phase 1 list combines the results of the literature review and the requirements identified for the study by CMHC. Further discussion of each cost category, including those categories that were not costed, is provided in Chapter 5.0. It is important to note that not all possible costs are included in the list. Rather, for the purpose of the feasibility work, the focus is on key cost variables. These variables will be fully costed as default settings in the model. The tool itself is proposed to have capacity to include a wider range of costs. These additional variables (e.g. user fees, land costs) can be input by clients where the data is available. In addition, it is expected that the model/tool will evolve, over time, to incorporate a wider range of variables as this becomes feasible.

Table 4.2: List of Cost Categories

Primary Category	Items Investigated in Phase 1	Additional Items Proposed for Consideration in Phase 2 in Conjunction with Tool Development
Hard Infrastructure	• Internal roads and utilities • Arterial roads • Water distribution service • Water treatment facilities • Sanitary sewers • Wastewater treatment facilities • Storm sewers • Stormwater treatment facilities • Schools • Recreational facilities	• Residual capacity for all services
Municipal Services	• Transit facilities / services • School transit • Fire services • Police services • Waste management services	• Residual capacity for all services
Private Costs	• Driving Costs • Home energy	
External Costs	• Air pollution • Climate Change • Motor vehicle collisions	• Land costs
Selected Non-traditional Infrastructure Costs[24]	• Bike lanes/paths • District heating/cooling systems • Traffic calming • Pervious pavement • Solar Orientation • Distributed power generation • Xeriscape landscaping • Alternative road standards	• Attempt full costing for all and add costing information for other items where the costing information is readily available.

[24] Where available, default costs will be included in the tool for these items.

Primary Category	**Items Investigated in Phase 1**	**Additional Items Proposed for Consideration in Phase 2 in Conjunction with Tool Development**
Revenues	• Property Taxes • Development Charges • User fees (by exclusion in relevant costs)	• User fees (explicitly) • Other assessments
Other Items Considered but Not Costed[25]	• Water Pollution • Land Consumption • Travel Time and Congestion	

4.2 Calculation of Generic Costs for Each Category on a Per Unit Basis

In this step, costs have been estimated for each cost category and type of direct cost based on the team's knowledge of development costing across Canada. The purpose of this costing is to provide default settings for the model. Chapter 5.0 describes how unit costs were calculated in detail for each cost category.

Costs are generally developed on a per unit basis. Depending on the specific cost category, costs could be developed on a per metre, per hectare, per capita or per household basis, whichever is most appropriate for the given category.

The quantitative costs for each of these categories are based on a large number of assumptions regarding infrastructure type and character. These assumptions have been carefully recorded for each category and will be subject to scrutiny during the development of the tool. . For example, width of roads, types of pipes, types of construction and infrastructure geometric assumptions must be made to generate costs. Some of these assumptions are generic in nature. Others vary specifically for each scenario and are discussed in the following chapter.

It was considered necessary to produce generic per unit costs in order to allow the eventual model to respond to scenarios that are created by users (rather than the six produced by the CMHC model as test cases). These generic costs are adjusted to apply to each scenario as appropriate.

4.3 Calculation of Costs for Each Scenario

Selection and development of scenarios is described in Chapter 7.0 and all parameters required for costing are defined in the scenario definitions. Therefore, the development of scenario costs is a matter of applying the unit costs to the scenario variables.

[25] See Section 5.5 for an explanation for these items.

This exercise provides feedback for testing the accuracy of the generic costing basis. Costing for scenarios helps guide the development of the costing framework and ultimately the tool development, ensuring that a range of potential variables and corresponding costs are reflected. It also allows us to test the results against previously completed studies.

4.4 Calculation of Lifecycle costs

Life cycle costs of a particular infrastructure item depend on the following:

- Initial capital cost
- Annual operating costs
- Replacement costs
- Salvage value at end of analysis period (assumed to be negligible)

For this initial report, it was decided that lifecycle costs would be expressed in annualized terms. In other words, the annualized lifecycle costs represent the amount that would need to be expended each year (in present dollars) in order to support the development over a 75-year period. Where a certain infrastructure element has a lifespan of less than 75 years, replacement costs are included in the model. Typical replacement periods by type of infrastructure are discussed in Section 8.4. It is also recognized that some types of infrastructure, including roads, may require refurbishment over their lifetime, without complete replacement. For example a road might be resurfaced one or two times before a complete replacement is required. Practices for major maintenance may vary by jurisdiction and budget constraints. Inclusion of an option for infrastructure rehabilitation within the model could be considered. For example, the user would have the option of specifying time intervals between complete replacement as well as time intervals between major rehabilitation, with the two being interrelated. The drawback of this is that it adds another layer of complexity to the model and requires more assumptions on the part of the user, since there is no one single practice for determining rehabilitation intervals. This issue will be reviewed in Phase 2 during the model development.

Expression of lifecycle costs in annualized terms allows a direct comparison with annual revenues such as property taxes. However, it presents challenges when comparing costs to one-time revenues such as development charges. In this case, comparing costs to revenues is more appropriately done using a Net Present Value (NPV) approach.

In development of the tool, different options will be examined for comparing lifecycle costs and revenues, including an annualized approach and an NPV approach. The tool will also allow the user to explore different discount rates for infrastructure financing.

For this initial report, operating costs are simply taken as the estimated annual values. To simplify the approach at this initial stage the effects of inflation were not taken into account.

4.5 Calculation of Revenues and Net Costs

Cost recovery or revenue generation from urban development comes from three major sources: property taxes, development charges and user fees.

Two types of revenues were explicitly considered for this Phase 1 study:

- Property taxes; and,
- Development charges.

Additionally, some municipalities are also realizing revenue from infrastructure by partnering with or becoming utilities, as is the case in Vancouver and Toronto, and these sources could be incorporated into the tool on a case-by-case basis.

For the purpose of testing initial scenarios and developing a conceptual framework, user fees were not quantified separately. With the exception of transit services and recreational facilities, user fees are not easily separated from revenues and costs. For example, most municipalities charge a fee for water usage, but operating budgets provided by selected municipalities for this study generally reflected a net cost only. For these costs, the net cost excluding user fees were used. Other user fees, such as telephone and cable, were excluded from the analysis since these are generally paid for by households according to usage. They are also a small percentage of total neighbourhood costs. The intention is that the tool will allow the use of refined costs which separate out user fees, where possible. One option for incorporating the impact of user fees within the tool would be to calculate the total costs of the infrastructure element or service and include a factor that would be covered by user fees. For example, total operating costs for water services would be calculated and, where it is known that the municipality recovers the full operating costs from user fees, the revenues (or user fees) would be 100% of the operating costs. The tool would present both gross and net costs.

Property taxes were estimated using assessment values and housing prices for Ottawa (as a representative case example). Figures were estimated for each housing type and for each location. Similarly, development charges were estimated on a per unit basis. Chapter 8.0 contains a more detailed description on options for including these costs in the lifecycle cost estimates tested in Phase 1.

4.6 Consideration of Sustainable Infrastructure Alternatives

The Terms of Reference for this study provided a list of sustainable municipal infrastructure alternatives for potential consideration in the costing model[26]. From this list, the study team selected eight sustainable infrastructure alternatives for more detailed assessment in Phase 1. The selection was made based on the likelihood that the costs will vary significantly by urban form/scenario as well as an assessment of which alternatives are most likely to be of interest to municipal decision makers.

Essentially, most of the sustainable infrastructure alternatives could be applied to any scenario. Therefore, it was decided that the most appropriate approach for including these alternatives in the costing framework was to consider them as enhancements to the basic scenarios. The level of detail in terms of quantifying the cost of sustainable infrastructure alternatives varies by measure. For example for bike lanes, it is a fairly straightforward exercise to estimate the linear cost of a bike lane and add this to the scenario cost. On the other hand, quantifying the impacts of alternatives such solar orientation is extremely complex.

For the purpose of this Phase 1 report, the potential costs and/or impacts of sustainable infrastructure alternatives are discussed in detail (Chapter 6.0), but not applied to the individual scenarios. It is intended that the tool will include a mechanism for users to apply costing for sustainable infrastructure elements as an option.

It is noted that in the development of the costing tool, information on additional sustainable infrastructure alternatives may be incorporated (beyond the eight alternatives identified in Table 4.2), as information on the cost of such alternatives is advancing rapidly.

4.7 Other Considerations in Developing the Conceptual Framework

4.7.1 Consideration of Residential vs. Employment Lands

A key issue considered in the development of the costing framework was the degree to which the costing model would consider costs and revenues for non-residential development. From a sustainable development perspective, it is highly desirable to develop communities that include a mix of compatible land uses, both residential and commercial. The benefits of including employment opportunities within or near residential developments in order to improve live-work opportunities has long been recognized by planners. Similarly, including commercial uses such as convenience stores and restaurants in a residential neighbourhood can also reduce motorized transportation activity since people can walk to these services. Finally, a development with

[26] These included: Pedestrian and bicycle paths or lanes, traffic calming techniques, parking lots and rear lanes, biological waste treatment systems (living machines or solar aquatics), artificial wetlands, on-site water treatment systems, pervious pavement and pipe systems,on-site stormwater retention systems (underground tanks, rain barrels, green roofs, stream daylighting and naturalization, xeriscape landscaping approaches, tree preservation, community compost systems, community recycling, district energy systems (energy, heating/hot water, cooling etc.), renewable energy generation (wind, photovoltaics, water, methane recovery for power generation etc.)

mixed land uses tends to utilize infrastructure such as roads and sewers more efficiently, since peak usage times by residents and employees tend to be offset.

The challenge with including non-residential lands in the costing analysis is that there is a large range of potential non-residential uses including office, retail, light manufacturing and institutional, all with very different infrastructure requirements. Also, as discussed further in Chapter 8 of this report, when the costs associated with employment lands are included in the analysis, it is very difficult to compare neighbourhood scenarios with different mixes of land uses. For example, if one scenario includes commercial uses but the other does not, it is not reasonable to compare the two scenarios on a cost per household basis.

Various options were examined for including non-residential uses including the development of a standardized "unit," which would equate residential units to commercial floor space or number of employees. However, due to the wide variety of potential commercial uses, it is difficult to develop a standardized comparison.

The approach proposed for the costing framework is to include the "effects" of non-residential development (e.g. reduced travel effort due to mixed land uses) where possible, but not include the direct costs of developing the non-residential lands in the scenario comparisons. Essentially, the scenarios are developed to include both residential and non-residential uses, but in the scenario cost comparisons only the residential component of the development costs are considered.

4.7.2 Residual Capacity

Another key issue to be considered is the degree to which the model can address residual capacity (for infrastructure) for development in downtown and inner suburbs. Such residual capacity is site/area specific and may be counter-balanced by extraordinary costs of rehabilitation and replacement of older infrastructure. For the purpose of testing initial scenarios, the effect of residential capacities is not considered. However, the tool will allow users to input adjustments to account for residual capacity.

5 DEVELOPMENT OF UNIT COSTS

The purpose of this section is to provide a summary of the development of costs for each of the primary Phase 1 cost categories. At this stage, a distinction between different neighbourhood types is made only where the unit values would vary by neighbourhood type. Details on the costing results by scenario are presented in Chapter 8.

Background research and detailed unit costs for each cost category are presented in ***Appendix B***.

5.1 Hard Infrastructure

Hard infrastructure generally refers to physical infrastructure that is constructed at the time of neighbourhood development (e.g. internal roads) or is required to support the needs of the neighbourhood at the regional level (e.g. a sewage treatment plant). Hard infrastructure costs specific to an individual neighbourhood were generally estimated from 'first principles' using standard unit costs. Reflecting the fact that regional infrastructure costs are more difficult to allocate to a single neighbourhood, as well as data limitations, more simplified approaches were developed for incorporating regional infrastructure costs. Where relevant, these approaches are explained in ***Appendix B*** (e.g. arterial roads).

A brief description of the approach for developing costs for specific hard infrastructure categories and key assumptions are provided below with supporting documentation in ***Appendix B***.

5.1.1 Internal Roads and Utilities (Capital Costs)

Depending on the size of development, the construction of local roads and potentially collector roads may be required. For the purpose of this initial framework, local roads and collector roads have been grouped together and referred to as "internal" roads, as distinct from surrounding roads which would generally be arterial roads. In general, where new local roads are required, developers would be responsible for the capital costs. Collector roads are often constructed and paid for by municipalities through development charges, as are arterial roads. To reflect possible differences in "who-pays" for local collector and arterial roads, three categories may be required for the tool. For the purpose of this Phase 1 report, two categories have been maintained – internal roads (local or collector) and arterial roads.

Capital costs for internal roads were developed to include all components within the street right-of-way including sub-base, pavement, sidewalks, street lighting and utilities. As described in ***Appendix B***, unit costs were developed for each component of road construction is based on typical current materials and labour costs.

Internal road costs are closely related to length of roads, which is a function of the neighbourhood layout. Internal roads and related costs may also vary in terms of width. For example, local streets in traditional suburban neighbourhoods are typically constructed with a minimum 8.5 m pavement width. Alternative standards could see pavement widths of 7.5m or lower. Another possible variation on local road construction would be the provision on sidewalks, which might not be provided in an outer-suburban neighbourhood, or may be provided on one side only. Variations on local road length, pavement width and sidewalk provisions are considered in the development of scenarios in the following chapter.

5.1.2 Arterial Roads (Capital Costs)

The purpose of arterial roads is to provide regional access by connecting major development areas. In most Canadian Cities, basic arterial road systems are generally well developed. When new development occurs, arterial roads are generally in place, although the new development may trigger an extension or widening of a particular arterial road.

For this study, it was decided that the full costs of arterial roads should initially be reflected in the scenario costs. Within the tool, there will be a mechanism to reduce costs where particular development utilizes spare arterial road capacity.

The approach chosen to estimate the length of arterial roads associated with a particular development was to estimate arterial road length per area. In most cities, arterial roads tend to be more closely spaced in inner areas and less dense in outer areas. However, within inner areas, arterial roads provide access for much greater levels of development than in outer areas.

As described more fully in ***Appendix B***, costs for arterial roads were estimated on a cost/km basis using approximate linear costs. No attempts were made at this point to account for variations in arterial road width by neighbourhood type. Typically, arterial roads are either 4 or 6 lanes wide.

Although urban developments also generate a demand for expressways, costs for these facilities were not considered in the analysis due to the fact that expressways often tend to be constructed to serve intercity and inter-provincial transportation demands, irrespective of what occurs in an urban area.

5.1.3 Road Operating Costs

Road operating costs include costs such as street sweeping, snowplowing, sign maintenance, minor repairs and other ongoing maintenance requirements. These costs tend to vary significantly depending on the type of facility, age of facility and location of facility.

As described in ***Appendix B***, municipal road operations budgets for several cities were combined with information on road lengths to develop a preliminary unit cost ($/lane-km) for road operations. Since very little data exists on the breakdown of maintenance costs by type of facility, costs for local roads and arterial roads were combined in the preliminary costing work. In the modelling framework, operating costs for roads will be separated out for arterials, collectors and local roads since maintenance practices vary significantly by each type of facility.

For example, arterial roads are given priority for snow clearing. Users would then be given the option of adjusting the default road operating costs based on local practices. Additional discussions with municipalities will also be undertaken during Phase 2 of the project to determine the approximate relative differences between operating costs by type of facility.

5.1.4 Water Distribution Service

The cost of water distribution services within a neighbourhood is almost directly related to the length of internal roads. Therefore, costs were developed by multiplying the linear unit costs of standard water mains by the length of roads within the neighbourhood.

Water distribution costs include the cost of both local distribution lines as well as trunk lines. It was assumed that all internal streets would include distribution lines (150 mm diameter mains) and all arterial roads would include trunk lines (300 mm diameter mains). In general, internal distribution lines are paid for by the developer and regional distribution lines are paid for by the municipality through funds such as development charges.

5.1.5 Water Treatment Facilities

In most urbanized areas, water treatment occurs at centralized facilities. The primary capital costs associated with water treatment is the actual construction of the facilities themselves. The need for water treatment facilities is primarily related to number of households (or square footage, number of employees, etc. in the case of commercial development). Therefore, the basic approach for estimating the cost of water treatment was to apply a unit value reflecting an average cost per household. However, it is recognized that large single detached households tend to use more water on a per capita basis than a downtown apartment for example (mainly due to lawn and garden watering). Adjustments are made in the costing analysis to account for this.

The operating cost for water treatment facilities was also calculated on a per household basis and primarily includes the cost of treatment, as well as regular maintenance and repair costs

5.1.6 Sanitary Sewers Distribution

The cost of sanitary sewers was estimated in a similar manner as water distribution; that is, on a linear basis.

Sanitary sewer costs include the cost of both local collection lines as well as trunk sewer lines. It was assumed that all local streets would include distribution lines (200 mm diameter mains) and all arterial roads would include trunk lines (250 mm diameter mains).

Within the tool, the user would have the option of excluding or discounting the costs of trunk sewer lines if these already exist and have spare capacity.

5.1.7 Wastewater (Sewage) Treatment Facilities

The capital and operating costs of wastewater treatment facilities was estimated in a similar manner as water treatment facilities.

5.1.8 Storm Sewers

The capital and operating costs of storm sewers were estimated in a similar manner as water distribution; that is, on a linear basis.

Storm sewer costs include the cost of the local collection lines ranging in size from 300 mm to 1800 mm.

5.1.9 Stormwater Management Facilities

Stormwater management refers to measures that enable both the quantity and quality of storm runoff to be managed. In new lower density inner and outer suburbs current practice is to use excavated ponds for stormwater management since they would typically have sufficient space available for the ponds. High and medium density neighborhoods tend to use a range of stormwater management techniques depending on their specific site. These include storm ceptors, percolation basins, pervious pavement, and pervious parking lots (all of which represent extra costs over conventional methods), parking lot surface storage, landscape soak pits, building rooftop storage and catchbasin/manhole sumps. When combinations of the aforementioned techniques are used to address stormwater management, the overall cost will be less than the cost of a conventional stormwater pond. These technologies may not be as effective in some cases as a well constructed storm water pond, but are required in higher density areas due to space constraints. Based on the range of different practices used, a reduction in cost in the amount of up to 50% would be expected from low to high-density neighbourhoods. This ratio was then pro-rated through the different neighborhood scenarios.

One enhancement that will be made in the Phase 2 study will be the adjustment of SWM costs to reflect the amount of impervious area. At present, the unit value reflects a total average area.

Some municipalities are also moving towards cash-in-lieu type arrangements for stormwater management/treatment. For example, if an effective treatment mechanism cannot be developed on a site, the developer could contribute equivalent costs to shared facilities or improvements to other existing facilities. The Toronto and Region Conservation Authority is presently developing representative costs for cash-in-lieu approaches which will be available for Phase 2 of this project.

5.1.10 Schools

Previous research indicates that schools represent the largest single cost of a development, both in terms of operating and capital costs (CMHC, 1997). For the current study, school costs from annual budgets for selected school boards were used to develop a per capita cost (population 18 and under), which could be applied to the neighbourhood scenarios.

It was assumed that on a per capita basis, the cost of schools is fairly constant for different neighbourhood types and locations.

As for other costs, the proposed tool will allow for a reduction factor to account for spare capacity in schools where it may exist and be known.

5.1.11 Recreational Facilities

The provision of recreational facilities varies significantly by neighbourhood type, location and demographics. Operating budgets for medium to large municipalities were reviewed and a uniform level of service was attempted by selecting key recreational items. These included items designated as: parks, recreation, libraries, tourism, culture, heritage, arts programs, community centers, and arenas. Total operating budgets were then used to develop average values per capita. It was assumed that per capita expenditure on recreation facilities would not vary significantly by location, or at least the variation by location/neighbourhood would be substantially less than the basic variation in practices throughout an urban area.

5.2 Municipal Services

Municipal services refer to regular services required to support an urban population of which transit services, police and fire services and waste management services represent the major cost items. Most of these costs are ongoing operating costs, although there are some capital costs associated with the provision of municipal services (e.g. vehicle purchases). Very little data is available on the cost of municipal services for individual neighbourhoods since services such as policing tend to be provided on an area wide basis. The basic approach used for this study was to examine municipal operating budgets and develop average costs on a per capita basis.

A brief description of the approach for developing costs for key municipal services and key assumptions are provided below with supporting documentation in ***Appendix B***.

5.2.1 Transit Facilities and Services

The total cost of providing transit services within a neighbourhood is comprised of operating costs, which are partially recouped by revenue and partially by government funding, and capital costs, which are completely provided by government funding. Some municipalities also recover a portion of transit costs through development charges or other levies. Both costs are functions of service levels that are, in turn, functions of neighbourhood type.

Operating costs for selected transit properties were used to develop unit costs per vehicle-service hour. Costs then vary by neighbourhood depending on how much transit service is provided. Estimates of transit service levels for different neighbourhood scenarios were developed based on previous work conducted for CMHC (CMHC, 1999) as well as more recent reviews of overall service levels for different municipalities across Canada.

Developing estimates of the capital costs for transit, which are primarily related to vehicle costs in a bus-based system, is more difficult. As described in ***Appendix B***, after examining several different approaches, it was decided that the best way to reflect the capital costs of transit services was to relate bus requirements to vehicle service hours, and then estimate the capital cost of buses directly.

It is also recognized that for larger cities, transit systems may involve technologies other than surface buses running in shared right of ways. Such technologies include heavy rail transit, commuter rail, busways and Light Rail Transit. Because these systems vary widely by city, there is no way to generically quantify the costs of "higher-order transit" systems and assign them to neighbourhoods. However, the omission of these costs will be noted in the model as a reminder to the user to include them where appropriate. Another consideration in including these broader transit costs is that major transit facilities don't just serve one area or neighbourhood. In many cases, funding of these systems is also shared by provincial and federal governments.

5.2.2 School Transit

School boards across Canada generally assume financial responsibility for transporting elementary and secondary school students; the necessary funding is acquired from local tax revenues as well as government grants.

Requirements for school transit vary significantly based on whether or not students can walk to school or take regular transit. As part of this study, data from a recent household travel survey in Calgary was used to establish a relationship between housing density and school bus transit requirements. Total school bussing costs were then estimated by applying average bussing costs per student. A detailed description of the process is provided in ***Appendix B***.

5.2.3 Fire Services

Virtually all urban areas in Canada have in place maximum response times for emergency services. Lower density neighbourhoods tend to have a lower number of calls per area; however, the reduction in fire stations required is not linear since basic response times have to be maintained. Unfortunately, most information that could be collected on the cost of fire services was at an aggregate citywide level. Recognizing the limitations in the data, the cost of fire services was estimated on a per household basis using average values obtained from selected municipalities. Both capital and operating costs were estimated using the same process.

Further data is presently being generated by IBI Group for the City of Sudbury, including variances in costs by selected municipality and will be available for use in Phase 2.

5.2.4 Police Services

Costs for police services were estimated using the same approach as fire services. Discussions with the City of Windsor Police Department indicated that calls tend to be closely related to density levels.

5.2.5 Waste Management Services

The costs of waste management includes capital and operating costs for curb-side pick-up as well as for the construction and operation of landfills. However, due to the wide variation in landfill practices across Canada, and limited costing information, the costs of landfill were excluded from the analysis.

Operating budgets for representative municipalities were used to develop cost per household for waste management, which could be used in the scenario costing. No adjustments have been made at this point to the unit costs to reflect the fact that it is more efficient to serve higher density neighbourhoods.

5.3 Private Costs

The appropriateness of including private costs in a costing model such as this is open to debate. However, research has found that two significant private costs, home energy and vehicle costs, can vary significantly by neighbourhood location and form and for this reason these costs have been quantified. Ultimately, it will be left up to the user of the tool to decide whether these costs should be factored into the decision process.

5.3.1 Home Energy (Heating)

Home energy consumption is related to heating, air conditioning and hot-water heating. For this study, data for home heating only was considered. The costs of air conditioning have not been included because they vary by household and by location. For example, all households in Canada require heating, but air conditioning is an optional choice. The cost of hot water heating was not included because accurate data could not be acquired and also because the costs likely do not vary as much by urban form as home heating costs.

Consumption rates per household unit vary fairly significantly by size and type of dwelling. For example, apartments typically require about 40% less energy for heating than a single-detached home, not accounting for differences in size.

Data from a number of Canadian housing studies was used to generate a summary of the quantity and cost of residential energy consumption in new Canadian houses in Alberta, Ontario, and Nova Scotia by heating fuel, building standard, and house type. These unit costs were then applied to the respective number of units by type for each scenario to develop a total home heating energy cost estimate.

5.3.2 Vehicle Costs

Vehicle costs represent a considerable proportion of a household's annual expenditures. According to Statistics Canada, private vehicle costs accounted for more than 11% of total household expenditures in 1997 [27].

Although vehicle costs are a private user cost, they were considered significant in this study of costing mechanisms for two reasons. The first reason is that they represent a proportionately high percentage of household spending. The second and more important reason is that vehicle costs can vary quite substantially by neighbourhood type and location. It is envisioned that in the tool to be developed in Phase 2 of this study, there could be an option for the user to choose whether vehicle (or any other private) costs are to be included in the costing comparisons.

For this study, vehicle operating costs are estimated directly from vehicle-kilometres of travel (an output of the scenarios), whereas vehicle ownership costs are developed using an auto-ownership model from a previous CMHC study (CMHC 1999). Both vehicle usage and ownership estimates vary by neighbourhood type and location.

Vehicle operating costs include the cost of fuel, oil and maintenance. Annual ownership costs are fixed costs like insurance, licence fees, registration fees, taxes, finance costs and depreciation.

5.4 External Costs

In this study, external costs refer to those costs that are not directly related to the development of a neighbourhood, but occur as a result of the activities of people or workers within the neighbourhood. External costs are commonly defined as costs borne by others.

5.4.1 Motor Vehicle Collisions

Motor vehicle collisions and their associated costs are an outcome of vehicle travel, which is in turn a function of neighbourhood type and location. In the year 2000, there were some 2,900 deaths caused by motor vehicle collisions in Canada.[28]

Motor vehicle collisions are typically estimated or expressed using a collision rate based on vehicle-kilometres of travel (e.g. collisions per 100 million kilometres travelled). This rate can be applied on an overall system basis or by individual road facilities. In general, collisions tend to vary by type of road and by traffic volume conditions. In estimating the number of collisions associated with a neighbourhood scenario, it is appropriate to consider all travel by vehicles originating in the neighbourhood, as opposed to travel on neighbourhood roads only. Therefore, the starting point for estimating the costs of motor vehicle collisions is the vehicle-km of travel generated by the neighbourhood scenario. Because the VKT data includes all travel, not just

[27] Statistics Canada, Catalogue 62-202.
[28] Canadian Council of Motor Transportation Administrators (2000).

travel within the neighbourhood, it would be inappropriate to relate neighbourhood street patterns (such as frequency of intersections) to collision rates.

Using data on collision rates per vehicle-km, it is possible to estimate the number of collisions by type: property damage only, injury and fatality. A value may then be assigned for each type of collision and an aggregate cost for collisions can be calculated.

Appendix B provides a summary of the values assigned to different types of collisions along with the underlying assumptions.

5.4.2 Air Pollution

Transportation activity is a major contributor to air emissions and in turn air quality. For example, it is estimated that vehicles produce approximately half the pollutants that contribute to smog[29]. Air pollution and air quality is a significant concern for public health. Smog and other air emissions have been linked to increased hospitalizations and pre-mature-deaths. According to Environment Canada, "The are strong links between air pollution and health problems, especially for the elderly, children and for those with respiratory and cardiac problems. A large number of studies, including some from the Government of Canada, the Ontario Medical Association and the Toronto Public Health Department show that air pollution can lead to premature death, increased hospital admissions, more emergency room visits and higher rates of absenteeism."[30].

For the purpose of scenario costing, air emissions are estimated based on the amount of travel generated by the residents living within a neighbourhood. A value is then assigned to these emissions outputs in order to provide a broad cost estimate of air pollution. A total of five pollutants are estimated: ·Volatile Organic Compounds (VOC's), Carbon Monoxide (CO), Nitrogen Oxides (NOx), Sulphur Dioxide (SOx) and Particulates (PM10 and PM 2.5).

5.4.3 Climate Change

The analysis of the costs of climate change is separated from that of other air emissions impacts because the nature of the impacts are different. Furthermore, the level of uncertainty of emissions estimates for greenhouse gases is lower than other emissions. Climate change is also a very topical subject in Canada and may be of interest to users of the tool that will be developed as part of this study.

There is convincing evidence that increasing concentrations of certain emissions such as carbon dioxide (CO_2) are contributing to global warming or climate change, although there continues to

[29] Environment Canada, Air Quality Background, (2002) http://www.ec.gc.ca/transport/airquality.htm
[30] Environment Canada, (2002). www.ec.gc.ca/air

be a debate regarding the pace and nature of these changes. In 1997, transportation accounted for approximately 25% of all of Canada's greenhouse gas emissions[31].

The basic process used to estimate the costs of climate change or greenhouse gas emissions is essentially the same as for other air emissions in that emissions output is based on vehicle-km of travel generated by residents and then converted to costs using an approximate value per unit output of emissions.

5.5 Cost Categories Considered but Not Quantified

5.5.1 Land Consumption

There are two types of costs associated with land consumption. The first type is the direct cost of the land consumed for development (e.g. building lots, roads, etc.). Direct costs of land are generally paid for by developers and passed on to consumers, essentially in the same manner as the actual costs of buildings. Since the primary intent of the costing tool is to compare different development scenarios on the same parcel of land, it may not be necessary to include the cost of land in the comparison of scenarios. On the other hand, the tool might be used by someone who is comparing the cost of two different developments in different areas of a city, for example a developer who is speculating on whether to undertake a greenfield development or an infill project. In the latter case, it would be useful to allow the user of the tool to input a land cost if it is known.

The second type of land cost that could be considered in the costing model is the opportunity cost of land consumption. This cost would measure the amount of land that is taken out of such uses or that is otherwise rendered unavailable for related uses such as agriculture, recreation and personal enjoyment or urban development. Developing a cost of land consumption, other than direct costs, is a difficult process and requires extensive value judgements. Costs would also depend on the location of the land in question. For these reasons, the opportunity cost of land consumption is not considered in the costing framework.

5.5.2 Travel Time and Congestion

In many urban areas, congestion is a major issue. Commuters are spending more and more time travelling to work and the costs of goods movement is increasing because trucks are stuck in traffic. Location within an urban area can have an impact on travel time to or from a neighbourhood, however, many factors such as the location of an individual's place of residence compared to place of work can also have a significant impact on travel time. From a regional perspective, developments that encourage more vehicle use contribute to regional congestion problems. However, in both the case of individual travel time and incremental congestion, the problem is one that is imposed by users onto other users. In many cases, individuals make a trade-off between travel time and living in a location where they can afford a larger home away

[31] Environment Canada, Canada's Greenhouse Gas Emissions (2002).

from the urban area. It would therefore be inappropriate to include personal travel time costs in the costing model without including corresponding benefits.

There could be an argument made for accounting for the cost of increased congestion on goods movement; however, it is nearly impossible to credibly relate neighbourhood travel activity to region-wide congestion. Another problem with congestion is that solutions are often location specific, for example, widening an arterial road.

It should be noted that some of the costs included in the costing framework are related to vehicle travel and congestion including vehicle operating costs, air pollution and accident costs, all of which increase with congestion. All of these consider accessibility measures related to how much vehicle effort is generated by a particular neighbourhood scenario.

5.5.3 Water Pollution

Water pollution can be associated with many factors including transportation systems and water or wastewater plant operations. Within transportation systems, the main contributors to water pollution are motor vehicles and the road and parking systems in place to support vehicle traffic. Fluids that leak from motor vehicles, such as oil, brake fluid, antifreeze and toxic metals can mix with stormwater runoff and eventually infiltrate into watercourses or groundwater. Salt from road de-icing and herbicide from roadside vegetation maintenance are also toxic to groundwater and watercourses, having a negative impact on aquatic species and wildlife.

In 1997, The British Columbia Ministry of Transportation estimated that the cost of water pollution from motor vehicles averaged $0.02/vehicle km.[32] However, due to the absence of water pollution costs from other sources with which to compare and provide confidence in this value, the water pollution cost from transportation systems was not included within this study.

In regards to water and wastewater treatment facilities, contrary to transportation systems, there are industry standards that are required to be met for water pollution. These include the level of treatment provided and the discharge quality. As the facilities in this model incorporated quality upgrades into their cost, the facilities are to be kept at current operating standards with acceptable discharge quality. With these standards fulfilled, the system would not be considered to be contributing to water pollution. Therefore, a water pollution cost for water or wastewater treatment facilities was not included within this study.

[32] Victoria Transport Policy Institute, from the report: Dr. Peter Bein, *Monetization of Environmental Impacts of Roads, Planning Services Branch*

6 SUSTAINABLE INFRASTRUCTURE COST ALTERNATIVES

6.1 Overview of Sustainable Infrastructure Alternatives

The following list of environmentally enhancing infrastructure alternatives is limited to approaches already exploited in other regions but not yet widely adopted in Canada.

Because sustainable infrastructure alternatives are varied, and techniques may differ by location, site and current technologies, it is difficult to assess their costs and benefits in a generic scenario application. Actual examples are one way to estimate their practicality and economic impacts. In addition, many measures are multifunctional and synergistic and may therefore need to be considered as sets of options. We have provided general comments and indications of cost implications for a select number of sustainable infrastructure alternatives listed below. Accurate costing data for these measures is becoming available and will be added to the model in Phase 2 if feasible. The logistics of incorporating these (and additional) items into the model will be dealt with during the actual model development in Phase 2.

6.1.1 District Energy Services

Steam, hot water, and cold water are frequently distributed from central plants to provide space heating, cooling, and domestic hot water. Some of the environmental advantages include higher efficiency heat generation with lower combustion emissions, potential for co-generation and large-scale thermal storage, opportunity to take advantage of geothermal and renewable energy options, lower embodied energy of equipment, reduced noise and building-site impacts and the potential for exchanging energy between buildings with heat pumps.

Distributed solar thermal generation and central storage with district heating have been employed in Europe.

A lesser known application of district energy is district cooling. Opportunities include thermal storage with off-peak chiller operation, co-generation with absorption refrigeration, aquifer or deep lakewater cooling, and solar thermal cooling.

Chilled water distribution may be integrated into potable water supply. In addition to efficiency and renewable energy advantages, individual outdoor condensers with accompanying noise and system maintenance is obviated. Density of load and site ground conditions are the principal factors.

6.1.2 Distributed Power Generation

Local generation of electricity has several benefits for distribution and transmission infrastructure reducing line losses and equipment capacity. Typical site generation options include photovoltaics, urban wind turbines, co-generation, and power storage. It may be feasible to "island" local generation during power outages and generate collectively at a community scale. Net billing of green power is permitted in several Canadian and US jurisdictions.

6.1.3 Solar Orientation

Planning configurations that optimize for winter solar exposure for buildings provide opportunities to employ passive and active solar applications. Issues include street layout, shading by proximate structures, landscape parking accommodation, and rights-to-light easements or by-laws. Solar orientation has been much more thoroughly explored in Australia than in Canada and was featured in a number of studies reviewed, included ERM (2001) and EPA Victoria (1993).

6.1.4 Alternative Road Standards

Alternative road standards are part of alternative development standards or the 'Smart Growth' movement that attempts to incorporate mixed land uses and housing types at an increased density while maintaining a sense of community.

In particular, alternative road standards focus on decreasing the amount of infrastructure required within a development and creating streetscapes that are pedestrian and bicycle-friendly. Streets are typically narrower than conventional development and employ traffic-calming techniques such as on-street parking, reduced building setbacks, and the elimination of daylighting triangles to reduce vehicle speed. Rear lanes and rear lot garages are also encouraged.[33]

The road pattern itself can have a substantial effect on per unit cost of housing. It was found that a conventional square grid pattern typically uses 36% of the total development area for streets while cul-de-sac patterns use 24%. This increased the buildable area by 12% and lowered the unit cost of development.[34] By using a cul-de-sac pattern over a square grid pattern, a capital savings of as much as $1,000,000 CDN in road infrastructure could sometimes be achieved over a 16 ha neighborhood.[35] However, cul-de-sac designs typical of suburban developments do not provide adequate connections for transit vehicle, pedestrians and cyclists.

6.1.5 Xeriscaping

Xeriscaping is gardening and landscaping with minimal water requirements. This practice can have a significant impact during summer months when conventional lawns and gardens increase water usage by 50% or more. Xeriscaping also requires less maintenance and fewer chemicals like fertilizers, pesticides and herbicides. Planning and development of xeriscaped areas requires evaluation of soil conditions, average rainfall, exposure to sunlight and wind, and appropriate plant selection and placement.

[33] Ministry of Housing and the Ministry of Municipal Affairs. (1995)
[34] Fanis Grammenos and Doug Pollard. Canada Mortgage and Housing Corporation. (2002).
[35] Doug Pollard. Canada Mortgage and Housing Corporation. (2002).

In a cost comparison of thirty residential gardens in southern Ontario, four of which were xeriscaped, it was found that a xeriscaped garden is initially more expensive than a conventional lawn (\$0.80/m^2 installation cost compared to \$0.50/m^2) although a savings is seen on other items: annual water consumption (\$7L/m^2 compared to \$37L/m^2), annual gasoline consumption (0 compared to 33ml/m^2), annual fertilizer inputs (17gm/m^2 compared to 90gm/m^2) and annual pesticide inputs (0.75gm/m^2 compared to 5.2gm/m^2)[36] .

In southern Ontario's Region of Durham, a Water Efficiency Representatives Program working with residents to encourage water conservation was able to decrease water usage by 30% over 1,000 homes in 2001 and by 27% over 3,000 homes in 2002.[37]

6.1.6 Bike Paths and Bike Lanes

Bike paths provide a road structure for cyclists separate from vehicle traffic, encouraging non-motorized transit and increasing cyclist safety. A bike path that is separate from the road system is typically a 3-metre wide asphalt surface with a granular base layer and its own subdrain system. Bicycle lanes can also provide for separation of pedestrians and vehicles. Bike lanes are typically 1.5 m wide or greater.

6.1.7 Pervious Pavement

Pervious pavement is an alternative road or parking surface that allows a greater percentage of surface water to infiltrate into the ground than traditional concrete or asphalt pavement. Materials used for pervious pavement include concrete, asphalt, open-celled stones and gravel.

Pervious pavement reduces the need for additional stormwater management as traditional runoff is translated into groundwater recharge and irrigation. The water quality of the runoff is improved as aerobic bacteria in the pore spaces of the pavement breakdown pollutants. In the case of a large storm event, the increased potential for infiltration into the pavement also reduces the amount of standing surface water.

Reference to pervious concrete is prevalent in the southern US with Florida Concrete and Products Association establishing their own Portland Cement Pervious Pavement Formula. With void spaces between 15-25%, it has been estimated that 3-5 gallons of water per minute can pass through pervious concrete pavement. Pervious concrete pavement is also lighter in colour resulting in lower heat absorption and storage.

Pervious pavement however is not appropriate for heavy truck traffic. There is also potential for erosion and sediment runoff to clog the pores of the pavement. If clogging does occur, it has been found that pressure spraying can return the pavement to 90% of its original permeability.

[36] Canada Mortgage and Housing Corporation. (2000)
[37] Durham Region. (2001)
(Additional statistics provided by Durham Region Water Efficiency Coordinator: Glen Pleasance, 2002).

In Canada, the use of pervious pavement for streets may be limited by climate. The most promising application for pervious pavement may be for parking lots and other low traffic areas such as laneways.

One option for incorporating the impact of pervious pavement into the modelling framework is through the measurement of impermeable area, and associated stormwater treatment requirements.

6.1.8 Traffic Calming

Traffic calming, as defined by the Institute of Transportation Engineers in 1997, is *"the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorized street users"*. In Ontario, traffic calming has mostly been applied on local and collector streets in residential neighbourhoods as a way to mitigate the negative impact of vehicular traffic (such as speeding and high volumes) and improve the quality of life in neighbourhoods. Today, however, traffic calming is also being incorporated into new residential subdivision plans as a way to ensure that residential streets will operate as intended (a place for all street users, not just motor vehicles).

Traffic calming measures mainly include horizontal and vertical roadway deflections. Examples of these measures are: chicanes, traffic circles, speed humps, raised intersections, curb extensions and diverters. Typically, these measures are implemented as part of an area-wide plan (i.e. neighbourhood) rather than on a site-specific basis (i.e. one particular street), since isolated traffic calming measures have the potential to shift traffic problems to adjacent streets. While traffic calming can be effective in reducing speeds, traffic volumes and conflicts, they can also have negative impacts. Such impacts include restricted mobility for local residents and potentially slower response times for emergency vehicles. As such, serious consideration needs to be paid to both the benefits and drawbacks of traffic calming before proceeding with these measures in any location.

7 SAMPLE SCENARIO DEVELOPMENT

7.1 Purpose of Scenario Development

The purpose of identifying and quantifying alternative sample scenarios is twofold. Most importantly, the sample scenarios used in the model must reflect the key development characteristics (e.g. density) that affect infrastructure costs to ensure that an appropriate range of potential variables and corresponding costs are reflected for users. The scenarios will also provide default settings in the model for users to compare and contrast with their own development proposals. In addition, once the sample scenarios and associated costs are calculated, they provide an immediate basis for testing the validity of the conceptual framework.

The remainder of this section describes the development of the scenarios and the proposed initial values for each of the key variables.

7.2 General Scenario Definitions

The literature review has highlighted several factors that influence the cost of development. The main predictors of costs include:

- Development densities (an associated characteristics such as mixed uses);
- Distance from existing infrastructure; and
- Degree of continuity.

These factors were considered in the scenario development.

Other factors include demographics and service standards that, for the preliminary scenario development, are generally held constant. In the costing tool, it will be possible to vary demographic variables; however, for the comparison of scenarios, it was decided that holding these variables constant would provide a better measure of the "true" costs for each scenario. This is particularly relevant in the comparison of school costs, which represent a very large portion of the scenario costs. It is also noted that demographics tend to vary over time as a neighbourhood develops and redevelops. For example, an outer suburban neighbourhood may initial include young families with children, but 20 years later may consist of a higher percentage of retirees or "empty-nesters". Therefore, distinguishing by demographics over a 75-year lifecycle period may not be appropriate. On the other hand, it is unlikely that large families would move into smaller apartments typical of compact developments. Regardless, users of the tool would have the option of customizing demographic variables by scenario.

Previous studies conducted for CMHC provide a basis for developing scenarios for this costing mechanisms study including the *Tool for Evaluating Neighbourhood Sustainability: Greenhouse*

Gas Emissions from Urban Travel[38] and the *Consumer Information on Housing Choices Website Project*[39]. Benefits in maintaining some consistency with these two projects include the following:

- The GHG Tool has been tested extensively and has been shown to be a reasonable predictor of auto ownership and use for different neighbourhood development scenarios. The GHG tool can be adapted to provide the necessary input for developing auto-related costs.

- The Consumer Information material includes detailed descriptions of six alternative neighbourhood/location scenarios, including information that is specific to 11 Canadian cities. By maintaining general consistency with these scenarios, it will be possible for CMHC to cross-reference the different studies. For example, costs developed from this current study can be used to update the Consumer Information website material.

In the above CMHC work, three basic elements were used to define a development scenario:

- Location within the urban area;

- Neighbourhood characteristics; and

- Socio-Economic characteristics, which are assumed constant for all scenarios.

Location within an urban area can be generally defined by three categories: inner area, inner suburbs and outer suburbs. These three categories also provide a basis for establishing more detailed locational variables such as distance to existing municipal infrastructure, proximity to transit and transit service levels, access to employment, and travel behaviour.

Neighbourhood types or attributes can also be defined according to broad categories. In the most basic terms, neighbourhoods can be defined as low density, medium density and high density neighbourhoods. However, although density is a useful descriptor, it does not capture the full range of variables that influence the costs of development and ultimately features that reflect a neighbourhood's degree of sustainability. In addition to density, other factors defining a neighbourhood include housing type mix, land use mix, street patterns, transit service levels and incorporation of sustainable infrastructure alternatives.

If the three location categories and three neighbourhood type categories are combined, this results in a total of nine possible location/neighbourhood type combinations. However, it is recognized that some scenario combinations do not represent typical conditions, for example, low-density development in the inner area or high-density development in the outer suburbs.

[38] IBI Group for CMHC (2000).
[39] Consumer Information on Sustainable Community Planning, Draft Website Material, prepared by IBI Group for CMHC, (Work in Progress)

For initial testing purposes, six general scenarios have been defined. For each of the three locations within an urban area (inner area, inner suburbs and outer suburbs), two alternatives are defined, one that represents a higher density scenario with a greater degree of consideration of sustainable community development principles and one that represents a lower density scenario with less consideration of sustainable development practices. ***Figure 7.1*** provides a description of the scenarios in general terms.

It is important to note that the final costing tool to be developed in Phase 2 of this study will not be limited to a finite number of scenarios. That is, the user will be able to change any of the input variables to define a full range of possible scenarios.

Through the analysis of scenarios, the tool is intended to provide relevant, meaningful, usable, easy to understand information to inform land use planning decisions. It is intended to identify and compare the linear cost of infrastructure for new developments and the full cost implications of planning decisions over time so that the cumulative impacts of planning and other key decisions can be determined during the planning phase. The information generated is intended for community planners, community organizations and municipal departments who normally do not have ready access to costing information to determine whether a chosen strategic direction is appropriate from a cost perspective. As a result, the definition of scenarios does not need to be, and is not intended to be, precise in nature.

Figure 7.1: General Scenario Definitions

High Density Mixed Use Neighbourhood in the Inner Area characterized by:
- Primarily low rise and high rise apartments
- Mixed-use development
- Grid road network
- High level of transit service
- Potential excess capacity for municipal services

Medium Density Neighbourhood in the Inner Area characterized by:
- Mix of townhouses, apartments and single-detached housing
- Mixed-use development
- Grid road network
- High level of transit service
- Possible brownfield development

Medium Density Neighbourhood in Inner Suburbs:
- Mix of townhouses, low rise apartments and single-detached housing
- Mixed-use development
- Mainly grid road network
- Good transit service
- Possible brownfield development

Low Density neighbourhood in Inner Suburbs:
- Primarily single detached housing with some semi-detached and townhouses
- Primarily single-use (residential) development
- Curvilinear Road network
- Moderate transit service
- Greenfield development, close to existing services

Medium Density Neighbourhood in Outer Suburbs:
- Mix of townhouses, low rise apartments and single-detached housing
- Mixed-use development
- Mainly grid road network
- Good transit service
- Greenfield development, close to existing services

Low Density neighbourhood in Outer Suburbs:
- Primarily single detached housing
- Primarily single-use (residential) development
- Curvilinear Road network
- Low level of transit service
- Greenfield development, requiring new roads and servicing

7.3 Development of Scenario Input Variables

7.3.1 General Approach

There are two approaches that were used to establish the quantitative input requirements for each scenario. The first approach is to use actual data for a number of neighbourhoods, represented by census tracts. In this case, representative census tracts are selected according to broad criteria reflecting location and housing type breakdown as described in the next section. A second approach relied on examining actual neighbourhood layouts that typified a given scenario and then calculating various statistics from this neighbourhood layout. Both approaches were used for this study depending on the type of input required. In general, the former approach was used to obtain information on socio-economic variables as well as accessibility variables while the latter was used to obtain more specific details on hard infrastructure input requirements.

The following sections describe the basic approach for defining the scenario input requirements.

7.3.2 Socio-Economic Variables

The following variables are required for scenario development and costing:

- Average household size, which is required to relate population to number of households or units;
- Average adults per household, which is required to estimate vehicle ownership and usage;
- Average number of school aged children, which is required to estimate school costs and school transportation needs; and,
- Average household and individual income, which are required for the auto ownership and vehicle usage estimates.

As noted previously, for the comparison of sample scenarios, socio-economic variables are held constant; an average value is used for all scenarios. It is nevertheless important to have an understanding of how socio-economic variables differ by scenario because ultimately, users of the costing tool will have the choice of holding socio-economic variables constant, or entering actual values.

For the six representative scenarios, data from the City of Ottawa was used to establish socio-economic variables. Ottawa was chosen because its size is somewhere between the large three cities and the rest of the urban areas, as well as the fact that it contains a variety of neighbourhood and housing types. The approach used consisted of “tagging” individual census tracts that reflect the basic parameters of the given scenario, and then using these to develop average values for each variable.

Within the City of Ottawa[40], census tracts representative of the general scenarios were identified for the three locational contexts (Inner Area, Inner Suburbs and Outer Suburbs). These location areas were defined based on standard definitions used by the City of Ottawa.

Neighbourhood characteristics were basically defined by housing types, as follows:

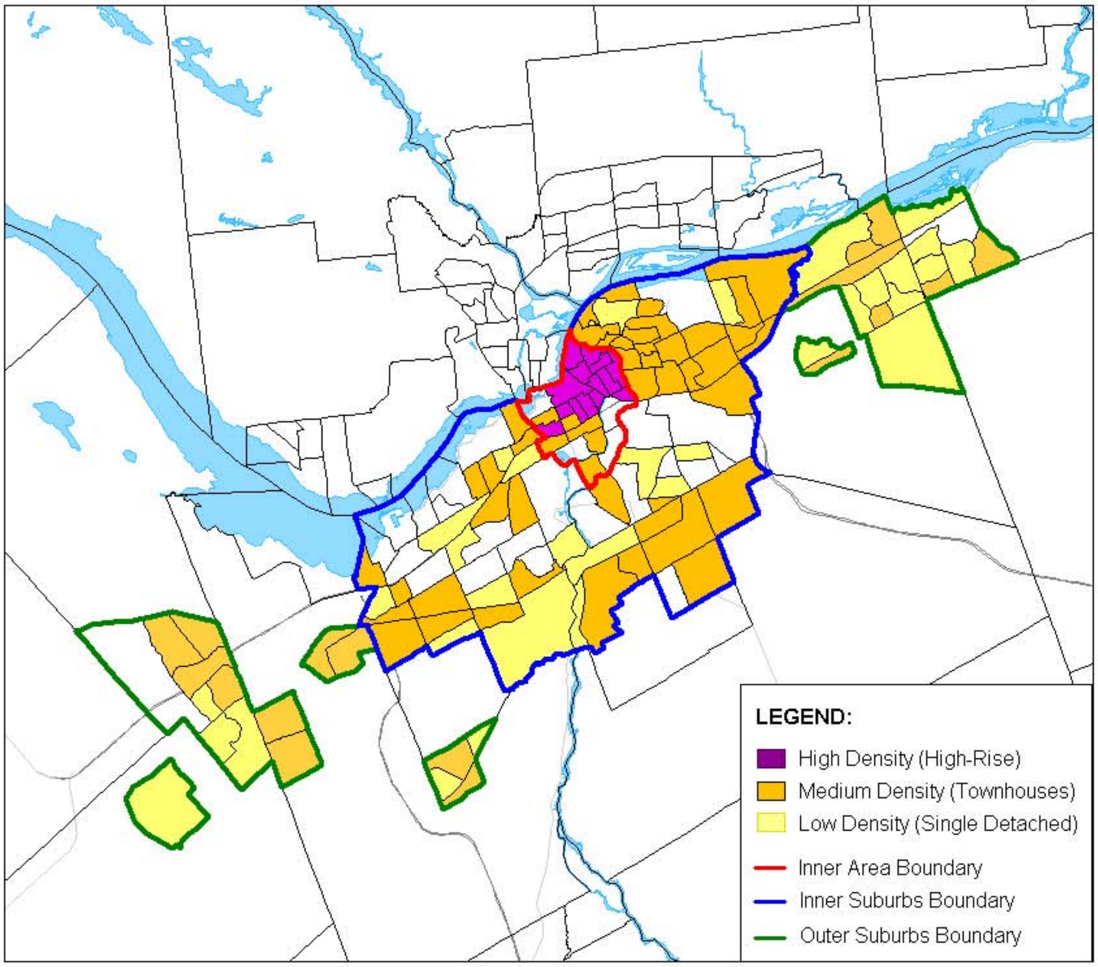
- High density: all census tracts where the combined percentage of high rise and low rise apartments or condominiums was greater than 60% or more in the mix of housing types.
- Medium density neighbourhood: all census tracts where the combined percentage of low rise apartments or condominiums, duplexes and row houses (i.e. townhouses) was greater than 30% or more in the mix of housing types.
- Low density: all census tracts where the combined percentage of single detached and semi-detached housing types was greater than 80% or more in the mix of housing types.

Figure 7.2 provides a map of the categorization of these census tracts. As shown, the above categories result in a reasonable sample of representative neighbourhoods for each location.

Values for key socio-economic variables for each of the six scenarios based on the representative census tracts are shown in ***Table 7.1*** along with the values adopted for the preliminary scenario costing.

[40] The City of Ottawa was used for defining the initial scenarios. In later stages of this study, the scenarios will be reviewed for consistency with other selected cities, namely Calgary and Halifax.

Figure 7.2: Categorization of Ottawa's Census Tracts (2001 Statistics)



High Density >60% high rise and low-rise apartments and condominiums
Medium Density >30% low-rise apartments or condominiums, duplexes and row houses
Low Density >80% single detached and semi-detached houses

Table 7.1: Scenario Input – Socio-Economic Variables

	DOWNTOWN CORE AREA		INNER SUBURBS		OUTER SUBURBS	
Scenario Attributes	High Density	Medium Density	Medium Density	Low Density	Medium Density	Low Density
	Values based on Averages for Representative Census Tracts					
Average Household Size	1.82	2.27	2.54	2.78	3.05	3.27
Average Adults (16+) per Household	1.66	1.95	2.00	2.30	2.25	2.37
Average School Age Children per Household	0.15	0.29	0.49	0.43	0.72	0.81
Average Household Income	$26,852	$39,501	$35,869	$51,641	$56,885	$61,608
Average Individual Income	$26,178	$30,225	$27,533	$38,883	$34,112	$35,149
	Values adopted for scenario costing					
Average Household Size	2.60	2.60	2.60	2.60	2.60	2.60
Average Adults (16+) per Household	1.98	1.98	1.98	1.98	1.98	1.98
Average School Age Children per Household	0.50	0.50	0.50	0.50	0.50	0.50
Average Household Income	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
Average Individual Income	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000

7.3.3 Land Use Variables

The primary land use variables that are required for the scenario costing are as follows:

- Gross land area, which is held at a constant 40 hectares for each scenario.
- Percentage of land that is considered non-developable, which includes roads, parks, open space, schools, institutional uses and rail and highway corridors.
- Net land area, which is calculated based on the above two parameters.
- Net housing Density, which is required to estimate the number of housing units, or households for the given land area and population.
- Land use mix, which reflects live-work potential and is a factor in the vehicle usage model.
- Housing type breakdown, which influences density as well as home heating costs.

As discussed previously, since the costing focuses primarily on the cost of the residential component of the development, an allocation of the amount of land devoted to residential and non-residential uses are also required.

Various methods were explored for developing representative housing densities for each scenario. A major challenge is that eventual users of the costing tool may know what the housing type breakdown is for a scenario, but not density, or alternatively they may know approximate densities but not housing type breakdowns.

Information from previous work provides a context for establishing net residential densities:

- In the City of Calgary[41], communities built during the 70's to early 90's ranged from 11 to 15 residential units per hectare. The Calgary Plan requires that all new communities achieve 15 to 20 units per hectare.

- A 1995 study of urban densities in the Greater Toronto Area[42] examined 10 well-known residential communities and found that densities range from a high of 55 units per hectare (Riverdale) to a low of 22 units per hectare (Willowdale). This study did not include higher density downtown core developments.

- A 1997 study prepared for CMHC examining Conventional and Alternative Development Patterns developed two scenarios with net residential densities of 21.7 units/ha (conventional plan) and 43.3 units/ha (alternative plan).

- The San Francisco League of Conservation Voters[43] has developed a website illustrating densities and provides typical densities for different development types as follows:

  0.1 Hh/Res Ac - Ranchettes.*1 Hh/Res Ac* - Lowest density of single-family dwellings in sprawl.
  3 Hh/Res Ac - Typical of single-family dwellings in sprawl.
  10 Hh/Res Ac - Row houses with occasional single-family dwellings and apartment houses. Examples: lower density areas of larger cities, and older suburbs.
  100 Hh/Res Ac - Mostly 3-5 story apartment houses with occasional mid- to high-rises and single-family dwellings. Examples: northeast San Francisco (Russian, Nob and Telegraph Hills, North Beach), River North in Chicago, Beacon Hill in Boston, along Connecticut Avenue in DC, and compact neighbourhoods throughout the country.
  500 Hh/Res Ac - Mostly mid- to high-rises. Examples: the Upper East and West Sides in Manhattan, and smaller neighbourhoods in Chicago, San Francisco and elsewhere.
  Note: 1 acre = 0.404 hectares

Another way to develop ranges of reasonable densities is to work from first principles. For a given housing type, it is possible to make assumptions about lot sizes and/or unit sizes in order to estimate net densities. ***Table 7.2*** provides a conceptual approach based on some very approximate assumptions about lot and unit sizes, and lot coverages. It is envisioned that this approach will be refined and included as a sub-routine within the costing tool.

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[41] City of Calgary, http://www.calgary.ca/DocGallery/bu/planning/pdf/cwinfo_resdensity.pdf
[42] Lehman Associates with IBI Group (1995).
[43] San Francisco League of Conservation Voters – http://www.sflcvg.org/density/index.html

Table 7.2: Net Densities by Housing Type

Type	Housing Type	Lot size (ft)	Lot Area (sq. m.)	Unit size sq. ft	Unit size sq. m	Floor Space Index	Calculated Units	Units/ha
1	*Single Detached*	40 x 130	483					21
2	*Semi-Detached*	20 x 100	186					54
3	*Row/Townhouse*	18 x 75	125					80
4	*HighRise*			800	74	3	404	404
5	*LowRise*			1100	102	2	196	196
6	*DuplexApt*	18 x 75	125					80
7	*OtherAttached*	18 x 75	125					80
8	*Mobile*	20 x 100	186					54

The above two sources of information were used to assign representative densities to each scenario.

The approach for calculating and assigning densities by scenario is summarized in ***Table 7.3***. It should be recognized that these densities are intended to be illustrative only and will ultimately be adjusted by the user of the tool based on individual circumstances. However, since density is a key influence on cost efficiency, it is important to establish reasonable ranges.

The breakdown of housing types shown is partially based on averages for representative census tracts in Ottawa (defined in the previous section) as well as the study team's appraisal of what the scenarios are intended to illustrate.

Table 7.3: Scenario Land Use Variables

	DOWNTOWN CORE AREA		INNER SUBURBS		OUTER SUBURBS	
Scenario Attributes	**High Density**	**Medium Density**	**Medium Density**	**Low Density**	**Medium Density**	**Low Density**
Land Usage						
Gross Land Area (ha)	40	40	40	40	40	40
% Non-developable (1)	20%	20%	30%	30%	40%	40%
Developable Land Area (ha)	32	32	28	28	24	24
% Residential Land Area	50%	60%	70%	70%	80%	100%
Residential Land Area (ha)	16	19	20	20	19	24
Non-residential land area (ha)	16	13	8	8	5	0
Land Use Mix (Jobs & Population)	1	0.50	0.50	0.25	0.50	0.10
Housing Type Breakdown						
Single Detached	*5%*	*25%*	*40%*	*80%*	*50%*	*95%*
Semi-Detached	*5%*	*25%*	*35%*	*10%*	*30%*	*5%*
Row	*5%*	*20%*	*15%*	*10%*	*10%*	*0%*
HighRise	*50%*	*10%*	*0%*	*0%*	*0%*	*0%*
LowRise	*30%*	*10%*	*5%*	*0%*	*10%*	*0%*
DuplexApt	*5%*	*10%*	*5%*	*0%*	*0%*	*0%*
OtherAttached	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Mobile	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Total	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
Net Residential Densities						
Density Using Housing Breakdown (units/ha	272	103	53	30	54	22
Assigned Housing Density (units/ha)	200	75	40	20	30	10
Calculated Variables						
Households (units)	3,200	1,440	784	392	576	240
Population	8,320	3,744	2,038	1,019	1,498	624
Employment	8320	1872	1019	255	749	62

7.3.4 Hard Infrastructure

Primary input requirements that will be required from the user for hard infrastructure costing include:

- Length and width of internal roads (local and collector).
- Length of arterial roads.
- Number of lots.

Within the tool or associated documentation, representative values will be provided to help the user estimate values from first principles if they do not have a set development concept. For example, a typical length of road per km2 of development could be provided.

Subsequently, these basic measures are used to calculate other hard infrastructure requirements such as length of water distribution pipes, sanitary sewers and storm sewers.

Length of roads within a community, and specifically the length of road required to serve a given number of units, is dependent on several factors including road layout and road spacing. It is reasonable to expect that users of the costing tool will know the approximate length of roads in the community they are assessing. However, for the purpose of testing illustrative scenarios, it is necessary to develop representative values.

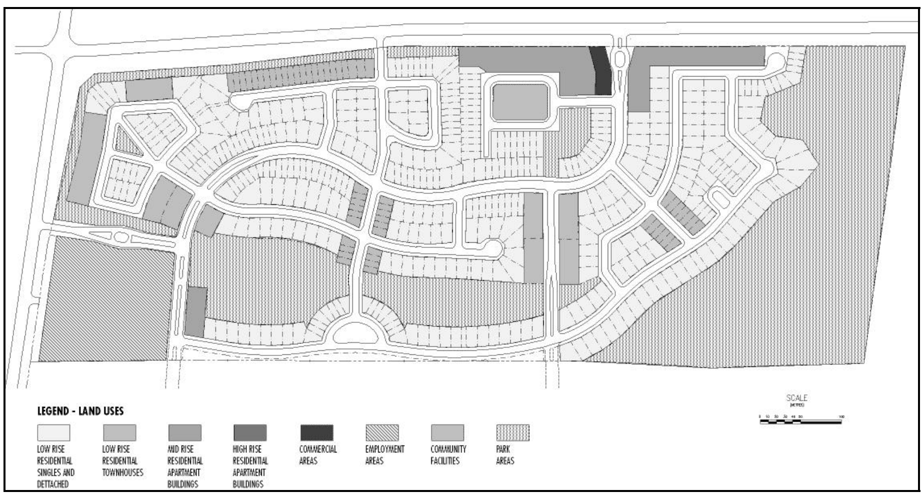
The approach used to estimate length of internal roads for each scenario is to look at sample neighbourhoods and measure the length of roads on a gross area basis. The sample neighbourhood designs prepared for the CMHC Tool for Evaluating Neighbourhood Sustainability (CMHC, 2000) provides a good starting point for developing representative factors for local road densities. These neighbourhood layouts are shown in ***Figure 7.3***. Statistics for these neighbourhood layouts are as follows:

- Conventional Suburban Development
  - 45 hectares gross area
  - 3,200 m of internal roads
  - 71 m of road/gross ha
- Medium Density Development
  - 41 hectares gross area
  - 4,200 m of internal roads
  - 102 m of road/gross ha
- Neo-Traditional Development
  - 32 hectares gross area
  - 2,770 m of internal roads
  - 86 m of road/gross ha

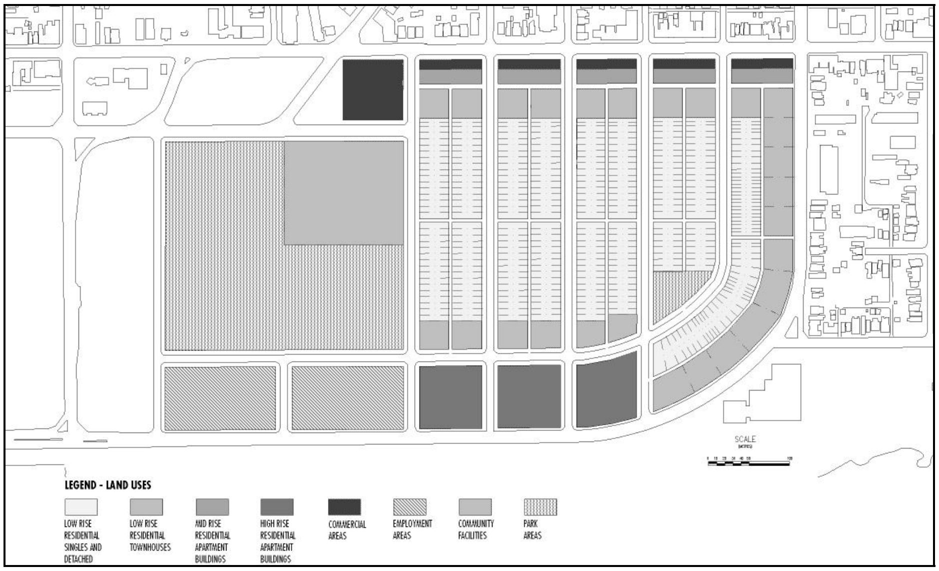
These figures are similar, but slightly lower that the values for the 1997 CMHC study of Conventional and Alternative Development Patterns, which were 114.5 m/ha for the conventional site and 131 m/ha for the alternative site.

Figure 7.3: Representative Neighbourhood Layouts

Conventional Suburban Development (Low Density)



Medium Density Development



Neo-Traditional Development (High Density)

Another source of information on road densities are GIS road files. Using available CanMap files for the city of Ottawa inner area, it was calculated that there are approximately 80 m of local roads for every hectare of land.

Based on all of these sources of information, representative average values for local road densities were developed for each scenario, as shown in ***Table 7.4.*** In general, neighbourhoods in inner areas tend to have a higher density of roads because lot sizes are smaller and densities are higher.

For arterial roads, the same general approach used to estimate local road requirements was used. Arterial road densities (km/sq. km) were calculated using GIS-based road maps for representative Census Tracts in Ottawa. These values are shown on ***Table 7.4***, along with the resulting road lengths by scenario.

It should be noted that, at this point in the study, it is assumed that individual developments would be responsible for the full cost of related infrastructure, even if the infrastructure (e.g. arterial roads) already exists. The ultimate tool will incorporate a method for accounting for residual capacity.

Table 7.4: Scenario Road Infrastructure

	DOWNTOWN CORE AREA		INNER SUBURBS		OUTER SUBURBS	
Scenario Attributes	High Density	Medium Density	Medium Density	Low Density	Medium Density	Low Density
Local Roads						
Total Road Length (m/ha)	100	100	100	80	80	70
Total Road Length (km)	4.0	4.0	4.0	3.2	3.2	2.8
Average Road Width (m)	8.5	8.5	8.5	9.0	9.0	9.0
Average Sidewalk Width (m)	2	2	1.5	1.5	1.5	0
Arterial Roads						
Arterial roads (km/sq km)	5.0	5.0	3.0	3.0	2.0	2.0
Arterial Road Length	2.0	2.0	1.2	1.2	0.8	0.8

7.3.5 Accessibility Measures

Several accessibility measures are required to estimate how much travel effort a particular neighbourhood scenario generates. These accessibility measures as well as the process used to estimate vehicle-kilometres of travel are adopted from the CMHC Greenhouse Gas Emissions Model from Urban Travel Study (CMHC 2000). This model has been calibrated using actual data from the Greater Toronto Area and validated against data from other cities. Vehicle-kilometres estimates have also been compared to estimates developed from fuel sales data for cities across Canada and have been shown to be reasonable.

Additional discussion on accessibility measures and their impacts was discussed in Section 2.7.

Values for accessibility measures were, for the most part, generated using the representative census tracts for the City of Ottawa and GIS files, both census and streetmap files.

Table 7.5 provides a summary of the accessibility measures for each of the six scenarios.

Table 7.5: Scenario Accessibility Values

	DOWNTOWN CORE AREA		INNER SUBURBS		OUTER SUBURBS	
Scenario Attributes	**High Density**	**Medium Density**	**Medium Density**	**Low Density**	**Medium Density**	**Low Density**
Local Accessibility						
Stores within 1 km	20	8	10	3	5	0
Schools within 1 km	6.8	5.4	4.2	4.7	3.4	3.5
Ratio of Bike Lanes to Road km	0.7	0.7	0.10	0.10	0.00	0.00
% Curvilinear Road Layout	0	0.00	0.05	0.20	0.25	0.95
% Rural Grid Road Layout	0	0	0	0.00	0	0.50
Housing Size (Rooms per Dwelling)	3.6	4.5	6.6	7.8	7.6	7.2
% Wide Arterial Roads	27%	19%	16%	16%	9%	12%
Road Connectivity (Intersections/km)	*4.5*	*4.50*	*3.50*	*3.50*	*3.50*	*1.50*
Wkday Transit Service Hrs within 1 km radius	*50.00*	*30.00*	*30.00*	*15.00*	*10.00*	*1.00*
Jobs within 1 km	22,129	9,142	3,110	2,808	412	262
Regional Accessibility						
% HH within 1 km of higher order transit	58%	58%	12%	12%	2%	2%
Nearest Higher Order Transit Station (km)	0.97	0.97	3.5	3.5	18	18
Distance to CBD (km)	1.6	1.6	8.7	8.7	25	25
Jobs within 5 km	200,000	200,000	68,200	68,200	1,900	1,900

8 SCENARIO COSTS AND REVENUES

With the scenarios in place, it is now possible to test the validity of the conceptual framework by calculating lifecycle costs for each scenario and then reviewing the results with informed stakeholders. This section presents the results of the application of unit costs described in Chapter 5 to the representative neighbourhood scenarios described in Chapter 7. Costs are initially presented by major category (e.g. capital or operating) and then carried forward into the lifecycle analysis. It is important to note that these cost calculations were completed in order to test the potential and validity of the conceptual framework for use in Phase 2. The scenarios, costs and formulae will be modified for Phase 2 based on the comments received on the Phase 1 work.

This chapter first describes how costs are apportioned to development types and then provides the lifecycle costing results by each cost category introduced in Chapter 5.0. Costs and revenues are presented both in terms of total absolute costs as well as costs per residential unit.

8.1 Apportion of Costs to Development Types

Since land use densities and land use mixes vary by scenario, it is necessary to develop a standard approach for comparing scenarios. The primary approach used for this study is to express costs in terms of $ per residential unit (other measures such as $ per hectare will be possible in the tool). Therefore, it is important to determine the proportion of total neighbourhood costs attributable to residential development. In other words, it would be inappropriate to allocate all development costs to residential uses if a significant portion of the development consisted of non-residential development.

Building on the approach used in a recent CMHC study (CMHC, 1997), ***Table 8.1*** summarizes the methods for allocating costs by category. In most cases, the ratio is based on the percentage of residential land or the ratio of population to employment identified for the scenario. Some argument could be made for different allocations; for example, a portion of recreational facilities may be allocated to employment lands.

Since all indirect/external costs (e.g. air pollution) are attributable to residents of the neighbourhood, no allocation of these costs is required.

Table 8.1: Allocation of Residential and Non-Residential Costs

Cost Category	Method	Percent of Costs Attributed to Residential Development					
		DOWNTOWN CORE AREA		INNER SUBURBS		OUTER SUBURBS	
		High Density	Medium Density	Medium Density	Low Density	Medium Density	Low Density
PRIMARY INPUTS	Ratio of Residential to Non-Residential Land Area	**50%**	**60%**	**70%**	**70%**	**80%**	**100%**
	Ratio of Population to Employment	**50%**	**67%**	**67%**	**80%**	**67%**	**91%**
HARD INFRASTRUCTURE COSTS							
Local Roads	Ratio of Residential to Non-Residential Land Area	50%	60%	70%	70%	80%	100%
Arterial Roads	Ratio of Residential to Non-Residential Land Area	50%	60%	70%	70%	80%	100%
Water Distribution	Ratio of Residential to Non-Residential Land Area	50%	60%	70%	70%	80%	100%
Water Treatment	Costs are estimated on a per household basis, therefore 100% of costs are residential	100%	100%	100%	100%	100%	100%
Sanitary Sewers	Ratio of Residential to Non-Residential Land Area	50%	60%	70%	70%	80%	100%
Wastewater Treatment	Costs are estimated on a per household basis, therefore 100% of costs are residential	100%	100%	100%	100%	100%	100%
Storm Sewers	Ratio of Residential to Non-Residential Land Area	50%	60%	70%	70%	80%	100%
Storm Water Treatement	Ratio of Residential to Non-Residential Land Area	50%	60%	70%	70%	80%	100%
Schools	Fully allocated to Residential	100%	100%	100%	100%	100%	100%
Recreational Facilities	Fully allocated to Residential	100%	100%	100%	100%	100%	100%
MUNICIPAL SERVICES COSTS							
Transit Services	Ratio of Population to Employment	50%	67%	67%	80%	67%	91%
School Transit	Fully allocated to Residential	100%	100%	100%	100%	100%	100%
Fire Services	Ratio of Population to Employment	50%	67%	67%	80%	67%	91%
Police Services	Ratio of Population to Employment	50%	67%	67%	80%	67%	91%
Waste management Services	Non-residential collection is typically paid for privately, therefore 100% of costs are residential	100%	100%	100%	100%	100%	100%

8.2 Initial Capital Costs / Ratio of Population to Employment

Initial capital costs represent the costs of construction at the time of development for hard infrastructure as well as infrastructure related to the provision of municipal services.

Figure 8.1 provides a summary of the distribution of initial capital costs for an average of the six neighbourhood scenarios (weighted by number of units). These percentages are based on the total neighbourhood costs, including both residential and non-residential development. Aside from road costs, school costs represent the highest single capital expenditure for a residential development. This is consistent with the literature, although the 1997 CMHC study of conventional and alternative development patterns (CMHC, 1997) estimated a much higher capital cost for schools, which made it the highest single capital cost component.

Figure 8.2 provides a summary of the initial capital costs by scenario both in absolute terms and on a per household basis. These costs represent the residential component of the development only, which is calculated using the allocations in ***Table 8.1.***

On an absolute basis, initial costs are generally higher for high-density development, primarily due to the fact that more roads are required to serve the same area. Initial costs are also higher as a result of school costs, which are in turn a function of population. However, on a per household or per unit basis, higher density developments are significantly more cost-efficient than lower density neighbourhoods. This is understandable given that higher density neighbourhoods serve more households with only marginally higher levels of infrastructure than low-density neighbourhoods. Based on the scenario definitions developed for this study, capital costs for a high density residential unit in the downtown core would be less than one tenth of the cost of a traditional suburban development in the outer suburbs. This does not account for the cost of land, which is excluded from the analysis at this stage. It is also noted that the figures do not reflect any cost savings that could be achieved by utilizing existing infrastructure. For example, in the Downtown High-Density Scenario, it is likely that all arterial roads would be built out and no additional roads would be provided as part of the development. These considerations could be explored in the tool.

Figure 8.1: Distribution of Initial Capital Costs (Total Neighbourhood Costs)

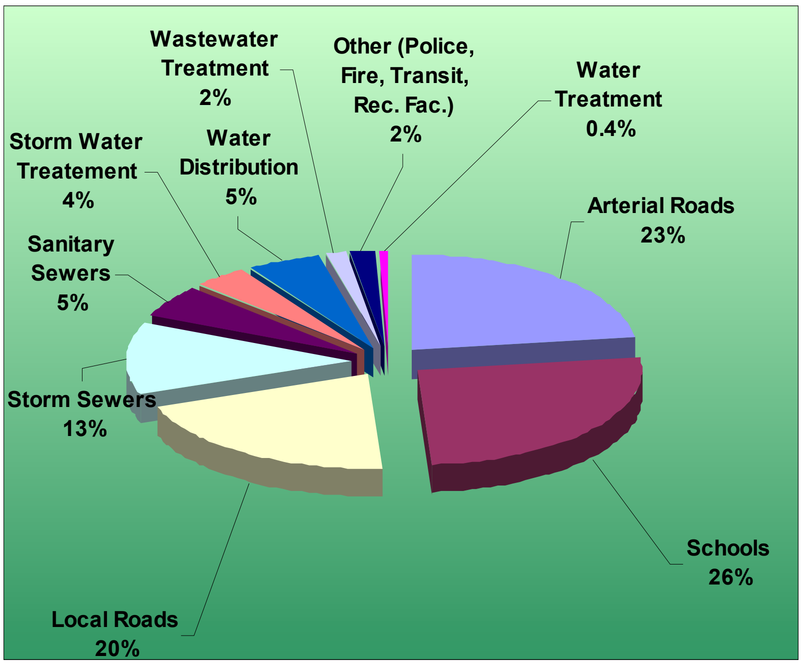
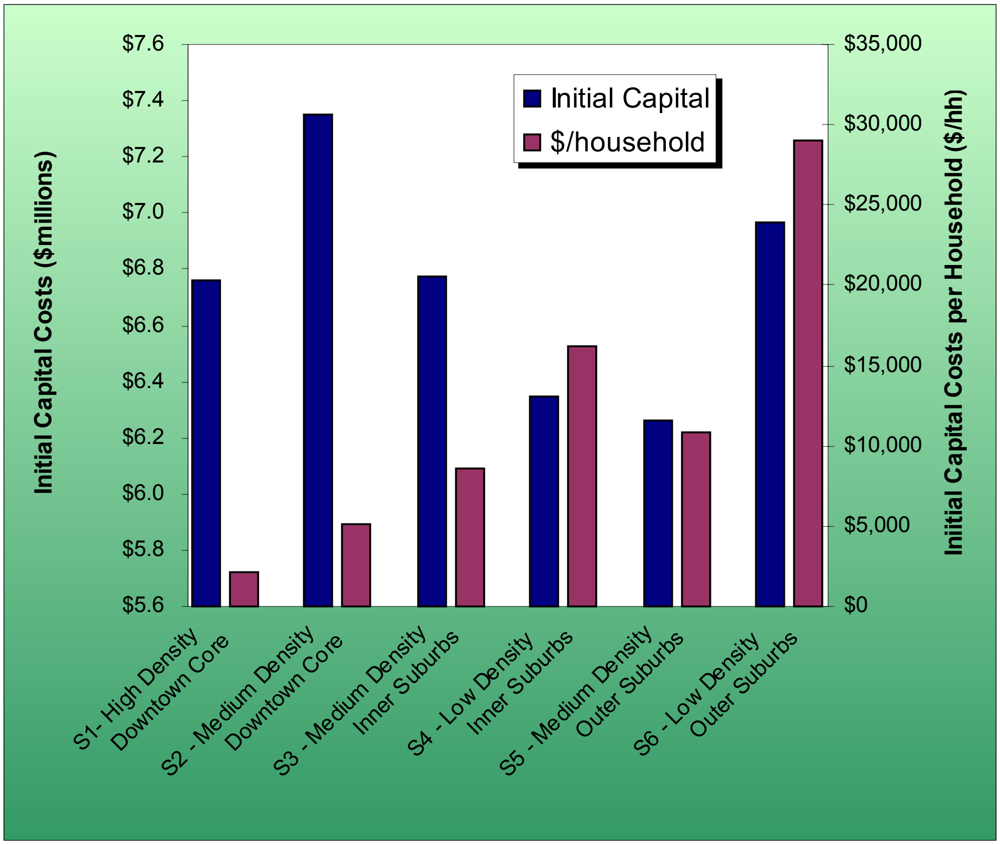


Figure 8.2: Initial Capital Costs by Scenario – Residential Component



8.3 Operating and Maintenance Costs

Figure 8.3 provides a summary of the distribution of operating costs for an average of the six neighbourhood scenarios (weighted by number of units). Again, these percentages are based on the total neighbourhood costs, including both residential and non-residential development.

The percentages shown in ***Figure 8.3*** exclude the operating costs of schools which, for an average neighbourhood, represent more than 60% of the operating costs and tend to overwhelm the results when they are displayed. Our results indicate that total operating costs related to schools is more than 70% of the total costs per household. This is consistent with other literature including the 1997 CMHC study of alternative neighbourhood patterns. Next to school costs, other significant operating costs include transit services as well as police and fire services.

Annual operating costs for the six neighbourhood scenarios (residential component only) are shown in ***Figure 8.4.*** Because operating costs are more directly related to consumption, operating costs per household do not vary substantially among scenarios. There are some savings for road operating costs because more households are utilizing the road infrastructure, but most other costs are fairly constant by scenario.

Figure 8.3: Annual Operating and Maintenance Costs – Average Neighbourhood (Total Neighbourhood Costs Excluding Schools)

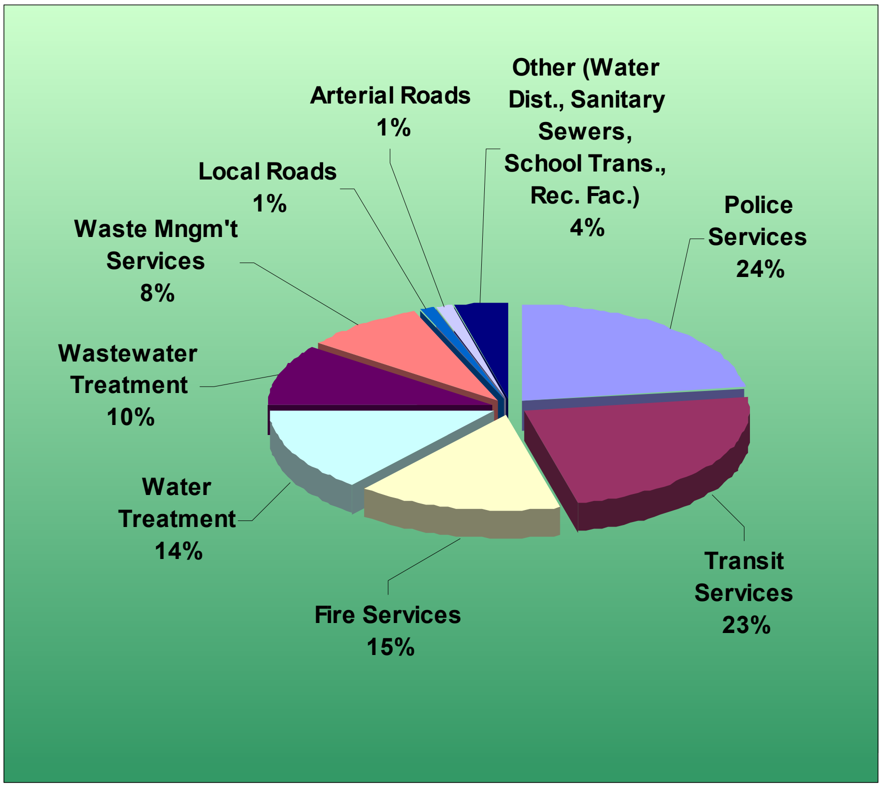
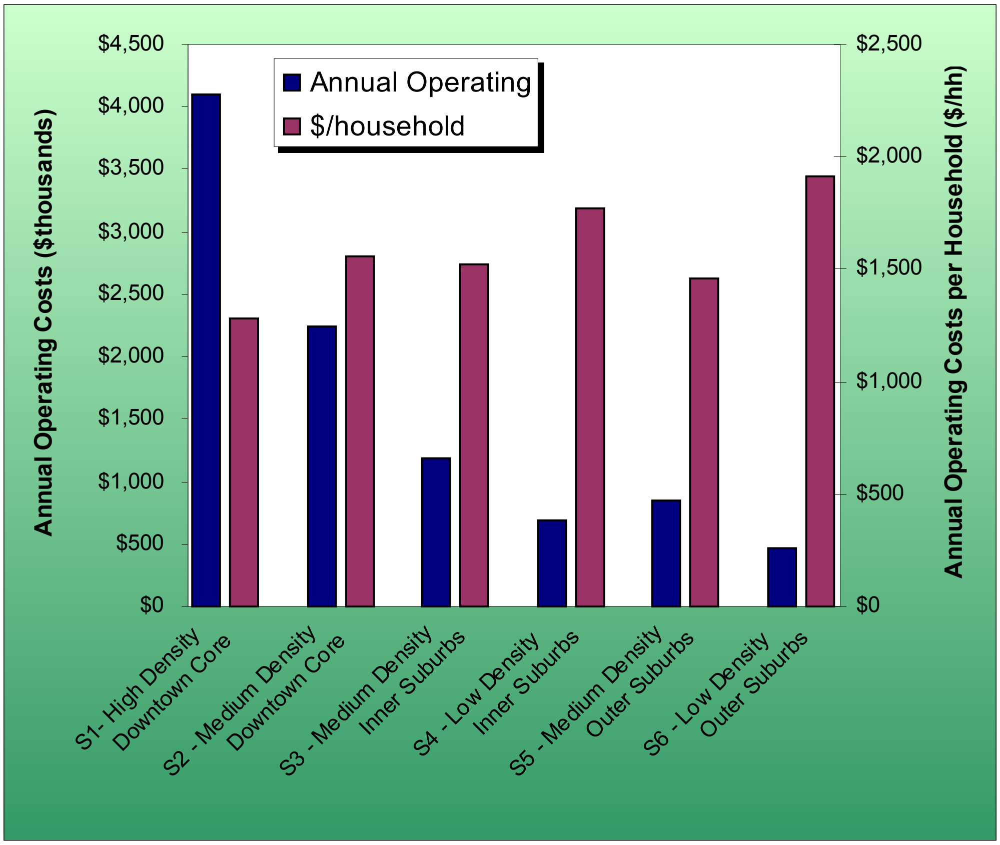


Figure 8.4: Annual Operating Costs by Scenario – Residential Component



8.4 Lifecycle Costs

In developing the costs associated with replacement, it was assumed that each infrastructure item would be fully replaced after its estimated lifespan. Frequency of replacement values are shown in ***Table 8.2***. The majority of these values were obtained primarily from the CMHC report: Conventional and Alternative Development Patterns Phase 1: Infrastructure Costs (1997). The replacement time for recreational facilities was taken as an average from the range given. Values for water and wastewater treatment facilities frequency of replacement were obtained through consultation with various municipalities.

Figure 8.5 summarizes the lifecycle costs, on an annual basis, for each of the illustrative scenarios. Several key conclusions can be drawn from this comparison:

- In all cases, when comparing two scenarios in the same location, the scenario with higher density attributes has a lower cost per household; the difference is much greater for the two outer area scenarios than the two inner area scenarios;

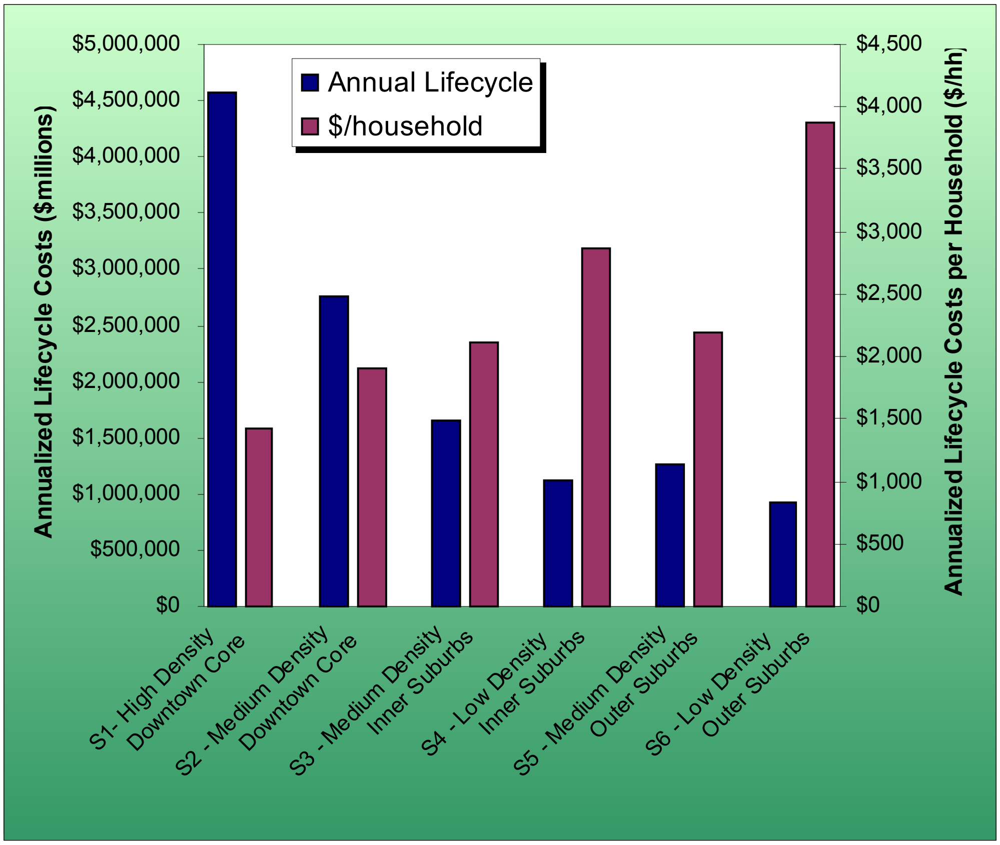
- When comparing similar development types by location, scenarios in the outer areas have a higher cost than scenarios in the inner area and core. This is largely a function of the differences in densities. If densities and other attributes were held constant by location, the values would be similar.

These results are consistent with the results of the literature review presented in Chapter 3.0.

Table 8.2: Frequency of Replacement Values

Cost or Revenue Category	Replacement Frequency (Years)
HARD INFRASTRUCTURE	
Local Roads and Utilities	65
Arterial Roads	25
Water Distribution Service	50
Water Treatment	50
Sanitary Sewers	75
Wastewater Treatment	50
Storm Sewers	75
Stormwater Treatment	75
Schools	60
Recreation Facilities	25
MUNICIPAL SERVICES	
Transit Services	15
School Transit	15
Fire Services	25
Police Services	25

Figure 8.5: Annualized Lifecycle Costs by Scenario – Residential Component



8.5 Revenue Generation

Two types of revenues were considered for this Phase 1 study:

- Property taxes; and,
- Development charges.

As discussed previously, user fees will also be separated out for the purpose of the model, but for now are reflected in the net capital and operating costs.

Property taxes were estimated using assessment values and housing prices for Ottawa (as a representative case example). Figures were estimated for each housing type and for each location as shown in ***Table 8.3.*** Total property tax revenues were then estimated by applying actual property tax rates for the City as follows:

- City 1.3501%

- Education 0.373%
- Total 1.7231%

Total tax revenues were then estimated by scenario according to the distribution of housing units by type. The resulting revenues, on an annual basis are shown on Figure 8.7.

Table 8.3: Assessment Values (Ottawa)

	Estimated Assessment Values		
	Central	Inner (Nepean)	Outer (Kanata)
Single detached	$ 365,000	$ 215,000	$ 210,000
Semi-detached	$ 314,000	$ 181,000	$ 190,000
Row	$ 314,000	$ 181,000	$ 190,000
High Rise	$ 200,000	$ 154,000	$ 115,000
Low Rise	$ 200,000	$ 154,000	$ 115,000
Duplex Apt	$ 200,000	$ 154,000	$ 115,000
Other attached	$ 200,000	$ 154,000	$ 115,000
Mobile	$ 50,000	$ 50,000	$ 50,000

Revenues from development charges were estimated in a similar manner using the values shown in ***Table 8.4***.

Since development charges are a one-time charge, usually collected at the time of development, it is not appropriate to express these as average annual revenue for a specific development scenario. A more appropriate comparison may be to look at the total costs of new development across a municipality and compare these to development charges collected, something that municipalities attempt to do in setting development charges.

The tool will allow the user to calculate development charges by scenario and compare these to different measures such as initial capital costs of infrastructure.

The revenues generated from development charges for each scenario are summarized on ***Figure 8.7***. These are total initial charges and have not been annualized.

Table 8.4: Development Charges by Type of Dwelling Unit

Regional Development Charges by Type and Area			
	Central	Inner	Outer
Single detached	$8,926	$8,926	$9,789
Semi-detached	$8,926	$8,926	$9,789
Row	$7,088	$7,088	$7,774
High Rise	$4,726	$4,726	$5,183
Low Rise	$4,726	$4,726	$5,183
Duplex Apt	$4,726	$4,726	$5,183
Other attached	$4,726	$4,726	$5,183
Mobile	$5,776	$5,776	$6,335
Local Development Charges by Type and Area including school charges			
There are no DCs in the former City of Ottawa			
	Central	Inner (Nepean)	Outer (Kanata)
Single detached	$0	$6,077	$8,821
Semi-detached	$0	$6,077	$8,821
Row	$0	$5,192	$6,781
High Rise	$0	$3,715	$4,484
Low Rise	$0	$3,715	$4,484
Duplex Apt	$0	$3,715	$4,484
Other attached	$0	$3,715	$4,484
Mobile	$0	$5,192	$5,246

Figure 8.6: Annual Property Taxes by Scenario

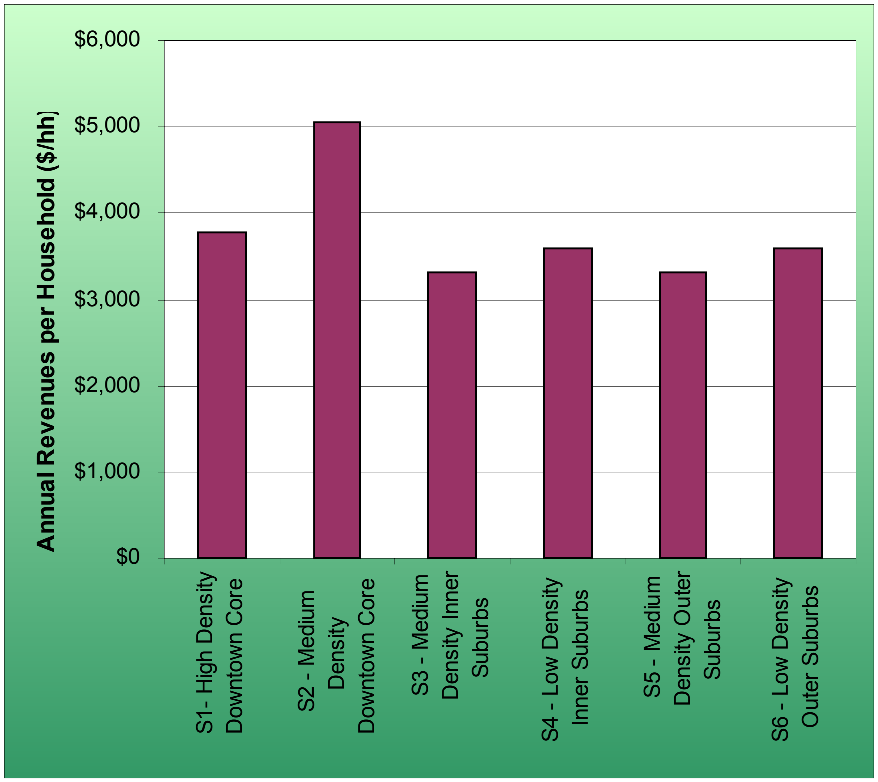
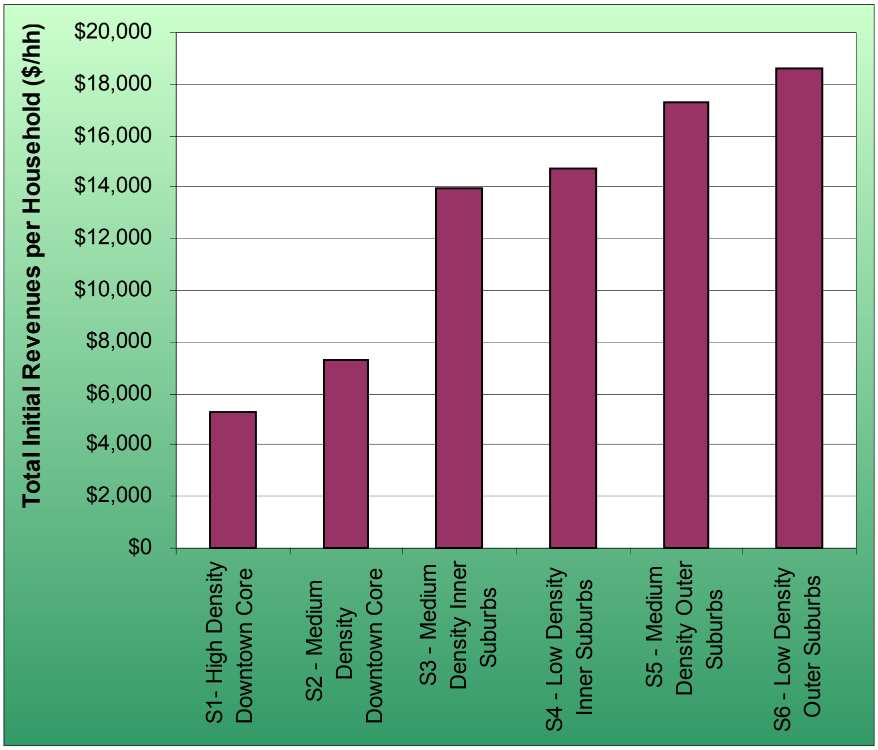


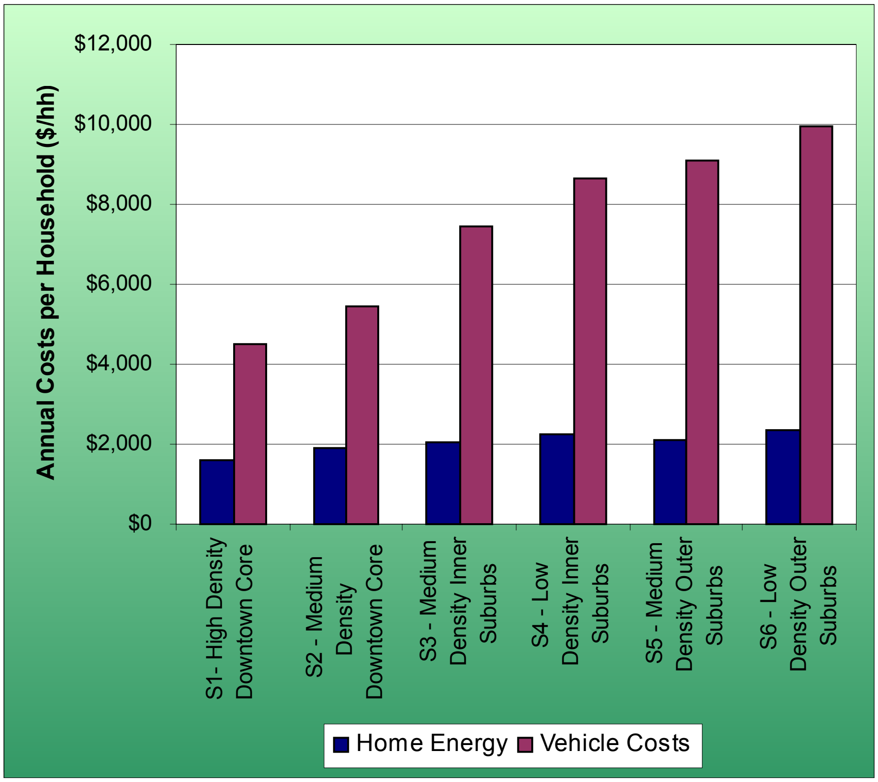
Figure 8.7: Total Initial Development Charges by Scenario (Not Annualized)



8.6 Private Costs

The two private costs quantified in this study are home heating and vehicle costs. ***Figure 8.8*** provides a summary of these major private costs by scenario. As expected, home heating costs are somewhat higher for lower density neighbourhoods reflecting a higher mix of detached homes. For vehicle costs, there are major differences by scenario, with the neighbourhoods in the outer suburbs exhibiting significantly higher per household vehicle costs than neighbourhoods in the inner areas. This result is consistent with findings of other studies, but something that is not well understood by consumers.

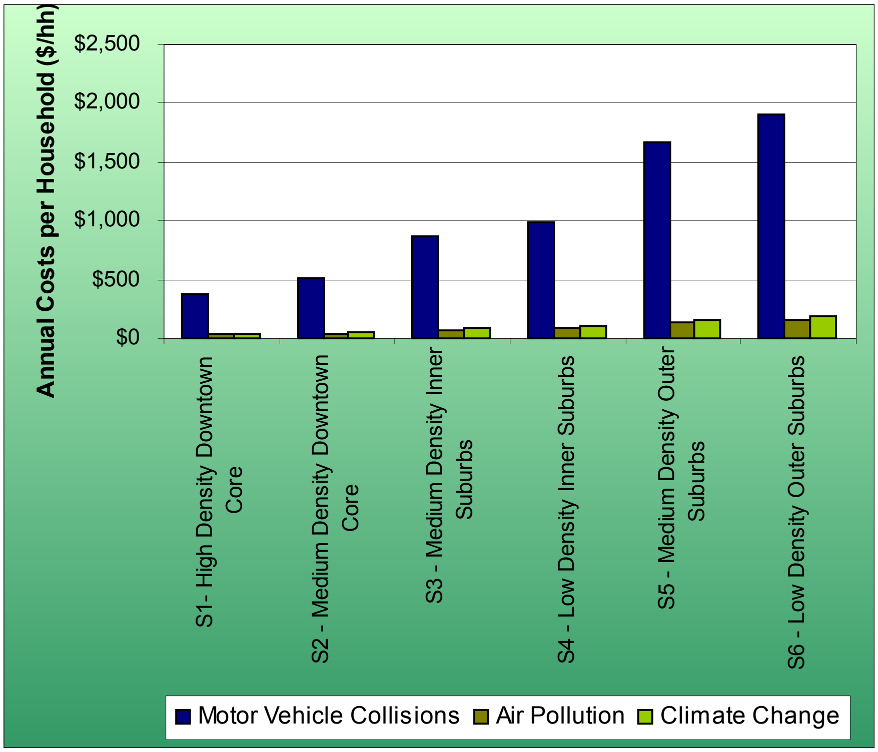
Figure 8.8: Annual Private Costs by Scenario ($/household)



8.7 External Costs

External costs considered in this study include air pollution, climate change and motor vehicle collisions. ***Figure 8.9*** shows how these costs vary by scenario on a per household basis. Differences in these costs by scenario are directly related to vehicle usage and therefore increase for the lower density outer suburban areas.

Figure 8.9: Annual External Costs by Scenario ($/household)



8.8 Cost Allocation

The question of "who pays" for development is one that is not well understood as it is a very complex issue. The cost of urban development is typically paid for through several sources including developers, municipalities, other agencies such as hydro and other governments (i.e. provinces). These costs are offset by charges to consumers, in the case of developer costs, property taxes, development charges and user fees. One of the key challenges in determining who pays, is that costs and revenues directly related to development are not easy to separate. For example a developer may pay for the initial construction cost of a street, but the municipality would pay for on-going maintenance and replacement. On the revenue side, property taxes collected by municipalities pay for the cost of development as well as other services such as social programs.

Another compounding issue is that practices for development charges vary considerably by jurisdiction and within a jurisdiction. For example, the City of Ottawa does not currently charge development charges in the former City of Ottawa area.

Table 8.5 presents a preliminary allocation of the cost of development. At this point in the study, these have not yet been applied to the absolute costs and revenues in order to develop a net cost-benefit statement, as further discussion of the desirability of including such a calculation in the costing tool is required.

Table 8.5: Preliminary Percentage Allocation of Costs

	CAPITAL COSTS					OPERATING / MAINTENANCE			REPLACEMENT	
	MUNICIPAL		DVLPR	USER	OTHER	MUNICIPAL		USER	MUNICIPAL	USER
	P taxes	DC's				P Taxes	User fee		P Taxes	
Internal (Local) roads			100			100			100	
Arterial roads	10	90				100				
Expressways					100					
Gas				100			100			100
Hydro				100			100			100
Phone / cable				100			100			100
Water distribution service										
local			100							
municipal / regional		100								
Water treatment facilities		100				varies*			100	
Sanitary sewers						varies*			100	
local			100							
municipal / regional		100								
Wastewater treatment facilities		100				varies*			100	
Stormwater management facilities						varies*			100	
local			100							
municipal / regional		100								
Schools									N/A	
Regional facilities									N/A	
Transit facilities / services										
School transit										
Fire services		100				100			N/A	
Police services		100				100			N/A	
Waste management services	100					100			N/A	

* Operating and maintenance costs for water and wastewater are recovered by varying degrees through water and sewer user charges.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions on Phase 1

This report describes the models in existence that may meet the objectives of the study and based on this research and a literature review, develops a costing framework for a costing mechanism/tool to facilitate sustainable community planning. It is intended that this framework set the stage for Phase 2 which is the preparation of the actual tool. The overall structure and inputs for the proposed tool are defined and six sample development scenarios are selected and costed to help validate and guide the development of the framework and costing tool.

The literature review provided information on key costing variables, key variables for scenario development and expected outcomes of the lifecycle costing. This information was used to select the costing and scenario variables and to validate the sample lifecycle costing work completed in Phase 1.

The review of existing models/tools indicates that there is no readily available model that meets all of the objectives of this study. The majority of studies, models and tools reviewed are focused on regional-level developed decisions and are not applicable at the community or neighbourhood levels. The review also identified models that address specific elements of community planning/development, but cannot be extended to a more comprehensive costing approach. However, there are components of existing tools and reports that can be used as building block in the development of a new comprehensive tool. Specifically, the CMHC Tool for estimating Greenhouse Gas Emissions, while not a costing tool per se, can provide useful input on the scenario development and establishment of relationships between urban form and performance measures such as vehicle use. The two reports conduced for CMHC in 1997 on conventional and alternative development patterns also provide a benchmark for the development of costs and revenues.

The bulk of effort in Phase 1 was devoted to creating a conceptual costing framework and establishing unit costs for each costing category to use as default settings in the tool in Phase 2. The goal was to identify representative (i.e. “default”) costs of interest to users across Canada but recognizing that the tool itself will allow users to input their own unique costs (as well as other variable information and formulae adjustments). Chapter 4.0 includes a listing of costs applied in Phase 1 as well as a listing of proposed costs to be considered in Phase 2 based on the (Phase 1) comments received.

With these costs in place, scenario costs and revenues were then calculated for each of the six selected sample scenarios to validate the conceptual framework. Based on the preliminary results of the costing framework, the following generalized conclusions on the cost of community development were identified:

- Cost efficiency is a function of density – more compact neighbourhoods have lower costs per household;

- Capital costs vary more by scenario than operating costs;
- On a lifecycle cost basis including both capital and operating costs but excluding school costs, revenues from property taxes and development charges, high density neighbourhoods in inner areas are as much as 60% more cost efficient than low density outer suburbs neighbourhoods when expressed on a per capita basis (See figure 8.5);
- External costs such as accidents and air pollution are significantly greater for low-density outer suburbs neighbourhoods.

These results are consistent with results of studies summarized in a literature review (Chapter 3.0).

At this point in the study, revenues have been calculated but a net cost of development has not. Comments received on the Phase 1 work indicate that, if possible, the ultimate tool needs to include capacity for users to identify all sources of revenue and compare these to the full costs of development, as well as assess "who pays".

9.2 Recommendations on Development of a Planning Tool

The work completed in Phase 1 both confirms that a tool meeting the objectives of the study does not currently exist and establishes a framework for a feasible and practical tool. The development of such a tool is not a simple exercise because of the countless ways in which urban development takes place, combined with the many different approaches taken across Canada when it comes to paying for and generating revenues from development. Some Steering Committee Members have also identified potentially significant effort that will be required to keep the tool up to date and current. All of this points to the need for a tool that is flexible enough to incorporate unique characteristics of different municipalities and different areas within an urban region while providing the user with enough direction and base input to provide credible and realistic results.

The following points provide direction for the development of a tool:

- Tools to estimate the total cost of community development are not readily available, thus a new tool is proposed that uses the costing framework outlined in Phase 1;
- An interactive and open tool is proposed that builds on the costing framework completed in Phase 1;
- Six sample scenarios do not capture the range of potential community developments, thus, the tool should offer the potential to examine a full range of scenarios as input by the user;
- The range of costs considered must be expanded as outlined in Chapter 4.0 sections 4.2 and 4.6;

- Sustainable infrastructure alternatives should be fully costed to the extent possible so that they can be used to replace conventional infrastructure in the costing model;

- The tool should have flexibility to input specific revenues including user fees and calculate net costs as appropriate to individual model users;

- The model should include capacity to allocate costs as directed by users to identify "who pays". It is not possible to pre-define such allocations in the model due to the variability in cost allocation across Canada;

- A mechanism to update and continuously expand and monitor the tool will improve its long term value. Options to achieve this could be a website where users could suggest enhancements or provide additional data/insights;

- In next stages of this study, further investigations will be made on how unit costs might vary, if at all, by location in Canada and how this might be best addressed in the model. One option would be for the tool to reference standardized cost indexing systems, such as those produced by R.S. Means Publications[44]

- A tool should be flexible as different users will have different needs/interests and inputs they will want to work with (e.g. unit costs, lifecycle formulae assumptions such as discount rates or timeframes for cost recovery, development scenario variables). The model should have mechanisms for users to input individual variables where possible or to use default values if preferred.This report provides a good starting point for the development of a costing tool in Phase 2. However, further research beyond the scope of either Phase of this study could be considered with respect to the following issues to provide for continuous improvement of the model:

- There is a need to develop more accurate measures of operating costs by neighbourhood type and form; most data available from service providers does not distinguish between development types;

- Further work is required to better quantify the issue of "who pays" for the cost of development, including a better link between costs and revenues.

9.3 Use of the Tool

An important consideration in the development of the tool will be to ensure that it complements, rather than duplicates existing resources that are already available. All indications are, based on this research report, is that there is a general lack of tools that can provide quick, yet reasonably accurate costing information for several different development scenarios. It is envisioned that the tool will fill this gap by providing a flexible, user friendly tool that can be easily applied to produce order-of-magnitude costs and revenues. This tool would be most applicable at the

[44] See www.rsmeans.com for more information on this database.

neigbbourhood or secondary plan level when major decisions are being made about infrastructure and development patterns. It could be applied after broad initial scoping exercises, that are informed by the use of visioning tools such as QUEST, but before detailed costing using more rigorous and data intensive models such as Infracycle. In summary, the tool will provide a much needed bridge between "gaming" type analyses and the final financial analysis of a specific development proposal.

Bibliography

Altshuler, A.A. and Gómez-Ibáñez, J.A, *Regulation for Revenue: The Political Economy of Land Use Exactions*. 1993. Washington, DC: Brookings Institution Press; Cambridge, Mass.: Lincoln Institute of Land Policy.

Anas, A., Boyce, D., Hopkins, L. and Knaap, G., *Project Summary: Infrastructure and Metropolitan Development*. 1999. National Science Foundation, Urban Research Incentive Grant.

Anderson, G., *Why Smart Growth: A Primer*. 2000. International City Management Association and The Smart Growth Network. www.epa.gov/smartgrowth/pdf/WhySmartGrowth_bk.pdf

Bank of America, *Beyond Sprawl: New Patterns of Growth to Fit the New California.* 1995. http://www.bankofamerica.com/environment/index.cfm?Menu_Sel=public&oth=urban1

Benfield, F.K., Raimi, M.D. and Chen, D.D.T., *Once there were Greenfields: How Urban Sprawl is Undermining America's Environment, Economy and Social Fabric*. 1999. Natural Resources Defense Council, Surface Transportation Policy Project.

Birrell, R., "*Infrastructure Costs on the Urban Fringe: Sydney and Melbourne Compared"*. 1991. Canberra, Australia. Working Paper 8 in Economic Planning Advisory Council, Background Papers on Urban and Regional Issues: Studies Prepared for the Office of Economic Planning Advisory Council, Australian Government Publishing Service.

Blais, P., *"The Economics of Urban Form"* Appendix E of Greater Toronto. 1995. Toronto, Ont. Greater Toronto Area Task Force.

Brueckner, J.K. and Fansler, D.A., "The Economics of Urban Sprawl: Theory and Evidence of the Spatial Sizes of Cities", *The Review of Economics and Statistics,* 1983. pg 65, 479-82.

Brueckner, J.K., "Property Taxation and Urban Sprawl." In Wallace E. Oates, ed., *Property Taxation and Local Government Finance.* 2001. Cambridge, Mass.: Lincoln Institute of Land Policy.

Burchell R.W, "Economic and Fiscal Impacts of Alternative Land-use Patterns". 1996. Rutgers University. A chapter from "*Land Use Decision Making: Its Role in a Sustainable Future for Michigan*" MSU Extension, January 9-10, 1996. pg 1-34.

Burchell R.W., Shad, N.A., Listokin, D., Phillips, H., Downs, A., Seskin, S., Davis, J.S., Moore, T., Helton, D. and Gall, M., *Costs of Sprawl 2000*. 2002. Transit Cooperative Research Program Report 74. Washington DC: National Academy Press.
http://www4.nas.edu/trb/crp.nsf/All+Projects/TCRP+H-10

Burchell, R.W. et al., *Development Impact Assessment Handbook*. 1994. The Urban Land Institute with Development Impact Assessment Model. (is Model correct?)

Canadian Council of Motor Transportation Administrators, *Canadian Motor Vehicle Traffic Collision Statistics, 2000*. 2000.
http://www.ccmta.ca/english/pdf/st2000e.pdf

Cambridge Systematics, *The Surface Transportation Efficiency Analysis Model (STEAM 2.0).* 2000. The Federal Highway Administration.

Canada Mortgage and Housing Corporation, *Definitely in my Backyard: Making the Best Choices for You and the Environment.* 2000.

Canada Mortgage and Housing Corporation, *Conventional and Alternative Development Patterns, Phase 1: Infrastructure Costs.* 1997.

Canada Mortgage and Housing Corporation, *Conventional and Alternative Development Patterns, Phase 2: Municipal Revenues*, 1997.

City of Calgary, http://www.calgary.ca/DocGallery/bu/planning/pdf/cwinfo_resdensity.pdf

City of Toronto, http://www.city.toronto.on.ca . 1998.

Condon, P. and Gonyea, A., *Status Quo Standards versus an Alternative Standard, East Clayton – two alternative development site standards compared.* 2000. Vancouver, B.C., University of British Columbia. James Taylor Chair in Landscape and Liveable Environments, Landscape Architecture Program.

Criterion Inc., *The Energy Yardstick: Using PLACE^{3}S to Create More Sustainable Communities*. 1996. PLACE^{3}S-"Planning for Community Energy, Economic and Environmental Sustainability", US Department of Energy Center of Excellence for Sustainable Development.

Dalhousie University, Urban and Rural Planning, Faculty of Architecture and Planning. "*Increased Infrastructure Costs".*
http://www.dal.ca/~arch/planning/maritime/sg_infrastructure_costs.shtml

Downs, A. "Some Realities about Sprawl and Urban Decline." In *Housing Policy Debate*. 1999. Fannie Mae Foundation, pg 955–974.

Duncan, James E., et al., *The Search for Efficient Growth Patterns*. 1989. Tallahassee, Fla. Department of Community Affairs.

Durham Region. *Household Guide to Water Efficiency 2nd Edition*. 2001.
(Additional statistics provided by Durham Region Water Efficiency Coordinator: Glen Pleasance, 2002)

Environment Canada, *Air Quality Background*. 2002. http://www.ec.gc.ca/transport/airquality.htm

Environment Canada, *Canada's Greenhouse Gas Emission.* 2002. http://www.ec.gc.ca

---, *Clean Air.* 2002. http://www.ec.gc.ca/air

Environmental Resources Management Australia Pty (is this correct?) Ltd (ERM), *Review Of The Economic And Financial Costs Of Urban Form*. 2001. Prepared for the Australian Department of Transport (Transport) and Ministry for Planning (MfP) in association with the Victoria Transport Policy Institute and Metropole Consultants.

Envision Utah and the Quality Growth Efficiency Tools (QRET) Technical Committee, *Envision Utah Scenario Analysis– Executive Summary.* 1999. http://www.governor.state.ut.us/dea/qget/Archives/Scenario_Analysis/scenario_analysis.htm

EPA, *The Victorian Greenhouse Neighbourhood Project.* 1993. Victoria, Australia, Office of the Environment.

Esseks J.D., Schmidt, H.E. and Sullivan, K.L, *Fiscal Costs and Public Safety Risks of Low-Density Residential Development on Farmland: Findings from Three Diverse Locations on the Urban Fringe of the Chicago Metro Area*. 1998. http://www.aftresearch.org/researchresource/wp/98-1/wp98-1.html

Essiambre Phillips Desjardins Associates Ltd. et al., *Infrastructure Costs Associated with Conventional and Alternative Development Patterns*. 1995. Summary Report and Final Report, prepared for the Canada Mortgage and Housing Corporation and the Regional Municipality of Ottawa-Carleton.

Ewing R., Pendall, R. and Chen, D., *Measuring Sprawl and Its Impact*. 2002. Smart Growth America.

Frank N, White, S., Peng, Z.R., Harris, K. and Sanders, W., *Exploring Sprawl: Findings of a Comprehensive Review of the Literature Related to "Sprawl" or What Do We Really Know?*. 2000. Presented at the Association of Collegiate Schools of Planning; November 2-5, 2000, Atlanta GA. http://www.uwm.edu/~frankn/Sprawl_Frank.htm

Frank, J.E, *Costs of Alternative Development Patterns: A Review of the Literature*. 1989. Washington, DC. Urban Land Institute.

http://www.greenhouse.gov.au/lgmodules/reduction/planning/targetareas.html#Greenhouse

IBI Group, *Summary Report, the GTA Urban Structure Concepts Study.* 1990.

---, *The GTA Urban Structure Concepts Study, Background Report No. 3, Transportation Systems.* 1990a.

---, *The GTA Urban Structure Concepts Study, Background Report No. 4, Water, Sewers and Solid Waste.* 1990b.

IBI Group, *Full Cost Transportation and Cost-Based Pricing Study*. 1995.

---, *The GTA Urban Structure Concepts Study Revisited: Broad Revision of Selected Cost Estimates*. 1995a.

---, *Tool for Evaluating Neighbourhood Sustainability: Greenhouse Gas Emissions from Urban Travel.* 2000. Prepared for Canada Mortgage and Housing Corporation.

---, *Toronto-Related Region Futures Study: Implications of Business-As-Usual Development.* 2002.

Kinhill Engineers, *Smart Planning not Sprawl. The Costs and Benefits of Alternative Fringe Development.* 1995. Canberra, Australia. Australian Urban and Regional Development Review Discussion paper #5.

Ladd, H.F., "Population Growth, Density and the Costs of Providing Public Services." *Urban Studies.* 1992. 29 (2) pg 273–275.

Lehman Associates, IBI Group, *Urban Density Study*. March 1995. Prepared for the Office for the Greater Toronto Area.

Marchand, C. and Charland, J., *The Rural Urban Fringe: A Review of Patterns and Development Costs*. 1992. Toronto: Intergovernmental Committee on Urban and Regional Research. http://www.icurr.org/english/pubs/fringe.htm

Ministry of Housing and the Ministry of Municipal Affairs, *Making Choices – Alternative Development Standards Guideline*. 1995.

Murphy, J.J. and DeLucchi, M.A., *A Review of the Literature on the Social Cost of Motor Vehicle Use in the United States*. 1998. University of California, Davis. Institute of Transportation Studies. http://repositories.cdlib.org/itsdavis/UCD-ITS-REP-98-22/

Natural Resources Defense Council, *Developments and Dollars – An Introduction to Fiscal Impact Analysis in Land Use Planning*. http://www.nrdc.org/cities/smartGrowth/dd/ddinx.asp

Ohls, J.C. and D. Pines (1975) "Discontinuous Urban Development and Economic Efficiency", *Land Economics,* 51, 224-234.

Ontario Ministry of Housing and Monaghan, M.M, *Urban Development Standards – 1990 Update: Part 1 – Engineering Standards and Costs* and *Part 2 – Planning Standards.* 1990.

Ottensman, J.R., "Urban Sprawl, Land Values, and Density of Development", *Land Economics.* 1997. 53, 389-400. The reference on page 4 says 1977

Parsons Brinckerhoff Quade & Douglas Inc., *The Full Social Cost of Alternative Land Development Scenarios (SCALDS) model*. 1998. The Federal Highway Administration's - The Cost of Alternative Land Use Patterns.

Peiser, R.B., "Density and Urban Sprawl", *Land Economics.* 1989. 65, 193-204.

Raimi, M., *"Sprawl, Subsidies and Smart Growth".* 2000. Natural Resources Defense Council. http://www.tea21.org/smartgrowth/fiscal.htm

Pollard, Doug and Grammenos, Fanis, *Planning for Opportunities and Profit - Residential Street Pattern Design*. 2002. Canada Mortgage and Housing Corporation.

Pollard, Doug, *CreatingOpportunities for Green Buildings as Infrastructure*. 2002. Canada Mortgage and Housing Corporation.

Real Estate Research Corporation (RERC), *The Costs of Sprawl*. 1974.

Rodriguez-Bachiller, A., "Discontiguous Urban Growth and the New Urban Economics: A Review", *Urban Studies.* 1986. 2, 79-104.

San Francisco League of Conservation Voters (SFLCV). *This View of Density.*
http://www.sflcv.org/density/index.html

Sheltair Group, The and Moffatt, S., *CityGreen – A Guide to Green Infrastructure for Canadian Municipalities*. 2001..

Sierra Club, *Density Calculator.* 2001. Unavailable as of December 2002.

Snyder, K. and Bird, L., *Paying the Costs of Sprawl: Using Fair-Share Costing to Control Sprawl*. US Department of Energy. http://www.sustainable.doe.gov/articles/sprawl.pdf

Speir, C. and Stephenson, K., "Does Sprawl Cost Us All?" *Journal of the American Planning Association*. Winter 2002. 68 (1) 56-70. State of Maine 1997 *The Cost of Sprawl*. http://www.state.me.us/spo/publications/publications.htm

Stephenson K., Speir, C., Shabman, L. and Bosch, D., *The Influence of Residential Development Patterns on Local Government Costs and Revenue*. 2001. Virginia Tech, Department of Agricultural and Applied Economics. www.reap.vt.edu/publications/reports/r51.pdf

Surface Transportation Policy Project and Center for Neighbourhood Technology, *Driven to Spend*. 2000. http://www.transact.org/report.asp?id=36

Surface Transportation Policy Project, "*Another Cost of Sprawl: The Effects of Land Use on Utility Service Costs and Geographically-Sensitive User Rates*". 2000. http://www.smartgrowth.org/sgn/partpublist.asp?part=12

The 1,000 Friends of Oregon, *List of Resources on Costs Related to Growth*. http://www.friends.org/resources/cstgrow.html

University of British Columbia, *Quest (Envision Sustainability Tools)*. 2002-ongoing. Sustainable Development Research Institute (SDRI).

Victoria Transport Policy Institute, *Transportation Cost and Benefit Analysis – Water Pollution*. http://www.vtpi.org. From the report: Dr. Peter Bein, *Monetization of Environmental Impacts of Roads, Planning Services Branch.* 1997. Victoria, B.C. Ministry of Transportation and Highways www.th.gov.bc.ca/bchighways

TABLE OF CONTENTS

Appendix A to Chapter 2.0 Literature Review

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Table A-1:
Summary – Local Savings

Note: the following table refers to savings identified in a selection of studies focusing on the local, or neighbourhood realm. Typically, these studies are not based on complex, multi-variable scenarios at the regional level but on varying net (lot) density and gross (neighbourhood) density through the use of alternative standards like narrower roads.

Overall savings related to density

	Variables	Cost Savings	
Wheaton and Schussheim	Net densities 11 to 32 uph	30%	Capital, operating and maintenance
		41%	Capital only
Stone	Net densities 22 to 70 uph	63%	Development costs
RERC	Net densities 7 to 75 uph and different development pattern	40%	Capital costs
CMHC	Conventional vs. alternative	9%	Lifecycle infrastructure costs
		16%	Capital only
EPA (Victoria)	Conventional 1980s, "VicCode 1" [improved code], "TND"	18% (improved vs. conventional) to 55% (TND vs. conventional)	"urban infrastructure costs"

Savings strictly on frontage costs[45]

	Variables	Cost Savings	
Wheaton and Schussheim	Net densities 3-4 to 11 uph	14-27%	Frontage Capital Costs
Isard and Coughlin	Net densities 10 to 40 uph	50%	Frontage Capital Costs (less water supply)

45 Local and collector roads, sewer pipes, stormwater infrastructure and water pipes

RERC	All net compared to 12 uph clustered single family:		Streets and utilities (sewer, water, storm)
	25 uph townhouses	29%	
	30 uph mix	24%	
	37 uph garden apts	51%	
		33%	
CMHC	Conventional vs. alternative		Frontage Capital Costs (account for only 29-37% of the total costs but 81% of the potential savings)

Table A-2:

Comprehensive Study – Local Level

Condon and Gonyea	Savings (East Clayton vs. conventional)
Land Cost	
Per Unit	63.2%
Per Parcel	44.9%
Building Cost	
Per average size unit 2300 vs. 1661 s.f.	27.8%
Per equal size structure 2000sf	0.0%
Infrastructure Cost	
Roadworks	-17.3%
Asphalt paving	-55.8%
Storm sewer vs. swale	61.1%
Boulevard Landscaping	-20.2%
Water Mains	-48.7%
Water tie-ins and connections	-170.7%
Sanitary sewers	-69.9%
Sanitary tie-ins and connections	-170.7%
Street lighting	-46.6%
Lot grading and/or swales	0.9%
Hydro/telephone installation (buried services)	-170.7%
Boulevard tree planting	-20.3%
Utilities	-66.4%
Block interior pathways and emergency access	100.0%
Block interior pathways landscaping	100.0%
Total Cost - entire site	-26.7%
Total Cost - per unit	53.2%
Total Cost - per parcel	29.8%
Total cost of an average unit	
Average size 2300 s.f. vs. 1661 s.f.	41.7%
Total cost per square foot of interior space	
Average size 2300 s.f. vs. 1661 s.f.	19.2%
Total Cost of equal sized infrastructure	
Equal sized structures 2000 s.f.	18.8%

Note: a negative percentage indicates that costs were lower in the conventional subdivision. But while the conventional subdivision contains 41 parcels and 41 units, East Clayton is subdivided into 74 parcels and 111 units.

Table A-3:

Summary – Regional Savings

Note: the following tables present savings identified between different scenarios at the regional level, including costs incurred at the neighbourhood level but found to vary between different regional scenarios.

Burchell 2002	Savings - controlled vs. uncontrolled
Land Consumption	21%
Water Infrastructure	7%
Sewer Infrastructure	7%
Road Infrastructure	12%
Net Fiscal Impact	10%
Residential Development Costs	9%
Nonresidential Development Costs	2%
Travel Costs	2%

IBI 1995a

Revised Capital Costs

	Savings - Central to Spread	Savings - Nodal to Spread
Transportation	**16%**	**7%**
Transit	-69%	-29%
Roads	36%	16%
Hard Services	**41%**	**28%**
Water/Sewer	0%	0%
Local Services/Roads	49%	33%
Transportation and Hard Services Sub-Total	**29%**	**18%**
Greening/Environment	**0%**	**0%**
Passive Open Space (Land)	0%	0%
Stormwater Quality	0%	0%
Human Services	**-3%**	**3%**
Hospitals	-24%	-7%
Social and other health services	0%	0%
Educational facilities	34%	25%
Protection	0%	0%
Culture and Recreation	0%	0%
Parks (Land)	-83%	-22%
Human Services/Greening Subtotal	**-2%**	**2%**
Total	**16%**	**12%**

Operating Costs

Transportation	**17%**	**7%**
Roads Departments	13%	4%
Auto Traveller Costs	21%	10%
Transit Properties	-21%	-17%
School Bussing	37%	19%
Handicapped Transit	18%	0%
Hard Services	**0%**	**0%**
Solid Waste Disposal	0%	0%
Total	**16%**	**7%**

External Costs

Emissions, publicly-borne healthcare costs, policing of auto accidents, congestion, parking, land used by automobiles	**28%**	**19%**

IBI (2002)

	Consolidated compared to BAU	Multi-centred compared to Business as Usual (BAU)	Dispersed compared to BAU
Transportation			
% change from BAU 2000-2031			
Provincial Highways	-14.90%	0.00%	13.35%
Arterial Roads	0.43%	0.43%	0.00%
Municipal Transit	33.31%	27.72%	0.00%
Rapid Transit	0.00%	0.00%	0.00%
GO Rail	7.92%	42.47%	0.00%
Total capital costs	-0.84%	8.10%	5.62%
% Change from BAU 2031			
Average annual public sector capital expenditures	-0.80%	8.10%	5.60%
Net annual public sector O&M expenditures	9.90%	7.60%	0.70%
Total annual public sector expenditures	3.20%	7.90%	3.40%
Annual auto driver expenditures (from avg CAA figures)	-6.40%	-1.30%	2.50%
Annual public sector plus auto driver expenditures	-4.20%	0.80%	2.70%
Average auto trip time (minutes, AM peak)	-8.00%	-7.10%	-4.40%
Environmental Impact			
% Change from BAU 2031			
Kilotonnes of Nitrogen Oxides (NOx)	-6.10%	-1.60%	2.40%
Kilotonnes of Carbon Monoxide (CO)	-13.10%	-8.20%	-5.00%
Kilotonnes of Volatile Organic Compounds (VOCs)	-15.40%	-7.00%	-4.00%
Kilotonne Equivalents of Carbon Dioxides (CO2)	-7.20%	-2.40%	1.50%
Billions of litres of fuel	-6.80%	-2.10%	1.40%
Water/Wastewater System Costs			
% Change from BAU 2000-2031			
System renewal	0.00%	0.00%	0.00%
System upgrades	0.00%	0.00%	0.00%
Growth related	-3.46%	-0.75%	0.75%
Total capital costs	-0.68%	-0.15%	0.15%

Envision Utah 1999

	Scenario A (least compact) - Savings compared to B	Scenario C (more compact) - Savings compared to B	Scenario D (most compact) - Savings compared to B
Water	0%	17%	17%
Transit	0%	-283%	-683%
Roads	-59%	6%	1%
Municipal and Developer	-10%	43%	53%
Total	-28%	21%	17%

in M$

	Savings compared to B	Savings compared to B	Savings compared to B
Regional Water	-2%	13%	13%
Regional Transit	0%	-294%	-701%
Regional Roads	-58%	6%	1%
Subtotal Regional	-53%	-9%	-33%
Residential Development	-13%	42%	53%
Municipal Roads	1%	54%	68%
Municipal Water	-2%	37%	46%
Municipal Wastewater	0%	46%	57%
Subtotal Local	-10%	43%	53%
Total	-28%	21%	17%
VMT in Millions/day	-8%	3%	4%
Emissions in tons/day	-6%	0%	0%
Water Use in acre-feet/day	-8%	15%	19%

SEMCOG 1997

	Savings, compact vs. current scenario
Local Road Costs	10%
State Road Costs	18%
Water Infrastructure Costs	8%
Sewer Infrastructure Costs	6%
Housing Costs	6%
Non-Residential Costs	5%
Cost Revenue Impact	41%

Developable land, including agricultural and fragile land	13%
Agricultural land	13%
Fragile land	12%

Duncan 1989

	Savings, compact vs. current scenario
Roads	60%
Schools	7%
Utilities	40%
Other	-2%
Total	35%

Appendix B - Unit Cost Analysis

Table of Contents

INTERNAL (LOCAL) ROADS

Description:

Internal roads refers to the basic street network within the subject neighbourhood. This would primarily include local roads, and potentially collector roads. Both capital (i.e. construction) costs as well as operating costs are estimated for internal roads. Capital costs for internal roads were developed to include all components within the street right-of-way including sub-base, pavement, sidewalks, street lighting and utilities.

Costing Methodology:

The capital cost of internal roads is a function of length, width and the types of design features included in the right-of-way. Unit costs were developed for each individual component on a per m (length) or per m^2 (area) basis. As a base assumption, it was assumed that roadways were asphalt paved with curb and gutter and sidewalks one side of the road for low-density development and on both sides of the road for medium to high-density development. Street signs, street lighting and silt fencing were also included in the construction cost. Utilities included the cost of natural gas, telephone and cable.

For internal road operating costs, municipal road budgets were used to develop average costs per lane-kilometre, which could then be applied to the neighbourhood scenarios. Operating costs included road maintenance and winter control (snowplowing and road salting).

Background and Unit Costs:

Unit costs for road construction were developed using average tendered unit prices obtained from the Greater Toronto Area. These costs have not been adjusted for different geographic locations, but could be in the next phase of this study.

The following values have been adopted for costing internal roads:

- Linear Costs (Trimming and Shaping, curb and gutter, subdrains, silt fence, street lighting, utilities) - $280/m

- Area Costs (clearing and grubbing, sub-base, asphalt, sidewalks) - $78/$m^2$

Operating costs for roads were obtained from various sources as discussed below. As a starting point, information from the Transportation Association of Canada Urban Transportation Indicators Survey was used to establish operating and maintenance costs for various municipalities. Municipalities generally do not distinguish between costs for local roads and costs for arterials. Therefore, the approach adopted was to develop unit costs on the basis of lane-kilometres, regardless of road type, and apply these as appropriate to derived lane-km for each scenario. Information on road lengths was obtained from GIS Streetfile databases for selected cities, and converted to lane-km by assuming average road widths.

The development of unit costs is shown in the table below.

Road Operating Costs From Transportation Association of Canada

	Annual Road O&M budget (2001) (1)	Arterial Roads and Municipal Highways			Local Roads			Arterials and Local Roads	
		Length (km) in CMA (2)	Average Width (lanes)	Lane-km	Length in CMA (km) (2)	Average Width (lanes)	Lane-km	Total Lane-km	Cost per Lane-km
Windsor	$3,630,000	300	4	1200	927	2	1854	3054	**$1,189**
Niagara	$13,290,585	962	4	3848	1005	2	2010	5858	**$2,269**
Kitchener	$18,341,400	536	4	2144	1137	2	2274	4418	**$4,152**
Hamilton	$39,616,643	911	5	4555	1547	2	3094	7649	**$5,179**
Ottawa-Hull	$60,500,000	2646	5	13230	2735	2	5470	18700	**$3,235**
Toronto	$100,116,500	2801	5	14005	9537	2	19074	33079	**$3,027**

(1) Transportation Association of Canada, Urban Transportation Indicators Survey, 1996 Survey 2, December 1999
(2) Calculated from MapInfo Streetpro Files

In addition to the above values, the following estimates for road operating costs were obtained from selected Ontario Municipalities. These were readily available, since, in 2001 the provincial government introduced through legislation the 'Municipal Performance Measurement Program" requiring Ontario municipalities to provide information on a number of clearly set out indicators.

Road Operating Costs for Selected Municipalities

Municipality	Operating and Maintenace ($/lane-kilometre)	Winter Maintenace ($/lane-kilometre)	Total ($/lane-kilometre)
Sudbury	$2,503	$3,936	$6,439
Barrie	$4,161	$3.328	$7,489
Hamilton	$3151	$2159	$5,310
Markham	$649	$1,798	$2447

On a per lane-kiloemtre basis, the values range from $2,500-$$7,500 per lane-kilometre. The lower value for Markham may be explained by the fact that most of the roads in Markham are relatively new as it is a rapidly growing area. The values from the above table are higher, but in the same range as those derived from the TAC Indicators Survey. For the initial costing, a value of $4,000 per lane-km was used.

Assumptions and Limitations:

- Capital costs are based on representative unit values and may vary by location depending on local practices and materials costs. Variations are expected to be small.

- Establishing precise operating costs for different types of facilities in different locations is difficult. The costs developed for this study are intended to provide "order-of-magnitude" estimates of road operating costs.

Primary Data Sources:

Transportation Association of Canada, Urban Transportation Indicators Survey,1996 Survey 2, December 1999.

Webistes of selected Ontario Municipalities reporting under the "Municipal Performance Measurement Program"

Streetpro (MapInfo) Street network Files

ARTERIAL ROADS

Description:

Arterial roads refers to roads that provides access to and from the local neighbourhood. Both capital (i.e. construction) costs as well as operating costs are estimated for arterial roads. In some cases, these could include collector roads, although for simplicity the term arterial road is maintained.

Costing Methodology:

The process used to estimate the cost of arterial roads was to estimate the length of arterial roads associated with a particular development and then multiply this by a representative unit cost.

Several options were considered for establishing the length of arterial roads for a given neighbourhood scenario. The approach chosen was to estimate the amount of arterial roads on an area basis. This is appropriate given that in most urban areas, arterial roads are fairly regularly spaced.

Operating costs for arterial roads are based on an average cost per lane-km as discussed above for internal roads.

Background and Unit Costs:

GIS Street network files were used to estimate the length of arterial roads per square-km. The resulting values for the City of Ottawa are shown in the table below.

	Area	Highways			
	sq km	municipal km	provincial secondary km	total km	km/sq km
Outer Suburbs	2930	2441.4	141.3	2582.8	0.9
Inner Suburbs	809.6	788.2	118.2	906.4	1.1
Inner Area	10.28	36.6	20.0	56.5	5.5

As with internal roads, unit costs for arterial roads ($/m) are ‘all-inclusive’ of utilities, sidewalks, etc. Unit costs were developed from ‘in-house’ costing estimates from Dillon Consulting and IBI Group and are reflective of a typical arterial road consisting of a 26m right-of-way, 4 lanes at 3.25 m each and sidewalks on both sides of the street. The resulting unit cost is $2,330 per m of roadway.

Assumptions and Limitations:

- Capital costs are based on representative unit values and may vary by location depending on local practices and materials costs. Variations are expected to be small.

Primary Data Sources:

Streetpro (MapInfo) Street network Files

In-house unit roadway costs – IBI Group and Dillon

WATER DISTRIBUTION SERVICE

Description:

Water distribution refers to the system that delivers water from the trunk water system to individual households or units. Capital costs mainly consist of piping and associated infrastructure (valves, hydrants, etc.) while operating costs primarily consist of maintaining the system. The cost of water treatment is not included in water distribution, but rather water treatment (see Water Treatment).

Costing Methodology:

The cost of water distribution services within a neighbourhood is almost directly related to the length of internal roads. Therefore, costs were developed by multiplying the linear unit costs of standard water mains by the length of roads within the neighbourhood.

Water distribution costs include the cost of both local distribution lines as well as trunk lines. It was assumed that all local streets would include distribution lines (150 mm diameter mains). In addition, allowances were made for trunk lines by assuming that trunk lines would represent about 15% of the total water system length. All trunk lines were costed on the basis of (300 mm diameter mains).

Background and Unit Costs:

For a conventional neighbourhood, unit costs are $137/m for distribution lines and $180/m for trunk lines. For neo-traditional neighbourhoods, the costs are $196/m for distribution lines (includes 150 mm diameter commercial connections) and $186/m for trunk lines. The higher costs for neo-traditional neighbourhoods are mainly attributed to the 50% increase in the number of low-rise residential buildings (smaller lot size) compared to conventional neighbourhoods and the corresponding increase in service connections.

Assumptions and Limitations:

- Unit costs for water distribution are reflective of typical neighbourhood layouts and may vary depending on road pattern and development patterns.
- Allocations for trunk lines are notional only and would vary depending on whether the development is located in an area with existing capacity or requiring new capacity.
- Operating costs for water distribution were frequently grouped with operating costs for water treatment as a total collection and treatment cost, thereby reducing our possible data sources.

Primary Data Sources:

Capital costs were derived on first principles using typical layouts for conventional and neo-traditional neighbourhoods obtained from the report: Tool for Evaluating Neighbourhood Sustainability (IBI Group 2000). Unit costs consisted of average tendered prices from the Greater Toronto Area. These costs have not been adjusted for different geographic locations, but could be in the next phase of this study.

Operating costs were obtained from the City of Ottawa 2002 Municipal Budget and from consultation with the Municipality of Tecumseh.

WATER TREATMENT FACILITIES

Description:

Water treatment facilities are centralized facilities that purify water prior to distribution to developments. Both capital and operating costs for water treatment have been estimated. Operating costs are primarily related to the cost of the treatment itself.

Costing Methodology:

The basic approach for estimating the cost of water treatment was to apply a unit value reflecting an average cost per capita.

Background and Unit Costs:

Capital costs were obtained from the Neptis Foundation Toronto-Related Region Futures Study, Draft Interim Report: Implications of Business-As-Usual Development (June 2002). The business-as-usual approach uses the most realistic future conditions based on historic trends and current practices. This included three components; system renewal cost, system upgrade cost and growth-related cost (cost of new infrastructure to service development growth). System renewal cost was based on the assumptions that water asset value is $2200/capita (lower than wastewater asset value due to the use of groundwater) with annual investment cost of 1.75% of total asset value for replacement purposes. Water treatment plant upgrades included residue management plans, provision of UV disinfection and taste and odour control. Growth-related costs include treatment plants, pumping stations, water reservoirs and trunk distribution mains.

Capital cost was also obtained from the City of Ottawa Municipal Budget. This was used as a comparison with the Neptis findings but was not used directly as less background information was provided on the cost. The Neptis cost of water treatment was estimated at $55/capita for a large municipality compared to $46/capita for Ottawa.

Very little data was found relating the operating cost of water treatment facilities to different types of developments. Therefore, costs for water treatment relied on overall municipal budgets, which were then used to develop average values per household. However, a significant portion of the collected data had to be disregarded as it combined water treatment and water distribution costs in a single collection and treatment cost.

Operating Cost ($/capita)	Ottawa	Calgary	Peterborough	Brantford	Kingsville	Tecumseh
Water Treatment	$20	--	--	--	--	$22
Water Treatment & Distribution	--	$115	$276 / megaL	$350 / megaL	$39	--

Assumptions and Limitations:

- Since unit costs for operating (e.g. treatment and consumption) are based on municipality wide averages, they do not reflect differences in water consumption by development type. It is reasonable to expect that low density detached houses would consume more water than an apartment dwelling.
- Water Treatment Costs reflect the net costs to the municipality. Therefore, municipalities that recover a large portion of operating costs from user fees would have a low net cost.

Primary Data Sources:

Neptis Foundation Toronto-Related Region Futures Study, Draft Interim Report: Implications of Business-As-Usual Development (June 2002)

City of Ottawa 2002 Budget

Consultation with the Municipality of Tecumseh and Kingsville.

Data from selected municipalities.

SANITARY SEWERS

Description:

Capital costs for sanitary sewers primarily include the construction cost of the sewer mains and related infrastructure. Operating costs primarily consist of pipe maintenance costs.

Costing Methodology:

Capital cost estimates for sanitary sewers were developed for representative neighbourhoods (a neo-traditional neighbourhood and a conventional neighbourhood) and then used to develop a unit cost per length of pipe, which could be used in the costing of scenarios.

Operating costs were estimated using a similar manner as water distribution. That is, operating budgets from selected municipalities were used to develop average costs per capita.

Background and Unit Costs:

For the sanitary sewer system, the trunk line diameter was 250 mm with 200 mm diameter collection pipes. Pre-cast manholes were 1200 mm diameter placed at an average depth of 5.0 metres. Residential connections were sized at 100 mm diameter including plugs and 200 mm diameter for commercial connections. Also included were the cost of flushing and cleaning the sewers prior to the end of the maintenance period as well as the TV inspection.

Based on these assumptions, the unit costs for capital were $163/m of pipe for a traditional neighbourhood and $210/m of pipe for a neo-traditional neighbourhood. The differences in costs are related to an increased number of service connections required due to a higher density of single detached homes and townhouses. In general, the majority of costs are for excavation and installation and the incremental costs for different size pipes is small.

Operating costs from selected municipalities are provided in the table below. These ranged from $1-$5/capita for smaller municipalities to $11 for a larger municipality. In the scenario costing for this study, the value for larger municipalities was adopted.

Assumptions and Limitations:

- Operating costs are based on average values from representative municipalities. Therefore, they do not reflect differences in operating and maintenance needs by type of development. These differences are expected to be small.

Primary Data Sources:

Neptis Foundation Toronto-Related Region Futures Study, Draft Interim Report: Implications of Business-As-Usual Development (June 2002)

Capital costs were derived on first principles using typical layouts for conventional and neo-traditional neighbourhoods obtained from the report: Tool for Evaluating Neighbourhood Sustainability (IBI Group 2000). Unit costs consisted of average tendered prices from the Greater Toronto Area. These costs have not been adjusted for different geographic locations, but could be in the next phase of this study.

WASTEWATER TREATMENT FACILITIES

Description:

Wastewater treatment facilities are centralized facilities that treat household and commercial sewage. Both capital and operating costs for wastewater treatment have been estimated. Operating costs are primarily related to the cost of the treatment and disposal.

Costing Methodology:

The basic approach for estimating the cost of water treatment was to apply a unit value reflecting an average cost per capita.

Background and Unit Costs:

Capital costs were obtained from the Neptis Foundation Toronto-Related Region Futures Study, Draft Interim Report: Implications of Business-As-Usual Development (June 2002). As noted previously, the business-as-usual approach used the most realistic future conditions based on historic trends and current practices. System renewal costs were based on the assumption that wastewater asset value is $3300/capita with annual investment cost of 1.75% of total asset value. Wastewater treatment plant upgrades included increased aeration capacity for nitrification, sand filtration for tertiary treatment and UV disinfection. Costs included treatment plants, pumping stations, wastewater collection trunks and forcemains.

Capital cost was also obtained from the City of Ottawa Municipal Budget. This was used as comparison with the Neptis findings but was not used directly as less background information was provided on the cost. The Neptis cost of wastewater treatment was estimated at $79/capita for a large municipality compared to $47/capita for Ottawa.

Operating costs from selected municipalities are provided in the table below. These range from $30/capita for smaller municipalities to $85/capita for a larger municipality. In the scenario costing for this study, the value for larger municipalities was adopted.

Operating Cost ($/capita)	Ottawa	Calgary	Peterborough	Brantford	Kingsville	Essex	Tecumseh
Wastewater Treatment	$16	$85	--	--	$33	$30	--
Wastewater Collection & Treatment	--	--	$187 / megaL	$328 / megaL	--	--	$51

Assumptions and Limitations:

- Sewage treatment practices vary fairly substantially across Canada.

- Operating costs are based on average values from representative municipalities. Therefore, they do not reflect differences in sewage output by type of development.

Primary Data Sources:

Neptis Foundation Toronto-Related Region Futures Study, Draft Interim Report: Implications of Business-As-Usual Development (June 2002)

City of Ottawa 2002 Budget and data from selected municipalities.

STORM SEWERS

Description:

The cost of storm sewers is based on the cost of pipes, catchbasins and related facilities. The cost of the actual treatment of storm run-off is included as a separate item (Stormwater Treatment). Operating costs (e.g. cleaning of catchbasins) have been included within the capital cost of the storm sewers as these are relatively small.

Costing Methodology:

Capital cost estimates for storm sewers were developed for representative neighbourhoods (a neo-traditional neighbourhood and a conventional neighbourhood) and then used to develop a unit cost per length of pipe, which could be used in the costing of generic scenarios.

Operating costs for storm sewers were not available as a separate cost item.

Background and Unit Costs:

Stormwater sewer costs include the pipe cost as well as flushing and cleaning of the sewers prior to end of guarantee inspection, the TV inspection, and the silt traps required in the catchbasins during road construction. Manholes, catchbasins and all respective leads and connections were factored into the cost.

Rear yard catchbasins were included in the capital cost in the conventional neighborhood with catchbasins typically shared between a minimum of five lots.

Assumptions and Limitations:

- Costs are based on the provision of separated storm and sewer systems, which is the practice in most urban areas.

Primary Data Sources:

Capital costs were derived on first principles using typical layouts for conventional and neo-traditional neighbourhoods obtained from the report: Tool for Evaluating Neighbourhood Sustainability (IBI Group 2000). Unit costs consisted of average tendered prices from the Greater Toronto Area. These costs have not been adjusted for different geographic locations, but could be in the next phase of this study.

STORMWATER TREATMENT

Description:

Stormwater treatment costs primarily include the cost of the facilities required to manage and treat storm run-off. Operating costs associated with these facilities were not available.

Costing Methodology:

The amount of runoff for a particular neighbourhood or development is a function of surface area, and in particular the amount of impermeable surface area. Therefore, costs were developed from examining a typical neighbourhood and expressing it on a per hectare basis. In the next stage of this study, consideration will be given to allowing the user of the tool to distinguish between permeable and impermeable surfaces and based the calculation of stormwater treatment on the amount of impermeable surface.

Background and Unit Costs:

In new lower density inner and outer suburbs current practice is to use excavated ponds for stormwater management since they would typically have sufficient space available for the ponds. High and medium density neighborhoods tend to use a range of stormwater management techniques depending on their specific site. These include storm ceptors, percolation basins, pervious pavement, and pervious parking lots (all of which represent extra costs over conventional methods), parking lot surface storage, landscape soak pits, building rooftop storage and catchbasin/manhole sumps (which do not represent an additional cost). When combinations of the aforementioned techniques are used to address stormwater management, the overall cost will be less than the cost of a conventional stormwater pond. However, the effectivness of treatment may not be the same. These mechanical treatment methods also have higher maintenance costs and would require replacement over the lifecycle of a development. Based on the range of different practices used, a reduction in cost in the amount of 50% would be expected from low to high-density neighbourhoods. This ratio was then pro-rated through the different neighborhood scenarios.

The cost of the stormwater management pond (for lower density neighbourhoods) included earthwork, headwalls, inlets, sewer piping, storm by-pass, geotextile layers and landscaping. A 1.5 m high chain link security fence was included in the headwall cost. The geotextile was 150 mm diameter Rip-Rap to a depth of 300mm with a river stone cover. The landscaping included a terraweb cellular confinement system on the slopes with topsoil and hydroseeding.

The basic unit cost for storm water management adopted for this study is $16,000 per hectare. This figure is reduced for higher density developments, which employ different treatment methods as discussed above.

Assumptions and Limitations:

- Basic costs for storm water management assume typical surface coverage and surface treatments. If alternative practices are used (e.g. pervious pavement), stormwater treatment requirements are reduced.

Primary Data Sources:

Stormwater pond costs obtained from tendered unit prices in the Greater Toronto Area. These costs have not been adjusted for different geographic locations, but could be in the next phase of this study.

For medium to high-density neighbourhoods, the percent reductions in stormwater treatment costs were determined through consultation with various municipalities and from past experience in stormwater management.

SCHOOLS

Description:

Capital costs for schools included the construction cost of both elementary and secondary schools. Operating costs are "all-inclusive" and include the costs for maintaining buildings, administration and governance, and school operations. School transportation costs are considered separately and discussed later.

Costing Methodology:

Capital and operating costs were obtained from selected school boards and converted to unit costs per student capita (population under 18 years of age).

Background and Unit Costs:

The School Board Funding Projections for the 2002-03 School Year from the Ontario Ministry of Education were used to obtain total allocations for operating purposes and the total student-focused funding allocation for capital cost. Enrolment data from the report totaling the number of elementary and secondary students was used to obtain an operating and capital cost per student. Statistics Canada 2001 census data, citing the population of Ontario during that period, was used to calculate an operating cost per capita and a capital cost per capita. The report, updated October 2002, is located on the Ministry of Education website. The funding projection includes English, French and Catholic school boards in Ontario.

Also within the Province of Ontario, the operating budgets for York Region District School Board (2002-2003), Durham District School Board (2002-2003), Peel District School Board (2001-2002), Kawartha Pine Ridge District School Board (2002-2003) and Grand Erie District School Board (2002-2003) were referenced. Budgets were posted on the respective school board websites. Populations for the regions were obtained from City of Mississauga Planning and Building Department and are based on 2001 statistics. Budget amounts were then converted into an operating cost per capita. As these school boards only represented English public schools, the values obtained from the Ministry of Education were given preference.

Based on these sources, the following values were adopted for schooling costs:

- Operating costs - \$6,541/student
- Operating costs - \$6,949/student

Assumptions and Limitations:

- It was assumed that on a per capita basis, the cost of schools is fairly constant for different neighbourhood types and locations. The only caveat is that land costs may be more expensive in inner areas contributing to a higher capital costs per capita.

Primary Data Sources:

Ministry of Education website: www.edu.gov.on.ca

York Region District School Board: www.yrdsb.edu.on.ca

Durham District School Board: www.durham.edu.on.ca

Peel District School Board: www.peel.edu.on.ca

Kawartha Pine Ridge District School Board: www.pcbe.edu.on.ca

Grand Erie District School Board: www.gedsb.edu.on.ca

City of Mississauga Planning and Building Department, 2001 Census Update, March 2002 (www.city.mississauga.on.ca)

RECREATIONAL FACILITIES

Description:

Recreational facilities costs include the cost of operating and maintaining parks, recreation, libraries, tourism, culture, heritage, arts programs, community centers, and arenas.

Costing Methodology:

Operating budgets for medium to large municipalities were reviewed and a uniform level of service was attempted by selecting key recreational items as noted above. Total operating budgets were then used to develop average values per capita.

Capital costs vary widely and therefore only a notional estimate is provided.

Background and Unit Costs:

Operating costs for recreational facilities were obtained from selected municipalities and are shown in the tables below along with the resulting per household values.

Large-Sized Municipalities

Operating Cost	Calgary	Halifax	Windsor	Vaughan	Mississauga	Toronto	Average
$/capita	$123	$117	$143	$106	$92	$156	**$123**
$/household	$329	$291	$337	$355	$284	$400	**$333**

Medium-Sized Municipalities

Operating Cost	Barrie	Kingston	Thunder Bay	Average
$/capita	$60	$149	$152	**$120**
$/household	$169	$365	$382	**$305**

A capital cost of $18/capita for recreational facilities was obtained from consultation with the City of Thunder Bay Parks Director. This correlated to a $15/capita average (Halifax and Ottawa) for large municipalities and a $28/capita average (Branford and Kingston) for medium-sized municipalities obtained from the respective capital budgets.

Assumptions and Limitations:

- The provision of recreational facilities may vary by jurisdiction and neighbourhood demographics.

Primary Data Sources:

Consultation with the City of Thunder Bay Parks Director and data from selected municipalities.

TRANSIT SERVICES (OPERATING)

Description:

The total cost of providing transit services within a neighbourhood is comprised of operating costs, which are partially recouped by revenue and partially by government funding, and capital costs, which are completely provided by government funding. Both costs are functions of service levels which are, in turn, functions of neighbourhood type. This section addresses operating costs while the next section addresses operating costs.

Costing Methodology:

Operating costs increase directly with increases in service levels, that is, if no service is provided, there is no operating cost. On the other hand, there must be some minimum initial capital investment before any service is provided at all. Because of this, capital costs are less affected by neighbourhood type than are operating costs. While it is still important to consider both, the majority of the variation in the cost of providing transit services to varying neighbourhood types will be from the operating portion of the equation.

The method for determining the operating cost of providing transit to a given neighbourhood is to multiply the estimated neighbourhood transit service level (represented by Vehicle Service Hours - VSH) by the net cost to provide that service level, where the net cost is the difference between gross costs and revenues collected. Although gross costs would not vary significantly for a constant level of transit service, net costs may vary significantly by neighbourhood type depending on the load factors for the service (e.g. the number of passengers per bus).

Background and Unit Costs:

The Canadian Urban Transit Association (CUTA) maintains extensive service and cost statistics for each transit system in the country. As these statistics are system-wide, it is not possible to differentiate them by neighbourhoods within each service area (to determine which neighbourhoods are more cost-effective). The cost-effectiveness of various systems, however, can be used as a proxy for neighbourhood type; that is, the system service areas can be thought of as homogeneous neighbourhoods with their own cost performance characteristics. In this way, the variance in cost-effectiveness by neighbourhood can also be accounted for rather than using a generic value. For example, a high density neighbourhood in Toronto could be expected to have a low net cost per vehicle service hour, reflecting a high cost recovery, whereas a low density neighbourhood in the outer areas of the Greater Toronto Area may have a cost more similar to Mississauga or Burlington.

The table below shows the 1998 to 2001 average gross and net direct operating cost per vehicle service hour for the three study cities as well as Toronto, Mississauga and Burlington, which are included as representative of high, medium and low density urban area servicing transit systems, respectively. The importance of considering both gross and net operating costs is clear. Of the latter three, Toronto's gross operating cost is the highest of all at $90/VSH due to the high-order transit service provided to its users (i.e. subway rapid transit), yet produces the lowest net costs at $15/VSH. Burlington, on the other hand, shows the lowest gross cost at $56/VSH but the highest net cost at $30/VSH.

In terms of the level of service provided for each neighbourhood scenario, two sources of insight were used. The CMHC GHG Tool study estimated daily VSH for given neighbourhood types based on actual service levels in Toronto. For the current study VSH per capita were also calculated for different transit properties using City-wide averages. For Ottawa, the value has remained fairly constant at 3 annual hours per capita. Applying this level to the estimated scenario populations provides figures that are higher than the previous CMHC study. However, the former approach (of using neighbourhood type specific values) was felt to be appropriate for the initial model development. Guidance on how to adjust these values by municipality will be provided in the model.

Average Gross and Net Operating Cost per VSH ($/VSH), 1998 to 2001

Transit System	Avg. Total Direct Oper. Cost/VSH	+/-	Avg. Net Direct Oper. Cost/VSH	+/-
Calgary	83.3	4.3	40.4	4.9
Halifax	51.2	1.9	12.4	2.9
Ottawa-Carleton	78.5	1.5	33.7	1.7
Toronto	90.4	0.8	14.8	1.6
Mississauga	67.8	2.0	23.0	2.4
Burlington	55.5	1.7	29.6	2.2

Source: CUTA Canadian Transit Fact Book, 1998 to 2001
Notes: Values for Calgary Transit are based on 1998 to 2000 data only as there was a transit strike in 2001 (resulting in the higher variance).

Assumptions and Limitations:

- Operating costs per vehicle service hour are based on an average neighbourhood scenario
- There is no feedback mechanism between assumed transit service levels and modal splits and auto vehicle-km, although the vehicle-km estimates are based on transit service levels which are appropriate for a given neighbourhood type and location.

Primary Data Sources:

Source: CUTA Canadian Transit Fact Book, 1998 to 2001

TRANSIT CAPITAL

Description:

Transit capital costs include the cost of vehicles only. All costs are based on a bus-based system. Ancillary costs such as maintenance facilities, which do not vary by neighbourhood type, are not included.

Costing Methodology:

The approach adopted for estimating capital costs assumes that the capital cost of providing service to a given neighbourhood varies solely with the number of buses required to provide that service level. This implies that the cost of other supporting infrastructure (e.g. stops and garages) is a system-wide cost and therefore does not vary by neighbourhood type. The neighbourhood-dependent transit service capital cost is then determined given the vehicle service life of 18 years and purchase price of $500,000.

Background and Unit Costs:

There are several key, interrelated issues that make transit capital costs fundamentally less relatable to transit service level within a neighbourhood or even across a whole system, including:

- As there must be a minimum, initial level of infrastructure present before the operation of any transit system, there is less variance in the capital cost of providing service to given neighbourhoods *with respect to the service levels associated with each of them* as compared to the operating costs;
- Capital costs are much more driven by "system-wide" service levels (and types) than are operating costs (i.e. bus fleets are purchased to meet the needs of the system, not a neighbourhood);
- Capital funding needs are erratic and vary over time in relation to the age and state of the facilities and vehicles (i.e. buses have an average lifespan of 18 years) and are often a function of major infrastructure project investments rather than system rehabilitation;
- 100% of transit capital cost funding is provided by government sources, resulting in erratic funding levels over time that are more dependent on current government policies and objectives rather than on service level provided; and
- Given that no capital costs are recouped through revenues, there is no way to account for service efficiency or cost-effectiveness, as they are not as inherently related to ridership levels which are, in turn, related to neighbourhood type.

The impact of these issues on the average capital cost per vehicle service hour can be seen in the table below. Capital expenditures per service hour over the 1998 to 2001 period are much more varied, both within themselves during this period and between each other. Therefore, the approach of estimating average fleet requirements from vehicle service hours provides a more realistic estimate by neighbourhood scenario.

Average Capital Cost per VSH ($/VSH), 1998 to 2001

Transit System	Avg. Capital Cost/VSH	+/-
Calgary	27.7	19.8
Halifax	3.6	4.8
Ottawa-Carleton	23.4	11.7
Toronto	62.0	22.2
Mississauga	5.2	5.5
Burlington	0.0	0.0

Source: CUTA Canadian Transit Fact Book, 1998 to 2001

The table below shows the average number of buses required per 1,000 vehicle service hours for the various transit systems. The values shown vary only with the differing hours of service provided by each system, with the exception the Calgary and Toronto systems. These are generally lower because the total VSH of these systems includes vehicles other than standard buses (i.e. light and heavy rail vehicles). Therefore, the values for the Halifax, Ottawa-Carleton, Mississauga and Burlington transit systems only are used to calculate the representative value of 0.323 buses per vehicle service hour to determine a proxy for neighbourhood transit service capital costs.

Average Number of Buses per 1000 VSH, 1998 to 2001

Transit System	Avg. No. Active Buses/1000 VSH	+/-
Calgary	0.284	0.022
Halifax	0.315	0.015
Ottawa-Carleton	0.300	0.033
Toronto	0.180	0.005
Mississauga	0.359	0.017
Burlington	0.318	0.046
Overall	0.323	0.024

Source: CUTA Canadian Transit Fact Book, 1998 to 2001
Notes: Overall value determined from Halifax, Ottawa-Carleton, Mississauga and Burlington transit systems only.

Assumptions and Limitations:

- Capital assume a bus-based system. Capital costs for other transit technologies such a LRT or Subway may be substantially different.
- Capital costs for maintenance facilities and other supporting transit infrastructure are not included in the analysis.

Primary Data Sources:

Source: CUTA Canadian Transit Fact Book, 1998 to 2001

Recent research by IBI Group on the capital cost of buses.

SCHOOL TRANSIT

Description:

The cost of school transit primarily consists of school busing costs. Costs are inclusive of both capital and operating costs. A variety of arrangements are available for providing student transit: school boards can administer student transit directly (buses can be leased or owned by the boards), or they can enter into contractual agreements with school transit providers or with local public transit systems to convey students.

Costing Methodology:

Data from a recent household travel survey in Calgary was used to establish a relationship between housing density and school bus transit requirements. Total school busing costs were then estimated by applying average busing costs per student.

Background and Unit Costs:

For a starting point to estimate annual school bussing costs, in York Region, Ontario, a recent annual student transport budget was $40 million, for over 50,000 return student trips per day. At about 180 million trips per year, the cost works out to roughly $4.50 per student per day, or about $800 per student per year. School transit costs are not fixed, as costs can be reduced by using longer routes, combining transportation for more than one school, or staggering transportation times to allow the same buses and drivers to service more than one school per day. These options require fewer drivers and buses in total but may not be desirable as they result in longer bussing or waiting times for students. Using an average student transit cost of $800 per student per year where school transit is required provides a reasonable basis for costs, given the wide variability in bussing arrangements. (Where students' average distance to school is known to be significantly larger or smaller than average for a given neighbourhood scenario, this average cost figure can be increased or decreased accordingly to reflect this.) This cost can be multiplied by the number of students requiring bus transportation in a neighbourhood to estimate annual school transportation costs for a given neighbourhood scenario.

An analysis of the City of Calgary's travel data from the 2001 Household Activity Survey shows a moderately strong relationship at the expansion zone level between housing density and school transit mode shares for trips to school. (A regression equation of the relationship has an R^2 of 25%.) The regression equation for school transit mode shares can be used to estimate the percentage of students requiring school bussing for a given scenario, given household density. This estimate would then be increased by 10%, as bussing service must be provided to each eligible student daily, even though a certain percentage does not make use of the service due to being absent from school, getting to school by automobile, etc.

The resulting equation to estimate student transportation costs is therefore as follows:

School Transit Costs = (Average annual cost per bus transit student)(percentage of students requiring school bus transit)(total number of students)

= (\$800){[-0.0633 ln (housing units per km^2) + 0.5868]*1.10}(total number of students)

The number of elementary or high school age students in the neighbourhood is calculated as a given percentage of the total population.

Assumptions and Limitations:

- The number of students in a given neighbourhood would vary depending on demographics.

Primary Data Sources:

City of Calgary, 2001 Household Activity Survey

York Region, Student Transport Budget estimates.

FIRE SERVICES

Description:

This cost category includes the capital and operating cost of fire protection services.

Costing Methodology:

The cost of fire services was estimated on a per household basis using average values obtained from selected municipalities. Both capital and operating costs were estimated using the same process.

Background and Unit Costs:

Larger municipalities provided operating costs for fire services per household. Fire services costs were also obtained from operating budgets of medium to large municipalities where it was typically combined with the cost for emergency measures or emergency medical services. Small municipalities were contacted directly for operating cost information per capita and per household.

Another source for operating costs for fire service included the International City / County Management Association (ICMA) which provided a cost per capita for the medium sized municipality of Thunder Bay. Operating costs by municipality are shown in the tables below.

Large-Sized Municipalities

Operating Cost	Calgary	Halifax	Ottawa	Windsor	Vaughan	Mississauga	Toronto	Average
$/capita	$147	$103	$150	$125	$98	$64	$158	**$121**
$/household	$393	$256	$386	$294	$328	$198	$407	**$323**

Medium and Small-Sized Municipalities

Operating Cost	Barrie	Kingston	Thunder Bay	Average
$/capita	$80	$137	$90	**$102**
$/household	$255	$336	$226	**$272**

Kingsville
$29
$82

Capital costs for fire service were obtained from the Burlington Fire Department Fire Master Plan, December 2002. Included were annualized costs for aerial and associated equipment, traffic signal pre-emption and a fire station. Capital costs ranged from $22/capita or

$57/household for large municipalities and from $7/capita or $17/household for medium municipalities.

Assumptions and Limitations:

- The data as collected was on a city-wide level and does not differentiate between neighbourhood densities.

Primary Data Sources:

International City / County Management Association (ICMA), 2000.

Burlington Fire Department Fire Master Plan, December 2002

Data from selected municipalities.

POLICE SERVICES

Description:

This cost category includes the capital and operating cost of police protection services.

Costing Methodology:

The cost of fire services was estimated on a per household basis using average values obtained from selected municipalities. Both capital and operating costs were estimated using the same process.

Background and Unit Costs:

Larger municipalities with Performance Measurement Programs provided operating costs for police services per household. Police services costs were also obtained from city operating and capital budgets of medium to large municipalities except for Halifax whose costs were listed regionally. Small municipalities were contacted directly for operating costs per capita and per household.

The Toronto Police Service and the Windsor Police Service were contacted for discussion on operating and capital costs. In Toronto, the Budgeting and Control Department provided tables listing Expenditures and the Gross Operating Budget from 1997 to 2001. In Windsor, a staff planner provided insight into police demand as related to density, home ownership, land use and urban design.

The operating costs by municipality are shown in the tables below.

Large-Sized Municipalities

Operating Cost	Halifax	Ottawa	Windsor	Toronto	Average
$/capita	$106	$175	$254	$233	**$192**
$/household	$264	$449	$598	--	**$437**

Medium and Small-Sized Municipalities

Operating Cost	Peterborough	Brantford	Barrie	Kingston	Thunder Bay	Average
$/capita	--	--	$171	$156	$193	**$173**
$/household	$355	$388	$481	$382	$485	**$418**

Kingsville
$101
$286

Capital costs were found to vary from $12/capita or $30/household for large municipalities to $7/capita or $17/household for medium-sized municipalities.

Assumptions and Limitations:

- The data as collected was on a city-wide level and does not differentiate between neighbourhood densities.

Primary Data Sources:

Consultation with a planner from the City of Windsor Police Department

Consultation with the Budgeting and Control Department of the City of Toronto Police Service.

Data from selected municipalities.

WASTE MANAGEMENT SERVICES

Description:

The costs of waste management include capital and operating costs for curb-side pick-up as well as for the construction and operation of landfills. However, due to the wide variation on landfill practices across Canada, and limited costing information, the costs of landfill were excluded from the analysis.

Costing Methodology:

Operating budgets for representative municipalities were used to develop cost per household for waste management, which could be used in the scenario costing. For the purpose of this initial costing framework, no adjustments were made to the unit costs to reflect the fact that it is more efficient to serve higher density neighbourhoods. Adjustments may be applied within the tool.

Background and Unit Costs:

For waste management services, the smaller municipalities provided data in cost per capita or per household while medium to large cities provided an operating budget or a cost per tonne collected as part of their performance measures programs. For the latter, municipalities were contacted for the total tonnage of waste in order to obtain a cost per capita. Performance measurement programs listed solid waste management as the collection, disposal and diversion of waste from curbside collection for mostly residential areas by a contracted agency. Waste generated by small businesses on existing collection routes was included but industrial waste was not.

No capital costs were estimated for this category due to a lack of data. It was found that most municipalities contracted out waste management services to private organizations and thus did not incur capital expenses.

Large-Sized Municipalities

Operating Cost	Halifax *	Calgary	Ottawa	Vaughan	Average
$/capita	$123	$48	$41	$56	**$67**
$/household	$306	$128	$105	$188	**$182**

Medium and Small-Sized Municipalities

Operating Cost	Brantford	Kingston	Peterborough	Average
$/capita	$45	$72	--	**$59**
$/household	$115	$177	--	**$146**
$/tonne	$91	--	$50	**$71**

Essex	Kingsville	Average
$44	$39	**$42**
$118	$109	**$114**
--	--	**--**

* Costs may be lower than indicated here as costs may include contracting out of landfill management.

Assumptions and Limitations:

- The data as collected was on a city-wide level and does not differentiate between neighbourhood densities. Subjective adjustments were made to reflect a higher efficiency in serving high-density neighbourhoods.
- If municipalities were to use methane gas from landfills to produce power, some revenue may be generated to off-set costs.

Primary Data Sources:

Data from selected municipalities.

MOTOR VEHICLE COLLISIONS

Description:

Motor vehicle collisions and their associated costs are an outcome of vehicle travel, which is in turn a function of neighbourhood type and location. The cost of motor vehicle collisions includes the direct costs of fatal, injury and property damage collisions. These costs implicitly include the costs of health care.

Costing Methodology:

Motor vehicle collisions are typically estimate or expressed using a collision rate based on vehicle-kilometres of travel (e.g. collisions per 100 million kilometres travelled). This rate can be applied on an overall system basis or by individual road facilities. In general, collisions tend to vary by type of road and by traffic volume conditions. In estimating the number of collisions associated with a neighbourhood scenario, it is appropriate to consider all travel by vehicles originating in the neighbourhood, as opposed to travel on neighbourhood roads only. Therefore, the starting point for estimating the costs of motor vehicle collisions is the vehicle-km of travel generated by the neighbourhood scenario.

Using data on collision rates per vehicle-km, it is possible to estimate the number of collisions by type: property damage only, injury and fatality. A value may then be assigned for each type of collision and an aggregate cost for collisions can be calculated. Details of the methodology and sources for rates and costs are discussed below.

Background and Unit Costs:

Collision Rates

Collision statistics are generally maintained by individual province and are widely reported in aggregate terms. For example, the Ontario Road Safety Annual Report is published annually and reports the overall annual collision rate for the province as well as a breakdown by collision type. Similar reports are available for Alberta and Nova Scotia, the provinces containing the other cities being considered in this study. One both Alberta and Nova Scotia report collision rates by population only, not by vehicle-km.

For Ontario, the overall rate was 2.5 collisions per million vehicle-km. Of these, 0.34% were fatal collisions, 25.1% were personal injury collisions and 74.5% were property damage only.

Collision rate per vehicle-km are not broken down by municipality making it difficult to determine how rates would vary by location. Collision frequency and population are reported by municipality, although it would be difficult to translate these into rates per vehicle-km as the distance driven per person would vary by location.

For preliminary estimation purpose, it is proposed that the average collision rates for Ontario be used as a starting point with adjustments made by province on the basis of collision rates per capita.

Cost per Collision

The literature on the cost of motor vehicle collisions is as extensive as it is varied. Significant challenges exist in putting a value on the cost of a fatal collision. This study will not attempt to review all possible literature with respect to the cost of collisions but will instead rely on a selected number of recent studies.

The cost of collisions can generally be broken down into two types of costs: market costs and non-market costs. Market costs include items such as property damage, income loss, emergency services and medical treatment. Non-market costs include factors such as pain and suffering and lost quality of life. These latter costs are more difficult to estimate.

One of the most recognized and cited sources for motor vehicle collision costs is a 1994 report by the Federal Highway Administration. These costs have recently been adjusted to current dollars in a report for Transport Canada and are as follows:

- Fatal Collision - $3,590,000
- Injury Only Collision - $49,340
- Property Damage Only Collision - $5,084

Annual Collision costs can be translated into full life-cycle costs by extrapolating the costs over the chosen life-cycle period.

Assumptions and Limitations:

- There are significant limitations in applying an average collision rate for neighbourhoods in different locational contexts. For example, collisions rates tend to increase with traffic density and congestion, but the severity of the collisions is less.
- Another limitation of collisions statistics are that they generally include reportable collisions only. For example in Alberta only collisions over $1000 are reported.
- It should be noted that in addition to motor vehicle collisions, accidents or collisions also occur with other types of travel, including bicycles and transit. These are considered to be relatively small and are not considered in the costing model.

Primary Data Sources:

Ministry of Transportation, Road Safety Program Office, ***Ontario Road Safety Annual Report***, 2000 http://www.mto.gov.on.ca/english/safety/orsar/orsar00/

Alberta Transportation, Driver Safety, Research and Traffic Safety Initiative, Alberta Traffic Collision Statistics, 2001 (http://www.tu.gov.ab.ca/Content/doctype47/production/2001ar.pdf)

Nova Scotia Department of Transportation and Public Works, 2001 Motor Vehicle Collision Statistics http://www.gov.ns.ca/tran/Publications/index_2001_stats.stm

Litman, T., Transportation Cost and Benefit Analysis, Safety and Health Costs, 2002, http://www.vtpi.org/tca/tca0503.pdf

Motor Vehicle Accident Costs, Technical Advisory T 7570.2, US Department of Transportation, Federal Highway Administration, October 1994. http://www.fhwa.dot.gov/legsregs/directives/techadvs/t75702.htm

Transport Canada, Sustainable Development Branch, Cost-Benefit Framework and Model for the Evaluation of Transit and Highway Investments, prepared by HLB Decision Economics, February 26, 2002.

AIR POLLUTION

Description:

Most air pollution is caused by the burning of fossil fuels in motor vehicles, home furnaces, factories, industrial plants, and thermal power plants. These human activities account for most of the common air pollutants, such as sulphur dioxide, nitrogen dioxide, carbon monoxide, airborne particles, and volatile organic compounds (VOCs) (Environment Canada, 2002). The two sources which vary most by neighbourhood design are motor vehicles and home heating. This study will focus on vehicle emissions only.

Costing Methodology:

The development of the costs of air emissions is a two-stage process similar to that used for collisions. The first step is to estimate the vehicle-km generated by a particular neighbourhood scenario. This would include all vehicle-km generated by persons living in the neighbourhood, not just the kilometres driven in the neighbourhood. The second step involves applying an emissions rate per vehicle-km to determine the total emissions by neighbourhood scenario. A value in dollars per tonne is then applied to the emissions estimates.

Background and Unit Costs:

Development of emissions factors for Canada has been lacking and consequently most work in Canada relies on data from the US, specifically the US Environmental Protection Agency (US EPA, 2000). This is generally accepted since vehicle fleet characteristics are similar in Canada and the US.

Environment Canada has developed internal estimates of emissions factors for Canada based on the US data. These factors were published in a recent study for Transport Canada (Transport Canada, 2002) and are proposed for using in this current study. Emissions factors are provided for both private vehicles and for transit modes and include the following pollutants:

- Volatile Organic Compounds (VOC's);
- Carbon Monoxide (CO);
- Nitrogen Oxides (NO_x);
- Sulphur Dioxide (SOx); and
- Particulates (PM10 and PM 2.5).

Emissions factors are generally reported in grams per kilometre, which translates directly into tonnes per million vehicle-kilometre.

One of the biggest issues with respect to the application of average emissions factors to overall vehicle activity from a neighbourhood is that emissions factors vary by speed and driving conditions, some increasing and some decreasing with speed. It would be virtually impossible to estimate speed profiles for vehicles from a given neighbourhood because each vehicle and individual would be travelling in a variety of travel conditions. As a result, weighted average emissions factors were developed assuming 50% of the travel from a neighbourhood is at 90 km/hr and 50% is at 50 km/hr. Conceivably, these distributions of travel speeds could be varied by neighbourhood location, but the level of accuracy gained is unlikely to out-weight the level of error embodied in the base emissions factors.

Unit Cost of Emissions

As noted in the now widely quoted Full Cost Transportation Pricing Study (IBI Group, 1995), there are essentially two methods that have been employed for valuating air emissions: a damage value method and a cost-control method. The damage method relies on models to estimate the actual value of damage on humans and building from a given concentration of pollutants. The cost control method, or cost-avoidance method, is similar to a ‘willingness to pay’ approach and attempts to quantify the marginal cost of meeting a specific emissions reduction target. The cost control method theoretically represents that value society places on the reductions of emissions.

Below is a summary of emissions values reported by HLB Decision Economics in a recent Transport Canada Report.

- VOC $1,000/tonne
- CO $100/tonne
- Nox $1,000/tonne
- Sox $500/tonne
- PM10 $1,000/tonne

Understandably, there is a high degree of variation in the values, largely due to the fact that estimates are typically produced for a specific city or area.

It would be appropriate, in the development of the costing model, to acknowledge the range of uncertainty in the emissions values. For example, one could compare the cost of two neighbourhood scenarios excluding the cost of emissions and then look at what the cost of emissions would need to be in order to make the two scenarios equivalent, and then compare these costs to those from other studies.

Assumptions and Limitations:

- The valuation of air emissions is an extremely complex matter largely due to the fact that the impacts of air emissions are highly variable and depend on a number of factors such as exposed population, location, ambient air quality and many others.

Primary Data Sources:

Environment Canada, National Environmental Indicators Series, Urban Air Quality, 2002 http://www.ec.gc.ca/soer-ree/English/Indicators/Issues/Urb_Air/default.cfm

US EPA, Office of Transportation and Air Quality, Compilation of Air Pollutant Emissions Factors, Volume II, Mobile Sources (AP-42), November 2000.

Transport Canada, Sustainable Development Branch, Cost-Benefit Framework and Model for the Evaluation of Transit and Highway Investments, prepared by HLB Decision Economics, February 26, 2002.

IBI Group in Association with Boon Jones and Associates, Full Cost Transportation Pricing Study, prepared for the Transportation and Climate Change Collaborative, March 1995.

CLIMATE CHANGE

Description:

The analysis of the costs of climate change is separated from that of other air emissions impacts because the nature of the impacts are different. Furthermore, the level of uncertainty of emissions estimates for greenhouse gases is lower than other emissions. Climate change is also a very typical subject in Canada and may be of interest to users of the tool that will be developed as part of this study.

Greenhouse gas emissions are measured in tonnes of CO_2 equivalent. The primary greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), of which CO_2 accounts for about 80% of the total impact from transportation. Direct CO_2 emissions can be estimated from transportation activities if the type of fuel used is known since the factor is essentially the same for any given type of fuel, regardless of mode.

Costing Methodology:

The basic process to estimate the costs of climate change or greenhouse gas emissions is essentially the same as for other air emissions except that an intermediate step is required to estimate fuel consumption. Estimates of greenhouse gas emissions can then be developed from vehicle-km using average fuel consumption ratios (i.e. L/100 km). Fuel consumption can then be translated directly into GHG emissions using standard conversion factors. The cost of these emissions is then estimated based on the estimate value of a tonne of GHG emissions.

Background and Unit Costs:

Emissions Factors

Emissions factors are available for gasoline fuel are from Natural Resources Canada and are on average, about 2,500 g/L. These emissions factors are applied to fuel consumption estimates, which are in turn based on average fuel consumption ratios (11 L/100km is used). Similar to emissions factors for air contaminants, fuel efficiency depends on the type of travel in question, average speeds and type of vehicle. As it is not feasible to capture all of these variables, average values are adopted.

Unit Cost of Emissions

Due to the recent evolvement of CO_2 emissions trading programs in Europe, as well as recent work carried in support of Canada's decision to ratify Kyoto Agreements, the range of uncertainty regarding CO_2 emissions is perhaps less than that of air contaminants. Even still, the range of values is considerable.

For the purpose of the costing model a value of $25/tonne was used, based on research presented in the HLB Report listed below.

Assumptions and Limitations:

- Valuations of the cost of Climate Change vary significantly depending on the costing methodology and assumptions used.

Primary Data Sources:

Greenhouse gas emissions factors and CO_2 equivalents as supplied by Natural Resources Canada to the Climate Change Process Tables.

Transport Canada, Sustainable Development Branch, Cost-Benefit Framework and Model for the Evaluation of Transit and Highway Investments, prepared by HLB Decision Economics, February 26, 2002.

HOME ENERGY

Description:

Home energy consumption is related to heating, air conditioning and hot-water heating. For this study, data for home heating only was considered.

Costing Methodology:

Data from a number of Canadian housing studies was used to generate a summary of the quantity and cost of residential energy consumption in new Canadian houses in Alberta, Ontario, and Nova Scotia by heating fuel, building standard, and house type. These unit costs were then applied to the respective number of units by type for each scenario to develop a total home heating energy cost estimate.

Background and Unit Costs:

The core data used to generate the summary was taken from "New Housing Benchmark 1994", a 1997 study by the Canadian End-Use Energy Data Analysis Centre (CREEDAC). This report generated a comparison of average annual household energy consumption for new houses in 1994, versus new houses built to National Energy Code for Housing (NECH), and new houses with R-2000 Standard upgrades.

The New Housing Benchmark study used data from the New Housing Survey (NHS) 1994: a study of 2300 single detached houses built in 1994 from across Canada. The NHS data was used, in conjunction with several other studies[46], to generate Hot2000 input files for all 2300 new houses. Hot2000 Batch v7.14 energy simulation program was used to obtain estimates of annual unit energy consumption (UEC) of new houses built in 1994. The results were verified by comparing UEC estimates with actual billing data from 660 of the houses.

Hot2000 simulations were also performed on the NHS data using NECH and R-2000 Standard upgrades. The study found that the average UEC for new houses built in 1994 was 131 GJ/year, and that upgrading these houses to NECH and R-2000 standards would reduce energy consumption to 116 and 97 GJ/year respectively.

Detailed results were also provided for each province by heating fuel and end-use. This data was used as the starting point for this study.

Since the NHS contains data for single detached houses only, information was required for single attached houses and apartment units.

[46] See the bibliography of "New Housing Benchmark 1994", references, 3-10.

Data from another CREEDAC report entitled "UEC of Canadian Homes in 1997" was used to generated a percent decrease in energy consumption for single attached compared to single detached houses by province. The data in this report was generated using the 1997 Canadian Residential Energy End-use Model (CREEM-1997), which is comprised of data from the 1997 Survey of Household Energy Use (SHEU) database, containing detailed information on 4414 houses from across Canada, and other several other sources[47].

The SHEU database contains information on single detached and single attached houses, where single attached refers to doubles, and row or terrace houses.

The results of this report were a summary of UEC for houses by province, house type (single attached or single detached), and energy source (electricity or fossil fuel). The relevant data from this report is reproduced in the table below and used to determine the percent decrease in UEC of attached versus detached houses for each province by energy source. These values were then used to interpolate the household energy use and cost for single attached houses by province, building standard, and heating fuel.

Residential Energy Consumption by Province, Housing Type, and Fuel

Province	Housing Stock	No. of Houses	Total UEC GJ/house
Alberta	Single Detached	697,060	176.4
	Single Attached	112,493	139.3
	Total/Average	809,553	**171.2**
Ontario	Single Detached	2,484,586	150.4
	Single Attached	580,641	115.3
	Total/Average	3,065,227	**143.8**
Nova Scotia	Single Detached	250,157	153.2
	Single Attached	19,385	103.7
	Total/Average	269,542	**149.6**
Canada	Single Detached	6,685,044	149.4
	Single Attached	1,248,188	109.7
	Total/Average	7,933,232	**146.5**

Source: "UEC of Canadian Homes in 1997" Report by CREEDAC, Table 4

The average annual energy consumption of apartment buildings across Canada (79.4 GJ per unit) was taken from "Analysis of the Annual Energy and Water Consumption of Apartment Buildings in the CMHC HiSTAR Database"[48]. This data was used in conjunction with average

[47] See the bibliography of the "UEC of Canadian Homes in 1997"
[48] This study used data from 40 apartment buildings across Canada, built between 1920 and 1993. By using this data to extrapolate from 1994 new housing data, the energy use of new buildings may have been slightly over estimated.

UEC for single detached houses (from "New Housing Benchmark 1994") to extrapolate a general relationship between the UEC of single detached houses and the UEC of apartment units.

The local utility rates for Calgary, Ottawa, and Halifax, were used in calculating the cost of household energy use in Alberta, Ontario, and Nova Scotia respectively (See table on following page). Natural gas was the fossil fuel assumed for both Ottawa and Calgary; however, natural gas is not currently available to customers in Halifax, so oil was assumed.

Province	Fuel	Cost	Units	Cost	Units	Monthly Charges
Alberta	Electricity	0.06	$/kWh	17	$/GJ	5.967
	Natural Gas	7.941	$/GJ	8	$/GJ	13.79
Ontario	Electricity	0.08	$/kWh	22	$/GJ	6.85
	Natural Gas	0.59	$/m^3	16	$/GJ	10
Nova Scotia	Electricity	0.09	$/kWh	24	$/GJ	10.83
	Oil	0.6	$/L	16	$/GJ	10

Assumptions and Limitations:

- Home energy practices and costs vary by location and also over time. The cost estimates developed are intended to replicate current practices to the extent possible.
- Energy efficiency varies by housing construction type (e.g. NHS, NECH, R-2000). Costing values are based on an assumed breakdown by housing construction type.

Primary Data Sources:

CREEDAC, (1997), New Housing Benchmark 1994. Prepared for Natural Resources Canada
http://www.dal.ca/~creedac/reports/pdfs/newhouse.pdf

CREEDAC, (2000), Unit Energy Consumption of Canadian Homes in 1997, Prepared for Natural Resources Canada
http://www.dal.ca/~creedac/reports/pdfs/sheu97.pdf

CMHC, (2000), Analysis of the Annual Energy and Water Consumption of Apartment Buildings in the CMHC HiSTAR Database, Prepared for Natural Resources Canada
http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/tech01-142.htm

VEHICLE COSTS

Description:

Vehicle costs include both the cost of operating and owning a vehicle. Vehicle operating costs include the cost of fuel, oil and maintenance. Annual ownership costs are fixed costs like insurance, licence fees, registration fees, taxes, finance costs and depreciation.

Costing Methodology:

Annual vehicle-km from neighbourhood residents are estimated using the CMHC GHG Tool as are auto ownership levels. These values are then converted to annual costs using data from the Canadian Automobile Association. Both automobile ownership and total kilometres travelled per household are higher on average for suburban neighbourhood compared to inner area neighbourhoods due to several factors including land use patterns and availability of transit.

Background and Unit Costs:

The Canadian Automobile Association has produced a brochure entitled "Driving Costs, 2001 Edition," which is a helpful starting point in determining personal vehicle travel costs.

Annual ownership costs are fixed costs like insurance, licence fees, registration fees, taxes, finance costs and depreciation. In general, these change little with the amount and type of driving. However, some may change: for example, a car would depreciate in value more quickly when the total distance driven is significantly more than average, thereby increasing annual ownership costs. A typical car would have annual ownership costs of over $6,600, or in the order of $18 per day.

Operating costs, however, do change with the amount a vehicle is driven. Average annual operating costs per kilometre total 12.55 cents: 8.09 cents for fuel (based on gas prices of 79.8 cents per litre) and oil, 2.86 cents for maintenance, and 1.60 cents for tires.

Average vehicle ownership rates were determined using the vehicle ownership sub-model in the CMHC Tool. The Tool was also used to estimate annual driving distances (vehicle-kilometres of travel, or VKT), which were then translated into vehicle operating costs. Annual driving distances were also used to estimate annual vehicle depreciation costs. The equations are as follows::

a) Average number of vehicles per home x CAA annual ownership costs per car (including depreciation based on average km driven per year)

b) annual VKT per home x CAA operation costs per VKT

Assumptions and Limitations:

- Auto ownership costs are represented by averages and may vary by individual depending on income and lifestyle choices.

Primary Data Sources:

Canadian Automobile Association, Driving Costs, 2001 Edition

SELECTED MUNICIPALITIES

Large-Sized Municipalities: 125,000+

	Calgary	Halifax	Ottawa	Windsor	Vaughan	Mississauga	Toronto
Population	951,395	359,111	774,072	208,402	182,022	612,925	2,481,494
Number of Dwellings	356,370	144,410	301,770	88,533	54,359	198,235	965,554

Medium-Sized Municipalities: 50,000 – 125,000

	Peterborough	Brantford	Barrie	Kingston	Thunder Bay
Population	71,446	86,417	103,710	114,195	113,000
Number of Dwellings	29,175	33,845	36,855	46,605	44,915

Small-Sized Municipalities: 0 – 50,000

	Kingsville	Essex	Tecumseh
Population	19,700	19,700	25,105
Number of Dwellings	6,950	7,281	7,629

Primary Data Sources:

City of Mississauga Planning and Building Department. 2001 Census Update. March 2002.

Statistics Canada website – Community Profiles 2001. www.statcan.ca/start.html.

Consultation with the Municipalities of Kingsville, Essex and Tecumseh.

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