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Developing a Framework for Analysing the Impacts of Urban Transportation

by

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Abstract

The growing number of people settling into urban areas underscores the importance of responsible urban planning. Many dimensions of urban life, including transportation, are potentially hazardous to ecosystems and human health. The purpose of this study is to identify all potential impacts from urban transportation, and integrate them into an impact assessment framework that could serve to increase policy makers', and the general public's understanding of transportation issues.

The framework is applied to a case study of an intended roadway widening scheme in Edmonton, Alberta. Qualitative indicators in the framework are derived from a pilot study of major stakeholder perceptions. Of the quantitative indicators considered, only respiratory health costs were directly estimated, and were assessed at over $4 million. Since roadway widening encourages private vehicle use, and this has significant direct health costs, more attention should be given to mass transit, bicycle and pedestrian infrastructure to affect healthy public policy.

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Needed resources to perform this research were provided by the International Development Research Centre, and the West Edmonton Transportation Coalition (WETC). WETC deserves special recognition because their concern regarding a local transportation issue provided me with my thesis topic.

Last but never least, I acknowledge the dedication provided to me by my wife, Tammy, who stood by me over the past two years. Your love I will always cherish.

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AST	Appraisal Summary Table
BC	British Columbia
CBA	Cost Benefit Analysis
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COMEAP	Committee on the Medical Effects of Air Pollution
CFC	Chlorofluorocarbons
CST	The Centre for Sustainable Transportation
DALY	Disability Adjusted Life Years
DPSEEA	Driving Force – Pressure – State – Exposure – Effect – Action
ECMT	European Conference of the Ministers of Transport
EHIA	Environmental Health Impact Assessment
EIA	Environmental Impact Assessment
GHG	Greenhouse Gases
HIA	Health Impact Assessment
IAF	Integrated Assessment Framework
IDRC	International Development Research Centre
IIAF	Integrated Impact Assessment Framework
IAM	Integrated Assessment Model
MCA	Multi Criteria Analysis
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
N_2O	Nitrous Oxide
O_3	Ozone
OECD	Organisation for Economic Co-operation and Development
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PM_{10}	Particulate Matter less than 10 microns in diameter
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
SACTRA	Standing Advisory Committee on Trunk Road Assessment
SEA	Strategic Environmental Assessment
SOx	Sulphur oxides
UK	United Kingdom
VMT	Vehicle Miles Travelled
VOC	Volatile Organic Compound
WETC	West Edmonton Transportation Coalition
WHO	World Health Organization

Chapter 1 Introduction

1.1 Purpose

The purpose of this thesis is to develop a framework for examining the positive and negative impacts that transportation has on human health and the environment, and to quantify them in economic terms. Transportation impacts that occur in urban areas and specifically related to the perceived need for the expansion of road-based transportation, will be examined. Several approaches will be reviewed that integrate impacts into an assessment framework that are useful for urban transportation planning policy. From the list of frameworks reviewed, both a theoretical basis as well as a practical foundation for addressing a local problem in Edmonton, Alberta, will be established. Using the frameworks, a multi-criteria assessment framework will be developed that will enable urban decision-makers to include the public health and environmental impacts that certain transportation infrastructure has on society.

1.2 Background

The concept of health, as the World Health Organization (WHO) defines it, is complete physical, social, and emotional well-being. This concept is different from the traditional medical model approach that views the absence of disease and treatment, to bring about health. Of these two approaches to health, the broad WHO definition of health will be followed in this thesis. Given the breadth of the WHO health concept, it is important to recognize that a multiplicity of factors affect human health. The Lalonde report (1974) first organized the determinants of health based on four major influences: human biology; environment; lifestyle; and organization of health care. This was a landmark study because the authors gave credence to the fact that environmental factors play an important role in individual health, as well as living habits (Forget & Lebel, 2001). Over the years, the determinants of health have developed into a broader range of factors from several sources including the Ottawa Charter for Health Promotion (1986). A list of the determinants of health given in the Lalonde report, and as they have

developed since then, are shown in Table 1. This list of determinants is still expanding, and they are crucial to the philosophical foundation of this thesis.

Table 1 Determinants of Health

Lalonde Report (1974)	Post-Lalonde Report
Human biology	Genetics
Environment	Socio-economics
Lifestyle	Individual characteristics and coping
Organization of health care	Health care services
	Personal health practices (e.g. nutrition, exercise)
	Biophysical environment (e.g. pathogens, vectors, pollutants)

The last item listed in the post-Lalonde Report column, the biophysical environment, is the main focus of this paper. The biophysical environment, or ecosystem, is made up of both the natural environment (e.g. water, soil, trees, air), and the built surroundings (e.g. buildings, transport infrastructure). The two are inextricably linked because pollution from the built environment, such as electrical generator emissions, affects the natural environment in the form of air quality degradation. In turn, this can affect human health because air pollution affects respiratory functioning. Tomalty, Gibson, Alexander, and Fisher (1994) describe the essence behind ecosystem planning as recognizing that humans are not distinct from the natural world, but a part of it. They point out that the human-built environment is dependent on, and responsible to nature.

One major ecosystem is the urban environment, where more and more people worldwide are settling. For example, in 1998, 59% of humans lived in urban settings, compared to 32% in 1955 (WHO, 1998). Rapid urbanization has become a major issue for the WHO, as evidenced by their Healthy Cities Programme. The goal of that project is to ameliorate those aspects of the urban environment that adversely impact health such as housing conditions, infrastructure, and food (WHO, 1996). Another one of the key issues targeted by this project is urban transportation.

Transport can be defined as the movement of people and goods between places according to the British Medical Association's study (as cited in Mason, 2000). Transportation encompasses such modes as air, water, rail, and road travel. Transportation via rail, air, and waterways is important, but most urban travel is done on land by automobiles, is the most extensively covered in the literature, and hence will be examined further in this thesis. Further, the most prominent impacts of urban transportation involve automobiles and roadways.

Transportation in Canada and the rest of the developed world has increasingly been associated with road travel and use of the automobile. In 1999, there were over 16 million light vehicles on the road in Canada, or one for every 1.85 people (Transport Canada, 1999). In the province of Alberta, the number of registered vehicles has increased over 300% between 1961 and 1999, and the average kilometres per vehicle has increased since 1990 (Pembina Institute, 2001). In the European Union, the number of cars per 1000 inhabitants has increased from 390 in 1989, to 454 in 1998 (Eurostat, 2001).

In the less developed world, rates of automobile growth have also increased. For instance, in India, between 1990 and 1997, the number vehicles increased from 19 million to almost 41 million (Tata Energy Research Institute [TERI], 2002). The concerns of increased motor vehicle usage are particularly acute in developing countries because of: higher lead concentrations in the fuels used, older vehicles generally burn fuel more inefficiently than newer vehicles, and two-stroke engines produce more air pollution than four stroke engines (TERI, n.d.).

1.3 Objectives

The six objectives of this thesis are to:

1. Identify all of the potential impacts of urban transportation, focusing on the human health impacts from published literature. Review frameworks that identify all impacts

of urban transportation alternatives, emphasizing health, environment, and economics.

2. Use the impacts and frameworks reviewed in objective one to develop an Integrated Impact Assessment Framework (IIAF) that comprehensively examines the health, environmental, and economic considerations associated with urban transportation infrastructure.
3. Apply the IIAF to a case study of a roadway widening plan in Edmonton, Alberta, using the Ecosystem approach to human health. To verify the usefulness of the IIAF, conduct a pilot study interviewing community members and experts to identify their perceptions of the importance of health, environmental, and economic considerations, in transportation planning.
4. Compile baseline information for one health and environmental impact (air pollution) and estimate its economic costs for Edmonton.
5. Compare four different future scenarios involving a combination of transportation options for the Whitemud Drive corridor, including widening.
6. Disseminate the framework, and the empirical assessment to enhance knowledge about the impacts of transportation alternatives to facilitate policy development.

1.4 Significance and relevance of the study

Increasing the awareness of health and environmental concerns to urban decision-makers in their evaluation of transportation infrastructure planning will be the significance of this thesis. The thesis will include reviews from the published literature of impacts and approaches used around the world to assess the impact that transportation has on society. These approaches all have strengths and weaknesses that will be discussed because they have been applied to urban transportation issues to varying degrees. The significance of the inclusion of this review is that it has not been done before, to the researcher's knowledge, and will provide a compendium of approaches to urban transportation planning policy.

The thesis is also significant because community and expert perceptions are determined to verify the approach taken in the IIAF. The pilot study is detailed in the

methods section of the thesis. Community members, Transportation Planners, environmental and health experts were included to provide needed data and urban transportation expertise. By bridging the perceptions of community stakeholders with government officials, this study is an attempt at examining the differences that separate these two important perspectives in the decision-making process.

Concern about increasing automobile use and its environmental effects globally makes the findings of this thesis all the more relevant. Health and environmental considerations will be identified and integrated, in a full accounting framework, into transportation planning, using stakeholder perception and economic quantification where possible. The issue of sustainable well-being, that is, using resources and managing wastes that will allow future generations to meet their needs (The Centre for Sustainabale Transportation (CST), 1998), is pivotal to this study. The increasing use of automobiles is seen as unsustainable from an energy, as well as an environmental and health perspective (McCarthy, 1999). Fossil fuels needed to power automobiles are a non-renewable resource, resulting in emissions that are detrimental to ecological integrity and human health. Thus, a full evaluation in planning new transportation projects would include, for example, the role of private vehicular transportation in relation to alternatives such as publicly accessible mass transit. While alternative sustainable energy and fuel (e.g., hydrogen fuel cells and hybrid-powered vehicles) are emerging, they are not expected to become economically viable alternatives to existing fossil fuel-based technologies in the near future.

Finally, urban planners around the world struggle to contain increasing levels of automobile use. The integrated impact assessment framework developed in this thesis will provide a conceptual basis upon which urban planners can understand the broad range of health, environmental, and economic consequences associated with different transportation options by identifying all transportation-related impacts, positive as well as negative. Thus, a basis for informed discourse on the topic of urban transportation will be facilitated.

1.5 *Ethical Considerations*

The University of Alberta's Health Research Ethics Board approved this study on February 4, 2002. All information obtained from community members and experts for this thesis remains anonymous and, although linkable, safeguards have been put in place to ensure privacy. Informed consent documents are on file.

Partial funding for this thesis came from the West Edmonton Transportation Coalition and the Laurier Heights Community League. Their viewpoint and request for assistance into a transportation matter in West Edmonton provided the impetus for this study. While the two groups can be seen as advocacy associations, given their opposition to the widening of Whitemud Drive, the author and the supervisory committee ensured objectivity and scholarly excellence by synthesizing the differing viewpoints that occur, and maintaining an arms length relationship with the stakeholder groups.

1.6 *Organization of this thesis*

A broad array of literature on the subject of transportation and its association with human health, the biophysical environment, and economics has been written. The next chapter is a literature review that examines the linkages among these disciplines. Because the focus discipline of this thesis is human health, the first section of the literature review is provided to highlight the association between health and transportation. In the next section, the impacts associated with urban transportation are identified. Approaches that attempt to integrate the health, environment, and economic impacts into transportation planning are then examined. Following this, the preferred framework is identified, which lays the foundation for the Integrated Impact Assessment Framework (IIAF) presented in Chapter 3.

The utility of the IIAF is assessed in a pilot study, presented in Chapter 4. Here, an urban transportation issue, yet to satisfy the concerns of all the major stakeholders, is presented. The case study focuses on the widening of Whitemud Drive, a major arterial roadway in Edmonton, Alberta, Canada. The IIAF developed in Chapter 3 is utilized as

an analytical tool to help address some of the major impacts involved, and to solicit different stakeholder perceptions of these impacts. Since community stakeholder involvement is critical to the rigour of the study, methods for incorporating community and expert input are addressed in this section.

One impact within the IIAF, air pollution health effects, is examined more closely in Chapter 5. There are other impacts that could have been analysed, but air pollution has been mentioned as a significant concern relating to urban transportation projects, and this is the sole focus of Chapter 5. Time and resource needs precluded the inclusion of other effects. However, methods for analyzing the expected air pollution health costs related to four different scenarios for the Whitemud Drive corridor are included.

The results of the pilot study stakeholder survey and its applicability to the IIAF is presented in Chapter 6. Differences among the stakeholders are highlighted in response to different questions.

The results of the air pollution health effects are presented in Chapter 7 using an estimate of respiratory related conditions and their economic costs. These results are approximations and should not be deemed completely accurate because of the uncertainty involved in estimating air pollution health effects.

Chapter 8 follows with the discussion, and Chapter 9 closes with conclusions and recommendations.

Chapter 2 Literature Review

2.1 Transportation and public health overview

The public health concern over increasing private automobile use and roadway proliferation in an urban setting is well documented in the literature. The following is a selection of articles that detail the connection between road transportation and human health.

Granados (1998) conducted a comprehensive literature review on the negative consequences of automobile traffic on human health. He described the following as harmful characteristics of vehicle traffic:

a) Mortality/morbidity from injuries;
b) Air pollution effects;
c) Promotion of sedentary lifestyle;
d) Cities that cater to automobiles tear at the social fabric;
e) Opportunity cost of spending on highways and roads; and
f) Carbon dioxide emissions contribute to climate change.

Granados examined the detrimental effects and costs of automobiles, and referenced a World Bank report that stated traffic injuries were the ninth leading cause of disability adjusted life years (DALY's) lost. He concluded that traffic volume must be reduced to preserve public health. The author provided evidence for the detrimental effects of vehicle use, but did not mention any associated benefits.

Dora (1999) studied the link between transport and health and stated that transport policies are a key determinant of health. He suggested several health impacts related to transport including physical activity, accidents and injuries, climate change, air pollutants, noise, and psychosocial effects. He noted the worldwide trend of increasing car use coupled with less bicycling and less public transit use. For this reason, more emphasis on Health Impact Assessments of transport projects is needed, as well as evaluating the health costs of transport projects and strategies. Dora noted that although traffic at slower speeds may reduce accidents, it increases air pollution. He stated that

society must ultimately decide whether accidents or air pollution are more critical in transportation planning. Dora's article is one of the most cited publications on transport and health in the literature. However, the statistics are European, and the author focussed only on the negative health impacts of transportation.

McCarthy's (1999) study is an extensive overview of transportation and health, and he is one of the first authors to state that transportation is a social determinant of health. The issue of sustainable development is raised as a central focus to the debate on transport and health, because of the increased energy consumption needed to power society's appetite for the automobile. The author noted that the health impacts related to transportation include heart disease (from decreased physical exercise), mental health, respiratory disease, and accidents. Interestingly, the author stated that linking outdoor air pollution to respiratory diseases is troublesome and cannot be convincingly shown because people spend so much of their time indoors. The author stated that the policy interventions needed in transportation planning are priority for walking and cycling, more public transit, and less private motor vehicle use. The author quoted motor vehicle fatality sources that may be of questionable quality, but overall the author provided an overview of health and transportation policy.

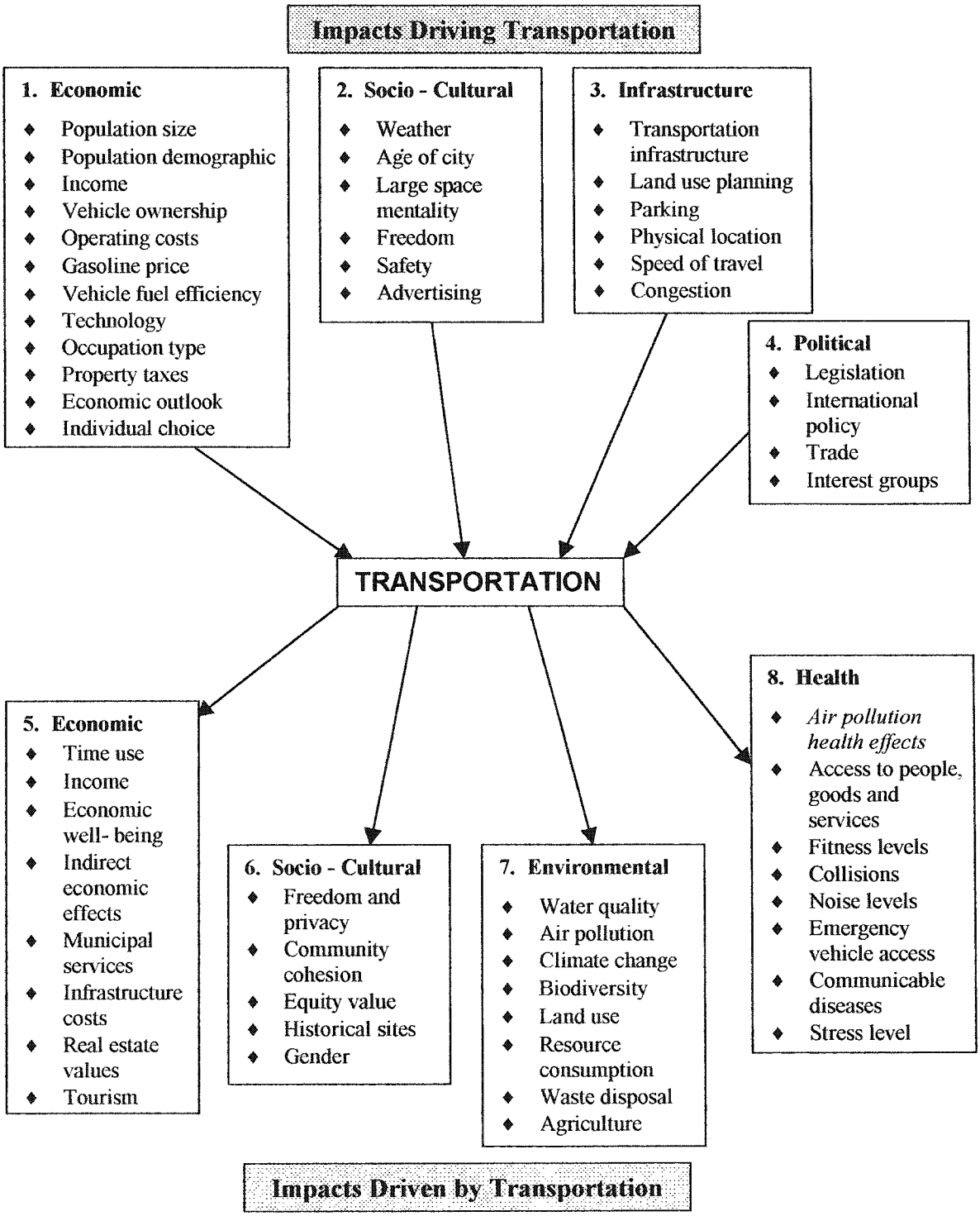
The above articles very broadly display the link between transportation and human health. However, more impacts are associated with transportation, and are described below.

2.2 Impact Diagram

To appreciate the complexities involved in making transportation decisions, it is necessary to determine the full scope of how transportation impacts on society. Figure 1 diagrammatically identifies all of the factors (or pressures), that impact on transportation (top half of Figure 1, numbered 1-4), and the impact that transportation has on society (bottom half of Figure 1, numbered 5-8). Not all impacts have been derived from the published literature, and where not referenced, it comes as an original contribution by the author. Note that the impact diagram is a select list of impacts and is not an exhaustive

list. The reader is referred to other publications that incorporate different lists of impacts (Organisation for Economic Cooperation and Development [OECD], 1997b; European Commission, 1996). The reader is alerted to the fact that air pollution health effects, shown in italics, will be analysed later in this thesis.

Figure 1 Impact Diagram



Impacts Driving Transportation

The impacts that drive transportation activity have been grouped into four categories: Economic, Socio - Cultural, Infrastructure, and Political. This grouping was designed for ease of categorization. The factors in the top half of the impact diagram (numbered 1-4) will now be more closely examined, with justification for their inclusion in the diagram. Where no reference is provided, these are original contributions.

2.2.1 Economic Impacts

Table 2 includes summaries of main points about how each of the economic variables, listed in Figure 1, drives the need for transportation.

Table 2 Economic Drivers of Transportation

Economic Drivers	Summary	Source
Population size	More people settling into an urban area creates an increased demand for transportation	Newman & Kenworthy, 1989
Population demographics	In the United States, those aged 65 and over and those less than 25 years of age are less automobile dependent than those aged 25 – 64	Pucher, Evans, & Wenger, 1998
Income	Higher household income equates to more trips per day and more travel kilometres per day than those in any other income group	Applications Management Consulting (AMC), 1995; Giuliano, 1999; Pucher et al, 1998
Vehicle ownership	Individuals who have more vehicles rely on automobiles for more of their trips than individuals who have less	AMC, 1995; Giuliano, 1999; Newman & Kenworthy, 1989; OECD, 1997b;
Operating costs	Operating costs of automobiles and the costs of public transit impact on how much people travel, though the precise relationship is unclear	OECD, 1997b;
Gasoline price	There is a significant correlation between gasoline price and automobile use (i.e., if gasoline price rises by 10%, automobile use has been shown to decrease by 8.5%). Gasoline price can also affect public transit fares	Newman & Kenworthy, 1989
Vehicle fuel efficiency	Vehicle fuel efficiency is a main determinant of car use and gasoline consumption. However, emissions are also dependent on vehicle-kilometres traveled, so even with increased fuel efficiency, emissions can still increase	Newman & Kenworthy, 1989

Technology	Technology in the form of new types of powered vehicles using solar, electricity, and hydrogen fuel cells could conceivably change how people are transported	No published references located
Occupation type	♦ Timing of work schedules, has an impact on travel, though it is unclear whether new trends such as work at home will increase or decrease the need to travel ♦ In Edmonton, 32% of workers had flexibility in their starting times. 20% of all trips are to and from the workplace in Edmonton, verifying work as an important determinant of travel	AMC, 1995; OECD, 1997b;
Property taxes	Property taxes were high in the downtown core in Canada in the early 1900s, and this encouraged businesses and working class individuals to locate to suburban locations, increasing the need for more roadways	Tindal & Tindal, 1984
Economic outlook	♦ Economic boom signals more suburban private land development, while slow economic times contract cities inwards ♦ Municipal governments' preoccupation with private land ownership drives land use planning at the expense of the public good	Newman & Kenworthy, 1989; Tindal & Tindal, 1984
Individual choice	The following individual choices are included in many transportation demand modelling systems in industrialized countries: Trip generation – whether or not to travel at all; Trip distribution – what destination fulfills purpose of trip; Trip scheduling – when is the best time to travel; Modal choice – what is the best mode to take; Traffic assignment – what is the best route to take; Vehicle occupancy – travel alone or with somebody; Trip frequency - how often to make the trip in a time period	Hills, 1996

2.2.2 Socio - Cultural Impacts

Table 3 includes summaries of main points about how each of the socio - cultural variables, listed in Figure 1, drives the need for transportation.

Table 3 Socio - Cultural Drivers of Transportation

Socio - Cultural Drivers	Summary	Source
Weather	Warmer weather means people not only choose to travel more, but also choose modes like bicycling or walking that are less pleasant to do in cold weather conditions	Newman & Kenworthy, 1989
Age of City	Many cities that were built before the mid-1800s were built around walking because of the high density of people per land area. Public transport, followed by the automobile, served to lower densities and hence increased travel distances	Newman & Kenworthy, 1989
Large space mentality	♦ Older countries in Europe have a tradition of conservative urban planning, which newer countries do not possess ♦ Large space mentality towards planning, coupled with large tracts of land, contributes to the low density of newer cities	Newman & Kenworthy, 1989
Freedom	♦ People enjoy the experience of driving in their automobile and "getting away from it all"	No published references located
Safety	♦ Large vehicles being purchased in recent years in North America can, at least partially, be attributed to the safety aspects that large vehicles possess (e.g., ability to maintain structural integrity in collisions better than smaller vehicles) ♦ Bicycling on roadways with automobiles can be a deterrent for people because of the risk of being hit by an automobile	Hillman, 1993; OECD, 1997b; Wolff & Gillham, 1991
Advertising	♦ There seems to be a "love" for the automobile, propagated by advertising from large automakers. This has led to a tremendous increase in vehicle units sold in the past 30 years	No published references located

2.2.3 Infrastructure

Table 4 includes summaries of main points about how each of the infrastructure variables, listed in Figure 1, drives the need for transportation.

Table 4 Infrastructure Drivers of Transportation

Infrastructure Drivers	Summary	Source
Transportation infrastructure	♦ If there are no public transit alternatives, citizens are forced to either walk, bicycle, or use an automobile for their mobility needs ♦ The availability of bus/train services, roadway capacity, and bike and walking paths is a determinant of how people travel	Newman & Kenworthy, 1989; Transport and Health Study Group, 1991

Land use planning	Lower density planning, associated with more suburbs and shopping centres located outside the central part of the city, induces people to use automobiles, especially since public transit is effective only in high density locations	Dittmar, 1995; Giuliano, 1999; Newman & Kenworthy, 1989; OECD, 1997b
Parking	Parking can contribute to automobile dependency because of the convenience it provides for those using an automobile	Litman, 1999
Physical location	In cities that have no access to waterways, travel via water is not possible, as it is in Brisbane, Australia or Bangkok, Thailand	No published references located
Speed of travel	Higher average traffic speeds promote car use and detract from public transport especially for those individuals of higher income	Giuliano, 1999; Newman & Kenworthy, 1989
Congestion	♦ Congestion is the build up of vehicles on roadways that slow them below average traffic speed and typically occurs during peak hours ♦ One method that transportation planners have used to alleviate congestion is by adding capacity to existing roadways, although this method has not always been successful because of induced or extra traffic that is attracted to widened roadways	DeCorla Souza & Cohen, 1999; Goodwin, 1996; Hills, 1996; SACTRA, 1994

2.2.4 Political

Table 5 includes summaries of main points about how each of the political variables, listed in Figure 1, drives the need for transportation.

Table 5 Political Drivers of Transportation

Political Drivers	Summary	Source
Legislation	In North America, federal, state/provincial, and local government all have jurisdiction over aspects of transportation planning (e.g. local legislation occurs in strategic transportation planning for the municipality)	Dittmar, 1995; Tindal & Tindal, 1984
International policy	The United States' presence in the Persian Gulf to protect its interests in gaining access to oil used for transportation purposes is one example of international policy	No published references located
Trade	In countries that have open trade borders like the United States and Canada, freight is allowed to move relatively freely between the two countries that increases the amount of transport needed	No published references located

Interest groups	♦ The road lobby in California, comprising tire manufacturers, petroleum producers, and car manufacturers, effectively dismantled the electric rail system in the 1930s, signaling the start of automobile dependency in the United States and elsewhere in North America ♦ The way that governments award road construction contracts should be examined owing to potential conflicting interests	Beato, 1997; Newman & Kenworthy, 1989

Impacts from Transportation

While it is important to understand what the driving pressures are that impact transportation, it is also important to examine the corresponding impacts that occur as a result of transportation. These impacts are shown on the bottom half of the impact diagram (numbered 5-8), and also are grouped into four categories: Economic, Socio - Cultural, Environmental, and Health.

2.2.5 Economic

Table 6 presents summaries of main points from the surveyed literature about how transportation impacts each of the economic variables listed in Figure 1.

Table 6 Transportation Impact on Economic Variables

Economic Variables	Summary	Source
Time use	♦ Time differences can be a major determinant in travel behaviour and is relatively more important in travel choice decisions than other factors ♦ Time spent commuting estimated at 4% of Gross Domestic Product (GDP) in Alberta	Giuliano, 1999; Pembina Institute, 2001c
Income	The average Canadian household spent 13% of their budget on transportation in 1999, less than taxes and shelter, but more than food	"Taxes largest cost", 2001
Economic well-being	Transportation expenditures represent 15 - 20% of GDP in North America, and direct expenditure associated with personal automobile use in Alberta was 6.7% of GDP	Litman, 1999; Pembina Institute, 2001
Indirect economic effects	These are impacts that arise primarily from automobile collisions. Legal firms and automotive repair shops stand to profit financially from automobile collisions	No published references located

Municipal services	Municipal services are those that relate to providing law enforcement, street lighting, emergency response, planning, courts and driver training	Litman, 1999
Infrastructure costs	♦ Estimated roadway expenditures in the United States in 1993 cost $88.5 billion ♦ In Edmonton, Light Rail Transit costs $35 million per kilometre on the surface including stations	Edmonton Transit System Advisory Board, 2002; Litman, 1999
Real estate values	♦ By providing access to businesses and people, roadways and railways can increase land value ♦ However, in some cases, property values for homes located adjacent to a high volume roadway, decrease relative to properties further away	Huang, 1994; Litman, 1999
Tourism	♦ Access to never before seen landscapes such as mountain ecosystems, can have a positive effect on tourism ♦ However, because road based transportation is a leading contributor to smog, some people could be drawn away from a region that exhibits this source of pollution	No published references located

2.2.6 Socio - Cultural

Table 7 presents summaries of main points about how transportation impacts each of the socio - cultural variables listed in Figure 1.

Table 7 Transportations Impact on Socio - Cultural variables

Socio - Cultural variables	Summary	Source
Freedom and privacy	♦ People often enjoy travelling because of the freedom they feel ♦ Travel by automobile allows people to have private time	No published references located
Community cohesion	The proliferation of roadways can effectively isolate communities because of high vehicle traffic volumes, and the perceived difficulty and unpleasantness of crossing these streets by pedestrians and bicyclists	Dunt, 1998; Litman, 1999; Morton, 2001
Equity value	A transportation system that is focused on the movement of traffic rather than the movement of people, is biased against those that cannot drive, and hence is not equitable	Litman, 1999
Historical sites	Transportation projects, like roadways and railways, can sometimes eliminate historical structures or landmarks	OECD, 1998
Gender	♦ Women are more likely to carpool, use buses, make shorter trips and more off-peak hour trips than men ♦ Men are more likely to drive than women	Pucher, et al., 1998; OECD, 1997b

2.2.7 Environmental

Table 8 presents summaries of main points about how transportation impacts each of the environmental variables listed in Figure 1.

Table 8 Transportations Impact on Environmental variables

Environmental variables	Summary	Source
Water quality	♦ Transportation infrastructure is one of the major contributors influencing water quality ♦ Salts and other chemicals on roadways can affect water quality by seeping into aquifers close to ground level ♦ Air pollutants from vehicles can contribute to acid rain that then can affect drinking water supplies	Gibbs and Brown Landscape Architects, 2001; OECD, 1997b
Air pollution	♦ Emissions from automobile fuel combustion include carbon monoxide (CO), carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOCs) ground level ozone (O_3), polycyclic aromatic hydrocarbons (PAH), Lead (Pb) and particulate matter ($PM_{2.5}$ and PM_{10}) which can lead to smog and acidification in the atmosphere ♦ In addition, chlorofluorocarbons (CFC) from air conditioners, methane (CH4) from natural gas transport, and particulates from tyres are also attributable to vehicle use	European Conference of the Ministers of Transport (ECMT), 1990; Eyre, Ozdemiroglu, Pearce, & Steele, 1997; OECD, 1996; OECD, 1997b; Viegi & Enarson, 1998
Climate change	♦ The Intergovernmental Panel on Climate Change has stated that man's actions have "contributed substantially to the observed warming over the last 50 years", and this includes transportation ♦ Transportation is directly responsible for about 21% of all greenhouse gas emissions worldwide, and about 27% in Canada	CST, 1998; "The science and politics of global warming", 2000
Biodiversity	♦ Transportation projects can occupy tracts of land that can lead to biodiversity fragmentation and loss ♦ The local impact of habitat loss can be compounded by the cumulative effects of habitat fragmentation and longer-term genetic isolation	Treweek, Hankard, Roy, Arnold, & Thompson, 1998
Land use	♦ Roadways, parking and other transportation projects can account for one third of the total land available ♦ The land devoted to transportation use can increase demand for agricultural produce shipped from afar ♦ Land used for roadways can contribute to landslides because they can weaken the structure of hills and cause them to collapse	Birley, 1995; Litman, 1999; OECD, 1996; OECD, 1997b; Thomson & Yacyshyn, 1977

Resource consumption	♦ Transportation in Canada is responsible for about 30% of all energy use, primarily dependent on oil ♦ Concern that developed nations' appetite for the automobile is unsustainable given that CO_2 production from these countries is far greater per capita than what is acceptable globally	CST, 1998; McCarthy, 1999; OECD, 1997b
Waste Disposal	♦ Used tires, batteries, old cars and other hazardous materials contribute to the amount of waste that occurs in landfills ♦ Estimated that in the United States, the total annual cost of automobile waste is $4.2 billion	Litman, 1999
Agriculture	Crop damage can occur from vehicle-related air pollutants, especially ozone	Aunan, Patzay, Asbjorn-Aaheim, & Martin-Seip, 1998
Visual impact	The visual impact of transportation projects can be a concern for residents living next to them	European Commission, 1996

2.2.8 Health

Table 9 presents summaries of main points about how transportation impacts each of the health variables listed in Figure 1.

Table 9 Transportations Impact on Health variables

Health variables	Summary	Source
Air pollution health effects	See below for summary	
Fitness levels	See below for summary	
Injuries from collisions	See below for summary	
Noise levels	See below for summary	
Access to people, goods, and services	Transportation allows individuals access to people as well as goods and services that they need to maintain their quality of life	Morton, 2001; Transport and Health Study Group, 1991
Emergency vehicle access	Transportation allows emergency vehicles to gain access to disaster sites	Birley, 1995
Communicable diseases	♦ Road and rail projects cause pools to form in ditches, which are prime breeding grounds for mosquitoes carrying malaria, and filariasis ♦ Air travel allows people to quickly spread communicable diseases internationally	Birley, 1995
Stress levels	Some people who reside near roadways will experience stress related to anticipated noise, illness, and injury from traffic volume	Dunt, 1998

Air pollution health effects

Many articles have been written about the harmful health effects resulting from urban air pollution and, in particular, road traffic related air pollution. Because of the breadth of knowledge that exists on this subject, it would be difficult to synthesize the finding of all of the articles published that linked air pollution to health. This is a difficult task when looking at even one single air pollutant, that of particulate matter (Greenbaum et al., 2001). The following are selected articles that suggest evidence that traffic-related air pollution affects people's respiratory health, or are considered important articles linking particulate air pollution and health. Air pollution health affects for a case study are described more fully in Chapters 5 and 7.

McCarthy (1999) stated that although there is widespread concern about urban air quality, the relationship between transportation, poor air quality, and respiratory disease is complex. The author asserted that the health effects from vehicle air pollution can be divided into three categories:

a) *Poisonous emissions like benzene;*
b) *Greenhouse gases such as carbon dioxide; and*
c) *Small particulates.*

The pollution also acts in two different ways, from long-term exposure, and short-term acute episodes. McCarthy concluded by stating that since urban dwellers typically spend about 90 % of their time indoors, it is indoor air pollution that more greatly affects health, and that any effects resulting from outdoor air pollution occurs in those people already predisposed to respiratory illness.

While McCarthy casts doubt on the health effects from vehicle air pollution, Dora (1999) claimed that this is a serious health problem. He cited three studies linking particulate matter to increased mortality as well as increases in respiratory symptoms, increased drug utilization among asthmatics, reduced lung function, and hospital admissions. The connection to transportation is that 40% of all particulate matter in Northern Europe comes from traffic. Dora claimed that particulate matter can enter the indoor environment freely, thereby suggesting that there is an association between

outdoor and indoor air. Dora concluded by referring to four studies that found a linkage between respiratory problems and proximity to busy roads with heavy goods vehicles.

Morton (2001) claimed that, after motor vehicle accidents, the next most commonly attributed health effect of transport is air pollution. The author stated that air pollution health effects are greatest among vulnerable pockets of the population such as the elderly and those with respiratory conditions already. According to one study the author cited:

> *For particulate pollution, there is no evidence that there is any threshold below which we can say there is no population attributable risk.*

The author cited a number of studies linking decreased air quality, increased respiratory conditions, hospital admissions, and mortality for people living in close proximity to roads.

Ciccone et al. (1998) investigated road traffic and adverse respiratory effects in children and concluded that heavy vehicular traffic can increase incidences of lower respiratory tract infections, wheezing, and bronchitic symptoms at school age. The authors stated that particulate matter (PM) is a main contributor to these three health effects with this type of pollution occurring as a result of diesel-powered vehicles. Asthma by contrast is more closely related to nitrogen oxides produced by smaller automobile traffic.

A complete assessment of the public health impact from traffic related air pollution comes from Kunzli et al. (2000). The authors estimated mortality, respiratory hospital admissions, bronchitis, restricted activity days, and asthma attacks associated with air pollution caused by traffic. The study was limited to three countries in Europe: Austria, France, and Switzerland. The main pollutant examined in this study was PM_{10} (particulate matter less than 10 microns in diameter), and estimates of health outcomes were calculated based on published literature and national health data. The authors used PM_{10} because of the wealth of studies utilizing this pollutant, and because traffic substantially contributes to PM_{10} emissions. The main conclusion from the study was

that air pollution causes approximately 6% of all deaths, and that traffic is responsible for roughly half of these deaths.

Guo et al. (1999) studied children's asthma rates in connection with climate and traffic-related air pollutants in Taiwan. The authors found that traffic-related air pollution adjusted for non-summer temperature and winter humidity, were positively associated with the prevalence of asthma in middle-school children. The authors concluded that nitrogen oxides and carbon monoxide from traffic were connected with children's asthma rates, and not particulate matter.

Shima and Adachi (1998) investigated nitrogen dioxide (NO_2) and its impact on health. The authors stated that NO_2 is one of the main pollutants in automobile exhaust and that atmospheric levels of NO_2 are higher in areas next to roadways. The authors examined indoor NO_2 levels for homes located near heavy traffic roadways in Japan. They found that during the non-heating period (June and July) indoor NO_2 concentrations were significantly higher in homes close to heavy traffic roadways versus those further away. The conclusions verify that traffic contributes to NO_2 levels indoors.

Brunekreef, Janssen, de Hartog, Harssema, Knape, and van Vliet (1997) studied lung function in children who lived close to a freeway in the Netherlands. The authors used traffic density for trucks and cars on the motorway, and measured air quality in the children's schools as a proxy for exposure. The authors found that lung function was associated with truck traffic density and that the association was strongest for those children living within 300 metres of the motorway. The main health endpoint in this study was lung function, so it cannot be compared to other studies that analyse health endpoints such as mortality or morbidity.

The "six city study" conducted by Dockery et al. (1993) was a landmark article that examined the effects that PM_{10} and $PM_{2.5}$ (particulate matter less than 2.5 microns in diameter) had on daily mortality in six U.S. cities. After controlling for a number of factors, including smoking, the authors found significant associations between

particulate levels and mortality. The adjusted mortality rate ratio for the most polluted city compared with the least polluted was 1.26. Although transportation was not the focus of the source of the air pollution, it was mentioned that fine particulates ($PM_{2.5}$) were derived mainly from the combustion of fossil fuels used in transportation, manufacturing and power generation.

Finally, two meta-analyses are reviewed that examine health effects related to particulate matter, some of which use the results found in the above articles. Environment Canada and Health Canada (1999) produced a comprehensive study that examined the health effects of PM_{10} and $PM_{2.5}$. The authors examined the results from five studies on $PM_{2.5}$ and found an average increase in daily mortality of 1.5% for each 10 $\mu g/m^3$ daily increase in $PM_{2.5}$. The authors conclude, based on the evidence, that there is no level of particulate matter below which there is no effect on mortality. The authors found in nine studies that each 10 $\mu g/m^3$ increase in $PM_{2.5}$ was associated with an average 1.1% increase in respiratory hospitalizations and a 1.0% increase in cardiac hospitalizations. Based on four studies, the authors found that for every 10 ug/m^3 increase in $PM_{2.5}$ there was an increase of between 0.9% and 2.2% in respiratory health (lung function, symptoms, restricted activity days, and work absences). Long-term, chronic effects were examined, but the lack of data made this association uncertain. Overall, the authors claimed that, epidemiologically, there is evidence that ambient particulate matter is associated with respiratory effects.

The Committee on the Medical Effects of Air Pollution (COMEAP) (1998) conducted a meta-analysis on a variety of air pollutants including PM_{10} and their health effects. COMEAP chose PM_{10} because more evidence was available than on $PM_{2.5}$ but, they stated the choice of index does not matter much. The authors examined three studies (two are meta-analyses themselves) and found that every 10 $\mu g/m^3$ increase in PM_{10} is associated with a 0.75% increase in morality, this being lower than the results found by Environment Canada and Health Canada. The authors stated that every 10 $\mu g/m^3$ increase in PM_{10} is associated with a 0.8% increase in respiratory hospital admissions, again slightly lower than that found in Environment Canada and Health Canada's meta-

analyses. The authors made no attempt to quantify cardiovascular hospitalizations related to air pollution. Overall, the study confirmed the association between air pollution and respiratory effects.

Fitness Levels

Transportation can have an impact on individual fitness levels, and the following articles provide such evidence.

Roberts and Norton (1993) stated that physical inactivity is an important risk factor for cardiovascular disease and stroke. They pointed to three studies showing that regular exercise derived from cycling and brisk walking reduced the risk of coronary events like myocardial infarction, and cardiovascular mortality. They stated that the present car-oriented transportation system in New Zealand discourages people from cycling and walking, leading to decreased physical activity. The authors also make a comparison between trips made by bicycle in New Zealand (4 percent) versus the Netherlands (50 percent).

McCarthy (1999) stated that the most positive impact transport can have is on encouraging exercise through mainly cycling and walking, which is protective against heart disease. The author pointed to two studies done that showed those who cycled and walked regularly experienced fewer heart attacks and were at decreased risk of death overall than those who did not. The author also cited a study showing that the benefits of cycling (from reduced heart disease, hypertension, and obesity) outweighed the risks of death from cycling on roadways many times over.

Dora (1999) concluded that transportation in the form of walking and cycling for 30 minutes per day has the same effect of not smoking, and can halve the risk of developing diabetes, reduce blood pressure and improve functional capacity according to two articles cited. The author pointed to the fact that since over half of daily trips that people make are short, this provides them with an opportunity to incorporate physical activity in their daily lives.

Morton (2001) stated that transport can be an excellent form of physical activity. He referred the reader to sixteen articles proclaiming the health benefits of exercise. The benefits stated for increasing exercise include reduced coronary heart disease, stroke, colon cancer, obesity, osteoporosis, diabetes, gallstones, mental health, blood pressure, and cholesterol levels. Social class differences are introduced by the author, and he stated that those in lower socioeconomic groups are less likely to engage in physical activity. He cited two studies confirming higher obesity rates in females than males, which are a result of lower physical activity at work for females. The positive health benefits of cycling outweigh the health risks by a factor of 20:1 according to one study.

Mason (2000) stated that the benefits of exercise are a protective factor against such health risks as all cause mortality, colon cancer, psychological distress, osteoporosis, adult-onset diabetes, and obesity. The author promoted "active transport" which includes walking and cycling, and presents the case that if these activities were incorporated into individuals daily routine, then there would be no need for the outside time and financial commitments of gym memberships. The author referred to local programs in Glasgow, Scotland, and the United Kingdom that promote fitness for life and healthy transport, and calls for similar programs to be adopted in Australia.

Collisions

One of the most serious side effects of transportation is the injuries and fatalities that result from collisions. Motor vehicle collisions will be examined because the extent to which people travel in automobiles is much larger compared with all other modes of transportation in Canada.

Morton (2001) stated that motor vehicle collisions contribute largely to ill health. A total of 123,500 fatalities occur in the European region, with another 2.8 million injuries from motor vehicle collisions. These numbers include collisions that involve pedestrians and bicyclists. The relative risks per kilometre traveled are much greater for pedestrians and bicyclists than for motor vehicle users. The author noted that, in recent

years, the number of road deaths has fallen, though injury statistics keep increasing. One suggested reason for the decreasing death rates is that safety and engineering modification in automobiles provide vehicle occupants with greater security, which can be at the expense of more vulnerable road users (e.g. cyclists and pedestrians). The author postulated that walking and cycling fatalities are decreased because the perceived risks are much greater now than they used to be, and hence people are limiting their exposure to walking and cycling.

Richter (1998) stated that the costs of death and injury related to road transportation are massive, especially because many victims are young. He called upon environmental epidemiologists to pay more attention to this global problem, claiming that not nearly enough research has gone into the area of injury epidemiology. He stated that increased road provision to alleviate congestion will only increase the risk of injury and death because it allows greater speed. Richter cited the following equation found in Evans (1991), of the relationship between speed and fatality rate:

$$\text{(fatality crash rate after)/(fatality crash rate before)} = \text{(speed after/speed before)}^4$$

Using this equation, if speed were to increase by 10%, an increase in the fatality crash rate would be expected to increase by 46%. Conversely, because congestion on roadways brings speed down, Richter noted out that:

No-one gets killed in a traffic jam.

Richter pointed out that laws, not education, reduce traffic collisions as witnessed by Australia's vigorous law enforcement campaign to reduce collisions. Richter also called on the healthcare system to help fund speed cameras because they reduce death and injury, again evidenced in Australia. The benefits of speed cameras reducing speed and collisions has also been empirically found in Canada (Chen, Meckle, & Wilson, 2002).

Richter, Barach, Ben-Michael, and Berman (2001) published a report in response to a Centers for Disease Control (CDC) document that claimed motor vehicle safety is a public health achievement in the 20th century. The CDC claim is based on the fact that

deaths per vehicle mile traveled has reduced significantly over time. Indeed, from 1925 to 1997, fatalities per vehicle mile decreased by 90%. However, the authors noted that the main reason that death rates have dropped is that increased congestion has occurred on roadways worldwide, dropping speed, and hence dropping death rates. This point needs to be validated by empirical evidence because other technologies such as seatbelts and increased vehicle safety measures are likely contributors to the decreased rates of death. The authors argued that any number of deaths is inexcusable since they are all preventable and claimed that worldwide, annual motor vehicle deaths from collisions is over 1 million now, and could rise to 2.2 million in 2020. Overall, this article provides a comprehensive background about speed and its relation to traffic injuries and deaths.

McCarthy (1999) viewed more than speed as contributing to motor vehicle accidents. For instance, McCarthy noted that driver experience, alcohol consumption, social class, age, as well as speed are all contributing factors to the numbers of road deaths. The author pointed out that the British Medical Association concluded that speed caused about 30% of all road deaths, thus leaving room for some of the factors listed above. The author verifies Richter's claim about the significance of road fatalities in the year 2020. It is predicted that road crashes will be the third greatest cause of death and disability globally, just behind clinical depression and heart disease. McCarthy's viewpoints are well rounded because he has included more factors other than just speed in causes of road accidents.

Granados (1998) focused on traffic injuries as the main reason why vehicle use should be constrained. The author stated that in the industrialized countries, traffic injuries are among the top three causes of death behind cancer and heart disease. Granados referred to a World Bank study that placed traffic injuries in ninth place of all diseases for number of disability adjusted life years lost. He also noted that people from poorer areas are more likely than people from affluent areas to be killed by traffic collisions. The author provided a background about automobile use worldwide including developing nations.

Ginsberg, Fletcher, Ben-Michael, and Richter, (1997) examined the effect that a new 6-lane freeway would have on injuries and death in Israel. The new freeway was compared with a do-nothing and a sustainable transportation scenario of rapid transit, and bicycle paths, in the year 2010. The authors based their results on the demonstrated relationship of a fourth power increase in travel speed to death toll, as well as the spillover effect where increased speed on one route translates into increased speed on another. The authors predicted that in 2010 with the new freeway, annual death tolls could be between 990 and 1139, whereas in the do-nothing scenario the range is 665-850, and the sustainable transportation scenario, the prediction is under 300 per year. This was one of few case studies of the impact that a new road development could have on injuries, where the authors utilized the negative effect that speed has on motor vehicle collision and injury rates.

Jadaan and Nicholson (1988) report on the number of motor vehicle accidents before and after a new arterial roadway was built. The study location was in Christchurch, New Zealand and data were used for the years 1977-1985. The authors found that although the new arterial road caused traffic in the area to increase by 30%, an overall decrease of 28% was found for overall accidents. An explanation for this is that because the new arterial roadway was freer flowing than what was previously available, the number of accidents decreased because of less stop-and-go traffic.

Dora (1999) stated that in Europe, over 120,000 people die as a result of motor vehicle accidents every year. Speed is listed as a contributing factor in the severity of injury, and the author concluded that a 1% reduction in speed results in a 3% reduction in accident frequency.

Ansari, Akhdar, Mandoorah, and Moutaery (2000) stated that road traffic accidents are a major cause of death and disability in Saudi Arabia, comparable to cancer and heart disease in that country. Excess speed and failure to obey traffic signs are the main causes of accidents, and road accident victims take up one third of all hospital beds in Saudi military hospitals. The authors claimed that since road traffic accidents are a

large problem in Saudi Arabia, new measures to control excess speed, compulsory use of seat belts, and improved traffic information collection should be implemented to help control this public health problem.

Dougherty, Pless, and Wilkins (1990) claimed that after the first year of life, motor vehicle traffic accidents are the single largest loss of life category for children in Canada. Further, children from disadvantaged families in Canada are more likely to be at risk from injury or death from motor vehicles. This statement is confirmed by the fact that rates of injury from motor vehicles for children aged 0-14 were nearly six times higher in the poorest income group than the least poor. This information is dated owing to the fact that the figures are taken from the late 1970s and early 1980s.

In Canada, the number of fatalities from traffic collisions was at just over 2,900 with over 227, 000 injuries in 2000 (Transport Canada, 2001). These numbers have been falling since 1982, but still represent a considerable public health concern. In Alberta, the number of traffic related deaths per 10,000 registered vehicles have decreased from 1.9 in 1961, to 1.4 in 1999. However, injuries from traffic per 10,000 registered vehicles have increased during this time period from 1.5 in 1961, to 2.7 in 1999 (Pembina Institute, 2001b).

Noise Levels

It has not been proved convincingly that there are health effects from traffic related noise, but there are some studies to suggest that it is a concern.
In discussing the impacts of noise on human health, it is wise to consider first how transportation contributes to noise and second, what the likely effects might be.

According to Dunt, Abramson, and Andreassen (1995), noise affects health in the following ways:

- *Cardiovascular system;*
- *Sleep disturbance;*
- *The human psyche and behavioural disorders; and*
- *Annoyance.*

In Dunt's article, an acknowledged expert in the field of the medical effects of noise, stated that road traffic noise is the primary source of environmental noise in today's society. Sound level is dependent on many factors such as traffic flow, distance to the road, speed, type of vehicle, and road surface. Of the four broad health effects stated, sleep disturbance is considered to be the most important effect because it can increase an individual's fatigue levels, which then has a host of negative effects including impaired professional and family life. Normal recuperation of the central nervous system is also an indirect effect of a lack of sleep. This provides an overview of health effects from noise directly related to road transport.

Dora (1999) stated that about 65% of the European Union are exposed to sound levels that lead to annoyance, interference with speech and sleep disturbances. Noise can also interfere with memory, attention span and the ability to deal with complex problems according to one study referenced. Another study cited, claimed that road traffic is the main source of human exposure to noise in Europe except for those living near railways or airports, confirming the finding made in Dunt et al. (1995). Overall, this provides a review of traffic noise and health, but the statistics are limited to Europe.

Morton (2001) concluded that noise does have adverse affects on health, although they are difficult to quantify. He referred to three studies that showed some evidence of noise's impact on blood pressure, cardiovascular disease, and sleep disturbance. Of these effects, sleep disturbance is thought to be the most significant.

2.3 Frameworks for integrating health, environment, and economics into transportation planning

To fully integrate health, environmental, and economic concerns into transport planning, a framework or approach is needed. In reviewing the literature on complex frameworks, many approaches have potential relevance. The following is a review of selected articles pertaining to these frameworks.

2.3.1 Integrated Assessment Framework

The first approach identified is the Integrated Assessment Framework (IAF). This approach seeks to integrate social, economic, health and environmental issues using both scientific and stakeholder knowledge (Martens & Rotmans, 1999). A common definition to this relatively new approach is given by Rotmans (1998) as:

> *A structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision-makers.*

IAFs origins go back to the 1960s when Meadows et al. produced the Club of Rome "Limits to Growth" model (as cited in Aron, Ellis, & Hobbs, 2001). IAFs have increased in popularity in the 1990s and have almost exclusively focused on global climate change. A review of selected articles is listed in the following section.

Aron et al. (2001) described both Integrated Assessments and Integrated Assessment Models (IAM). The authors outlined two different approaches to integrated assessment. The first approach is modeling, which attempts to depict complex problems generally using computing software and includes sub-models linked together. The second approach to integrated assessments is the participatory approach that incorporates non-scientist participation in the final outcome for the model to better inform decision-making. The descriptions of the two approaches are theoretical and do not give any graphical representation about what an integrated assessment might look like for ecosystem change and public health. The issue of transportation is mentioned briefly when the issue of urbanization and its relation to public health is addressed. However, no direct connection to transportation and integrated assessments is made.

Epstein (1994) focused on IAF for climate change and used species counts as indicators of ecosystem vulnerability. The IAF incorporates ecosystems, climate and social systems acting upon and influencing each other. To enhance the richness of the framework, global driving pressures are depicted that impact on the three interlocking systems. One of these driving pressures is infrastructure development needed in the face of population growth and increased urbanization. This infrastructure could easily mean

transportation. The model shown is comprehensive, although there is no direct connection to transportation in the IAF presented.

Chan, Ebi, Smith, Wilson, and Smith (1999) studied climate change and infectious diseases and its impact on human health, the economy and society. The IAF presented linked climate change with ecology, sociology, and disease transmission. Of interest are that the links between the major subgroups are numbered, and a review of the research performed on these subgroups is summarized in a table. This is done to highlight areas in need of further research. For example, no work has been done on the link between migration/travel and its connection to biodiversity loss. This has direct implications for transportation because some transportation infrastructure directly interferes with the migration and feeding patterns of many animals. Besides this small piece of the framework, no direct mention is made of the usefulness of IAF outside the realm of climate change and infectious diseases.

Dowlatabadi (1995) gives an overview of IAMs and how they help explain IAFs. Some key points made in the article are followed in parentheses by the author's observations as they relate to transportation:

1) In climate change as with other complex problems, the familiar tradeoff of large up-front costs with long-term diffuse benefits is present. (This is true of transportation because any change to alternatively powered vehicles for example, will require large initial capital outlays and uncertain long term benefits from reduced pollutants in the atmosphere).

2) A single model of climate change is not possible because the topic is too complex. If it were to address every facet of the issue, then it would have to be at a very high level of abstraction. (A comparison can be drawn to complex urban transportation issues and the tradeoffs involved in urban transportation planning).

3) Our imagination limits our ability to predict an uncertain future. (Forecasting is a vital component of transportation planning and it is uncertain whether humans will consume an increasing amount of non-renewable resources (e.g., petroleum) or whether technology and policy issues will limit the amount of precious resources used).

Dowlatabadi provided a good overview of IAMs. However, there was no mention of what one might look like or any discussion of other sectors, such as transportation, that might use IAMs.

Parson and Fisher-Vanden (1997) stated that integrated assessments should be completed on a smaller scale to be useful to policy makers. They are most useful when tailored to a specific situation, not using a "cookie cutter" approach. The authors explained that modeling creates transparency and enables researchers from different disciplines to reach intelligibility. A valid point is raised regarding policy issues because most decision makers are responsible for a finite region, but climate change is a global problem. The same is true for transportation planning at a local level because comprehensive planning must address global climate change as an issue. The authors also stated that integrated assessment can do things disciplinary research cannot, but that it should be viewed as a supplement, and not a replacement, of disciplinary knowledge. Most encouraging is the fact that areas other than climate change are addressed in the following paragraph:

> *Ultimately, the most useful form of integrated assessment may involve abstracting away from particular environmental issues entirely, to examine fundamental policy choices that shape activities contributing to a variety of dimensions of global well-being, environmental and other.*

Clearly, transportation could be one of these issues.

IAFs are useful because they can frame complex questions logically for decision-making and research purposes, but, in reality, little has been done outside of global climate change. This is not to say that transportation issues could not be adapted to fit an IAF. However, this would take more time and resources than is provided for this study. A transportation IAF certainly could be an area for further research and be useful for transportation planners worldwide.

2.3.2 Health Impact Assessment

Health impact assessment (HIA) is a combination of procedures to determine how a policy, either inside or outside the health sector, impacts on population health. It is

enjoying increasing popularity in both regional and national policy making (Mindell, Hansell, Morrison, Douglas, & Joffe, 2001), and is linked to healthy public policy (Health Canada, 1997). Healthy public policy is the explicit concern for health and equity in all areas of policy (WHO, 1988), and HIA is a key method for determining how healthy a public policy is. A review of articles about HIA follows.

Scott-Samuel (1998) defined HIA as:

> *The estimation of the effects of a specified action on the health of a defined population.*

The author stated that HIA is a relatively new assessment method that builds upon the experience of environmental impact assessment. In Canada, British Columbia (B.C.) has taken the lead by announcing that HIA will be a part of all new government policy, programmes, and legislation. It is not known if other provinces have followed B.C.s lead on HIA. In determining the health impacts, the author stated that both quantitative and qualitative estimates are needed because the level of data sophistication is lacking. This article explains the theory behind HIAs although no mention is made of how to conduct one.

Kemm (2000) cited two United Kingdom references that state policy decisions in non-health areas like transport have greater importance in determining population health than health services alone. Therefore, there is a need to ascertain the health consequences of policies, programmes, and infrastructure. The author cited a report from Wales that suggests two streams of HIA; a broad focus that rarely attempts to quantify effects and has its roots in sociology, or a tight focus that emphasizes health aspects that are quantifiable and has its foundations in epidemiology. The author identified the added value of HIA for decision-makers as follows:

1) *Identify factors not previously recognized;*
2) *Quantify risk factors more precisely than otherwise could have been done;*
3) *Clarify the tradeoffs involved;*
4) *Allow mitigation;*
5) *More transparent decision-making with more stakeholder input; and*
6) *"Culture" change to consider health.*

Kemm then outlines the major steps involved in any HIA. These steps are:

1) *Screening – is the project likely to pose significant health problems;*
2) *Scoping – what are the benefits and hazards and the questions and issues to be addressed in the assessment process;*
3) *Risk assessment - better characterisation of the nature and significance of benefits and hazards;*
4) *Decision making – choice of options and modifications if necessary; and*
5) *Implementation and monitoring – observing the consequences after implementation*

The author noted the similarity to Environmental Impact Assessment (EIA) and suggests a trend combining the two into one environmental health impact assessment (see Fehr, 1999). The savings may be considerable in performing an environmental health impact assessment (EHIA), but the concern is that one discipline may overshadow the other. Kemm concluded by stating that decision-makers have many different issues that concern policy, with health being just one. However, health should always be considered against other policy aspects.

Lock (2000) suggested that HIA be conducted using a broad perspective of health. The author commented on the emergence of HIA from the Ottawa Charter on Health Promotion, which acknowledged that many policies not directly dealing with health have human health impacts. Lock stated that HIAs foundation comes from EIA and social impact assessment, though she noted that very few EIAs are done that include health. Because HIA is relatively new, there is not one gold standard or method of conduct. The author cited HIAs that have been completed (mostly in the United Kingdom), though fails to mention two that were done in Australia that are transportation related. Overall, the author presented the concepts of HIA, though did not seem to know of environmental health impact assessment literature, nor of all the HIAs completed for transportation.

Fleeman and Scott-Samuel (2000) presented results from an HIA of the Merseyside Integrated Transport Strategy in the United Kingdom. This HIA was focused at the programme and policy level whereas other HIAs are centred at the project level. The author's approach to this strategic level of HIA is built on the foundations of

Strategic Environmental Assessment (SEA), and policy analysis. The authors examined four priority impact areas:

1) *Road hierarchies;*
2) *Economic viability;*
3) *Air quality; and*
4) *Public transport.*

The authors then assessed each area for potential positive and negative impacts on health. For road hierarchies, the authors concluded that the health of people in Merseyside will be improved by the prioritizing of traffic. However, those residents near to the heavily trafficked roads will experience negative health effects. No impact could be predicted with regard to economic viability because of a lack of data. The authors predicted the transport strategy would have beneficial effects on air quality owing to more alternative fuelled vehicles on the roads and an upgrade in the bus fleet to cleaner fuel. The public transit impacts would have a mostly negative health effect because bus deregulation had resulted in many routes being dropped and the authors postulated that this would increase social exclusion of many people living in the fringe areas. This article provides a summary of an HIA that was actually performed, and one conducted at the policy level. However, no valid quantitative statements could be made because of a lack of measurable data.

Dunt et al. (1995) published the first road transportation related HIA of a new freeway development in Melbourne, Australia. The scope of the HIA was limited to three impacts:

1) *Injury from motor vehicle collisions;*
2) *Respiratory disease from air pollution; and*
3) *Noise pollution effects.*

The authors used 2001 as a future reference year to estimate the likely impact the development would have on the local community based on projected traffic volumes with and without the freeway. The authors estimated that with the freeway, there would be a reduction in the number of accidents because of smoother traffic flow on the freeway, as well as less traffic on the existing road network. Given that existing air quality guidelines had been met for every pollutant, except for particulate matter on two occasions, the

authors concluded that no significant air pollution effects would result from the freeway development for the 24,000 residents living in the immediate vicinity of the freeway. More complete analysis in the air pollution section could have been done because of evidence that there is no threshold below which health effects do not occur. Noise effects were not considered to be a significant factor for the residents close to the freeway because noise attenuation facilities were proposed for the freeway. While this was a noble first effort at HIA for transportation projects, more impacts could have been examined to make it more comprehensive.

Dunt (1998) conducted an HIA for another freeway proposal in Melbourne, though a more comprehensive view of health was utilized than in the previous study. A wider range of impacts was examined in this report, including motor vehicle accidents, air and noise pollution effects, stress levels, physical activity effects, and social isolation. All estimations were made for the year 2011, and were based on projected traffic flows. The author reported that the freeway would have positive effects on motor vehicle accidents, stating that there should be four fewer deaths and 185 fewer injuries. The freeway would have negative effects for the local community on noise pollution especially for those properties abutting the freeway. Uncertain impacts were predicted for stress levels, air pollution, and physical fitness levels given the lack of data available. While no definitive statements could be made regarding these impacts, this HIA was a progression from the earlier Dunt article because of the broad impacts examined.

Health impact assessments have come a long way since the late 1980s. There is no standard method of performing an HIA, given its recent introduction, and the fact that each local situation is different. This can be frustrating for practitioners in the field. While the strength of HIAs may be its focus on health, this may be its own weakness because it fails to recognize other factors in the decision-making process that fall outside of the public health realm, such as environmental and economic aspects. However, the emphasis on health will be utilized in the assessment framework developed later in this thesis, with its links to promoting healthy public policy.

2.3.3 Environmental Impact Assessment

Environmental Impact Assessment (EIA) has been used for many years to determine the environmental effects of various types of projects, including transportation. The following is a review of selected articles dealing with EIA.

The United Kingdom's Department of Transportation included the following definition of an Environmental Impact Assessment (as cited in British Medical Association, 1998):

> *Technique and a process by which information about the environmental effects of a project is collected, both by the developer and from other sources, and taken into account by the planning authority in forming their judgements on whether the development should go ahead.*

There are many approaches to conducting an EIA, and the above author offered one method:

1) *Screening*
2) *Scoping*
3) *Terms of Reference*
4) *Preparation of the environmental impact statement*
5) *Participation*
6) *Appraisal*
7) *Negotiation and risk management*
8) *Monitoring and surveillance*

Consultation

The author noted that EIAs are intended to assess individual projects and to develop mitigation strategies for those negative environmental aspects. The author suggested that human health considerations should be included in an EIA, and not run as a separate parallel activity. A review of 39 European EIAs is given with a total of 28% including health considerations. This shows that there is work to be done on the inclusion of health effects in EIAs, but that there is evidence of it happening.

Eyles (1999) argued for the inclusion of health considerations in EIA because of their:

1) *Contributions to population health strategies and sustainable development;*
2) *Ability to address public concerns; and*
3) *Ability to minimize the need for separate HIAs.*

He noted that the WHOs interest in Environmental Health Impact Assessment dates back to at least 1988. The author stressed that the biophysical environment is a key determinant of health and that impact assessments that address both environment and health together will enhance knowledge for the future. The author presents an overview of both environmental and health impact assessments and recognizes the complexity associated with integrating health and environmental concerns in one tool for use by decision-makers.

EIAs of large infrastructure projects have been legislated in over 100 countries (Joffe & Sutcliffe, 1997). There is a more standardized method of performing EIAs than any of the approaches that are analysed in this section, owing in part to its longevity. EIAs can have health included, though in a recent review of road based EIAs in Sweden, it was found that more work is needed to accomplish this goal (Alenius & Forsberg, 2001). EIAs have been used extensively in transportation infrastructure projects, and the methods are well established in Canada. However, weaknesses of EIAs are that they are narrowly focused at the project level, do not allow for alternative options to be considered at the policy level, and rarely consider health and socio-economic variables in the analysis.

2.3.4 Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) was first developed in 1969 for environmental issues in California, but has more recently come into favour especially with transportation issues in the 1990s. SEA is similar to Environmental Impact Assessment (EIA) with one important difference. EIAs are performed at the project level whereas SEA is conducted at the level of policy, plans, and programmes where costs and benefits of various alternatives can be compared. The emergence of SEA has been noticeable because of the growing concern over health and environmental issues related to transportation. The following is a review of selected articles related to SEA.

The ECMT (1998) report gave an overview of SEA as it relates to the transport sector, and describes international experience using SEA in practice. The definition given for SEA is:

> *...the term used to describe the environmental assessment process for policies, plans and programmes (PPP's) which are approved earlier than the authorisation of individual projects. More specifically, SEA can be defined as the formalised, systematic and comprehensive process for evaluating the environmental impacts of a strategic action and its alternatives, including the preparation of a written report on the findings of that evaluation, and using the findings in publicly accountable decision making.*

The author noted that SEA can be performed in any sector such as energy, tourism or waste management. The author stated that most SEAs performed in the transport sector are done on the plan (a set of co-ordinated objectives for the implementation of a policy) or programme level (a set of projects in a particular sector), and that more needs to be done at the policy level (guidance drawn up by government). SEA is seen as an improvement upon project level EIA for the following reasons:

1) *Ability to evaluate induced or indirect activities;*
2) *Allows consideration of alternatives not possible in EIA; and*
3) *Ability to assess cumulative or large-scale impacts.*

The article ends with a summary of international efforts of putting SEA into practice. The report is a first step in understanding SEA broadly, though no elaboration of quantitative methods was discussed. The author noted that SEA has had little influence on decision-making, but that it is a source of communication and furthers the goal of incorporation of environmental issues into policy.

Joffe and Sutcliffe (1997) argued that because many determinants of health occur outside the health service sector, policies in traditionally non-health areas should take health into account. The best way to do this at the project level is to incorporate SEA at a more strategic level. The authors described some limitations of SEA as:

1) *Techniques are not fully developed creating anxiety; and*
2) *Results are not precise.*

The authors concluded that more health considerations are needed in EIA, but would be more attractive if performed at the SEA level. The authors health focus for SEA is more thorough than any of the past articles reviewed.

Fischer (1999) stated that SEA is an instrument to bring about sustainable development. He claimed that SEA may address social, natural, environmental and economic components, and the focus of this article was on environmental aspects. The main purpose of the article was to see how transportation authorities used SEA and sustainable development. The author used surveys and interviews directed towards transportation planners in three European nations to determine how familiar the planners were with SEAs and the concept of sustainable development, and how often they put these ideas into practice. The author found that although sustainability is currently considered, it needs to be implemented more extensively. This article was useful in that it allowed for economic and social components to be included in a SEA, an insight not shared by other authors.

Diaz, Illera, and Hedo (2001) described SEA as a planning tool to be used in moving towards sustainable development. The first objective of the study was to develop a method for incorporating biodiversity within the SEA process. Secondly, the authors wanted to evaluate the impact that two development plans would have on biodiversity, specifically important bird areas in Spain. The authors mention that although SEA is typically done in the early planning stages, in this case the two development plans had already passed the approval stage. Because of this, the authors stated that their approach to the study resembled an EIA of a single project, but for a larger spatial scale. The evaluative methods used were mostly qualitative, stating whether the plans would have a positive or negative effect on the bird areas. An attempt was made at determining the economic costs the developments would have on game hunters in the area. The article lacks in quantitatively determining the actual effects the plans would have. However, it is a useful article because it shows how to narrow the focus on one aspect of an SEA, in this case, biodiversity.

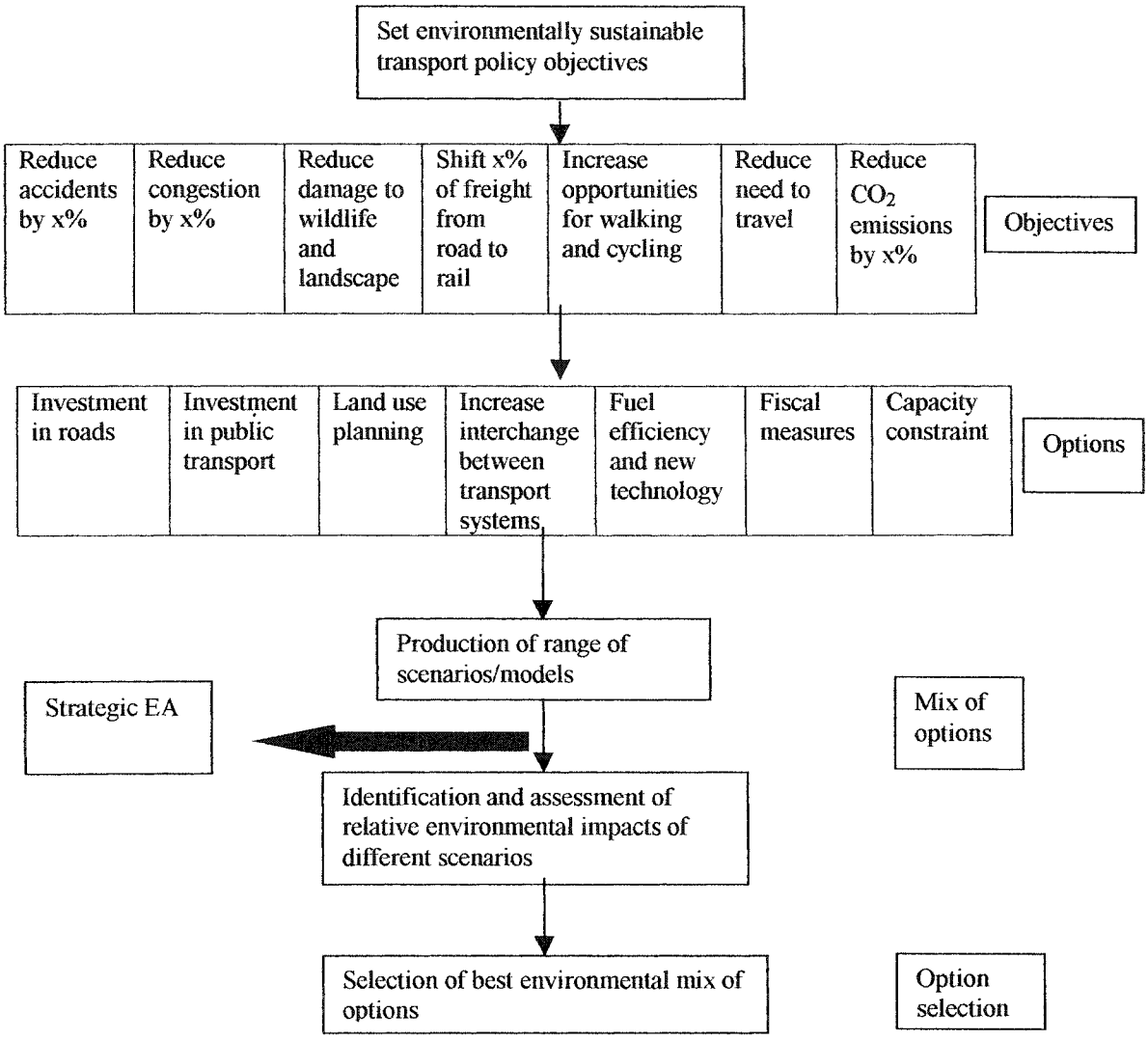
Von Seht (1999) gave a summary of five fundamental (of a possible 15 criteria), for a comprehensive SEA:

1. *Comprehensive SEA documentation;*
2. *Established SEA procedure;*
3. *Examination of every likely significant effect;*
4. *Examination of alternatives; and*
5. *Public participation.*

The author stated that no countries have been able to meet all 15 criteria. The author claimed that California's legislation on SEA comes closest to satisfying the criteria, and is superior to anything the European Commission has been able to achieve. This is most likely due to California's EA legislation being in place for over 20 years. The article is an excellent summary of issues that should be addressed when undertaking an SEA, and gives reference to those articles that deal with the more technical aspects of the assessment. The author also displayed a list of the advantages of SEA over EIA, which have been echoed previously, although this list is more comprehensive than most.

Sheate (1992) provided an overview of SEA and where it fits into the entire decision-making process. The author stated that the SEA should utilize an objectives based approach to policy. For instance, one objective for transportation planning could be to reduce carbon dioxide (CO_2) by 10%. The next step is to assess what sort of options are available, such as an increased investment in public transit, or a shift to more sustainable modes of transport like cycling. Next comes the mix of possible options or scenarios. The assessment of the scenarios' impacts on the environment is where the SEA would fit in. Each scenario would have to be assessed with the one most amenable to environmental considerations being the one finally selected. The whole cycle is depicted in Figure 2. The author also stated that public participation is vital to the success of any SEA and that it can be received at any point in the process. The article provides an understanding for how SEA might influence policy if done correctly.

Figure 2 Example of SEA from Sheate (1992)



SEA succeeds where EIA fails, in that it can be applied at a higher level in the decision making process to include other options. It has been applied to many transportation plans, mostly in Europe, though because it is more recent than EIAs, no standardized method for conducting an SEA has been utilized. There remains a need for health considerations to be more prominent in SEAs.

2.3.5 Ecosystem Approach to Human Health (Ecohealth)

The ecosystem approach to human health (Ecohealth) is a method of research that examines how the ecosystem affects human health and has several characteristics. This

approach is relatively new (since the early 1990s), and has yet to gain prominence among public health researchers. However, it is a promising method because it adopts a systemic approach to research that is complementary to reductionist approaches. The Ecohealth method has not been used for transportation problems to the author's knowledge, although it is flexible enough to be used in that capacity. The following are two articles reviewing the Ecohealth method.

Forget and Lebel (2001) produced a summary of the ecosystem approach to human health. The definition of an ecosystem is necessary to understand the Ecohealth approach and is as follows:

> *...the interaction between living and inert components of any system.*

The authors stated that an ecosystem has to have geographic boundaries, and while there has been debate regarding this point, essentially it is up to the researcher to decide what the physical boundaries of the ecosystem are (e.g. pond, urban subdivision, biosphere etc.). The authors gave examples of how ecosystem degradation caused by human intervention produce human health problems. These include a WHO report that stated that the poor quality of the environment was directly responsible for 25% of all preventable diseases. Acute respiratory infection is one of these diseases for which transportation is partially responsible. Forget and Lebel asserted that a wise approach to ecosystem management is needed to prevent further human health degradation. The Ecohealth approach is one way to do this and from it the authors state the three guiding characteristics that should be followed:

1) *Community participation where local stakeholders are brought together to guide the research and not just being the observers to the process;*
2) *Transdisciplinary collaboration on the research proposal, fieldwork, and the interpretation of the results; and*
3) *Social analysis including gender because men and women often occupy, use, and manage their surroundings in ways typical of their gender.*

The authors concluded by stating that the Ecohealth method is an ambitious approach because it is so broad and is different from the reductionist approaches that academics typically are rewarded for producing. The Ecohealth method can be used to analyse transportation and health.

Nielsen (n.d.) gave a summary of the Ecohealth approach. Ecosystems are described as nested spatial hierarchies of geographical units, all included in the biosphere. The author stated that because of their complexity, ecosystems can only be models of reality defined to serve human purpose, such that the researcher is in ultimate control of what they define as the ecosystem. Nielsen observed that frameworks to help simplify the relationships in the ecosystem are necessary, and lists the Pressure-State-Response framework as one way to do this. The author then identified the three principles of the Ecohealth approach as transdisciplinary, gender issues, and community participation. Interestingly, no theories or methods have been explicitly identified to achieve the community participation goal, though processes like participatory action research, and rapid rural appraisal have been used. While the article is useful in describing the Ecohealth method, no specific examples are given about how it could be applied to a transportation issue.

Similar to most of the frameworks listed in this section, the Ecohealth approach has features that make it very appealing for urban transportation problems as they influence the environment and subsequently human health. No previous studies on transportation using the Ecohealth approach have been found. The three principles of community participation, transdisciplinarity, and gender will be utilized in the application of the assessment framework developed later in this thesis.

2.3.6 Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) was first proposed as a technique to assist in public policy decision making in 1844 and is considered the gold standard of economic evaluation (Clemmer & Haddix, 1996). It quantifies the costs and benefits of an intervention into monetary terms in order to allow comparisons for each intervention. The final result from a CBA is a cost-benefit ratio or internal rate of return, and these measures are then compared for different options. CBA is aided by full cost accounting, which is the act of quantifying the external costs not typically borne by the user, such as environmental pollution from driving. The market does not typically account for these

significant external costs and benefits, which makes their measurement necessary for economic efficiency (Greene & Jones, 1997). A review of selected articles that pertain to CBA and urban transportation is presented below.

Boarman, Greenberg, Vining, and Weimer (1996) presented an overview of CBA as applied to a highway project in Texas. They present a conceptual layout of the steps involved in CBA:

1. *Decide on perspective;*
2. *Select the alternatives of the project;*
3. *Catalogue potential impacts and select measurement indicators;*
4. *Predict quantitative impacts over life of project;*
5. *Monetize all impacts;*
6. *Discount for time to find present values;*
7. *Sum: Add up the benefits and costs;*
8. *Perform sensitivity analysis; and*
9. *Recommend alternative with the largest net social benefits.*

The authors stated that the main benefit of CBA is the ability of decision-makers to assess the costs and benefits of an intervention on a comparable basis. However, the authors noted that CBAs are extremely expensive to perform in both time and money. They also acknowledge that some impacts are difficult if not impossible to quantify, such as the value of a human life.

DeCorla-Souza (1998) examined the benefit side of cost-benefit analysis for a corridor in California. The options for this four mile corridor were to build a new six lane freeway, a low build option, and a no build option. The analysis was viewed from three different levels: a narrow corridor analysis, a wider study area analysis, and a comprehensive region-wide analysis. The build alternative in this study produced the most traffic for three levels of analysis, although the corridor level produced the highest benefit. However, the author argued that the region-wide level of analysis should be used because it includes the benefits of non-users of the freeway. The main benefit listed was time savings for drivers, with "other" benefits being vehicle operating costs, accidents, air pollution, noise, and parking. These benefits are based on vehicle miles travelled

(VMT) although there is no mention of what figures are used to calculate these benefits. It is clear that the time saving for drivers is the main impact examined in CBA.

DeCorla-Souza (2000) raised issues that transportation planners must address in any CBA. The author stated that the common four-step travel demand models (trip generation, trip distribution, modal choice, and traffic assignment. See section 2.2.1) can significantly affect CBA. The author stated that most large urban areas in the United States are predicted to have severe congestion in the next 20 years, though he argued that this will never happen because people will travel at different times of the day (trip scheduling) or not travel at all (trip generation). Therefore, any alternative that includes building to reduce congestion has benefits that are likely to be exaggerated. The author suggests the following items need to be considered by planners:

1. *Time of day shifts (people leaving for work earlier to avoid peak hour travel). This will result in lower congestion levels;*
2. *Induced traffic (extra traffic generated by road development). This will reduce the average speed of vehicular travel and reduce benefits; and*
3. *Region-wide analysis must be included to avoid the narrow corridor level analysis that tends to overestimate benefits for road users.*

Overall, the author presents issues that planners must address when using CBA for determining the most suitable transportation option.

Henderson (1992) echoed the previous author's claim that CBA is misguided if time pattern travel changes are not accounted for. He argued that CBA leads to an overestimation of the benefits of capacity addition for roadways.

CBA is a method that has been applied to transportation projects in the past. Wright suggests that one of the weaknesses of CBA is the fact that those impacts that are not quantifiable (e.g. environmental, health) are either excluded from the analysis (as cited in Hau, 1994), or given reduced attention as compared to time travel savings. Because of this concern, and the fact that many health and environmental impacts have uncertain quantification, CBA is not seen as an appropriate approach to integrating economics, heath and the environment in transportation planning.

2.3.7 Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) is a form of assessment where effects given a monetary value, as well as those using subjective criteria, are provided to decision-makers and analysts for comparison (ECMT, 2001; OECD, 1997). The benefit of MCA is that it includes those impacts commonly excluded from Cost-Benefit Analysis. MCA has been applied to transportation decision-making and is used in France, Germany, Italy, New Zealand and the United Kingdom among other countries (ECMT, 2001; European Commission, 1996; McDermott, Toleman, & Lee, 1997). MCA is essentially a synthesis of environmental, economic, and social assessments combined into one overall assessment. The following are three articles found which utilize MCA with transportation infrastructure.

The MCA approach has been used in the United Kingdom under the slightly different name of multi-modal approach since 1998, in their appraisal of road projects. Price (1999) claimed that the multi-modal approach used in the United Kingdom (UK) came from the lack of satisfaction that arose from cost-benefit studies and the narrowness of environmental impact assessments. The author stated that the UK government was interested in a comprehensive framework to take into account five broad criteria:

1) *Environmental impact;*
2) *Safety;*
3) *Economy;*
4) *Accessibility; and*
5) *Integration.*

The heart of the multi-modal approach is the Appraisal Summary Table (AST), which is a one-page summary of the key impacts of a road or transportation option. The AST is based on data compiled in cost-benefit analysis, environmental impact assessments, and government regional offices. The approach uses qualitative and quantitative indicators to judge how each transportation option compares against each of the five broad criteria. Price concluded by giving an example of what the AST looks like. Overall this is a good overview of an MCA in an applied setting.

Glaister (1999) gave a more critical review of the multi-modal approach, stating that cost-benefit analysis is still the most important measure and it is included in the AST.

The author stated that the strength of using a comprehensive outlook to appraise road projects is also a weakness because of the multitude of stakeholders that need to be satisfied including government, engineers, economists, environmentalists, and motoring organisations. The author pointed out that the underlying theme to using the multi-modal approach has been to cast car dependency in a negative light, something that will not win over all stakeholders. Double counting is an issue in the multi-modal approach, but not in cost-benefit analysis if done properly. The author claimed that this virtue of CBA should not be ignored. Overall, Glaister suggests that the multi-modal approach is good, though needs refinement to be made better.

The European Commission (1996) reviewed CBA and MCA methods used in road construction projects in several European countries. The author stated that CBA employs more measurable and quantifiable impacts whereas MCA tends to involve a large degree of subjective assessment and judgement. Practical methods tend to fall somewhere in between these two extremes. The author suggested that the method used must be flexible enough to deal with a heterogeneous set of impacts because although some may be quantifiable, others cannot even be measured physically. This statement suggests that MCA is a more appropriate method than CBA.

Overall, it seems the MCA is an ideal method for considering all relevant impacts related to transportation infrastructure. This is because it has the flexibility of allowing different impacts whether they can be qualitatively or quantitatively assessed.

2.4 Framework Review Matrix

Now that the various approaches have been presented, it is necessary to identify which one of these is best suited to integrating health, environmental, and economic concerns into transportation planning. The following matrix, presented in Table 10, lists the type of framework in the rows, and criteria used to grade the frameworks in the columns. A checkmark placed in each column means that the framework meets that criterion, according to the author's assessment.

Table 10 Framework Review Matrix

	Disciplines used to complete	Understandable	Policy relevant	Long-term and short-term impacts	Examination of all impacts	Feasible to conduct within one year	Reliable	Community participation included
IAF	Public Health, Climatology, Meteorology, Economics			✓	✓			
HIA	Epidemiology, Public Health, Engineering, Transportation	✓	✓			✓		✓
EIA	Environment, Transportation, Engineering	✓	✓	✓		✓	✓	
SEA	Environment, Economics, Transportation, Epidemiology, Public Health			✓	✓	✓		✓
Ecohealth. Approach	Environment, Public Health, Geography			✓	✓	✓		✓
Cost-Benefit Analysis	Economics, Transportation, Public Health	✓	✓	✓		✓	✓	
Multi-Criteria Analysis	Economics, Environment, Public Health, Engineering, Transportation, Epidemiology	✓	✓	✓	✓			✓

Note: IAF – Integrated Assessment Framework
HIA – Health Impact Assessment
EIA – Environmental Impact Assessment
SEA – Strategic Environmental Assessment

2.5 Which Framework to use?

There is no ideal approach to use when examining a topic as broad as transportation and the interaction of transportation with health, environment, and economics. Multi-criteria analysis in appraising road projects and other transportation infrastructure is one of the most comprehensive and easy to understand of all the frameworks reviewed. The assessment framework developed in the next chapter will therefore use a multi-criteria approach, borrowing from work done in Europe and the United Kingdom.

The Ecohealth approach will be utilized when applying the multi-criteria framework to a case study in Edmonton, Alberta. The Ecohealth principles of transdisciplinarity, community participation, and gender will guide the application of the newly-developed assessment framework. The assessment framework, titled Integrated Impact Assessment Framework or IIAF, is presented next and it is argued that it best suits the task of integrating health, environment and economics to address transportation planning.

Chapter 3 Method I - Assessment Framework

Integrated Impact Assessment Framework (IIAF)

The major purpose in writing this thesis is the development of an assessment framework that can be utilized by decision-makers when deciding on transportation infrastructure. The assessment framework developed in this thesis uses the results from the approaches reviewed in section 2.3, as well as the impacts identified in section 2.2. The justification for the approach used, the impacts included, and an illustration and description of the assessment framework (titled the IIAF for Integrated Impact Assessment Framework) follows below.

3.1 Approach used for IIAF

Multi-criteria analysis (MCA) was the approach most closely followed in the development of the IIAF. MCA has a couple of important benefits in relation to other approaches reviewed. First, MCA can be seen as a most useful approach in assessing those impacts that result from an alternative, by its inclusion of quantitative measures where they are available and qualitative measures where they are needed for impacts that cannot be quantified monetarily. Second, MCA encapsulates the main features from the other approaches reviewed. For instance, where impacts can be monetized, it uses the philosophy behind Cost-Benefit Analysis to measure impacts on an equal basis. By including environmental impacts that occur at a local level, features of EIA are used, and where these impacts occur at a strategic or more global level, features of SEA are incorporated. Similarly, inclusion of health impacts incorporate main features in HIA. The MCA is therefore an appropriate method to combine a multitude of different approaches into a single framework.

One aspect typical of MCA that is not included in the IIAF developed for this thesis is weightings for each impact. In many MCAs, impacts that are thought to be more important than others would be given a higher weighted value. Because experts and local citizens most often assess qualitatively measured impacts, value judgements are made regarding their importance. It can be difficult for decision-makers to know what these

value judgements are (Bond & Brooks, 1997). Therefore, the information contained in the IIAF will be displayed with no weightings given for each impact. It will be up to the decision-makers involved to ascertain how much significance should be assigned to each impact. This can be aided by community participation and expert opinion, which should be conducted for any assessment. Consideration of each impact along with community participation, should allow consensus to be reached on transportation related decisions. The IIAF is presented in Table 11.

Table 11 Integrated Impact Assessment Framework (IIAF)

Option Title:			Cost of option:	
Category	**Impact**	**Quantitative Indicator**	**Qualitative Indicator**	**Data Source**
Health	Air quality	♦ Est. no. of air quality guidelines expected to be exceeded annually due to alternative ♦ Est. no. of people experiencing respiratory degradation from alternative and cost		♦ Air monitoring stations ♦ Epidemiologist
	Collisions	Est. no. of collisions occurring in network and cost of injuries/fatalities resulting	Likely impact on collisions in network	♦ Transport. Planning ♦ Police Dept.
	Noise	Est. no. of people exposed to noise above City guidelines and cost	Likely impact on noise levels	♦ Transport. Planning
	Fitness	No. of non-vehicular trips made	Likely impact on pedestrian and bicycling	♦ Transport Planning ♦ Stakeholders
	Stress levels		Likely impact on drivers stress levels	Stakeholders
	Community cohesion		Likely impact on community cohesion and barrier effect	Stakeholders
Environment	Climate change	Est. cost based on CO_2 emissions		Transport. Planning
	Biodiversity	♦ No. of wildlife road kills expected ♦ Amount of habitat land area loss	Potential effect on displacement of plants, animals in area	Environment Screening Review
	Water quality		♦ Potential for water contamination in area ♦ Risk of spills from hazardous goods	Environment Screening Review
Economic	Traffic volume	Daily average volume for network		Transport. Planning
	Journey times	Est. no. of minutes saved on journeys through network		Transport. Planning
	Real estate values		Likely impact on real estate values	Real Estate Board
Social /Cultural	Gender		Likely differential impact on both genders	Transport. Planning Stakeholders
	Equity		Likely impact on public transit accessibility	Transport. Planning Stakeholders

3.2 Categories in the IIAF

The IIAF is meant to be a summary sheet of relevant information regarding each transportation alternative. The top line of the IIAF allows for the transportation alternative's title, such as the status quo, or upgrade of roadway facility. Next to this would be the overall cost for the alternative that, for a project, would include all construction and maintenance-related expenses like materials, labour, land and property acquisition costs, in addition to projected repair, signage, and enforcement costs.

The four main categories in the IIAF are listed on the left-hand column:

(1)Health;
(2)Environment;
(3)Economic; and
(4)Socio - Cultural

These four categories correspond to the bottom section of the impact diagram listed in section 2.2 of this thesis. Within each of the categories are specific impacts that come from the impact diagram in section 2.2 and are explained in the next section.

3.3 Impacts Included in the IIAF

It is important to note that many impacts can be included in an assessment framework and the decisions about what impacts to include will vary depending on local context. The impacts included in the IIAF do not include all the impacts possible, but rather illustrates those that were thought to be significant based on the published literature. Different impacts can be incorporated into the framework for different local contexts.

3.3.1 Health

The health category includes five impacts:

1) Air quality;
2) Collisions;
3) Noise;
4) Fitness; and
5) Community cohesion.

For illustrative purposes, the air quality impact alone, analysing hospitalization and mortality rates, will be examined closely for a case study example presented in the next chapter.

3.3.2 Environment

The environment category includes three impacts:

1) Climate change;
2) Biodiversity; and
3) Water quality.

3.3.3 Economic

The economic category includes three impacts:

1) Traffic volumes;
2) Real estate values; and
3) Journey times.

Traffic volumes are the main drivers of many other impacts and they are included in this category out of necessity.

3.3.4 Socio - Cultural

The socio - cultural category includes two impacts

1) Gender; and
2) Equity impacts.

To properly measure the effect that a transportation alternative has on each impact, it is necessary to have indicators of the effect. These indicators are explained in the next section and are divided into quantitative and qualitative indicators.

3.4 Quantitative Indicators

Many different indicators can be used to measure each impact included in the IIAF. The utility of the IIAF is that local context can be taken into account when the indicators are included.

Time frames are crucial when examining the results of the quantitative indicators because most transportation infrastructure is expected to last many years into the future. For the IIAF, the indicators will primarily look at the difference resulting from the project-opening year to 15 years into the future.

Within the air quality impact, two indicators are included. These are the numbers of exceedances of the ambient air quality guidelines, and the number of people experiencing respiratory degradation with the economic costs associated. The collision impact includes the estimated number of collisions occurring in the road network and the cost of injuries and/or fatalities resulting. The noise impact includes human exposure to noise over and above the regions noise guidelines. The fitness impact includes the number of non-vehicular trips made as a result of the transportation alternative. Climate change impact includes the cost of carbon dioxide (CO_2) emissions from the road network because CO_2 is a main greenhouse gas. Biodiversity indicators include number of road kills, and the amount of natural habitat lost as a result of the policy or project. Economic indicators include the daily traffic volume on the road network, the estimated number of minute's saved, and likely affect on real estate values in the area of the project or policy.

3.5 Qualitative Indicators

Qualitative indicators are needed when quantitative indicators are not measurable or do not exist at all. In many cases, qualitative indicators can be derived from expert and community opinion for the expected effects of a transportation alternative. For the IIAF, the following list is an example of qualitative indicators. For the fitness impact, the likely impact the alternative has on pedestrian and bicycling activity is a qualitative indicator. For community severance, the qualitative indicator is the likely impact the alternative has on community stress levels and the barrier effect. For water quality, qualitative indicators are the risk of spills from hazardous goods and likely impact on fish habitat. For the gender impact a qualitative indicator is the likely impact the alternative has on either gender. Finally, the equity impact has a qualitative indicator of the likely accessibility to public transport by people from the alternative.

A summary of the results from each indicator of an impact can be analysed for each transportation alternative. In this way, the IIAF is meant to provide a summary sheet of the significant impacts associated with transportation alternatives and supporting

documentation is required for each of the impacts and indicators included in the framework where lengthy calculations may be needed. The supporting documentation is beyond the scope of this thesis, but an examination of air pollution effects is presented.

3.6 Applying the IIAF

The Ecohealth approach is used to test, on a very limited basis, the usefulness of the IIAF, for a case study of a roadway widening scheme in Edmonton. The three Ecohealth principles of community participation, transdisciplinarity, and gender, are incorporated into the testing of the IIAF. Community participation is included in the form of a pilot study, where various stakeholders' perceptions are included to confirm the significance of the impacts included in the IIAF and as a resource for qualitative indicators in the framework. Transdisciplinarity is shown by including experts from a wide range of backgrounds in the pilot study and because the IIAF itself is composed of impacts from many different disciplines in a new approach. Finally, gender issues are included using a question from the pilot study. Methods for the pilot study are shown in Chapter 4, and the results are shown in Chapter 6.

Additionally, one of the quantitative indicators in the IIAF, traffic related air pollution health effects, is tested using the case study in Edmonton, Alberta. The method and results for the testing of this indicator are shown in Chapters 5 and 7.

A summary of the results from the case study, is shown in Chapter 8. The limited application of the IIAF is emphasized, since proper decisions about the full effects from transportation options can only be understood once all of the indicators are addressed.

Chapter 4 Method II - Pilot Study

Background to the city of Edmonton, Alberta is given in the following section, along with an examination of a local transportation issue. In order to understand transportation issues that impact local citizens, input from them as well as experts in the field is needed. In the final section of this chapter, a review of the community participation methods used for this study is presented. The community participation aids in verifying the impacts that should be included in any assessment framework.

4.1 Local Setting

The City of Edmonton is a growing metropolitan city located in northern Alberta. The census metropolitan area population is approximately 827,000 for the year 2000, and includes the city of St. Albert, Strathcona County and the Leduc area. Population demographic information for Edmonton is listed in Table 12. As can be seen, Edmonton is very close to the Alberta and Canadian averages in all age groups.

Table 12 Age Group Comparison

	Edmonton				Alberta	Canada
Age Group	**Male**	**Female**	**Total**	**% of total pop'n**	**% of total pop'n**	**% of total pop'n**
0-4	30,320	29,380	59,700	0.07	0.07	0.07
5-14	66,570	62,845	129,415	0.15	0.16	0.14
15-19	30,765	29,740	60,505	0.07	0.07	0.07
20-24	30,235	31,010	61,245	0.07	0.07	0.07
25-54	199,920	200,725	400,645	0.46	0.46	0.45
55-64	33,295	33,650	66,945	0.08	0.08	0.09
65-74	23,560	27,065	50,630	0.06	0.06	0.07
75+	12,285	21,230	33,515	0.04	0.04	0.05
Total	426,960	435,640	862,595	1.00	1.00	1.00

Source: Statistics Canada (1996)

Ethnic status information is listed in Table 13. Immigrant and aboriginal population percentages in Edmonton are slightly higher than the Canadian average.

Table 13 Ethnic Status Comparison

	Edmonton				Alberta	Canada
Ethnic Status	**Male**	**Female**	**Total**	**% of total pop'n**	**% of total pop'n**	**% of total pop'n**
Non-immigrant	344,190	347,420	691,610	0.81	0.84	0.82
Immigrant	77,055	81,315	158,375	0.19	0.15	0.17
Non-resident	2,030	2,215	4,245	0.00	0.00	0.01
Aboriginal	15,515	17,305	32,825	0.04	0.05	0.03
Total	423,275	430,950	854,225	1.04	1.05	1.03

Source: Statistics Canada (1996)
Note: Aboriginal figures are not included in the total columns but are presented for comparison purposes. Also, total population figures do not correspond from Table 12 to Table 13.

Table 14 shows that the average annual income for Edmonton residents is between the Canadian and Albertan averages.

Table 14 Income Comparison

	Edmonton			Alberta	Canada
	Male	**Female**	**Total**	**Total**	**Total**
Average Annual Income	$32,224	$19,164	$25,728	$26,138	$25,196

Source: Statistics Canada (1996)

4.2 Transportation Statistics for Edmonton

A background on selected transportation related statistics for Edmonton, is displayed in Table 15. Note that the population figures are different than those presented in Table 12. The table divides Edmonton into Edmonton City, which includes the central core of the city and surrounding suburbs, and Edmonton Region, which includes Sherwood Park, St. Albert, and two farther regions. Edmonton CMA is the summation of Edmonton City and Edmonton Region. A comparison of the two groups is given in Table 15 according to various measures with some statistics only being available for Edmonton City. As can be seen from the table, residents of Edmonton Region are more likely to have household incomes greater than $60,000 annually, and have more automobiles per household than Edmonton City residents. The combination of greater income and automobiles contributes to Edmonton Region residents making more trips per day than Edmonton City residents. Income is correlated with the number of trips a person

makes since those individuals with less than $15,000 annual income travel far less in a day (approximately six trips) than those whose annual income is greater than $60,000 (approximately 13 trips). Residents living in Edmonton City generally have a smaller household size, are less likely to own an automobile, have fewer drivers per household, make fewer trips, and are more likely to hold a transit pass than those living in the Edmonton Region.

Table 15 Selected Transportation Statistics in Edmonton City and Region

	Edmonton City	**Edmonton Region**	**Edmonton CMA**
Population	628,383	232,495	860,878
Household income annually greater than $60,000	24.8%	40.4%	
Employed full time	37.0%	37.7%	
Retired	11.8%	7%	
Persons per household	2.56	3.17	2.70
Automobiles per household	1.58	2.21	1.72
Bicycles per household	1.49	2.17	1.65
Licensed drivers per household	1.72	2.11	
Transit pass	14.0%	2.0%	
Daily person trips per household	9.17	11.09	
Daily person trips per household with annual income less than $15,000	5.58	5.91	
Daily person trips per household with annual income greater than $60,000	12.63	13.11	
Percentage of walking trips made in a day	11.5%	6.7%	
Automobile occupancy persons per automobile	1.41	1.45	

Source: Applications Management Consulting (1995)

Table 16 shows that the automobile is the fastest form of transportation in Edmonton by virtue of the average driver trip length being eight kilometres with an average time of 20 minutes. This is faster than either transit or walking modes of transit.

Table 16 Selected Transportation Statistics for Edmonton City

Average trip length	6.7 km
Average trip time	19.7 minutes
Average auto driver trip length	8.1 km
Average auto driver trip time	19.5 minutes
Average transit trip length	6.9 km

Average transit trip time	35 minutes
Average walk trip length	1.2 km
Average walk trip time	14.9 min.

Source: Applications Management Consulting (1995)

4.3 Transportation Policy in Edmonton

The City of Edmonton produced a Transportation Master Plan that was a vision for transportation in Edmonton up to the year 2020. The impetus for this plan was the forecasted population growth for metropolitan Edmonton, expected to increase by one third to 1.17 million in 2020 (City of Edmonton, 1998). In congruence with the population growth was the fact that the city was predicted to continue its decentralized pattern of expansion in the suburban areas of the city. Hence the city felt it necessary to have a planning document to guide them in future transportation decisions.

In the Transportation Master Plan report, the city identified the need to balance private automobile use with improved public transit, bicycling and pedestrian provisions. It was noted that no roadway improvements would occur inside the "inner ring loop", an area roughly corresponding to the Edmonton City classification used in Table 15. Instead, all transportation improvements in this city core area would focus on public transit, bicycle and pedestrian links. For the outer areas, roadway improvements were thought to be needed to facilitate the cross-town traffic that was expected to increase because of the more decentralized pattern of the city with more rapid growth occurring in the south west portion of the city. As part of the effort to provide capacity for cross-town traffic, Whitemud Drive was selected as part of the inner ring road because it is a key roadway that links western and southern portions of the city. While most of Whitemud Drive is six lanes of through traffic, there is a section between 122nd street and 149th street that provides only four lanes of through traffic. Because of this narrowing of Whitemud Drive, congestion arises, especially during the morning and evening peak hours. Therefore, the City of Edmonton planned to widen Whitemud Drive by one lane in each direction, including expanding the Quesnell Bridge to eight lanes from six lanes.

4.3.1 Whitemud Drive Planning Process

Although not legally required, stakeholder involvement is critical to the successful planning for roadway transportation projects in the City of Edmonton (Menzies, 2002). The City of Edmonton, through Stantec Consulting, embarked on a large scale community participation process that spanned from May, 1999 to May, 2001 (Stantec Consulting, 2001). Ten stakeholder meetings and six open house meetings occurred over that time period. The purpose of the community participation process was to identify the most preferred alternative for the Whitemud Drive widening including the Quesnell Bridge. The result of the process ended in the preferred alternative, as determined by the stakeholder and open house group, of adding one lane to Whitemud Drive between 122nd street and 149th street including the Quesnell bridge, as well as building a separate bridge for pedestrians and cyclists. One group of citizens were not satisfied with the City's decision and objected to the fact that public health concerns were not adequately addressed in the planning process. This group of citizens were called the West Edmonton Transportation Coalition (WETC) and consisted of members from eight West End communities in the Jasper Place area.

The City of Edmonton did respond to WETC concerns by formalizing a downstream assessment study that examined the impacts that a widened Whitemud Drive would have on the neighbourhoods adjacent to the Whitemud. The study focused on air quality and health concerns, safety, traffic noise, traffic shortcutting, neighbourhood severance, and impacts on property values. This report failed to appease WETC concerns because no significant detrimental community impacts were predicted from the widening of Whitemud Drive. However, air quality concerns were not addressed specifically, because needed Alberta Environment data were not available on time.

The community consultation process by the City of Edmonton was thorough, although it could be seen as being narrow in scope. That is, Whitemud Drive had already been identified as a key component of the Transportation Master Plan and the City of Edmonton was reluctant to examine other options that did not include widening/upgrading the roadway in this corridor. The public participation process

facilitated by Stantec Consulting was an exercise to see what modifications to the project the community wanted to make, but did not include looking at other transportation alternatives other than widening, like providing designated public transit lanes on Whitemud Drive or Light Rail Transit. This lack of consideration of other transportation alternatives and the fact that public health concerns were not adequately integrated into the decision-making process, were what seemed to present problems for the WETC and other community members.

4.4 Community Participation Pilot Study

To adequately address the concerns of the citizens involved, an impact assessment framework has to include those impacts that the community, experts, and decision-makers feel are important. The information gathered from the community participation component of this study was used to verify the impacts that were included in the IIAF, and to include expert knowledge of one of the impacts; air pollution health effects. Stakeholder input from six different groups was sought for this study to provide a balanced viewpoint on transportation in Edmonton and the Whitemud Drive widening in particular.

4.4.1 Stakeholder Groups

The first stakeholder group that was contacted for this study was local citizens involved in the West Edmonton Transportation Coalition (WETC). Input from this group was sought because of their close involvement with the study and their opposition to the Whitemud widening.

The second stakeholder group included was local citizens who live in the same Jasper Place community as WETC members, but who were not a part of WETC. This group was included because their viewpoints may be different from those associated with WETC (i.e., they may be more in favour of widening Whitemud Drive).

The next four stakeholder groups could be considered "expert" groups. First, representatives from the City of Edmonton's Transportation Planning Branch of the Transportation and Streets Department were included because employees working in this office are responsible for the overall planning of transportation infrastructure. Employees working here were instrumental in the planning of the Whitemud Drive widening project and had intimate knowledge of it.

Second, officials at Alberta Environment's Air Quality and Data Management Department are responsible for air quality monitoring for the City of Edmonton, and their expertise was sought to understand how vehicular traffic impacts on air quality. Alberta Environment was also familiar with the Whitemud Drive project and had set up air monitoring stations close to the roadway.

Third, representatives of Capital Health Authority's Environmental Health Division were asked to participate because of their expertise in linking air quality to human health. Employees here were also aware of the Whitemud Drive issue because they had been in consultation with citizens and transportation officials.

Finally, Edmonton City Councillors, who are the final municipal decision-making body in the city, were contacted to participate in the study. This group was asked to participate because of their unique decision-making position on major transportation matters for Edmonton.

Owing to time and resource considerations, these six groups were the only stakeholders contacted for this pilot study. There are many other groups that have a stake in urban transportation issues, including trucking companies, homeowner associations, municipal economic development authorities, railway corporations, parks officials, and the general public. During the City of Edmonton's Whitemud planning process, effort was made to bring together these stakeholder groups, and information gleaned from these documents (Equus Consulting Group, 2001) will supplement any of the findings presented in this thesis.

4.4.2 Instrument Used

Data needed from the stakeholder groups had to be timely in fashion, yet in-depth enough to not constrict participants in their answers. With this in mind, a questionnaire was developed that consisted of both closed-ended and open-ended sections. This mixed methodology was chosen because it can expand the scope and deepen the information collected in a study (Sandelowski, 2000). The closed-ended or quantitative responses allowed timely data to be collected, and the open-ended or qualitative responses allowed more depth to be received.

The questionnaire was divided into three sections. Sections one and two were given to all six stakeholder groups, and included close ended demographic questions and open-ended questions. Comparison of responses between groups was a goal of the research and sections one and two were key in facilitating the comparisons. The purpose of the questions in sections one and two are given in Tables 42-47 in Appendix 1. Each stakeholder group was given a different section three, more appropriate to that group. The purpose of questions in section three for each stakeholder group are also given in Appendix 1.

4.4.3 Access to Groups and Sampling Method Used

Each of the stakeholder groups contributed to the development of the instrument used. An individual was contacted within each stakeholder group who was asked to complete the questionnaire and to suggest changes to make it clearer and more understandable. This process of pre-testing the questionnaire was invaluable since it was a new and untried instrument and it was necessary to receive feedback on it. Only one iteration of pre-testing within each group was feasible given the small samples and the time and resources provided.

The initial contact individual acted as a "gatekeeper", allowing the researchers (the principal investigator and the author of this thesis) access to other individuals within the stakeholder group. The form of this access was a list of names and telephone numbers of the potential participants. This type of sampling method is called snowball

sampling, where one individual names others who would be likely candidates for the research (Bernard, 2000). Snowball sampling is useful in the conduct of pilot studies. The following section outlines the method of contact for each of the stakeholder groups.

One of the leaders of the City of Edmonton's Transportation Planning branch was contacted to pre-test the questionnaire. This individual was familiar with the Whitemud widening proposal and was thought to be a key informant in the process. This individual then suggested names of other employees who would be useful in completing the questionnaire. The other individuals were then contacted by telephone and a time was arranged to meet with them individually to administer the questionnaire. Note that if an individual did not return telephone calls after three tries, no further attempts were made to contact them. This applies to all stakeholder groups.

One of the key people associated with Alberta Environment's monitoring stations was contacted to pre-test the questionnaire. This individual was familiar with air monitoring and also with the Whitemud Drive widening and was able to suggest other individuals who would be useful to complete the questionnaire. This list of people was split into those with more technical knowledge and those who were in a position of decision-making authority. These individuals were contacted by telephone and a time was arranged to meet with them individually to administer the questionnaire. Where times were not convenient, the questionnaire and covering letter were mailed to the individuals in self-addressed stamped envelopes. Completed questionnaires were then received in the mail.

One of the leaders of the Capital Health Authority's Environmental Health division was contacted to pre-test the questionnaire. This individual was familiar with the Whitemud Drive widening and was able to suggest other names and phone numbers of employees who would be useful for the study. These individuals had knowledge of air quality issues and their associated health implications and were thought to be useful participants in the survey. The individuals were contacted by telephone and times were

arranged to meet with the three of them collectively to administer the questionnaire. A fourth individual was contacted and completed the questionnaire individually.

City Councillors were contacted in a different way from the other stakeholder groups. One Councillor, who represented the ward of the principal investigator was contacted via electronic mail to ask if he would be willing to pre-test the questionnaire. The Councillor agreed to pre-test the questionnaire, but made changes only to section three since sections one and two had already been officially tested at this point. The Councillor then suggested that the best method of contacting the other 11 Councillors was to write their executive assistants a covering letter explaining the purpose of the questionnaire and ask for their participation. The covering letter was delivered, and a follow-up telephone call to the executive assistants was placed. Times were arranged with those Councillors that were available to meet with the researchers personally. Not all of them were able to meet individually, so a questionnaire was dropped off at their office with a self-addressed stamped envelope and this was mailed back when they completed the questionnaire.

For the WETC group, one leader who had attended earlier supervisory committee meetings, was contacted to pre-test the questionnaire. The individual then arranged a meeting with several other WETC members to attend an evening meeting. The questionnaire was administered to the group by the researchers.

Finally, a leader of a local community group located in Jasper Place was contacted to pre-test the questionnaire. This individual then arranged for the researchers to attend an executive meeting to administer the questionnaire to the group.

The covering letters given to Alberta Environment and City Councillors are displayed in Appendix 2. The six different questionnaires, along with the information letters are presented in Appendix 3. The results of the survey are given in Chapter 6.

Chapter 5 Application of IIAF - Air Quality

The IIAF developed in Chapter 3 is applied in this chapter to a limited degree because only one impact, that of health effects resulting from air pollution, will be examined. The impact that four different transportation scenarios in the Whitemud corridor will have on air quality and human health will be analysed using the indicators:

1) Number of exceedances of air quality guidelines; and
2) Number of respiratory conditions expected and costs.

5.1 Driving force – Pressure – State – Exposure – Effect – Actions (DPSEEA) Model

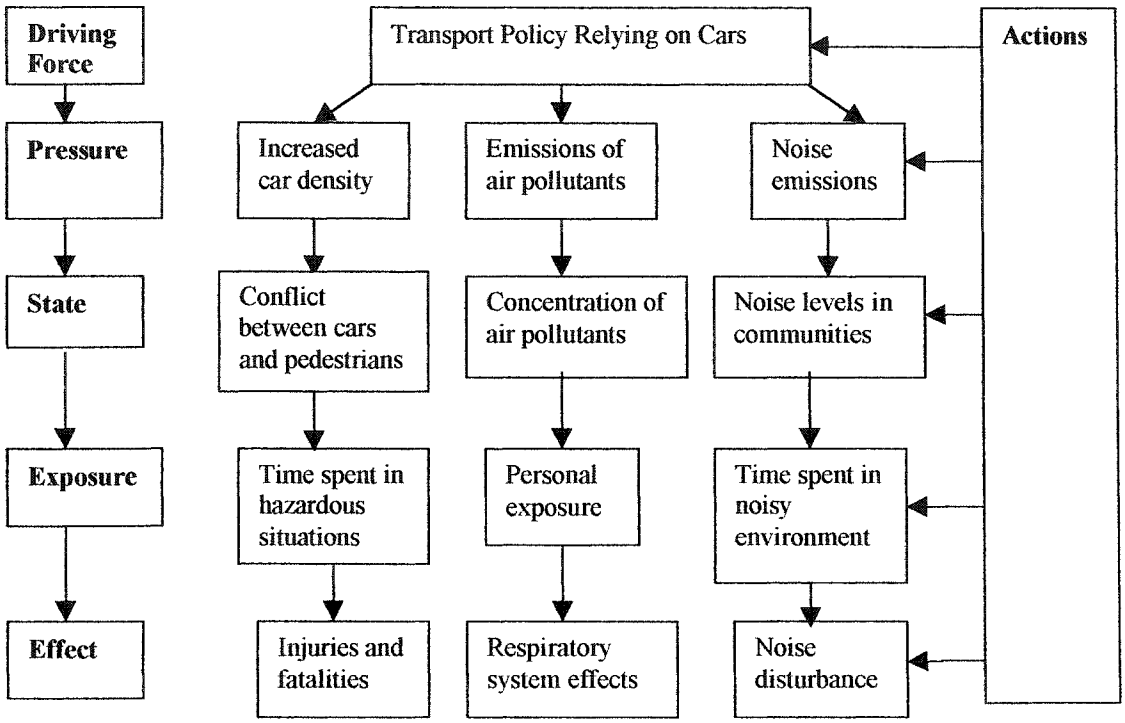
When assessing the impact on human health caused by air pollution from traffic, it is useful to refer to a model to understand the complexities involved. The DPSEEA model is most useful in explaining how pollution from automobiles can cause human health effects. The DPSEEA framework was developed with assistance by the WHO, United Nations Environment Programme, and the United Stated Environmental Protection Agency (Corvalan, Nurminen, & Pastides, 1997). The framework conceptualizes the environment-health chain by making it useful for the study of many environmental factors. The DPSEEA acronym is explained in Table 17:

Table 17 DPSEEA Framework Explained

D	Driving Force	e.g. population growth, technology, economic development
P	Pressure	e.g. the release of pollutants into environment
S	State	e.g. state of the environment is modified from air pollution
E	Exposure	e.g. people have to be present at the time and place of the hazard to be affected
E	Effects	e.g. health effects like increased mortality and morbidity
A	Actions	e.g. lifestyle changes that necessitate policy intervention

An example of the DPSEEA model is shown in Figure 3 and has been replicated from a previous work (Racioppi, 2001). Three separate effects are addressed in this illustration: injuries, respiratory effects and noise.

Figure 3 Example of DPSEEA from Racioppi (2001)



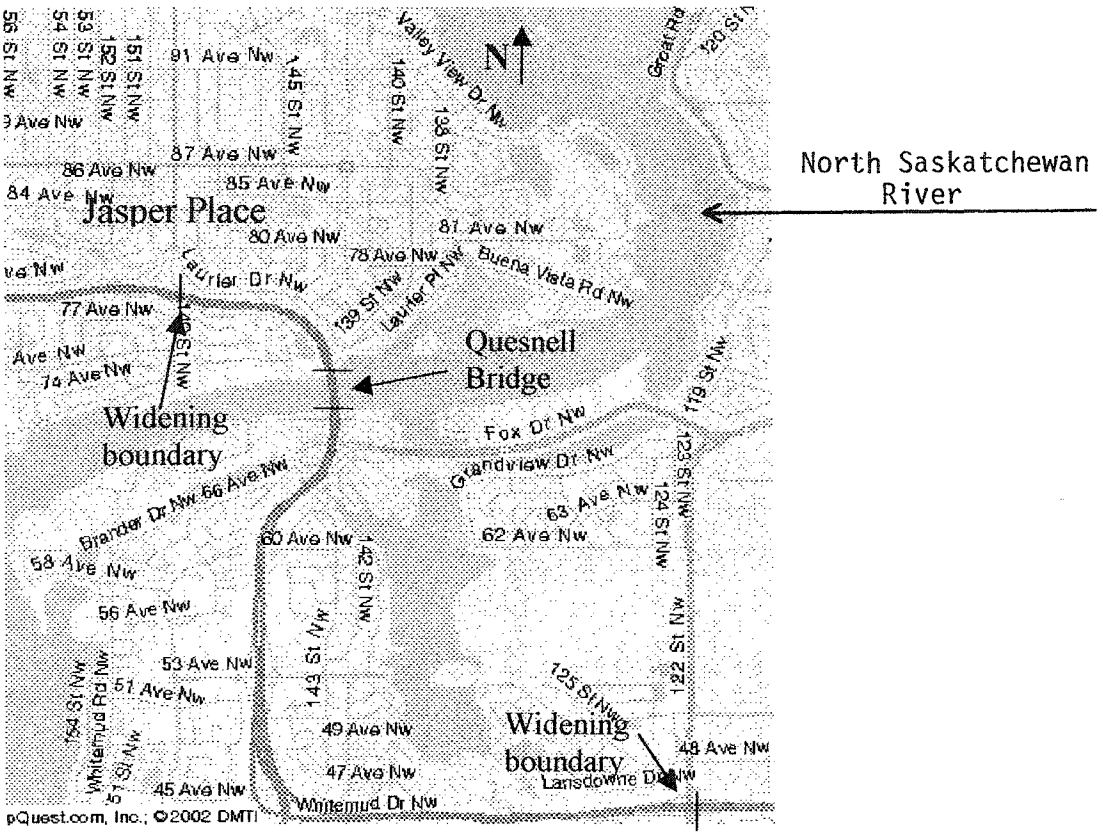
The DPSEEA model is a useful illustration of the cycle of environmental hazards, from driving force through to actions. It should be seen as an improvement over the similar DPSIR model (European Environment Agency, 1999), which leaves out exposure in its model. Exposure is key when looking at health impacts because people have to be exposed to a pollutant before health is affected. The DPSEEA model is a sound illustration of environmental effects. However, a shortcoming is that is can be difficult to differentiate between a Pressure and a State. Regardless, the theoretical basis it provides is useful for understanding the complexity surrounding air pollution health effects.

5.2 Spatial Analysis

When examining air quality impacts on health derived from transportation, it is necessary to choose a geographic area. Air pollutants from transport have impacts at the local, regional, and global level (OECD, 1997b). Therefore, a decision about "level of analysis" must be made. For this impact in the IIAF, a local level of analysis will be used, partly because regional and global levels of detail are covered under the climate change impact in the IIAF. Once the local level of analysis is chosen, it is necessary to

analyse one area of a city. In this case, the local level examined will be the area of Jasper Place in Edmonton. This area, and the entire area of the Whitemud widening, is shown in Figure 4.

Figure 4 Whitemud Drive Study Area



Source: Mapquest, 2002

Many areas of the city of Edmonton could have been chosen for this analysis. However, the Jasper Place area was selected because it borders Whitemud Drive to the north, and was the area of the city where the most vocal community concern had been raised about health and environmental effects resulting from the widening of Whitemud Drive. This was also the area where Alberta Environment had set up its mobile air monitoring laboratories to measure ambient air levels surrounding Whitemud Drive.

Jasper Place has an age distribution similar to the City's, except for the group aged 65 and over which comprise 16% of Jasper Place residents versus 10% for the City of Edmonton (City of Edmonton, 2002). Jasper Place residents have an average

household income level of $50,884 which is higher than the City average of $46,697, though their education levels are equal to the City average (City of Edmonton, 2002). This information is useful when examining community health status because higher income and education levels generally correspond to better health status, though older age is associated with higher health risks.

5.3 Pollutant Analysis

Another choice when analysing air quality is selecting a pollutant. Several pollutants from motor vehicle transport are relevant to local level analysis, including Pb, SOx, CO, CO_2, NO_x, VOC, O_3, and PM (ECMT, 1990; OECD, 1996; Eyre et al. 1997; OECD, 1997b; Viegi & Enarson, 1998; Pickrell, 1999). PM is seen as a useful indicator of several sources of outdoor air pollution primarily because of the complexity of this component owing to its air pollution mixture (Kunzli et al, 2000; Aunan, 1996). Transportation-related particulate matter comes from the incomplete combustion of fossil fuels, from tire contact with the road, brake lining strewn off vehicles when brakes are applied, and from the interaction of several other air pollutants (Colvile, Hutchinson, Mindell, & Warren, 2001). Particulate matter has been well-published in the literature concerning its association with human health effects, (Environment Canada & Health Canada, 1999; COMEAP, 1998; WHO, 2000). Relying on these and other studies, it was decided for this thesis that particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) would be the pollutant examined. The limitation in this decision is that the interaction of a number of different air pollutants will not be examined, so that any health-related effects calculated in this analysis would likely be underestimated.

To assess transport's contribution to particulate matter levels in a local area, two approaches can be used. The first is a top down approach that seeks to determine the pollution source in order to calculate environmental damage (Spadaro & Rabl, 2001). While this type of analysis may lend itself to easier economic quantification of health effects, it is not entirely realistic to expect that pollution emitted from the source is of the same magnitude as that in the outside air. Calculating health effects using the ambient or outside concentration of a pollutant is termed the bottom up approach. The

concentrations of pollutants in the air is generally considered more important than the actual levels of pollutants emitted as measured in the top down approach (OECD, 1997b). With help from emission inventories, which essentially list the chemical properties of the $PM_{2.5}$, the source of an air pollutant can be ascertained (e.g., from vehicles, industrial sources and wood burning). One has to acknowledge that transport's contribution to $PM_{2.5}$ may not be easily determined because a significant portion of PM_{10} in an urban area can come from distant point sources (Colvile et al., 2001). However, for areas near busy roadways, $PM_{2.5}$ levels are significantly affected by traffic volume.

5.4 Air Quality in Edmonton

A prior study had been done in the Edmonton area measuring air quality. Between 1985 and 1995, $PM_{2.5}$ concentration decreased by 4.7% per year in the Edmonton area (Cheng, Sandhu, Angle, & Myrick, 1998) and the mean $PM_{2.5}$ level in 1995 was 11.2 $\mu g/m^3$. Approximately 60% of fine particulate matter in Edmonton comes from transportation and road dust (Cheng et al., 1998), which is consistent with one finding (ECMT, 1990), though higher than another (Environment Canada & Health Canada, 1999). It is important to note that concentrations for $PM_{2.5}$ have been decreasing while the vehicle kilometres driven has increased during a similar time period (Pembina Institute, 2001).

For this study, air quality monitoring measurements were taken from Alberta Environment's permanent station in Northwest Edmonton. The results of the air quality estimations of exceedances of air quality guidelines and number of expected respiratory conditions are presented in Chapter 7. In the next chapter are the results from the pilot study.

Chapter 6 Pilot Study Results

Questionnaire Results

The purpose of the community participation pilot study was to capture some of the context about how transportation decisions are made in the City of Edmonton. Input was sought about what impacts were thought to be important when examining local transportation infrastructure, and more specifically with roadway widening. Six separate stakeholder groups were contacted for this study and each group participated by completing a questionnaire. Table 18 lists the groups, the number of participants as suggested by our contacts within each group, and the actual number of individuals who completed the questionnaire.

Table 18 List of Participant Groups for Questionnaire

Stakeholder Group	Number suggested by pre-test contact	Final number of participants including pre-test
City of Edmonton Transportation Planning Branch	6	4
City of Edmonton Councillors	11	8
Alberta Environment	7	6
Capital Health Authority	4	5
Local citizens in WETC	10	7
Local citizens not in WETC	11	6
Total	48	36

The results of the questionnaire include the pre-test responses. Where the questions changed significantly between the pre-test and the final version used, the pre-test responses were excluded. The response rate was 63% (30/48), not including the six participant pretests. The discrepancy between the suggested number and actual number can be attributed to many factors. One factor is that some individuals declined to return telephone calls, or declined participation outright. One reason given for declining participation was that the participant did not feel that he/she had adequate knowledge of the subject. Another factor was that for the community groups, some people did not show up, and there was no method for contacting these individuals. Those individuals

outside the community groups who did not respond to at least three callbacks were not attempted again.

The timelines for the questionnaire are given in Table 19. The time from the development of the questionnaire to the analysis of the data took approximately six months.

Table 19 Questionnaire Timeline

Stage	Time Period
Development of questionnaire	November-December 2001
Ethics approval	January 2002
Pre-test with changes	January-February 2002
Data collection (administering questionnaires)	February-March 2002
Analysis	March-April 2002

The following paragraphs list the results from each question of the questionnaire. Where appropriate, comparisons between the different stakeholder groups are given.

6.1 Results Sections One and Two

The results of sections one and two of the questionnaire will be analysed first, followed by section three for each stakeholder group. The results will be analysed qualitatively and quantitatively depending on the type of question. It should be noted that the results from such a small sample size can not be generalized to other populations and this limitation is important. However, the results from this small group are useful because a sampling of such diverse groups has, to the researcher's knowledge, never been done before and this pilot study may lead the way for other larger-scale studies. In the following tables, the total percentages are shown as 100%, but the totals may be different because of rounding error.

There were many more males than females that filled out the questionnaire as shown in Table 20. This can happen when a snowball sampling method is used where the researcher has minimal control over the participants selected. It is interesting to note that out of the 16 participants from Alberta Environment, Capital Health, and City of Edmonton Transportation Planning, only one was female.

Table 20 Gender of Participants

Sex	Number of Participants	Percentage
Males	28	78
Females	8	22
Total	36	100

The majority of participants were those from age 46 to 65 years of age as illustrated in Table 21. Those participants from the non-WETC community group were the youngest of any group with three of the nine being in the 36-45 age category and two of the three being in the 26-35 category.

Table 21 Age of Participants

Age group	Number of Participants	Percentage
25 years or less	0	0
26-35	3	8
36-45	9	25
46-65	21	58
65 years and over	3	8
Total	36	100

Most participants had a university or graduate/postgraduate degree (25 out of 36) as shown in Table 22. This can be attributed to the high number of professionals and civic leaders that were sampled, in which 19 of these 23 participants had at least a university degree. Interestingly, many community participants had at least a university degree (6 of 13).

Table 22 Highest Level of Education Completed by Participants

Education level	Number of Participants	Percentage
Less than high school	0	0
High school	4	11
Diploma	7	19
University Degree	8	22
Graduate/Postgraduate	17	47
Total	36	100

Question four of the questionnaire asked whether the participants felt that congestion on Whitemud Drive between 122nd street and 149th street was a problem. The pretest responses are included in this analysis even though the wording changed from

159th street to 149th street. This is not seen as a major change since most congestion happens between 122nd and 149th streets. A majority of those asked said congestion was a problem (26 out of 36), as shown in Table 23. This response was expected given answers in an earlier questionnaire where congestion and high traffic volume was most often listed as a problem on Whitemud Drive (Equus Consulting Group, 2001). A large portion of those who said congestion was not a problem were from the WETC (3 out of 4).

Table 23 Is Congestion a Problem on Whitemud Drive?

	Number of Participants	Percentage
Yes	26	72
No	4	11
Don't know	4	11
No Answer	2	6
Total	36	100

Question five asked if those respondents who said that congestion was a problem in question four, then what methods would they propose to reduce congestion on Whitemud Drive. In this question the respondents could list more than one method, and a slight wording change was made from the pretest to the final version to acknowledge this. The most suggested method to reduce congestion was to widen the roadway or upgrade it, followed by providing alternate routes and improved public transit, as illustrated in Table 24.

Table 24 Suggested Methods to Reduce Congestion on Whitemud Drive

Methods to reduce congestion	Number of Responses	Percentage
Widen Whitemud Drive	16	34
Use alternate routes	12	26
No answer due to Question 4 response	6	13
Improved public transit	5	11
Improved on-off ramps / widen shoulder	2	4
Transportation Demand Management	1	2
Car pooling	1	2
No answer	1	2
Straighten curves before bridge	1	2
Increase speed limit	1	2
Don't know	1	2
Total responses	47	100

For questions six through eight respondents were asked to consider Whitemud Drive in its current state, that is, not widened. The responses were categorized into major groups and are presented in the following tables.

Question six asked if respondents had any concerns about how Whitemud Drive affects the environment if at all. The range of concerns are displayed in Table 25, with the two most often mentioned environmental concerns being air and noise pollution. Noise pollution was one impact that came up as a major concern in a previous study (Equus Consulting Group, 2001).

Table 25 Environmental Concerns with Whitemud Drive

Environmental concerns	Number of responses	Percentage
Air pollution	17	35
Noise pollution	15	31
No concerns	5	10
Generic environmental concerns	3	6
Water pollution	3	6
Wildlife / greenspace	2	4
Excess use of fuel	1	2
Community separation	1	2
Concentration of fluids on roadways	1	2
Total responses	48	100

Question seven asked if respondents had any concerns about how Whitemud Drive affects people's health if at all. Air pollution health effects were of most concern, followed by injuries from collisions and noise effects as displayed in Table 26. As one City Transportation Planner assessed:

> *There is a relationship between vehicle emissions, ambient air quality, outdoor and indoor air quality levels, people's personal exposure to air, and human health. Therefore, use of Whitemud at some level affects human health.*

In a previous study, safety and noise considerations were important considerations for local residents and air quality not as much (Equus Consulting Group, 2001). One reason for air quality being listed number one is because many of the respondents

(Capital Health, Alberta Environment, WETC) knew that air quality was an issue that was going to be asked on the questionnaire.

Table 26 Health Concerns with Whitemud Drive

Health concerns	Number of responses	Percentage
Air pollution	18	42
Injuries from collisions/Safety concerns	7	16
Noise	7	16
No concerns	7	16
Stress	1	2
Community separation	1	2
Water pollution	1	2
No answer	1	2
Total responses	43	100

Question eight asked if respondents had any concerns about how Whitemud Drive affects Edmonton's economy if at all. Many respondents said that Whitemud Drive was crucial to the economy of Edmonton and that it was the only link from west to south Edmonton and was important for the movement of goods and people, as shown in Table 27. Some respondents had trouble understanding the question or thought it was too open ended to respond to.

Table 27 Economic Concerns with Whitemud Drive

Economic concerns	Number of responses	Percentage
Important link	18	60
No or little effect on economy	5	17
Don't know	5	17
Transportation key to Edmonton economy	1	3
Not my job to examine economics	1	3
Total	30	100

Question nine had both a quantitative and qualitative component to it and the results are shown in Tables 28 and 29 respectively. The quantitative component asked participants to respond to the statement that city planners typically consider economic, engineering, community and environmental concerns when deciding on transportation options. An overwhelming majority of those either agreed or strongly agreed (30 of 36).

Four of the five who either disagreed or strongly disagreed, came from the WETC and non-WETC community groups.

Table 28 Do Planners Consider Economic, Engineering, Community, and Environmental Issues when Deciding on Transportation Options?

	Number of respondents	Percentage
Strongly agree	13	36
Agree	17	47
Neutral	1	3
Disagree	3	8
Strongly disagree	2	6
Total	36	100

The qualitative component to this question asked if respondents had any comments to make. Of those participants that responded, it seemed that economic and/or engineering concerns were rated higher than community and environmental concerns. As one City Councillor wrote:

> *Would love to believe this [that planners consider economic, engineering, community and environment], but planners also work to make developers and politicians happy.*

Similarly, an Alberta Environment employee responded:

> *I believe all of the above are considered, however economic and public pressure supercedes the others and environmental the least of all.*

Table 29 Additional Comments from Question 9

Comments	Number of responses	Percentage
No comment	13	43
Economic and engineering concerns given most weight, environment least	9	30
Planners consider everything in full	4	13
Public health should be priority	1	3
Environment different than health	1	3
Bridge crossing should be straight	1	3
Planners side with cities agenda	1	3
Total	30	100

Question 10 had both a quantitative and qualitative component to it and the results are shown in Tables 30 and 31 respectively. Question 10 asked whether respondents thought city planners should consider the area of human health when they consider

transportation options. The majority of respondents either agreed or strongly agreed with this statement (29 out of 36).

Table 30 Should Planners Consider Health when Deciding on Transportation Options?

	Number of respondents	Percentage
Strongly agree	11	31
Agree	18	50
Neutral	3	8
Disagree	1	3
Strongly disagree	2	6
No Answer	1	3
Total	36	100

The qualitative component asked for additional comments. There does not seem to be an underlying major theme to these comments other than many responded that health was important. One issue to note is that some respondents took this question to mean in the specific context of Whitemud Drive, whereas the purpose of the question was to ask whether City Planners should consider health in a general sense. One community participant stated:

> *Issues related to noise and air quality were considered in this plan. This was the first ever project that utilized both Capital Health and Alberta Environment to look into health concerns and make recommendations.*

Table 31 Additional Comments from Question 10

Comments	Number of responses	Percentage
No comment	9	30
Priority for health	8	27
Difficult to quantify health	4	13
Health already considered	4	13
Listen to what public says	2	7
Health should not be heavily weighted	2	7
Mature neighbourhoods will pay price	1	3
Total	30	100

The question that puzzled most participants was Question 11. This question asked if Whitemud Drive were widened, would males benefit more than females. This question was asked because of the International Development Research Centre's (IDRC) mission of examining differential impacts according to gender. The majority of

respondent's thought that there would be an equal benefit between males and females (18 out of 36), as shown in Table 32. Many respondents were unsure or supplied no answer. Of the three participants that thought males would benefit more than females, they cited the fact that truck drivers were more likely to be male and that males used Whitemud Drive more than females.

Table 32 What Sex Would Benefit More from Whitemud Drive Widening?

Who would benefit more	Number of respondents	Percentage
Males more than females	3	8
Females more than males	1	3
Equal benefit	18	50
Not sure	10	28
No answer	4	11
Total	36	100

Additional comments were requested from participants. Most participants had no comments to make on this question, and many others felt confused as shown in Table 33.

Table 33 Additional comments from Question 11

Comments	Number of respondents	Percentage
No comment	17	57
Strange question	5	17
Can't think of one sex benefiting more than other	4	13
Males might benefit more	4	13
Total	30	100

Question 12 was a matrix that asked participants to estimate what, if Whitemud Drive were widened, would likely happen over the next 20 years compared to the situation today. The list of 11 criteria was taken from section 2.2 in this thesis. The intent of the question was to see what impacts were thought to be most significantly affected by Whitemud Drive widening, and to use this information to verify those impacts included in the IIAF. The small sample size limits the generalizability of these results, though they are potentially useful as a basis for further research.

As displayed in Table 34, noise levels near Whitemud Drive, economic benefits to the city, the time it takes for trips, water pollution and air pollution effects, are the

impacts thought to be most affected by the widening of Whitemud Drive. The mean values for these impacts were most different from three, which was the no effect value. However, the values were not that much different from three so that only a moderate increase or decrease is expected for the majority of the impacts listed.

Table 34 Perceived Effect Whitemud Drive Widening would have on Impacts Over 20 years

Categories	Mean scores 1=signif. increase 3=no effect 5=signif. decrease	Difference from no effect value of 3*	Rank by largest difference from no effect value of 3
Noise levels near Whitemud Drive	2.00	1.00	1
Economic benefits to the city	2.46	0.54	2
Time it takes for trips	3.50	0.50	3
Water pollution in North Saskatchewan river	2.60	0.40	4
Air pollution health effects	2.63	0.37	5
Community cohesion	3.34	0.34	6
Real estate values in homes located near Whitemud Drive	3.33	0.33	7
Stress levels for drivers	3.26	0.26	8
Contribution to global climate change	2.85	0.15	9
Motor vehicle collisions including pedestrians and bicyclists	3.12	0.12	10
Physical fitness levels of Edmonton citizens	3.00	0.00	11

* Denotes absolute values

Table 35 presents how each stakeholder group ranked the impacts. The responses included pre-test answers since the question did not change significantly from the pre-test to the final version. The answers show that there are wide discrepancies between some of the groups as to how they thought the impact of a Whitemud widening might be. For instance, WETC members thought real estate values would decrease significantly (4.5), whereas City Councillors thought they would increase slightly (2.7). All groups except WETC thought that community cohesion would be relatively unchanged, whereas WETC thought that there would be a moderate decrease in cohesion. The WETC group also thought that air pollution was going to increase because of a widened Whitemud (1.5) whereas Alberta Environment and Capital Health thought it was going to decrease (3.8

and 4.0 respectively). Stress levels and collisions also were expected to increase according to WETC, but were not expected to increase according to Alberta Environment and Transportation Planning. The answers illustrate how far apart the stakeholder groups are in their perceptions of the expected impacts of a widened Whitemud Drive.

Table 35 Stakeholder Comparison of Responses to Question 12

Categories	AB Envir.	Capital Health	Transport Planning	City Councillors	Non WETC	WETC	Total
Trip time	3.6	4.0	2.5	3.8	3.5	3.4	3.5
Economic benefits	2.2	2.2	2.0	2.6	2.3	3.0	2.5
Real estate values	3.2	3.0	3.0	2.7	3.5	4.5	3.3
Motor vehicle collisions	3.8	3.3	3.8	3.4	2.7	2.3	3.1
Stress levels	4.2	3.6	3.5	3.3	3.3	2.1	3.3
Community cohesion	3.0	3.0	3.0	3.3	3.2	4.3	3.3
Air pollution	3.8	4.0	3.8	2.1	2.0	1.5	2.6
Noise levels	2.6	2.3	2.5	2.1	1.6	1.2	2.0
Water pollution	3.2	2.6	2.5	2.6	2.5	2.3	2.6
Physical fitness levels	2.8	3.0	2.8	3.1	3.0	3.1	3.0
Global climate change	3.4	3.5	3.3	2.6	2.7	2.3	2.9

Question 12 included a section for comments and the responses are shown in Table 36. It is difficult to know, based on the wording of the question, how people actually interpreted this question. This is summed up in the following quote by a City Transportation Planner:

> *This question mixes two factors. Changes over 20 years and an improved Whitemud. It will be difficult from the answers to interpret the perceived effect of each of them separately.*

In other words, over 20 years there is assumed to be growth in traffic and that may not significantly change even with a widened Whitemud Drive. Another limitation of the question is that it is difficult to know if participants thought that any of the 11 impacts were a problem now. For instance, even if they thought that the Whitemud

widening would not significantly affect water pollution any further, it could be affecting water quality in its present state.

Table 36 Additional Comments from Question 12

Categories	Number of Respondents	Percentage
No comments	16	47
Assumption of growth and need to keep pace	7	21
Difficult to answer because of other variables	3	9
Anthony Henday will take pressure off Whitemud	3	9
20 years long time to forecast	2	6
Little effect on the environment and health	1	3
Benefits from widening short lived	1	3
Widening detrimental to community	1	3
Total	34	100

The next part of the analysis examines section three of the survey, for each of the stakeholder groups separately.

6.2 Results Section Three

6.2.1 Alberta Environment

The general theme of questions that were asked of employees at Alberta Environment centred on issues relating to transportation's impact on air quality.

Question 13 asked respondents to assess how accurate the air monitoring stations were at identifying different sources of $PM_{2.5}$, which is the fine portion of particulate matter. Two of the four respondents answered that $PM_{2.5}$ is not divided up into the source contribution by the air monitoring stations so that it is not possible to know how much transportation impacts on this pollutant.

Question 14 asked respondents to estimate what percentage of $PM_{2.5}$ comes from private automobiles in Edmonton. One of the respondents answered that 60% of $PM_{2.5}$ comes from transportation activities including road dust in the City of Edmonton. This is

verified in a published study which states that 60% of $PM_{2.5}$ is transportation related (Cheng et al., 1998).

Question 15 asked respondents how much the level of traffic would have to increase to adversely affect air quality near Whitemud Drive. All respondents said they did not know or had no comments. One individual summed up the complexity of the issue by stating:

> *This is a complicated issue. Increased traffic will increase the amount of pollutants emitted. Yet a free flow traffic on road ways will decrease the pollutant emissions.*

This response exhibits an argument made by some that widened roadways reduce emissions because of "less stop and go" traffic, which tends to increase emissions.

Question 16 asked how much pollution from $PM_{2.5}$ emitted from vehicles would people be exposed to at gradient distances from Whitemud Drive. A matrix was presented that listed distances from the roadway in the rows, and significant, marginal, and no air quality concerns in the columns. Two of the respondents answered that they did not know, while two others thought that there were significant air quality concerns within 10 metres of the roadway, and at least marginal effects on air quality up to 100 metres away. It is difficult to know based on the small sample of respondents, how far way from Whitemud Drive that air quality is perceived to be affected.

Overall, Alberta Environment employees did not seem certain about the extent to which much transportation affects air quality (in particular $PM_{2.5}$) in the Edmonton region. This uncertainty may be attributable to the fact that air quality is affected by many factors. It is difficult to predict with certainty how any one variable, such as roadways, affects ambient air quality.

6.2.2 Capital Health Authority

The general theme of the questions asked to Capital Health Authority focused on air quality issues as they pertain to human health.

Question 13 asked whether public health professionals should be consulted when local government is considering transportation infrastructure. The majority of respondents (4 out of 5) thought that health professionals should be consulted. One of the respondents had this assessment:

> *[yes] With qualifier. Roadway modification/improvement is part of urban living. To consult health every time a roadway is planned would be a waste of time and money. Only if health has been identified as a concern should health department be involved.*

Question 14 asked about how the interaction among many different air pollutants impacts on human health. Overall the respondents did not give a definitive answer because of the complexity of the question. As one individual stated:

> *It depends on the chemicals, whether the synergistic effect increase. Whether carcinogens are produced.*

Question 15 asked whether there was a safe threshold for air pollutants below which no human health effects are likely to occur. Again, no definitive response was offered, in part, because of the large scope of the question and possibly because of the ongoing debate on this subject. One respondent stated that the susceptibility of individuals is different, and that the adverse health effects can range from irritation to mortality.

Question 16 asked how health concerns manifest themselves in terms of lung functioning etc. Asthma episodes were the most common response, along with increased respiratory complaints/hospital admissions especially in susceptible members of the population (elderly or children).

Question 17 asked how much pollution from $PM_{2.5}$ emitted from vehicles would people be exposed to at distances from Whitemud Drive. A matrix was presented that listed distances from the roadway in the rows, and significant, moderate, and little or no health risks in the columns. This is very similar to Question 16 posed to Alberta Environment. Two people said that there was a significant amount of pollution enough to cause adverse health effects up to 100 metres from the roadway. Others said they did not

know and that it depends on local meteorological conditions. This is similar to what officials at Alberta Environment concluded.

Question 18 asked how much would the level of traffic have to increase to present a health impact to those living near Whitemud Drive. Many respondents said they did not know, but one respondent stated that there are complaints now from idling vehicles due to congestion, and that one solution may be traffic reduction.

Again, the small sample size prohibits generalizing these results to all Capital Health employees. Generally, the responses indicate that there is uncertainty about how traffic related air pollution impacts human health.

6.2.3 City Transportation Planners

The questions for City of Edmonton Transportation Planners focused on issues of planning for transportation infrastructure and questions about the impacts of Whitemud Drive on traffic in communities adjacent to the roadway.

Question 13 asked the methods by which the department of transportation planning assesses the engineering, economic, environmental and community aspects of transportation infrastructure now. A range of opinion was given on this question, with one respondent answering that environmental impact assessments, a review of community impacts, and whether the project adhered to national engineering standards were the methods utilized. Another individual commented that a detailed functional plan is conducted first, followed by forecasting for vehicle usage. It is difficult to know based on the answers given if there is a formal assessment method in place, and if there is, whether it is dependent on the size of the project.

Question 14 asked whether adding human health considerations in a formalized assessment approach would be helpful for the department. One individual said yes and the other two were unsure. Of the unsure individuals, one stated that the health impacts from traffic noise were not understood nor documented.

Question 15 asked what features of an assessment approach would be of most benefit to planning department, and respondents were asked to choose from a predefined list or come up with some of their own. Two features that appeared most often were having the impacts quantifiable and that the assessment would not be overly time-consuming to complete. The answers to the last two questions suggest that including quantifiable impacts into the assessment approach is important, although with a total of three participants, it is difficult to generalize this to the entire Transportation Planning Branch.

Question 16 asked what planners thought would happen to traffic volumes in the vicinity of 149th street if Whitemud Drive were widened. This question was asked because this seemed to be a major point of conflict between the WETC and City Transportation Planners. Two of the three respondents (not including pre-test), thought that there would be no significant change in that area. One respondent stated:

> *Capacity analysis has shown little scope for increase unless 149th street is 'improved'.*

Question 17 asked respondents to consider if people would be less likely to short cut through neighbourhoods in Jasper Place if Whitemud Drive were widened. Two of the respondents said yes while one respondent did not know. One of the yes responses is listed in the following quotation:

> *If Whitemud drive is backed up, people look for alternative routes and quite often take what they perceive as shortcuts through neighbourhoods.*

All of the City Transportation Planners had extra comments that included:

> *If Whitemud drive is not widened, traffic may simply divert to other routes, migrating a human health problem somewhere else (if there is one).*

It is difficult to make generalizations based on three responses given from City Transportation Planners. However, the responses suggest that any impacts included in an assessment framework should be quantifiable. The widening of Whitemud Drive is thought to have minimal affect on those residents in Jasper Place because it likely will

not significantly impact traffic volumes in the area, and short cutting through their neighbourhood may be reduced. These statements need to be verified by more members of the staff at the City of Edmonton's Transportation Planning branch before they can be generalized.

6.2.4 Edmonton City Councillors

Section three for Edmonton City Councillors focused on traffic volumes for those living in Jasper Place and the decision-making process involved in transportation.

Question 13 asked if the Councillors had participated in the public meetings of the Whitemud Drive planning process. Of the eight Councillors who completed the questionnaire, three had participated in the public meetings. This might mean that their knowledge of the issues was not as high as other participants who had been involved.

Question 14 and 15 were identical to questions 16 and 17 asked of the City Transportation Planners. Six of the eight Councillors thought that there would be a moderate increase in traffic near 149th street, with only two stating that there would be no change. The next question had to do with shortcutting in Jasper Place and the effect that Whitemud Drive would have on it. The answers were split fairly evenly, with two responding that drivers would be less likely to short cut, and three stating that they would not be less likely to shortcut.

Question 17 asked how satisfied the City Councillors were with the decision-making process on transportation infrastructure. The overwhelming majority of respondents said they were satisfied, including one respondent who stated:

> *So long as there is opportunity for solid and rational community input and consultation as well.*

While the one respondent who said "no" stated:

> *Concern that information is too filtered by the time it gets collated.*

Finally, most Councillors had comments to make at the end of the questionnaire. One respondent stated:

Unnecessary! Anthony Henday can take much of the traffic. Delays are minimal, expansion should happen only well into the future.

While another respondent offered a more pragmatic approach, as illustrated in this response:

We live in a big (getting bigger) city. We must manage congestion in a spirit of give and take, and use best practices where possible.

6.2.5 Community Groups

Section three for both the WETC and non-WETC groups was identical, so analysis of this section will be combined and, where differences exist between the groups, they will be mentioned. Section three is similar to section three given to City Councillors.

Question 13 asked individuals if they had participated in the public meetings dealing with the Whitemud Drive planning process. Of the eleven people surveyed, seven had participated, three did not and one had no answer. Of the seven who had participated, six were from the WETC group.

Question 14 and 15 were identical to questions 14 and 15 asked of City Councillors and questions 16 and 17 asked of the City Transportation Planners, which asked about the effect Whitemud widening would have on traffic volumes on 149th street. Seven of the members thought that there would be at least a moderate increase including four who thought it would be significantly increased (three of the four were WETC members). This is quite different than the responses offered by the City Transportation Planners and City Councillors. This issue was one of the main sources of conflict between WETC and City Transportation Planners.

The next question had to do with shortcutting in Jasper Place and the effect that Whitemud Drive would have on it. Five respondents thought that a widened Whitemud Drive would not reduce short-cutting in their neighbourhood, while only one said yes. This is in stark contrast to City Transportation Planners where two of the three planners thought that it would reduce shortcutting. This is an issue that had brought about tension

between the community group (especially WETC) and City Transportation Planners. Even though a majority of community respondents thought that a widened Whitemud Drive would not reduce short-cutting, some were not certain about this phenomenon as stated in the following quotation:

> *This question is complex. Surveys must be conducted to find an answer.*

Some additional comments in question 16 were as follows:

> *I think it should be done but I think a lot more planning should take place and meetings with communities for more input.*

> *While this may be outside the scope of this study, the process of dealing with the City and the Transportation Dept. has been a very frustrating and disappointing experience. The process is heavily weighted towards the business community and the transportation and construction industry rather than the citizens of Edmonton.*

It can be seen that based on the small sample size, the majority of community respondents, and especially those from WETC, thought that a widened Whitemud Drive would increase traffic in their neighbourhood.

What was the point of the community participation process? Essentially it was to see what the varying perspectives were from different stakeholders in a local transportation case study. It was also useful to know if the impacts included in the IIAF are reasonable based on what the participants listed as their concerns. It seems that although none of the impacts listed except for noise were thought to be significantly affected by a widened Whitemud Drive, the impacts could still be useful in other transportation projects. There seems to be much uncertainty from the "expert" group of Alberta Environment and Capital Health about the effect transportation has on air quality and health.

6.3 Limitations of the Pilot Study

There were limitations in the way in which the community participation pilot study was conducted. First, the small sample size does not allow generalizations to be

made outside the 36 individuals who completed the questionnaire. The study was a pilot study that could be expanded in future studies but until that happens, the results are limited to the group of participants involved.

Second, there could have been interviewer bias present since in almost all instances (32 out of 36) the researchers were present while the participant completed the questionnaire. This may have led participants to answering the survey as they thought the researchers wanted it answered, or they may not have been honest in their responses. This, however, is difficult to discern.

Third, sampling bias could have been present especially with the snowball sampling method used. When participants for a study are enrolled based on the suggestion of a main contact individual, there is a danger that the participants are "like minded", and that the sample will not be representative of the population. Sampling bias could have easily occurred with the "expert" groups.

Fourth, there was variability in the way in which the questionnaire was administered. Most participants were met individually by the researcher(s) and they completed the questionnaire immediately. For other groups, like the two community groups, the participants were in a room with four or five other individuals who were also completing the questionnaire. It is not clear if this group dynamic had any effect on the responses. Still, other members had the questionnaire mailed to them for completion. In this way, the researchers were not able to help clarify any misunderstandings for these participants.

Fifth, the instrument was a newly-developed tool so that its reliability and validity is unknown. It cannot be shown for certain that each participant understood each question the same way, or that each question was asking what it meant to. This lack of knowing the construct validity of the instrument (Bernard, 2000) is a limitation of this study, but if the instrument were to be used again, it may help to improve the construct validity. The validity issue was partially addressed through the pre-test process. Because

only a small number of individuals were available in each group, it was difficult to justify more than one pre-test per stakeholder group. Again, if the instrument were used with a larger sample, its validity may be improved.

Chapter 7 Results of Air Quality

7.1 Number of Exceedances of Air Quality Guidelines in Edmonton

What are the quantitative measures that need to be estimated in the air quality impact in the IIAF? The first measure is the number of times air quality guidelines for particulate matter $PM_{2.5}$ are expected to be exceeded. Table 37 lists the baseline conditions of traffic volume on the Quesnell Bridge, a major link on Whitemud Drive, the $PM_{2.5}$ levels for Edmonton Northwest station, and the number of exceedances (for 24 hours) of the air quality guidelines for $PM_{2.5}$. It then lists, for each of four different transportation scenarios, the future projected traffic volumes, along with estimated $PM_{2.5}$ levels, and the number of exceedances of the air quality guidelines. All of the numbers that have been estimated by the author are listed in bold.

It should be noted that Alberta Environment had set up 11 Mobile Air Monitoring Laboratories along Whitemud Drive between June 2000 and May 2001. The purpose of the monitoring was to measure the air parameter concentrations and compare them to Alberta's one-hour air quality guidelines (Alberta Environment, 2000). Despite Alberta Environment's every intention to have these data available initially in the Fall of 2001, and then delayed to March 2002, the results of these air monitoring readings were still not available at the time of writing this thesis. As such, data from the permanent Northwest air monitoring station was utilized instead. It was decided to use this station's data because it is closest to the study area on Whitemud Drive.

For Alberta, the Ambient Air Quality Guidelines for suspended particulates are 100 $\mu g/m^3$ for 24 hours and 60 $\mu g/m^3$ annually (Alberta Environment, 2000b). $PM_{2.5}$ guidelines are 30 $\mu g/m^3$ for 24 hours based on Canada wide standards for particulate matter.

Table 37 Estimation of $PM_{2.5}$ Levels and Exceedances of Air Quality Guidelines near Quesnell Bridge

Transportation Scenario	Traffic volume (vehicles per day)	Estimated $PM_{2.5}$ average annual level	Number of $PM_{2.5}$ exceedances (24 hour)
Baseline (2000)	110,600 (a)	11.2 $\mu g/m^3$ (d)	0 (d)
2020 without widening	130,000 – 140,000 (b)	**13.7 $\mu g/m^3$**	**0**
2020 with widening	135,000 – 145,000 (b)	**14.2 $\mu g/m^3$**	**0**
2020 with widening for public transport	**130,000 – 140,000**	**13.7 $\mu g/m^3$**	**0**
2020 with reduction by one lane	**104,000 – 112,000 (c)**	**9.0 $\mu g/m^3$**	**0**

(a) City of Edmonton (2001).
(b) Stantec Consulting (2001).
(c) Using methodology from Cairns, Hass-Klau, & Goodwin (1998).
(d) Clean Air Strategic Alliance (2002).

How much do particulate matter levels increase for a given increase in traffic volume on Quesnell Bridge? Table 37 indicates that traffic volume on the Quesnell Bridge will increase from 110,600 to an average of 135,000 vehicles per day in 2020, in the case of the no widening scenario. These figures are based on the EMME/2 program that predicts future traffic volume and this program is utilized by the City of Edmonton. This presents an increase of 22% in traffic volume from 2000 levels. Does that mean that $PM_{2.5}$ levels will increase by the same 22%? This is unlikely given the fact that there are many confounding variables, like improved vehicle emissions, vehicular speed of travel, air temperature, wind, transboundary and other sources of pollution that make a direct linear comparison difficult. However, assuming these confounding variables are kept constant, a direct linear comparison can be made and this method will be used here. If $PM_{2.5}$ ambient levels did increase 22%, and assuming that the average $PM_{2.5}$ level near Quesnell Bridge is the same as for the city itself, the average level would increase from 11.2 $\mu g/m^3$ to 13.7 $\mu g/m^3$. This is still well below the 30 $\mu g/m^3$ guideline. The number of exceedances of the 24 hour guideline would still be expected to be 0, although this estimate is a crude one because many variables (e.g. wind speeds, temperature, other sources of particulate pollution) contribute to maximum PM levels, and it is difficult to predict occurrence of these variables with any certainty.

For the scenario of widening by one lane in each direction, traffic volume per day is projected to increase to an average of 140,000 in 2020. This presents an increase of 27% from 2000 levels. Using the same straight line comparison method, if $PM_{2.5}$ levels increased by 27%, then the 2020 $PM_{2.5}$ levels would be 14.2 $\mu g/m^3$, which is 27% higher than the baseline measure of 11.2 $\mu g/m^3$. This is still well below the 30 $\mu g/m^3$ guideline, and only 0.50 $\mu g/m^3$ more than in the no widening scenario. The number of exceedances would be expected to remain at 0 noting the assumptions from above.

The third scenario of widening for the primary use of public transit and carpool vehicles, utilizes the same traffic volume predictions as in the no widening scenario. This is likely since private vehicular traffic will be able to utilize the same six lanes, and the two additional lanes would be exclusively for public transit and carpool vehicles. The same $PM_{2.5}$ level of 13.7 $\mu g/m^3$ is estimated in this scenario, with 0 exceedances expected.

The final scenario of reducing the Quesnell Bridge by one lane in each direction is expected to reduce traffic flow by an estimated 20%. This figure is consistent with the evidence found in Cairns et al. (1998) in their meta-analysis of roadway reductions. The authors found on average that the affected roadways traffic volume decreased by an average of 20%. It should be noted that arterial roadways are not included in this estimate, only Quesnell Bridge. With the 20% reduction from the no widening option, daily traffic volumes in 2020 are estimated to decrease to an average of 108,000. A 20% reduction in the baseline measurement would produce $PM_{2.5}$ levels of 9 $\mu g/m^3$, for a decrease of 4.7 $\mu g/m^3$. The same number of exceedances of 0 is expected.

In summary, the various scenarios are not expected to exceed the air quality guideline for $PM_{2.5}$. This is reasonable since projects that do not increase traffic flows by more than 10% are not expected to bring about significant changes in air quality (Department of Environment, Transport, and the Regions, 2000). In this case, the widening by one lane is projected to increase traffic by 3.7% compared to the no

widening scenario. Yet, even if air quality remains within the guidelines, this does not mean that people are not impacted. For example, annoyance from fuel odours can become a factor (Lercher, Schmitzberger, & Kofler, 1995; Williams & McRae, 1995). There may be a need for further research into this area. In addition, it is claimed that there is no safe threshold level below which there are no attributable risks to the population from particulate pollution (COMEAP, 1998).

The estimates listed in this table represent a crude analysis, because the association between traffic volumes and air pollution health effects are not known with certainty. However, quantification of health effects is crucial if it is to be included by Transportation Planners in their assessment of transportation options, and this table attempts to quantify air pollution effects. The assumptions made are open to debate, but it would lead to more critical health assessments from transportation in the future.

7.2 Estimated Traffic Related Respiratory Conditions in Edmonton

If air quality guidelines for $PM_{2.5}$ are not expected to be exceeded in the case of Whitemud Drive, are there any health effects from vehicle emissions that can be quantified? The second quantitative indicator in the IIAF is the number of expected respiratory conditions and their economic cost. In order to calculate this, the scope of the analysis must be expanded to include all of Edmonton and not just Jasper Place. This is necessary since traffic volume was shown to increase only 3.7% in the previous section and this is not expected to produce any significant change in ambient $PM_{2.5}$ levels.

The first step is estimating the economic health costs in the baseline year. To do this, the method used in a previous study (The Health of Londoners Project [HOLP], 2001) will be utilized. The method examines what the actual number of respiratory morbidity and mortality are now, and attributes a percentage to traffic emissions. For this exercise, 3% of all respiratory hospital admissions, emergency room visits, and respiratory deaths are assumed to be attributable to traffic emissions. Reference for these numbers is found in Kunzli et al. (2000) and the HOLP (2001). In addition, the total

vehicle kilometres travelled in Edmonton are linked to each health effect to give a total vehicle kilometres per event. The results of the estimates are displayed in bold in Table 38.

Table 38 Estimate of Respiratory-Related Health Conditions from Traffic Pollution all of Edmonton

Column	(1)	(2)	(3) = (1)*(2)	(4)	(5) = (4)/(3)
	Number of events per year	**Traffic Portion**	**Number attributable to traffic pollution**	**Vehicle kms per year (000s)**	**Vehicle kms per event (000s)**
Respiratory Admissions	2,395 (a)	0.03 (b)	**72**	**3,613,500 (c)**	**50,188**
Respiratory Deaths	168 (a)	0.03 (b)	**5**	**3,613,500 (c)**	**722,700**
Respiratory Emergency Room Visits	22,841 (a)	0.03 (b)	**685**	**3,613,500 (c)**	**5,275**

Source:(a) Capital Health Authority (2000)
(b) Kunzli et al. (2000)
(c) Applications Management Consulting (1995)

The above values should be treated with caution as variables such as wind conditions, vehicle emissions, speed of travel, air temperature, and other sources of pollution are not controlled for and are assumed to be constant. It is estimated that in the Edmonton area, 72 respiratory admissions, five deaths, and 685 respiratory admissions each year are attributable to traffic pollution. These estimates are considered conservative since cardiac conditions are not analysed and are also thought to be influenced by particulate matter (HOLP, 2001; Peters, Dockery, Muller, & Mittleman, 2001; Magari et al. 2002; Pope et al. 2002). For future analyses, the most useful values may be the vehicle-kilometres-per-event figures, because they show how many respiratory health effects are estimated for a given level of vehicle kilometres travelled. This means that in a case where traffic is expected to increase because of a road widening, estimates of respiratory health effects can be made.

7.3 *Estimated Traffic Related Costs of Respiratory Conditions in Edmonton*

What are the economic costs associated with these figures? Table 39 displays the approximate health care costs for respiratory admissions and emergency room visits, as well as willingness to pay values for human life associated with the effects estimated from Table 38.

Table 39 Estimated Respiratory Health Costs Related to Traffic in Edmonton

	Number attributable to traffic pollution	**Cost per outcome**	**Total cost per year in Edmonton**
Respiratory Admissions	72	$3,300 (a)	**$237,600**
Respiratory Deaths	5	$810,000 (b)	**$4,050,000**
Respiratory Emergency Room Visits	685	$111 (a)	**$76,035**

Source: (a) Alberta Health (2001)
(b) Carrothers, Graham & Evans. (1999).

Respiratory admissions for chronic obstructive pulmonary disease average $3,300 in Alberta and emergency room visits for general respiratory visits average $111 (Alberta Health, 2001). These numbers do not reflect indirect costs of time off work, transportation costs of going to the hospital, and others, so it is likely underestimated. The most controversial number is the cost associated with mortality. In this case, a value of $540,000 US is associated with preventing an air pollution death and is taken from the United States Environmental Protection Agency, (as cited in Carrothers et al., 1999). This value is seen as more representative than other values because the average air pollution death reduced life expectancy by 4.5 years. The $540,000 US value is then converted into Canadian dollars using an exchange value of $1.50 Canadian per $1.00 American dollar to obtain $810,000 per human life.

7.4 *Estimated Traffic related Respiratory Conditions for Whitemud Drive Transportation Scenarios*

How do the transportation scenarios along Whitemud Drive affect vehicle kilometres and, subsequently, respiratory mortality and morbidity figures? To answer this question, the vehicle-kilometres-per-year are calculated for each scenario in Table 40. These figures are then compared with the vehicle-kilometres-per-event statistics calculated in Table 38 to estimate the respiratory health effects from differing transportation scenarios.

Table 40 Changes in Vehicle Kilometres for differing Transportation Scenarios

Transportation Scenario	Quesnell Bridge traffic volume (vehicles per day)	Length of Whitemud Drive (122nd to 149th streets)	Vehicle kilometres per year (000s)	Difference in veh. kms per year from baseline (000s)
2020 without widening	135,000	6 kms	295,650	0
2020 with widening	140,000	6 kms	306,600	+10,950
2020 with widening for public transport	135,000	6 kms	295,650	0
2020 with reduction by one lane	108,000	6 kms	236,520	-59,130

The vehicles per day expected on the Quesnell Bridge are assumed to travel the entire six kilometre length between 122nd street and 149th street. The widening of Whitemud Drive by one lane is expected to produce an additional 11 million vehicle kilometres above the baseline scenario. This would produce an estimated two respiratory related emergency room visits, and contribute to additional hospital admissions and mortality on an annual basis. Widening for public transport use is not expected to generate any more traffic than at baseline levels. Reducing Whitemud Drive by one lane, assuming traffic volume decreases by 20%, reduces vehicle kilometres per year by 60 million vehicle kilometres. This would result in a savings of 12 emergency room visits, one hospital admission, and contribute to savings in respiratory mortality. It is difficult to estimate what the incremental health savings or costs would be in 2020, but this table

shows what the estimated health effects might be from changes in vehicle kilometres on Whitemud Drive.

It is reiterated that Tables 37 - 40 represent a crude attempt at the quantification of respiratory-related conditions and costs associated with traffic volumes in an urban area. Their inclusion in this thesis is to increase the awareness that transportation does have a measurable impact on population health and that more precise assessments of incremental impacts are needed in the future.

Chapter 8 Discussion

The purpose of this thesis was to develop a framework for examining the positive and negative impacts that transportation has on human health and the environment, and to quantify them in economic terms. In addition, the framework developed was applied in a limited fashion to an actual case study in Edmonton, using the Ecohealth approach, complete with stakeholder input and the analysis of air pollution data.

8.1 Impacts Identified

The first objective of this thesis was to identify all of the potential impacts associated with transportation, and more specifically with road-based urban transport. This was demonstrated in section 2.1 with an impact diagram that described those factors that influence transportation, and then what influence transportation has on a set of other factors. The impact diagram, while not an exhaustive list, included many of the important impacts included in other studies (OECD, 1997b; European Commission, 1996). The IIAF included the following impacts:

Category	**Impacts**
Health	Air quality Collisions Noise Fitness Stress Community cohesion
Environment	Biodiversity Climate change Water quality
Economic	Journey times Traffic volumes Real estate values
Socio – Cultural	Gender Equity

The impact diagram was a starting point so that the significant impacts listed in the IIAF then could be traced back to this diagram.

8.2 *Frameworks Reviewed*

The development of the IIAF was aided by a review of similar frameworks and approaches that are used to comprehensively examine complex problems. These frameworks all had theoretical or applied components to them and are displayed as a framework matrix in section 2.3. The frameworks reviewed were:

- Integrated Assessment Framework
- Health Impact Assessment
- Environmental Impact Assessment
- Strategic Environmental Assessment
- Ecosystem Approach to Human Health (Ecohealth)
- Cost-Benefit Analysis
- Multi-Criteria Analysis

The Multi-Criteria Analysis (MCA) approach seemed most appropriate for integrating issues of health, environment, and economics into a transportation policy framework. This is because it includes impacts that can be quantified as well as those that can only be qualitatively assessed. Ideally, the external costs associated with impacts included in the IIAF should be quantitatively measured, as in a full cost accounting approach. However, a more flexible MCA approach was used that allowed for a qualitative assessment of those impacts that were not easily quantified. MCA has been used in many regions of Europe including the United Kingdom (European Commission, 1996), which lends credibility to the approach.

Indicators, both quantitative and qualitative, were included for each impact in the IIAF. Many different indicators could have been chosen, and the relevance of an indicator should be determined from the local context. The indicators included for the IIAF are presented in Table 11. Only the indicators for air pollution were estimated, but it would have been interesting to estimate other indicators. For example, it would be useful to test to see whether Richter's prediction of roadway widening leading to increased collisions causing injuries and deaths as a result of increased speed, would actually occur for this case study.

Where impacts are difficult to measure, then qualitative indicators must be used and these are shown in Table 11. These qualitative indicators were gathered from stakeholder opinion, and the application of any framework should include a community or stakeholder component (ECMT, 1998).

8.3 Application of IIAF

Many growing cities are faced with the problem of increasing congestion on urban roadways, and are seeking solutions to this problem. The IIAF was applied to a case study of a transportation corridor in south west Edmonton using the Ecohealth approach. This case study centred on Whitemud Drive, which is a high volume roadway in which congestion is found during peak hours of the day. The City of Edmonton, following through on its Transportation Master Plan, will widen the road by one lane, to relieve congestion and to better prepare that area of the city for future traffic growth.

The IIAF was applied to this study, first by seeking stakeholder input on their perceptions of how the widening will affect various impacts in the IIAF, and second, to analyse the expected air pollution health effects associated with different transportation scenarios. Stakeholder opinions were sought for this study from six divergent groups, from local citizens, to health, environmental, and transportation experts, and City Councillors. The purpose of soliciting these opinions was to assess the importance of the impacts included in the framework to stakeholders, and to supplement quantitative data with qualitative data, based on perceptions.

Stakeholder opinion was obtained through a questionnaire given to a small sample. This was a pilot study, and it should be stressed that the findings should not be generalized outside this context. In addition, the questionnaire developed for this pilot study has uncertain reliability and validity. Only from other studies using a larger sample size will the reliability and validity of the questionnaire be ascertained. Previous work done by the City of Edmonton (Equus Consulting Group, 2001) was used to supplement some of the findings from the pilot study.

The stakeholders approached for this study provided input as to what impacts they thought would be most affected by the Whitemud Drive widening. The impacts that were expected to change the most from a widened Whitemud Drive, as identified from Table 34, were:

- An increase in noise levels
- An increase in economic benefits for the City of Edmonton
- A decrease in the time it takes for trips
- An increase in water pollution
- An increase in air pollution

These impacts were expected to change only moderately, revealing that this stakeholder group as a whole did not expect the widening of Whitemud Drive to have significant costs or benefits. This viewpoint appears to be inconsistent with the reviewed literature (Litman, 1999; Greene & Jones, 1997; Morton, 2001) where transportation is thought to have significant external costs and benefits. Part of this discrepancy could be attributable to the fact that the questionnaire was focused on an incremental change to one roadway in a city. Stakeholders may have considered only the local level of analysis, whereas many of the authors referenced in the literature review consider transportation on a larger regional or national scale.

While as a group, only moderate change was projected for certain impacts, there was a broad range of answers across stakeholder groups. For example, the two community groups and City Councillors thought air pollution would increase with the widening of Whitemud Drive, but the three expert groups perceived a decrease in air pollution. The expert group thought that an increase in pollution is caused by congestion because of more idling, and stop and go traffic. Therefore, if the widening were to reduce idling and stop and go traffic, then air pollution should decrease. Richter and Reingold (2002) claimed that maximum fuel efficiency is achieved at speeds between 40 – 75 kilometres per hour, and that congestion increases air pollution. However, the community groups and Councillors are also correct in thinking that the widening will increase air pollution because of the fact that widening roadways produces extra or induced traffic (Hills, 1996, SACTRA, 1994), that generates extra pollution. The subject

of whether road capacity increases or decreases air pollution is much debated (Dowling & Colman, 1998), but it seems clear that if roadways encourage extra traffic where there otherwise would not have been, then extra pollution is created. This approach was taken in the quantification of air pollution health effects in Chapter 7.

The two community groups thought that collisions would increase with the widening of Whitemud Drive, but the other four groups thought that no change would occur. The community group's thoughts are consistent with some authors' viewpoints (Richter, 1998; Richter et al., 2001). However, one case study in New Zealand demonstrated that a new highway actually decreased collisions in the study area after it was opened compared to before its construction (Jadaan & Nicholson, 1988). More before and after studies are needed on this debated topic before a clearer picture is revealed.

Differences in opinion, especially between community groups and experts is expected because citizens living close to the roadway in question, will have a much different perception than experts, who analyse the situation from a more distant perspective. These two differing perspectives are apparent in the analysis of the questionnaire.

There was agreement on some questions. The majority of participants thought that a widening, or the development of a new route, would ease congestion on Whitemud Drive. The majority of participants also thought that City Transportation Planners should consider health in planning, although how this might happen was not explicitly stated. A framework such as the IIAF may be useful especially if one focus is on health impacts.

Each stakeholder group was asked a different set of questions in section three of the survey. Alberta Environment confirmed that the majority of particulate matter (60%) in Edmonton is traffic-related, and this is consistent with other studies (Greene & Jones, 1997; ECMT, 1990). Alberta Environment also confirmed that ambient $PM_{2.5}$ levels have been decreasing in recent years despite higher vehicle-kilometres travelled, and this

is part due to more stringent emissions controls from vehicles (Pickrell, 1999). Overall, Alberta Environment employees who participated thought that air pollution would decrease over 20 years after the widening of Whitemud Drive. This has been the trend for certain pollutants, and it may very well continue in the near future with increasingly stringent emissions controls (Pickrell, 1999).

The Capital Health Authority employees surveyed also thought that air pollution would decrease over 20 years with a widening, but could not be conclusive about how far from Whitemud Drive respiratory health effects would occur. A manual used by the U.K. government claims that beyond 200 metres from the roadside, vehicle emissions do not contribute significantly to local pollution levels (DETR, 2000). This is an important point for those citizens living up to 200 metres from Whitemud Drive, because their air quality may be affected. The air quality monitoring data along Whitemud Drive, being awaited, from Alberta Environment, should help to clarify this matter.

City Transportation Planners were unsure about whether health should be included in a formal assessment approach. However, two features they thought important were quantifiable impacts and timeliness. The importance of quantifying the external effects has already been discussed, and a full cost accounting of the indicators within each impact would be extremely helpful for Transportation Planners. Planners also thought that traffic would not increase significantly in the neighbourhoods surrounding Whitemud Drive after the widening because an "improved" Whitemud Drive would draw more cars to it from nearby arterial roads. Again, more before and after studies are needed to confirm the Planners' thoughts on this point.

City Councillors overall were happy with the decision-making process for transportation planning, where, for major projects, significant community input is obtained prior to a final decision being made. The City of Edmonton should be commended for its efforts in acquiring community input into this project. However, it is unlikely that they would consider WETCs request to stop the widening of Whitemud

Drive since this was a key point to the Transportation Master Plan, a document that had consumed significant time and resources.

The two community groups thought, in general, that the widening would increase traffic in nearby neighbourhoods, and this opinion was prominent in the WETC group. Again, the basis for this judgement is the fact that roadways tend to induce traffic, and any increase on Whitemud Drive would have a downstream affect on the communities living nearby. On this point, there is disagreement between WETC and the capacity analysis projections provided by the City of Edmonton.

The pilot study was unique, because to the researcher's knowledge, this formal type of survey had not been conducted before with community, expert and decision-making groups. This could lead to more formal studies in the future and act as a means towards community and expert groups communicating on contentious issues.

8.4 Air Pollution Analysis

In addition to obtaining qualitative data on stakeholder perceptions of impacts, traffic related air pollution health effects and costs were estimated for Edmonton as a whole, and then, more focused on Whitemud Drive. Owing to the complexity of attributing health costs associated with a single roadway, baseline information was estimated for the City of Edmonton as a whole. It was estimated that five respiratory related deaths, 72 respiratory admissions, and almost 700 emergency room visits each year, for a total health cost of almost $4 million, were attributable to traffic. This is likely a conservative estimate because only direct health costs were considered for admissions and visits, and does not take into account indirect costs like time off work and transportation to clinics. Other possible health effects such as cardiac conditions were not included that are thought to be affected by traffic related pollution. The method used to calculate the health effects were borrowed from two previous studies (HOLP, 2001; Kunzli et al., 2000), but further studies are needed to verify these estimates. Therefore, caution should be taken when examining these figures.

From the analysis of Edmonton as a whole, estimates of the health outcomes per vehicle-kilometres travelled were calculated. The estimates obtained were significantly higher than those found for a similar study in London, England (HOLP, 2001) with the main difference being the number of vehicle-kilometres travelled being higher in Edmonton than London. This point needs to be clarified before these figures can be extrapolated for use elsewhere.

The crude estimates were then applied to four transportation scenarios in the Whitemud corridor. It was estimated that the widening would produce an extra 11 million vehicle-kilometres-travelled-per-year with incremental health effects of two more respiratory emergency room visits, and contribute to increased respiratory hospital admissions and deaths. A reduction by one lane on Whitemud Drive was estimated to save 12 respiratory emergency room visits, and one hospital admission. Again, these figures are crude estimates and need further studies to confirm their reliability.

Even though relatively minor respiratory health effects are likely in the case of a widening by one lane, air quality outside of Alberta's borders could very well be affected. This is because particulate matter travels long distances affecting regions many kilometres away, as in the case of the eastern seaboard of the United States where industrial pollution affects air quality in southern Ontario (Colvile et al., 2001).

8.5 Summary of Impacts related to Whitemud Drive

The final summary using the quantitative and qualitative indicators for selected impacts related to the widening of Whitemud Drive is presented in Table 41. It is revealed that two additional respiratory emergency room visits per year are likely from the widening, along with contributions to respiratory hospital admissions and deaths, but that no exceedances of air quality guidelines are expected. For the qualitative indicators, aside from moderate increases expected in noise and economic benefits to the city, no changes in the impacts listed are expected from the widening of Whitemud Drive according to the stakeholders involved. However, more detailed quantitative analysis is needed to complete the IIAF for the case of widening Whitemud Drive. Only a

completely tested IIAF is useful for decision-makers when deciding on transportation options. Therefore, drawing inferences from Table 41 would be premature.

Table 41 Impact Summary Table

Option Title: Widening of Whitemud Drive by one lane primarily for private vehicle use			
Category	**Impact**	**Quantitative Indicator**	**Qualitative Indicator**
Health	Air quality	♦ **0 exceedances of guidelines** ♦ **2 ER visits annually expected Contribution to hospital admissions and mortality**	**No change expected**
	Collisions		**No change expected**
	Noise		**Moderate increase expected**
	Fitness		**No change in fitness levels expected**
	Stress levels		**No change expected**
	Community cohesion		**No change expected**
Environment	Climate change		**No change expected**
	Water quality		**No change expected**
Economic	Traffic volume	**140,000 vehicles per day**	**Moderate increase in economic benefits expected**
	Journey times		**Moderate decrease in trip time expected**
	Real estate values		**No change expected**
Socio - Cultural	Gender		**No change expected**

8.6 Other Issues

The following section lists other issues that are related to the thesis.

8.6.1 Induced Traffic

One issue that is central to this thesis is induced traffic, defined as any infrastructure change that results in short-run or long-run increases in vehicle-kilometres travelled (Noland, 2001). The City of Edmonton Transportation Planning Branch seems to have accounted for induced traffic in their projections. Some studies suggest that once a roadway is widened, congestion relief is only short-term. In practice, the volume of traffic soon increases to congestion levels the same as it was before the road was widened (Goodwin, 1996; SACTRA, 1994). Similarly, roads that are reduced in capacity (e.g.,

from lane closures), decrease traffic levels not only on the affected roadway, but also on the road networks close to it (Cairns et al., 1998). The evidence referenced suggests that provision of roadways is directly associated with volumes of traffic. This brings into question the value of widening roadways as a strategy to reduce congestion. It may be the most obvious method to alleviate congestion on urban motorways in the short term (less than 5 years), but evidence suggests it may not be the most effective in the long term. Other methods of managing congestion, such as variable speed limit indicators, currently used in England and the United States (National Highway Cooperative Research Program, 2002), could be utilized in Edmonton and other jurisdictions in Canada. These other methods could act in concert with the promotion of alternative modes of transport and speed cameras, to manage congestion.

8.6.2 Municipal Policy

A more appropriate level of analysis in the future for transportation issues may be at the policy level (i.e., higher than the project level). In this case study, the Transportation Master Plan, (a high-level policy document) dictated the widening of Whitemud Drive to allow a freer flow of cross-town traffic. Any planning pertaining to the Whitemud corridor stemmed from the Transportation Master Plan, and the City of Edmonton was reluctant to change course after a great deal of time and resources were invested in the plan.

The context of how municipal governments make decisions is worth noting. Municipal governments in Canada have increasingly concerned themselves with acquiring tax revenues from private land developments in the face of decreased transfer payments from provincial and federal governments (Bradford, 2002). From this perspective, the sprawling nature of most major Canadian cities is to the financial benefit of municipal government because it gives them much needed tax revenues. However, this rationale makes it difficult for public transit to be effective because high density developments typically are needed to make public transit efficient (Newman & Kenworthy, 1989).

Public consultation at the local level is also an issue of relevance in this case. The City of Edmonton seemingly made every effort to reach consensus on an approved option for the Whitemud corridor, although backlash was raised by a group of concerned citizens. Even after the City of Edmonton commissioned a downstream assessment study to look at issues of concern, local residents were not happy because no significant health or safety concerns were estimated with the roadway widening. It is rare that true consensus on issues as highly politicized as transportation infrastructure would ever be reached, which accentuates the need for more evidence from research to critically examine these issues and provide a rational basis for discussion.

8.6.3 Measurability

The measurability of each impact is an area of concern, especially for transportation planners who have to evaluate how each impact is affected by transportation projects or infrastructure. The measurability of impacts aids in the development of a full cost accounting approach, similar to that used in cost-benefit analysis. The application of the IIAF would have been improved had all of the quantitative indicators been estimated, but given the time and resources available, only the air pollution indicators were analysed.

The likelihood of an IIAF or similar impact assessment framework being utilized by Transportation Planners is dependent upon quantifiable impacts being included. However, both quantitative and qualitative assessments are required in any assessment framework because they compliment each other: quantitative assessment provides evidence based arguments and qualitative assessment provides a perspective on the opinions and values of the stakeholders. The IIAF allows for both quantitative and qualitative impacts to be examined.

Chapter 9 Conclusions and Recommendations

All six of the objectives of this thesis were met. The first objective of identifying a multitude of urban transportation impacts, along with a review of approaches to complex problems was conducted in Chapter 2. This background aided in the development of an Integrated Impact Assessment Framework, which was the second objective. The third objective of applying the IIAF to a case study, using the Ecohealth approach, with stakeholder input was described in Chapters 4 and 6. Baseline information was compiled for air pollution health effects in Edmonton as a whole as in the fourth objective, and not strictly for the Whitemud corridor. The fifth objective of comparing four different transportation scenarios and their impacts on air pollution health effects is detailed in section 7.4. The final objective is to disseminate the findings of this thesis to facilitate transportation planning and policy development. An executive summary of this thesis will be presented to each of the stakeholder groups involved in this study. Presentations and a submission to a peer-reviewed journal are also intended.

9.1 Pilot Study

Stakeholder opinion was useful in determining the significance of impacts related to Whitemud Drive and in the analysis of air pollution effects on health. There was a wide range of opinion about how the Whitemud Drive widening would affect certain impacts, especially among community residents and City Transportation Planners and other experts. There was no consensus about whether the widening would increase or decrease air pollution. Interestingly, those from Alberta Environment and Capital Health Authority were skeptical that the widening would increase air pollution at all. In general, according to the stakeholders, the widening of Whitemud Drive was not expected to produce any significant impacts aside from increased noise.

The variation in stakeholder opinion suggests that more communication is needed between these groups to achieve consensus in transportation planning, and to understand the complex interactions when examining how transport can impact on people's health.

More evidence on the link between roadways, traffic-related air pollution, and health, for example, may help stakeholders reach a more common understanding. The findings of the air pollution analysis in this thesis could add to this growing body of evidence.

The questionnaire developed for this study should be refined and used on a larger sample size so that the results can be generalizable outside of the study group. This would also serve to increase the reliability and validity of the instrument.

9.2 Traffic-Related Air Pollution

Traffic-related air pollution is estimated to have measurable costs for the health care system in Edmonton and for the families of those affected. At the baseline level today, the direct cost of traffic-related pollution in Edmonton is estimated at $4 million. These figures are likely to be underestimated because only particulate matter was analysed, not all of the potential adverse health effects from $PM_{2.5}$ were considered, and indirect costs were not included. While the widening of Whitemud Drive will result in $PM_{2.5}$ levels still within acceptable limits, the widening will affect the respiratory health of citizens in Edmonton, with an estimated two additional respiratory-related emergency room visits per year expected, along with an increased contribution to respiratory-related hospital admissions and deaths. The analysis clearly shows that there is a measurable cost associated with motor vehicle driving, and that transportation infrastructure that encourages more vehicle kilometres travelled will lead to increased adverse health effects and costs.

Because of the importance of indoor air quality to human health, it is recommended that more detailed studies be conducted that measure indoor air pollution levels in homes and schools surrounding Whitemud Drive. This would provide a better picture of how much air pollution people are exposed to indoors, where people spend the majority of their time.

9.3 *Congestion and Induced Traffic*

One of the main arguments given to widen roadways is to manage congestion. However, according to the Pembina Institute, commuting times in Alberta have only increased from 24 to 25 minutes from 1961 – 1999 (Pembina Institute, 2001c). Therefore, the policy of continually expanding roadways to manage congestion needs to be critically examined. Roadway expansion is associated with more automobile growth, which leads to more congestion producing adverse health and environmental concerns, in a self-reinforcing cycle. Ideally, municipal governments would promote alternative mechanisms of moving people (such as through public transit and provision for bicycling and walking), to manage congestion. This would also help make public transit and bicycling and walking more competitive and convenient when compared to the private automobile.

The provision of more roadways is not seen as an environmentally sustainable option because of the induced traffic that results. The evidence from the literature clearly states that automobile dependency is harmful to public health from air and noise pollution, injuries and fatalities from collisions, and contribution to a sedentary lifestyle (Dora, 1999; Granados, 1998; Morton, 2001; Transport and Health Study Group, 1991). To promote public health, the city should examine funding for more public transit and bicycle paths, with these concerns weighed against economic considerations. One mechanism to weigh these social, economic, and health concerns from transport is the HAF.

9.4 *Policy Implications*

The findings from this thesis also suggest that more collaboration is needed among the various government organizations. Where the municipal government has jurisdiction over transportation, the provincial government has jurisdiction over air quality monitoring, and the regional health authorities have control over the health of individuals within their territory. On an issue as diverse as transportation, with consequences for air quality and health, it is crucial that a formal mechanism be put into

place so that governmental organizations can work together to address issues of local concern. The case study of Whitemud Drive is the first issue, to the researcher's knowledge, that transportation, environment, and health organizations have collaborated. The IIAF may be one mechanism to encourage these various agencies to work together to estimate the combined impacts associated with transportation options.

Federal and provincial governments should work to allocate more funding to municipal governments for their infrastructure needs. This would help to reduce municipal government's dependence on property taxes, which currently constitute 49% of all municipal revenue in Canada (Bradford, 2002). With increased funding to municipalities, more resources could be focused on public transportation infrastructure to mitigate the negative environmental and health effects of urban sprawl.

Municipal government also faces pressure from influential business groups who are typically in favour of roadways because they allow a freer movement of goods, not only people. The purpose of municipal government has traditionally been to serve property and to promote commerce (Magnusson & Sancton, 1983). The need to promote industry is a message that is consistently delivered by economic development groups to municipal government. There is no easy way to mitigate this influence, but one mechanism might be to allow other groups (i.e., environmental and community groups) an increased presence at public consultation meetings.

Land use planning is a major determinant of transportation in urban areas (Newman & Kenworthy, 1989). As municipal governments are increasingly stretched for resources, they naturally seek methods of bringing in extra capital, and land development is one way to do this. However, as low-density developments increasingly are built in suburban areas of cities, resulting in urban sprawl, transportation is needed to service these areas. In the future, land development and transportation planning should work together to satisfy the mandates of both of these departments while simultaneously serving the public good, both in the short and longer-term.

Researchers must by aware of the potential for government agencies that are unable to deliver on their data commitments. Alberta Environment did not produce the needed Whitemud Drive air monitoring data as promised, and because of this setback, the air pollution analysis had to be broadened to include all of Edmonton. There is no easy solution for this problem, but a written agreement between data provider and researcher that states exactly the type of data, and the availability of it would be helpful for all parties involved.

The IIAF developed in this thesis should prove useful for transportation planning in the future, especially because it includes public health. Healthy public policy should be a goal of any municipality, and the IIAF is a tool that could help to achieve this goal. By considering a comprehensive set of significant impacts likely associated with a transportation proposal, the IIAF makes transparent how each potential impact has been evaluated. By recognizing the wide range of impacts that need to be considered in any transportation plan, planners will be better able to address community, regional, and global concerns. This will be in the best interests of all citizens.

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Appendix 1

Table 42 Purpose of Questions in Sections 1 and 2

Question Topic	Purpose
Section 1	
Participant's sex	Demographic information for comparison between stakeholder groups
Participant's age range	
Participant's education level	
Congestion on Whitemud Drive and if a problem	Compare with public consultation already done
Suggested methods to alleviate congestion	
Environmental, health, and economic implications of Whitemud Drive now	Impacts to include in assessment framework
City planning practice about the different areas they should examine	Is assessment framework approach likely to succeed
Should city planning include health in a formalized assessment approach	
Widening and its affect on males and females	Gender issue important to IDRC mission
Section 2	
Rank impacts of widened Whitemud in 20 years	Verification of impacts included in assessment framework

Table 43 Purpose of Questions in Section 3 for Community Groups (WETC and Non-WETC)

Question Topic	Purpose
Participation in public meetings	To see if participants were formally apart of community discussions with City of Edmonton
Traffic volumes in communities surrounding 149th street if Whitemud widened	149th street connects to Whitemud and is a main roadway for many who live in these communities
The widening impact on short cutting through Jasper Place	Traffic impact on local community

Table 44 Purpose of Questions in Section 3 for City Councillors

Question Topic	Purpose
Participation in public meetings	To see if participants were formally apart of discussions on Whitemud Drive widening
Traffic volumes in communities surrounding 149th street if Whitemud widened	149th street connects to Whitemud and is a main roadway for many who live in these communities

The widening impact on short cutting through Jasper Place	Traffic impact on local community
Satisfaction with current process of decision making on transportation issues	To see if a formalized assessment approach would be useful for those making the final decisions

Table 45 Purpose of Questions in Section 3 for City Transportation Planners

Question Topic	Purpose
Method of assessing engineering, environmental, economic, and community aspects of transportation infrastructure now	To see how different concerns are assessed now in transportation planning
Would addition of human health considerations be helpful for the planning department	To see how important health is seen in an assessment approach
Features of an assessment approach that would be most useful in transportation planning	To see what features of an assessment approach would be useful for those making the final decisions
Traffic volumes in communities surrounding 149th street if Whitemud widened	149th street connects to Whitemud and is a main roadway for many who live in these communities
The widening impact on short cutting through Jasper Place	Traffic impact on local community

Table 46 Purpose of Questions in Section 3 for Alberta Environment

Question Topic	Purpose
Accuracy of air monitoring stations at identifying sources of PM2.5	To understand accuracy of monitoring stations at identifying the sources of particulate pollution
What percentage of PM2.5 comes from automobiles on roadways	How large of an impact is transportation on air quality
How much would traffic have to increase to adversely affect air quality around Whitemud Drive	How much traffic would it take to impact on air quality around Whitemud
Exposure to PM2.5 at set distances from Whitemud Drive	To understand the exposure that people living near Whitemud Drive might face

Table 47 Purpose of Questions in Section 3 for Capital Health

Question Topic	Purpose
Should health be consulted on transportation infrastructure	To understand how important generally they think transportation impacts health
Impact of many different pollutants on health	Traffic produces many emittants that each have potential impacts on health
Is there threshold below which no human health effects likely to occur	To understand the debate that exists between those who believe air quality guidelines protect the public, and those who don't
How would health concerns manifest from air pollution	To understand if it is primarily respiratory. related or if there were other impacts
Exposure to PM2.5 at set distances from Whitemud Drive	To understand the exposure that people living near Whitemud Drive might face
How much would traffic have to increase to adversely affect health of citizens around Whitemud Drive	How much traffic would it take to impact on human health around Whitemud

Appendix 2

Covering Letter given to two Alberta Environment Employees

Dear Mr.___
Alberta Environment
4946 89th Street
T6E 2K1

Dear Mr.___,

Thank you for agreeing to help in my thesis research examining the health, environmental, and economic impacts of urban transportation. Attached are one information letter and one questionnaire for each of you. The questionnaire is designed to access information from a variety of stakeholders regarding transportation infrastructure in general, and more specifically with the Whitemud Drive in Edmonton. Sections 1 and 2 are given to all stakeholders, while section 3 is targeted specifically to Alberta Environment. You have both been identified as key people within Alberta Environment for your knowledge on air quality.

If you could both complete the questionnaire individually and return it to me in the attached postage paid envelopes at your earliest convenience, I would be most grateful. If you have any questions about the questionnaire, do not hesitate to contact me at 432-1300.

Thank you again,

Josh Marko
Masters Student
Department of Public Health Sciences
University of Alberta

Covering letter template given to City of Edmonton Councillors

Name Date
Executive Assistant, Councillor Name
2nd Floor, City Hall
1 Sir Winston Churchill Square
Edmonton, AB T5J 2R7

Dear Name:

My name is Josh Marko, student in the University of Alberta's Department of Public Health Sciences. Together with my supervisor, Professor Colin Soskolne, we are conducting a study on the health, environment, and economic implications associated with expanding roadways. Our case study relates specifically to the widening of Whitemud Drive in Edmonton.

The main objective of the study is, within an assessment framework, to identify the impacts associated with urban transportation, to hopefully be used in future transportation planning in Edmonton, and around the world. The work has been approved by the Health Research Ethics Board at the University of Alberta. Our major funding is from the International Development Research Centre (IDRC) in Ottawa.

We are approaching this study in a scholarly and objective fashion. To this end, we are seeking input from a broad range of stakeholders, including: Edmonton City Councillors, City transportation planners, environmental experts, health professionals, and citizens. I am writing to ask if Councillor Name would consent to help us in this study.

As part of the participatory approach that we are employing, we would be grateful if Councillor Name would complete a questionnaire that we have developed, which should take no more than 30 minutes. I wondered if it were feasible to meet with Councillor Name to be present while she completes the questionnaire, to help clarify any issues she has at that time. Alternatively, I can drop off the questionnaire with a self-addressed stamped envelope, and Councillor Name could mail it back to me when she has completed it. All information provided will be anonymous and held in the strictest confidence.

We are hoping to receive all responses by March 1, 2002, and your assistance in helping us achieve this goal would be greatly appreciated.

I will telephone you in the week of February 18, to see if Councillor Name is willing and available to help with this study. Thank you for your consideration in this matter.

Sincerely,

Josh Marko

Appendix 3
Information Letter

Title
Integrated Impact Assessment of Transportation Alternatives in West Edmonton

Research team

Member Name	Affiliation	Contact Number
Dr. Colin L. Soskolne	University of Alberta	492 – 6013
Dr. John Church	University of Alberta	492 – 8604
Dr. Louis Francescutti	University of Alberta	492 – 6546
Mr. Mark Anielski	Pembina Institute	491 – 0696
Mr. Josh Marko	University of Alberta	432 – 1300

What is the purpose of the research?
The purpose of this survey is to gain understanding from several stakeholder groups about what their perceptions of transportation issues are in general, and of the Whitemud Drive widening in particular. The results from this survey will be used to complement the framework upon which this study is based.

In addition, community participation is required to fulfill funding requirements from the International Development Research Centre (IDRC), and your participation in this survey will help to satisfy this requirement.

What is the procedure for filling out the questionnaire?
Six different stakeholder groups will be contacted for this study. One of those groups is a Jasper Place community league, of which you are a part. The other five stakeholder groups are members of the West Edmonton Transportation Coalition, Edmonton City Councilors, Capital Health Authority, Alberta Environment, the City of Edmonton's Transportation Planning Branch.

A questionnaire will be handed out to all community members who attend a community league meeting in a Jasper Place neighbourhood. You will need approximately 30 minutes to participate, which includes the completion of the questionnaire. The researcher will be present during this time, so any questions can be directed to him.

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Yes, you have the right to withdraw and not complete all items in the questionnaire.

Do I have to answer every question?
No, you have the right to not answer any question.

Is there an additional contact name and number?
Dr. Colin L. Soskolne can be reached at 492-6013 should you have any concerns about this study.

Information Letter

Title

Integrated Impact Assessment of Transportation Alternatives in West Edmonton

Research team

Member Name	Affiliation	Contact Number
Dr. Colin L. Soskolne	University of Alberta	492 – 6013
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What is the procedure for filling out the questionnaire?

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A questionnaire will be handed out to all community members who attend a WETC meeting. You will need approximately 30 minutes to participate, which includes the completion of the questionnaire. The researcher will be present during this time, so any questions can be directed to him.

What are the benefits to me?

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Yes, you have the right to withdraw and not complete all items in the questionnaire.

Do I have to answer every question?
No, you have the right to not answer any question.

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What is the procedure for filling out the questionnaire?
Six different stakeholder groups will be contacted for this study. One of those groups is Edmonton City Councillors, of which you are a part. The other five stakeholder groups are members of the West Edmonton Transportation Coalition, a Jasper Place Community League, Capital Health Authority, Alberta Environment, and the City of Edmonton's Transportation Planning Branch.

A questionnaire will be handed out to Councillors either by mail or in person. You will need approximately 30 minutes to participate, which includes the completion of the questionnaire. The researcher may be present during this time, and any questions can be directed to him.

What are the benefits to me?
There are no direct benefits to those people who participate in the study. Indirectly, however, the benefit is that your ideas will be integrated into the findings of the research. For example, section two of the questionnaire will be compared with findings from other stakeholder groups, and to those found through other research, to provide a balanced perspective on what the major health, environmental, and economic concerns are with the proposed Whitemud Drive widening. A promising benefit of this research is that the City of Edmonton may be able to use these findings in their decision-making for transportation infrastructure in the future.

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What is the procedure for filling out the questionnaire?
Six different stakeholder groups will be contacted for this study. One of those groups is the City of Edmonton's Transportation Planning Branch, of which you are a part. The other five stakeholder groups are members of the West Edmonton Transportation Coalition, a Jasper Place Community League, Edmonton City Councilors, Capital Health Authority, and Alberta Environment.

A questionnaire will be handed out to employees of the City of Edmonton's Transportation Planning Branch. You will need approximately 30 minutes to participate, which includes the completion of the questionnaire. The researcher will be present during this time, so any questions can be directed to him.

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Six different stakeholder groups will be contacted for this study. One of those groups is Capital Health Authority, of which you are a part. The other five stakeholder groups are members of the West Edmonton Transportation Coalition, a Jasper Place Community League, Edmonton City Councilors, Alberta Environment, and the City of Edmonton's Transportation Planning Branch.

A questionnaire will be handed out to Capital Health Authority, Environmental Health Department employees. You will need approximately 30 minutes to participate, which includes the completion of the questionnaire. The researcher will be present during this time, so any questions can be directed to him.

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What is the procedure for filling out the questionnaire?
Six different stakeholder groups will be contacted for this study. One of those groups is Alberta Environment, of which you are a part. The other five stakeholder groups are members of the West Edmonton Transportation Coalition, a Jasper Place Community League, Edmonton City Councilors, Capital Health Authority, and the City of Edmonton's Transportation Planning Branch.

A questionnaire will be handed out to Alberta Environment employees. You will need approximately 30 minutes to participate, which includes the completion of the questionnaire. The researcher will be present during this time, so any questions can be directed to him.

What are the benefits to me?
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Do I have to answer every question?
No, you have the right to not answer any question.

Is there an additional contact name and number?
Dr. Colin L. Soskolne can be reached at 492-6013 should you have any concerns about this study.

Introductory remarks on how to complete the attached questionnaire

Thank you for agreeing to fill out the attached questionnaire. The purpose of this survey is to obtain information regarding aspects of transportation in the City of Edmonton. Your input is important because you are a stakeholder whose perspective needs to be recognized in any transportation planning.

Your answers will be held in the strictest confidence and will remain anonymous. They will be used to underscore the importance of including all stakeholder views in transportation planning exercises and will be included in the assessment framework developed in this study.

The questionnaire focuses on the proposed widening of Whitemud Drive in Edmonton. The plan is to widen Whitemud Drive by one lane in each direction from 122nd street to 149th street for the primary use of private automobiles. This includes the Quesnell Bridge being widened from a 6-lane to an 8-lane bridge. Any question that refers to the widening relates to the above-mentioned plan.

Please write legibly. If insufficient room is provided for you to answer a question, please feel free to use the back of the sheet. If you do not know the answer to a question, or if you have no opinion on it, then please state this in the space provided. Use a checkmark or an "X" to fill in all boxes on the questionnaire.

Please ensure that you have read the information letter before you proceed. Please hand the questionnaire back to the researcher when you have completed it (if present).

In gratitude for your help with this study,

Dr. Colin L. Soskolne
Professor
Department of Public Health Sciences
University of Alberta
Phone: 492-6013

Mr. Josh Marko
Masters student
Department of Public Health Sciences
University of Alberta
Phone: 432-1300

Questionnaire
Section 1

1) What is your sex?
   Male ❒
   Female ❒

2) What is your age?
   25 years or less ❒
   26-35 years ❒
   36-45 years ❒
   46-65 years ❒
   Over 65 years ❒

3) What is the highest level of education you have completed?
   Less than high school ❒
   High school ❒
   Diploma ❒
   University degree ❒
   Graduate/postgraduate degree ❒

4) Do you feel that congestion on Whitemud Drive is a problem between 122nd street and 149th street?
   Yes ❒
   No ❒
   Don't know ❒

5) If you said congestion was a problem in (4) above, what would you propose as the best method(s) for reducing congestion on Whitemud Drive?

.....

.....

.....

Consider Whitemud Drive in its current state (i.e., not widened) when answering questions 6-8:

6) Do you have any concerns about how Whitemud Drive affects the **environment**, if at all? Please explain.

.....

.....

.....

7) Do you have any concerns about how Whitemud Drive affects **people's health**, if at all? Please explain.

.....

.....

.....

8) Do you have any concerns about how Whitemud Drive affects **Edmonton's economy**, if at all? Please explain.

.....

.....

.....

.....

9) City planners typically consider economic, engineering, community, and environmental concerns when deciding on transportation options. How do you respond to this statement?

Strongly agree ❒
Agree ❒ Comments (if any).....
Neutral ❒
Disagree ❒ .....
Strongly disagree ❒

.....

.....

10) Considering your response to question (9), city planners also should consider the area of human health when they consider transportation options. How do you respond to this statement?

Strongly agree ❒
Agree ❒ Comments (if any).....
Neutral ❒
Disagree ❒ .....
Strongly disagree ❒

.....

.....

.....

11) If Whitemud Drive were to be widened, do you think that males would benefit more than females?

Yes, males would benefit more than females ❒ Comments (if any).....
No, females would benefit more than males ❒
Equal benefit to both males and females ❒ .....
Not sure ❒

.....

.....

Section 2

12) If Whitemud Drive were widened, what do you think would likely happen **over the next 20 years (compared to the situation today)**, affecting each of the items listed below. (Please place **only one check mark in each row**):

	Significant increase	**Moderate increase**	**No effect**	**Moderate decrease**	**Significant decrease**
Time it takes for trips (e.g. to work, shops, recreation etc.)					
Economic benefits to the city					
Real estate values in homes located near Whitemud Drive					
Motor vehicle collisions including collisions with pedestrians and bicyclists					
Stress levels for drivers					
Community cohesion (i.e. how connected the communities surrounding Whitemud Drive feel toward their neighbours)					
Air pollution health effects (i.e. breathing/lung related conditions)					
Noise levels near Whitemud Drive					
Water pollution in the North Saskatchewan river					
Physical fitness levels of Edmonton citizens					
Contribution of vehicle emissions to global climate change					

Comments on Section 2:

.....

.....

.....

.....

Section 3 for Community Groups

12) Did you participate in any of the public meetings involved in the Whitemud/Terwilligar planning process?

Yes ❒
No ❒
Don't know ❒

13) If Whitemud Drive were widened, what do you think would happen to traffic volumes in the communities surrounding 149 street?

Increase significantly ❒
Increase moderately ❒
No significant change ❒
Decrease moderately ❒
Decrease significantly ❒
Comments (if any):.....

.....

.....

14) If Whitemud Drive were widened, do you think that people driving would be less likely to short cut through neighbourhoods in Jasper Place? Please explain.

Yes ❒
No ❒
Don't know ❒

.....

.....

.....

.....

15) Are there any other comments that you would like to express about the proposed widening of Whitemud Drive? If yes, please explain.

Yes ❒
No ❒
No opinion ❒

.....

.....

.....

Section 3 for City of Edmonton Transportation Planning

13) By what method does your department assess the engineering, environmental, economic, and community aspects of transportation infrastructure **now**?

.....

.....

.....

.....

14) Would adding human health considerations in a formalized assessment approach of transportation infrastructure be helpful for your department?

Yes ❒
No ❒ Comments (if any) .....
Not sure ❒

.....

15) If you answered yes to (14) above, what features of an assessment approach would be of most benefit to your department?

Includes impacts from many disciplines ❒
Understandable to general public ❒
Includes impacts that are quantifiable ❒
Not overly time-consuming to complete ❒
Other – please specify

.....

16) If Whitemud Drive were widened, what do you think would happen to traffic volumes in the vicinity of 149 street?

Increase significantly ❒
Increase moderately ❒
No significant change ❒
Decrease moderately ❒
Decrease significantly ❒
Other .....

17) If Whitemud Drive were widened, do you think people driving would be less likely to short cut through neighbourhoods in Jasper Place? Please explain.

Yes ❒
No ❒ .....
Don't know ❒

.....

18) Are there any other comments that you would like to express about the proposed widening of Whitemud Drive? If yes, please specify.

Yes ❒ .....
No ❒
No opinion❒ .....

Section 3 for Capital Health Authority

13) Do you think that public health professionals should be consulted when local government is considering transportation infrastructure? Please explain.

Yes ❒
No ❒ .....
Don't know ❒

.....

.....

14) How does the interaction among many different air pollutants impact on human health?

.....

.....

15) Is there a safe threshold for air pollutants, below which no human health effects are likely to occur? Please explain your answer.

Yes ❒
No ❒ .....
Don't know ❒

.....

.....

16) How would health concerns manifest (i.e., respiratory hospital admissions, lung cancer, etc.)?

.....

.....

17) How much pollution from particulate matter (PM 2.5) emitted from vehicles would people be exposed to at the following distances from Whitemud Drive? **Place one check mark for each row.**

	Significant amount. Enough to cause adverse health effects.	**Moderate amount.** No health risks except in vulnerable members of the population.	**Little or no amount**. No health risk to any member of the population
Less than 10 metres			
From 10-100 metres			
From 101-250 metres			
From 251-499 metres			
From 500-999 metres			
1000 metres or more			

18) By how much would the level of traffic have to increase to present a health impact to those living near Whitemud Drive? Please specify.

.....

.....

19) Are there any other comments you would like to make? Please specify.

.....

Section 3 for Alberta Environment

13) How accurate are the air monitoring stations at identifying the different sources of PM 2.5?

Very accurate ❒
Accurate ❒ Comments(if any):.....
Not accurate ❒
Other ❒ .....

.....

.....

14) Approximately what percentage of PM 2.5 comes from private automobiles on Edmonton roadways?.....

.....

15) By how much would the level of traffic have to increase to adversely affect air quality for those people living near Whitemud Drive? Please specify.

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16) How much pollution from particulate matter (PM 2.5) emitted from vehicles would people be exposed to at the following distances from Whitemud Drive? (**Place only one check mark for each row**).

	Significant enough to cause adverse air quality.	**Marginal effects to air quality.**	**No air quality concerns.**
Less than 10 metres			
From 10-100 metres			
From 101-250 metres			
From 251-499 metres			
From 500-999 metres			
1000 metres and more			

17) Are there any other comments you would like to make? Please specify.

.....

.....

Section 3 for City Councillors

13) Did you participate in any of the public meetings involved in the Whitemud Drive/Terwilligar planning process?
Yes ❒
No ❒
Don't know ❒

14) If Whitemud Drive were widened, what do you think would happen to traffic volumes in the communities surrounding 149 street?
Increase significantly ❒
Increase moderately ❒
No significant change ❒
Decrease moderately ❒
Decrease significantly ❒
Comments (if any):.....

15) If Whitemud Drive were widened, do you think that people driving would be less likely to short cut through neighbourhoods in Jasper Place (i.e. Laurier Heights, Lynnwood, Parkview, etc.)? Please explain.
Yes ❒
No ❒
Don't know ❒

.....

.....

16) Are there any other comments that you would like to express about the proposed widening of Whitemud Drive? If yes, please explain.
Yes ❒
No ❒
No opinion ❒

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.....

17) Do you feel that the existing process of having the Transportation and Streets Department compile information, and then bring that information forward through a public hearing process, to be useful to you in making decisions on transportation infrastructure?
Yes ❒
No ❒
Not Sure ❒
Comments (if any): .....

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