Report on Public Health and Urban Sprawl in Ontario

A review of the pertinent literature

January 2005

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Executive Summary

This report summarizes pertinent information on the relationship between urban sprawl and health. It serves to identify the key issues that are relevant to the growing number of sprawl-related health problems in Ontario which is comparable to US situations and is far worse compared to Europe.

The best available evidence indicates that greenspace is an essential part of human health. People cannot continue to lead healthy lives without sufficient farmland to produce local food, forests to help purify the air, and protected watersheds to provide safe drinking water. Neither of these complementary goals - protecting environmental systems and protecting human health - can be accomplished, however, without curbing urban sprawl. By setting aside one million new acres for a Greenbelt in southern Ontario, the provincial government has taken strong steps towards protecting the environment, and building stronger, healthier, more compact communities. Other connected strategies, such as the proposed Growth Plan and the Planning Reform initiative, will also play key roles in controlling sprawling growth.

In this document, the pathway from urban sprawl to public health via vehicle emissions and air pollution will be examined, along with reviews of the relationship of sprawl to increased driving. Sprawling urban developments leads to increased driving, which results in increased vehicle emissions that contribute to air pollution and its attendant negative impacts on human health. Health effects of traffic-related air pollution, at both the local and regional levels, are described using Toronto and Ontario mortality and morbidity data. The effects of air pollution and greenhouse gas emissions on morbidity and mortality, particularly with reference to respiratory disease (including asthma), cardiovascular disease, and reproductive health are summarized. Some cancers such as leukemia in children have been linked to exhaust toxicants. Furthermore, the increased greenhouse gas emissions that result from a car-dependent society are counter-productive to the Canadian commitment to the Kyoto Protocol.

The future pattern of land development will shape the choice and mode of travel for future generations, as well as determine housing location and affordability. Evidence clearly shows that people who live in spread-out, car-dependent neighborhoods are likely to walk less, weigh more, and suffer from obesity and high blood pressure and consequent diabetes, cardio-vascular and other diseases, as compared to people who live in more efficient, higher density communities (Ewing et al, 2003a). The sprawl index used by Ewing is used to rank these areas and is calculated in such a way that the *higher* the index the *lower* the sprawl. Thus, road accidents and fatalities are found to decline as the index for localities increases. The low-walkability of sprawling neighbourhoods and the resulting increase in car use contribute to the growing obesity epidemic, especially in children. A lack of safe pedestrian thoroughfares and diminished natural environments also lead to the decline of social capital and psychological well-being. Other health implications of urban sprawl include social isolation and age segregation in the elderly and young (Pohanka, 2004). Sprawl impacts greatly on the elderly and disabled, who consequently become isolated and unable to access social or medical services.

Urban (or suburban) sprawl leads to increased traffic, which in turn leads to increased accidents and fatalities (motorists, pedestrians and cyclists), as well as negative mental health impacts (stress, road rage and anxiety). A greater number of fatalities occur where the population density is lower. Road accidents represent the most underestimated risk that people are exposed to in everyday life. The impact of fatalities and disabilities from traffic accidents on society cannot be underestimated. Thousands of pedestrians, motorists and cyclists die or are maimed every year in North America. Post-traumatic stress disorder is much greater in these groups than the national average, and psychiatric problems occur readily in children who have experienced even minor traffic accidents.

Vehicle drivers are experiencing increased levels of stress due to long commutes and greater distances to reach services. In addition to having deleterious effects on physical health, this stress has been found to impact on family life and work performance. Women bear an inordinate amount of this burden due to responsibilities with children, jobs, errands and elderly care-giving at home.

The environmental problems that result from uncontrolled urban growth are numerous, and have a significant impact on health. These problems include flooding, which results from increased impervious surfaces for roads and parking; increased temperatures from heat islands, which leads to a significant increased risk of mortality in elderly populations; decreases in natural areas and forests, and increased incidences of water pollution and water-borne disease.

The impact of the built environment on health is an emerging field of study and more rigorous research is needed, especially in Canada. Despite this, the results of current studies clearly indicate that serious public health problems will continue to escalate unless decisive and immediate action is taken to control urban sprawl and preserve sufficient greenspace, improve air quality, and protect water sources.

1. Background

Here in Ontario, the growth of sprawling development in the GTA has increased the number of cars on the road and traffic congestion. This has led to a corresponding increase in smog, air pollution, fatalities and the related health affects. Unless the current trends change, the hours of delay experienced by auto drivers is expected to rise by 300% over the next 27 years, with a 42% increase in carbon dioxide emissions per capita (Neptis Foundation, 2002). If we are to keep to our Kyoto commitment, these greenhouse gases must be attenuated.

Urban sprawl, as it has evolved in North America, cannot be separated from the use of private vehicles for transportation. Spread-out suburbs ensure that population densities are too low to support an efficient and comprehensive public transit system. In North America, there has been an inexorable decline in public transit services and, in particular, in dedicated rights-of-way such as railway and streetcar rail lines, which have the potential to offer fast and competing service. Yet the private automobile, with its supporting infrastructure of roads, highways and parking lots, continues to dominate as the primary mode of transportation. This has resulted in an increase in the amount of land used for transportation, impervious paved surfaces, associated problems of flooding and heat islands, and the resulting negative health effects, which will be discussed in more detail later in this report. The dependence on the private vehicle, and its resulting development patterns, seems to be irreversible and is self perpetuating: as the suburbs expand, their greater political weight increases the demand for more roads and more lanes, resists the financing of public transit infrastructure and accelerates declining ridership. In addition to providing adequate funding for public transportation and building at transit-supportive densities, innovation and change in the transportation sector must be made a priority.

Many people move to the suburbs in order to escape the perceived "ills of the city". Although there appears to be many benefits to suburban life: less exposure to noise pollution, less overcrowding, decreased stigma and fear of crime, and a greater experience of nature, there is a growing body of evidence that suggests that the negative health impacts are enormous and ultimately far outweigh these benefits. Escape from crowding can lead to extreme anonymity and isolation that results from a loss of community. As a sanctuary from life stress, sprawl communities have increased loneliness, inactivity, depression and commuting stress with which to contend. Ironically, the promise of increased contact with nature is contradicted by the fact that sprawling development reduces the amount and quality of natural areas.

1.1 Purpose of Study

The Ontario College of Family Physicians' Environmental Health Committee wanted to investigate the evidence concerning sprawl and its health impacts as it pertains to Ontario. We conducted a mapping of the literature on the direct and indirect effect of urban sprawl on health, but there were very few Canadian studies on this topic.

This subject was considered especially relevant given the current political and public interest in land-use issues, sprawl and the greenbelt in Ontario. As physicians we focused on the public health aspects due to sprawl.

1.2 Definitions

At present, there are many definitions of the word "sprawl". Sprawl tends to be defined by a series of characteristics: low densities; separation of land uses; leapfrog development; strip retail development; automobile-dependent development; development at the periphery of an urban area at the expense of its core; employment decentralization; loss of peri-urban, rural agriculture, and open space; and fragmented governmental responsibility and oversight (Johnson, 2001).

Most definitions refer to scattered, unplanned urban growth, commercial strip development, an increase in commuting time and distances, and an increase of low density development in suburban areas with a concurrent decrease in high density populations in the inner cities. This growth often occurs faster than the development of the infrastructure (e.g. schools, roads, sewer systems, water lines) needed for support (Pohanka, 2004).

Generally, there is little distinction given between "sprawl", "urban sprawl" and "suburban sprawl". Sprawl is said to occur when the rate at which land is converted to non-agricultural or non-natural uses exceeds the rate of population growth (USEPA, 2002b). It is also seen as scattered development that increases traffic, saps local resources, and destroys open space (Sierra Club, 2002). The built environment in a sprawl scenario includes a landscape of wide streets and driveways, cul-de-sacs, large parking lots, and single-use areas such as office parks or residential subdivisions with few sidewalks and few connections to other developments (USEPA, 2001).

Smart Growth America defines sprawl as the outcome of four related factors: low residential density; a poor mix of homes, jobs and services; limited activity centers and downtown areas; limited options for walking or biking, (Ewing, 2002), and shows that sprawl correlated directly with rising vehicle use.

National Geographic, 2001 gave sprawl the following characteristics: high volumes of traffic; scattering of businesses, shops and homes; inadequate public transportation; pedestrian unfriendly streets; zoning that divides neighbourhoods from offices, shops and restaurants; and large parking lots that push buildings back and farther away from each other. For the purposes of this document, the term "sprawl" will incorporate the above descriptions.

The link between sprawl and health falls under the discipline of Environmental Health. According to the U.S. Department of Health and Human Service's Healthy People 2010,: "In its broadest sense, environmental heath comprises those aspects of human health, disease, and injury that are determined or influenced by factors in the environment. This includes not only the study of the direct pathological effects of various chemical, physical, and biological agents, but also the effects on health of the broad physical and social environment, which includes housing, urban development, land-use and transportation, industry and agriculture".

1.3 Regions Most Affected in Ontario

Over the next 30 years, the region in southern Ontario known as the 'Golden Horseshoe' is expected to attract an additional four million people. This will put enormous development pressure on outlying city centres, suburban communities and agricultural land. If current "business-as-usual" patterns of growth continue, an additional 260,000 acres (1,070 km2) of rural land will be urbanized by 2031, an area that is almost double the size of the City of Toronto. Approximately 92% of this is classified as prime agricultural land (Neptis Foundation, 2002).

The growth of sprawl through development, especially in the GTA, has increased the number of cars on the road and traffic congestion**.** Unless the current trends change, the hours of delay experienced by auto drivers is expected to rise by 300% over the next 27 years, with a 42% increase in carbon dioxide emissions per capita (Neptis Foundation, 2002). If we are to keep to our Kyoto commitment, these greenhouse gases must be attenuated by decreasing vehicular use.

The City of Toronto provides many good examples of walkable, transit-supportive neighbourhoods. These areas support a diverse mix of housing, employment, shopping, parks and other opportunities, all within easy walking or cycling distance. This kind of increased, mixed-use density makes public transit convenient and efficient, and decreases reliance on the car as the sole means of transportation. In contrast, many outlying suburban communities do not achieve the same density as downtown areas. When density *is* increased in these areas, it is often done without providing for easy access to daily need requirements. People still have to drive in order to work, shop, or take their children to school.

The provincial government of Ontario has recognized the need for controlling urban sprawl, improving air quality, and conserving natural heritage and farmland. The proposed *Greenbelt Act, 2004* seeks to protect over 1.8 million acres of land, including the already protected Niagara Escarpment and Oak Ridges Moraine. This strategy is designed to work in conjunction with other provincial initiatives, including the Growth Plan and the proposed Planning Reforms. Taken together, these strategies aim to encourage higher density mixed-use development supported by easy access to public transit, thereby directing growth away from rural and natural areas.

2. Physical Health Impacts of Sprawl

2.1 Air Pollution

Sprawl leads to increased driving, and increased driving leads to vehicle emissions that contribute to air pollution and its attendant negative impacts on human health. This pathway from sprawl to public health via vehicle emissions and air pollution will be defined in this chapter.

Results of numerous studies in the US show that sprawling patterns of development lead to increased use of the private automobile as the primary mode of transportation. Low density levels, single purpose land useage, and poorly connected street networks are associated with more vehicle miles traveled (VMT), increased vehicle hours of travel (VHT), fewer transit trips, and greater vehicle

ownership (Frumkin, 2004). In Atlanta, travel distances are greatest at the region's periphery (i.e. the suburbs), and shortest near its centre (Criterion Planning Engineers, 2000). Research in the Central Puget Sound region showed that as household density and work tract employment density decreased (sprawl), vehicle emissions increased (Frank, 2000). In Ontario, the Joint Program in Transportation at the University of Toronto conducted the "2001 Transportation Tomorrow" survey (Joint Program in Transportation, 2001). In comparing the City of Toronto with the Regional Municipality of York, trends similar to the previous examples are evident, with residents in York Region taking more trips, and longer trips, per day. Peel and Durham have similar profiles to York.

	Household average Vehicles	Household average Trips/day	Daily trips/ person	Median auto driver trip length (km)
Toronto	1.1	5.1	2.3	5
York	1.9	7.2	2.7	6.4

The University of Toronto's Joint Program in Transportation also found that the average ownership rate for automobiles increased .0045 for every kilometer outside of the downtown Toronto core (Miller, 2004).

Increased motor vehicle emissions cause increased levels of air pollution and GHGs (greenhouse gases). Air pollution affects health directly, while increased GHG emissions contribute to climate change, with numerous resulting negative effects on public health. The remainder of this chapter will describe these relationships, and complete the pathway between vehicle emissions and public health.

2.1.1 How do Vehicular Emissions Lead to Air Pollution?

Automobiles are a major source of air pollution in Ontario. With the projected increased number of vehicles, vehicle kilometers driven and the introduction of larger, less fuel efficient vehicles, such as sports utility vehicles (SUVs) and minivans, they will continue to be a direct source of emissions contributing to poor air quality. Reductions in emissions per vehicle kilometer traveled, which are related to both improved emission control technology and cleaner fuel, as well as inspection and maintenance programs such as "Drive Clean" in Ontario, will not offset this increase in emissions (Bates, 2000).

In 2001, the percentage of pollutants in Ontario derived from transportation was as follows:

Oxides of Nitrogen: 33% of Oxides of Nitrogen (NOx) from road vehicles, and another 30% from other transportation,

Particulates: 20% of Particulate matter less than 2.5 microns ($PM_{2.5}$),

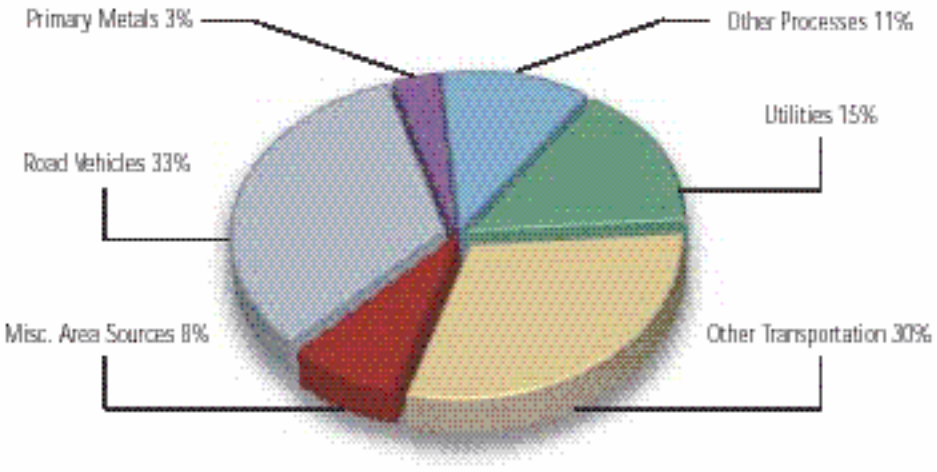
Carbon Monoxide: 58% of Carbon Monoxide (CO) derived from vehicular travel and another 27% from other transportation sources and

VOCs: 18% of Volatile Organic Compounds.

(Data: Ontario Ministry of the Environment, Air Quality in Ontario, 2002)

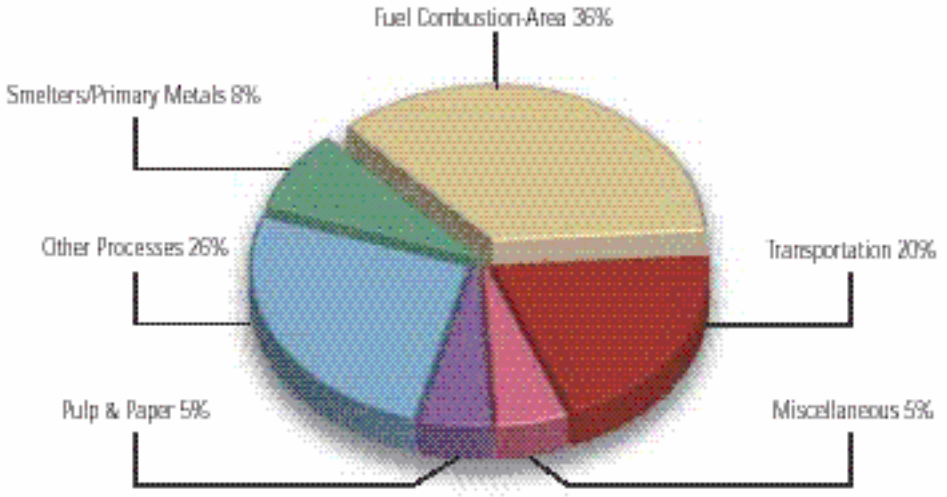
Sulphur dioxide (SO_2) is produced by fossil fuel combustion, but space heating and electrical power generation, rather than transportation, are thought to be the main sources (Pengelly, 2004).

Ontario Nitrogen Oxides Emissions by Sector
(Emissions From Human Activity, 2001 Estimates)



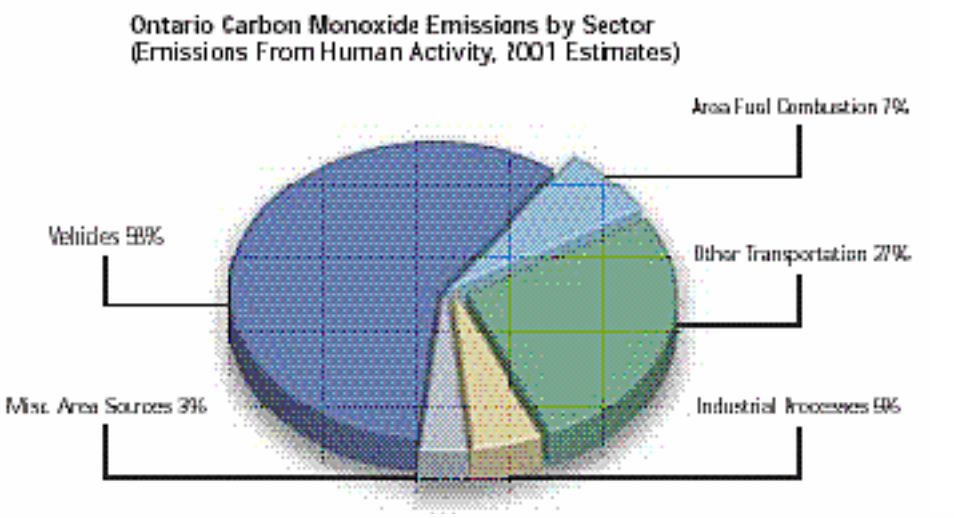
Note: Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.

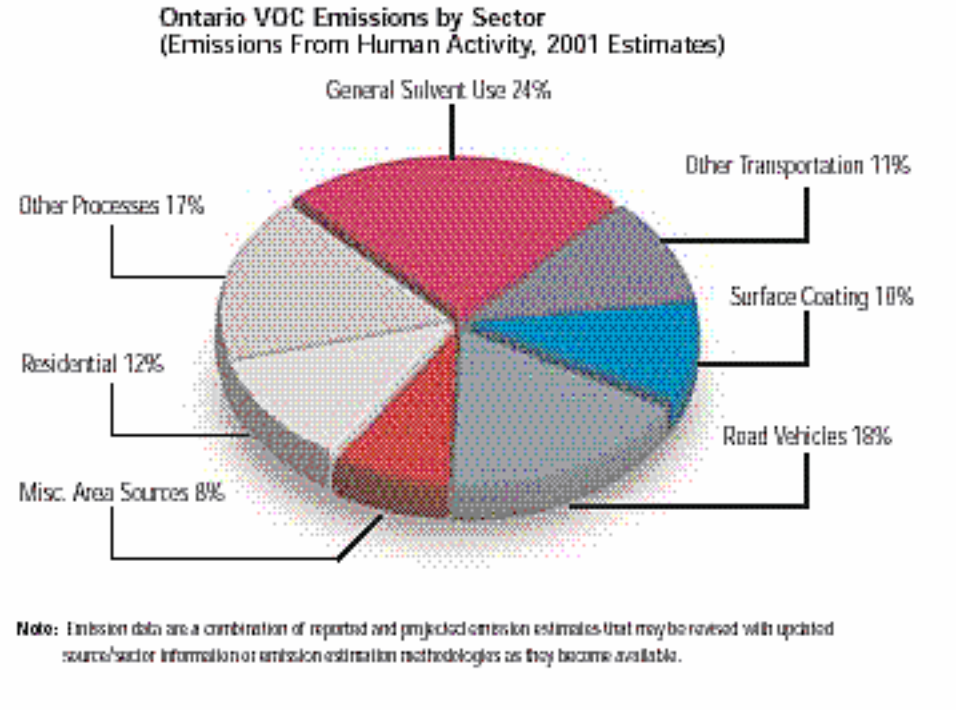
Ontario PM_{25} Emissions by Sector
(Emissions From Area/Point/Mobile Sources, 2001 Estimates)



Note: 1. Emissions from open sources (such as construction activity, agricultural activity, road dust) are not included. Emissions from open sources from the smelters are not available.

2. Emission data are a combination of reported and projected emission estimates that may be revised with updated source/sector information or emission estimation methodologies as they become available.





(Source: Ontario Ministry of the Environment, Air Quality in Ontario 2002 Report)

2.1.2 Local Pollution

While air pollutants can have impacts on health close to points of emission (fresh emissions or local pollution), they also contribute to the degradation of regional air quality.

Levels of fresh pollutants are higher near roads carrying higher volumes of traffic. Concentrations of particulates emitted from vehicles are greatest near the roadway, and decrease to background levels at 300m (Zhu, 2002). Levels of particulate ($PM_{2.5)}$ near busy roads can be 30% higher than background levels (Brook, 2002). CO and NOx follow a similar pattern (Zhu, 2002). A number of recent studies have looked at the health effects of living close to heavily trafficked roadways. The results are discussed below.

"Air toxics" are air pollutants emitted by motor vehicles but in much smaller quantities than the previously discussed criteria pollutants. They are known or probable carcinogens. They include benzene, formaldehyde, acetaldehyde, 1,3 butadiene and diesel particulates (Suh, 2000; USEPA, 1994).

2.1.3 Regional Pollution

Most studies linking air pollution to adverse health effects measure ambient air pollution, with monitors spread widely across a city or region. The "Air Pollution-Related Burden of Illness in Toronto" study (Pengelly, 2004) used data from downtown sites (Bay/Wellesley), Scarborough, North York, York, Oakville, Etobicoke and Mississauga.

Primary air pollutants are emitted from transportation, industrial, electrical power generation and other sources. Ozone and many of the particulates are called secondary pollutants, and are formed when these primary pollutants (or precursors) undergo complex aerochemical reactions. NO_2 (Nitrogen Dioxide) and VOCs (Volatile Organic Compounds) combine in a chemical reaction in the presence of sunlight and heat to form ground level ozone. Ozone levels are consequently higher in summer, and usually rise in the late afternoon and evening. They are also typically higher in suburban recordings than downtown, mainly as a result of the scavenging of ozone by nitric oxide originating from traffic emissions. This reduces the local levels, but ultimately contributes to higher levels downwind (Ontario Medical Association, 1998).

Particulate air pollution is a mixture of solid and liquid particles suspended in air. The size of the suspended particles varies, and they are classified according to size. PM_{10} refers to particulate matter with aerodynamic diameter <10μm. They are also called thoracic particles, and can penetrate into the lower respiratory tract. $PM_{2.5}$, or respirable particles, are less than 2.5μm in diameter, and ultrafine particles are smaller than 100nm. These smaller $PM_{2.5}$ and ultrafine particles, because they can penetrate into the gas exchange region of the lungs and are not cleared efficiently, are implicated more in increased mortality and other health effects associated with particulate matter (Laden, 2000; Brunekreef, 2002). PM_{10} consists mainly of crystal particles mechanically generated from agriculture, mining, construction and road traffic. $PM_{2.5}$ arises mainly from combustion of fossil fuels in motor vehicles, and coal, gas and wood for electrical power

generation and heating. The 2001 Ontario figures indicate that, while automobiles contribute 20% of fine particulate matter, motor vehicle emissions usually constitute the most significant source by number of ultrafine particles in urban environments, and 80% of particles in the urban environment are of the ultrafine size. (Zhu, 2002; Peters, 1997).

The term smog usually refers to a mixture of ozone and particulates that develops in the summer. In Ontario, it persists for a number of days due to large air masses moving over the Windsor-Quebec corridor. A significant amount of the summertime smog in Ontario originates in the USA as transboundary pollution (Ontario Medical Association, 1998); however, it is important to note that air pollution is also present and affects health outside of smog episodes, including in winter. Winter smog consists mainly of particulates.

2.2 The Burden of Illness from Air Pollution

The Ontario Medical Association has described a method, the ICAP model, for calculating the "Illness Cost of Air Pollution" (Ontario Medical Association, 2004). ICAP allows for regional estimates of the impact of smog-related air pollution (ozone and particulate matter) on mortality and morbidity. For 2003 in Ontario, the OMA estimates 2,060 premature deaths, 48,690 emergency room visits, $465.2 million in direct health care (hospital) costs, and $585.6 million in lost productivity costs (A.A. Personal communication). This model is limited to assessing the effects of short-term exposure to smog-related air pollution.
The Toronto Public Health Unit, in their recent APBIT (Air Pollution Related-Burden of Illness in Toronto) study of 2004, estimated that in the City of Toronto, approximately 1,700 premature deaths each year, and between 3,000 and 6,000 hospital admissions are associated with criteria pollutants: ozone, NO_2, SO_2, CO and PM_{10} inhaled by the public at large. These figures are based on air pollution levels for 1999, the most recent year for which there was adequate information (Pengelly, 2004). This study, in contrast to the ICAP study, included both summer and winter effects of these pollutants, the effects of low levels of pollution on health, and the health effects of long-term exposure to these pollutants.

2.2.1 The Health Effects of Traffic Pollution

There are three areas of research that directly address the question of whether traffic affects health. The first examines the question of exposure: are people in cars more exposed to vehicle pollutants? The second is a series of studies of people living near heavily trafficked roadways (long-term exposure) or affected by short-term exposure to traffic. The third looks at whether a reduction in traffic affects the numbers of people getting ill.

2.2.1.1 Exposure Studies

Spending more time in a motor vehicle increases exposure to vehicle related pollutants, including CO, PM_{10} and VOCs, such as benzene, methyl tert-

butyl ether (MTBE) and formaldehyde. Levels are higher than background levels (Rodes, 1998). Exposure of drivers and passengers inside buses and automobiles to particulates is higher than to cyclists on the same roads. Exposure is likely derived from the exhaust of surrounding vehicles, or due to limited ventilation (Adams, 2001; Gee, 2004). A study in California found that children riding in a school bus may be exposed to as much as 4 times the level of diesel exhaust as someone riding in a car ahead of it, especially if the child is toward the back of the bus, and the windows are closed. Exposure to diesel exhaust can trigger asthma, and as an air toxic, is a risk factor for lung cancer (Natural Resources Defence Council, 2001; Weir, 2002).

2.2.1.2 Health Effects of Living near a Roadway or Driving

The health effects of living near a major traffic route, and therefore higher long-term exposure to local pollution, has been a topic of recent research, both in Canada and Europe. Buckeridge, in an ecologic study in southeast Toronto, showed an association between exposure to $PM_{2.5}$ from motor vehicle emissions from living near a busy road, and hospital admissions for certain respiratory diseases, including asthma, bronchitis, COPD, pneumonia and upper respiratory infections (Buckeridge, 2002).

Local traffic-related air pollution also affects mortality. Finkelstein found that people living close to a major road had an increased risk of mortality, and that the mortality rate advancement period was 2.5 years. This is highly significant, when compared to the mortality rate advancement period for COPD at 3.4, chronic ischemic heart disease at 3.1, and diabetes at 4.4 years (Finkelstein, 2004). European studies have found similar effects (Hoek, 2002).

The effects of short-term exposure to traffic pollution have also recently been highlighted. Traveling in an automobile or bus, or riding a motorcycle or bicycle in polluted streets, is thought to be a triggering factor for myocardial infarction. Other triggering factors better known to physicians are exercise, anger, and cocaine use (Peters, 2004). The traffic effect is likely due to the acute effects of exposure to $PM_{2.5}$ (Peters, 2001).

The general conclusion of these types of studies relates higher mortality and morbidity rates to increased local traffic. This is more relevant to areas of higher urban density than to less dense areas. It might even be argued that sprawl, by separating higher traffic zones from housing, may mitigate this local effect on air quality. However, residents in sprawl areas spend significantly more time driving or as passengers in vehicles (Joint Program in Transportation, 2001), and are therefore more exposed during this time. It is also likely that the increased emissions from more vehicle kilometres driven associated with sprawl, would overshadow this mitigating effect by negatively impacting regional air quality (Frumkin, 2004).

2.2.1.3 Intervention Study

An interesting natural experiment illustrating the health effects of air pollutants from vehicles was observed in Atlanta during the 1985 Olympic Games.

Downtown traffic was severely restricted during the Games. Reduced traffic density, especially during the morning period, was associated with a prolonged reduction in ozone pollution and significantly lower rates of childhood asthma, as measured by reductions in pediatric visits for asthma to emergency rooms and physicians, as well as reduced hospital admissions (Friedman, 2001).

2.3 Regional Air Pollution and Health

A vast body of literature has developed over the last two decades, which describes the relationship between various air pollutants, or mixtures of pollutants, and adverse health effects. The research is both from epidemiology and from laboratory studies of exposure to pollutants. This section will give an overview of the heath effects of pollutants derived from vehicle traffic. The health effects can be categorized as increases in mortality and morbidity. Diseases affected include those of the respiratory system (asthma and chronic obstructive airways disease), cardiovascular system, cancer, and reproductive effects and birth defects. Another important distinction is between the studies on short-term exposure to air pollution, for example triggering an episode of asthma, and studies showing the effects of long-term exposure. Recent research suggests that long-term exposure to air pollution causes lung cancer, may cause asthma (as opposed to aggravating pre-existing asthma), and, most importantly, may affect normal development and growth of the lungs in children.

The 2004 APBIT study attempts to assess the relative importance of health effects of each of Toronto's critical air pollutants (Pengelly, 2004) (See table below). There has always been uncertainty in this exercise. It is difficult to tease out the attributable individual effects from the chemical soup that is urban air pollution and smog. The APBIT study also emphasizes the fact that air pollution does not only affect health during summer smog episodes, when the poor air quality is obvious. It also includes the effects of air pollution in winter, and calculates the negative impacts of low levels of pollution on human health. There is no evidence that a "safe level" exists. As described above, SO_2 emissions are not considered vehicle-related.

Table 7. Air-pollution related NT mortality and hospital admissions in Toronto (1999 data).

Pollutant	OUTCOME		
	Non-Traumatic Mortality	Respiratory Hospital Admissions	Cardiovascular Hospital Admissions
$PM_{2.5}$	1236	597	421
CO	20	272	
NO_2	249	1461	2857
O_3	219	337	2648 *
SO_2	30	215	104
Total	1754	2882	3382

Pengelly LD, Sommerfreund J. Air pollution-related burden of illness in Toronto: 2004 update. Technical report. Toronto Public Health, City of Toronto. March 2004.

2.3.1 Short-Term Exposure

2.3.1.1 Respiratory Effects

Numerous studies have found an association between short-term variations in pollutant levels and respiratory effects. This is measured as increased symptoms such as coughing or wheezing, increased medication use, increased absence from school for children or work for adults, aggravation of asthma, transiently reduced pulmonary function tests, increased visits to physicians or ERs, and increased admissions to hospital for respiratory illnesses. Vulnerable subgroups in the population include those more exposed, such as outdoor workers or athletes; and those more sensitive, such as persons with pre-existing asthma, COPD or heart disease, children and the elderly (Annesi-Maesano, 2003). Ozone, particulates, NOx and SOx are all implicated (Thurston, 2001; Brunekreef, 2002; Gent, 2003). Air pollutants may also interact with other factors to affect the respiratory system. High exposure to NO_2 in the week before the start of a viral respiratory infection, and at levels within current standards, is associated with an increase in the severity of a resulting asthma exacerbation (Chauhan, 2003; Pathmanathan, 2003) and ozone interacts with allergens (Hiltermann, 1997).

2.3.1.2 Cardiovascular Effects

Epidemiological and laboratory evidence suggests that elevated concentrations of particulate air pollution contribute to cardiovascular morbidity, hospitalization, and mortality. Daily variations in particulate levels are associated with cardiopulmonary mortality (Pope, 1995). More specifically, particulates increase susceptibility to myocardial ischemia. The mechanism of this effect is not understood, although particulates have been shown to have effects on the autonomic regulation of heart rate, coronary vasoconstriction, the viscosity of the blood, as well as causing inflammation of the lungs and vascular endothelium. (Pekkanen, 2002; Godleski, 2000; Brook, 2002; Pope, 2002). Elderly patients, those with underlying coronary or pulmonary disease, lower socioeconomic populations, and diabetics may be at particularly increased risk (Brook, 2002).

As described above, short-term exposure to traffic pollution, and therefore particulates, have been shown to be a triggering factor for myocardial infarction (Peters, 2004).

2.3.2 Long-term Exposure

Important recent research has defined the chronic effects of long-term exposure to air pollution, an area that was previously not well understood. There is growing evidence of delayed lung development. Children living in communities with higher levels of NO_2 and other traffic-related pollution, including $PM_{2.5}$, had lung function growth that was approximately 10% slower than that of children in lower air pollution communities. The rate of growth improved in children who moved to lower pollution areas. The effects of

delayed lung development on pulmonary disease later in life is not understood, but is of great concern (Gauderman, 2002).

The second important new finding, in relation to long-term exposure, is the higher incidence of newly diagnosed asthma in children who played sports, and are therefore more exposed to air pollution, in communities with higher ozone levels. Previously, it was thought that air pollution exacerbated asthma in children who already had the disease, rather than causing new onset asthma. Asthma is the most common chronic disease of childhood. The prevalence of childhood asthma has been increasing in developed countries during the past few decades. Causes for this epidemic are unknown, although changes in frequency and severity of early-life infections, diet, and exposure to indoor allergens have all been linked with asthma. Now outdoor air pollution must be added as a possible cause of the increasing rates (McConnell, 2002).

2.3.2.1 Cancer and Mortality

The effects of long-term exposure to combustion-related fine particulates in air pollution were studied in 500,000 U.S. adults, as part of a large study conducted by the American Cancer Society. Fine particulate pollution was associated with both lung cancer and cardiopulmonary mortality (Pope, 2002). This builds on two previous studies that evaluated the effects of long-term pollution on mortality (Dockery, 1993; Pope, 1995). The effects of air toxics as carcinogens have been described above (USEPA, 1994). A dose response relationship between exposure to diesel exhaust and ovarian cancer has been found in Finnish workers (Guo, 2004). The World Health Organization's 2003 report on the health aspects of air pollution estimates that long-term exposure to particulate matter has cost almost 6.4 million years of healthy lives worldwide (WHO, 2003).

2.3.2.2 Reproductive Effects and Birth Defects

A California study described the effects of exposure to CO and ozone on the mother during the second month of pregnancy, a vulnerable window of development for the fetus. An association was found with cardiac and orofacial birth defects (Ritz, 2002). Other studies have related air pollution to low birth weight, preterm birth, intrauterine growth retardation, and fetal mortality, as summarized in Ritz, 2002.

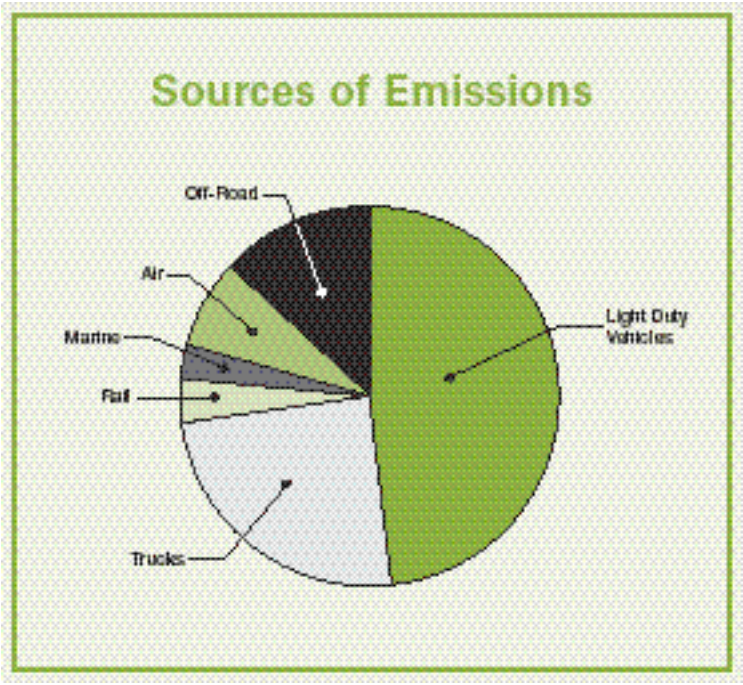
2.4 Climate Change.

Greenhouse gases (GHGs) produced by human activity are responsible for the climate change that is now being observed (IPCC, 2001). GHGs, especially carbon dioxide (CO_2), as with most air pollutants described above, are produced by fossil fuel combustion in vehicles, and are part of vehicular emissions. The transportation sector represents one of the largest sources of GHG emissions in Canada, accounting for 24.7% of total emissions in 2000 (179 MTons [Megatons]). On-road transportation was the largest contributor of total emissions in this sector, at 72.7%. These emissions increased 23% between 1990 and 2000, the fastest growing source of GHG emissions in Canada. Nearly all emissions

growth can be attributed to sports utility vehicles and minivans (Environment Canada, 2001).

In Ontario, the transportation sector was responsible for 61.2 of the total 181 MTons of CO_2 equivalents (one third) in 2001. On-road vehicles were responsible for 49.4, with gasoline automobile travel responsible for 20 and light duty trucks for 15 MTons (Environment Canada, 2001).

Estimates for the GTA indicate a 30% increase in GHGs and, for the Greater Golden Horseshoe, nearly 40% over the next 30 years, unless significant changes in daily trip patterns are made (Neptis Foundation, 2002). Sprawl, with its attendant increase in vehicle kilometres driven, will contribute to increased CO_2 emissions and climate change.



Source of emissions. Transportation.
http://climatechange.gc.ca/plan_for_canada/plan/chap_3_1.html

2.4.1 Climate Change and Health.

Review articles on the health effects of climate change describe direct and indirect pathways for health effects. Direct effects include the impacts of heat stress, as in Paris, 2003, where thousands of elderly people died of heat exhaustion; and increased weather variability, which leads to an increased number of storms, such as the ice storm in Quebec and eastern Ontario, and the hurricanes in Florida (Haines, 2000; Haines, 2004; Smoyer-Daniel, 2000).

Indirect effects are mediated through more complex pathways, such as increased precipitation leading to flooding, run-off contamination from manure in fields, contamination of wells, (as in Walkerton), or increased mosquito distribution causing increases in malaria and dengue. Other impacts might include reduced food supplies, droughts, sea level rise and subsequent migration of large displaced populations (Haines, 2000; Haines, 2004). The details of these health consequences are beyond the scope of this section.

2.5 Ecological Footprint

In their September 2004 report, the Federation of Canadian Municipalities assessed the ecological footprint of 26 municipalities in Canada. The ecological footprint is a measure of human demands on nature's 'goods and services'- the amount of land area and water bodies (lakes, oceans, rivers) we consume to meet our needs - relative to the biologically productive land and sea area. The average Canadian consumes 7.25 hectares of land and water. York region consumes 10.33 hectares, Halton 9.16, Peel 8.25 and Toronto 7.36 (Federation of Canadian Municipalities, 2004). The greatest contributing factor to a large ecological footprint is carbon intensive fuel supplies for transportation, electricity and heating. This enormous differential of the suburban sprawl municipalities illustrates in graphic form the problems of sprawl in relation to the broadest definitions of public health.

3. Lack of Physical Activity – Diabetes, Obesity and Hypertension

Obesity is increasingly becoming a major public health problem in Canada and around the world. According to the National Population Health Survey of 2001, almost half of Canadians are overweight and one in six Canadians is obese. The number of obese children has tripled over the past twenty years, and 10 - 25% of all teenagers have a weight problem (www.Obesitycanada.com). It is estimated that obesity and its concomitant health problems, such as hypertension, diabetes, heart disease and osteoarthritis, rival tobacco in their health impacts. There are many causes of this epidemic, including an increase in high-caloric food consumption. The decrease in physical activity that pervades our society, however, is a major contributing factor.

It has been suggested that the fairly recent trend of living in sprawling suburbs with design features that discourage walking and bicycling, and which encourage residents to drive more, may be a contributing factor to this epidemic of obesity. One of the first links between urban sprawl and obesity was made in the United States when the percentage of obese adults reached 20% in the southern states, where many of the highest levels of urban sprawl occur (Lopez, 2004). Recently, researchers have begun to study the relationship between urban sprawl, obesity and rates of physical activity.

Consistently, studies show that people who live in low-density suburban areas are more overweight, walk and bicycle less, use cars more (even for short trips), and have higher rates of obesity-related illnesses (Cervero et al, 2003; Ewing et al, 2003a; Lopez, 2004; Saelens et al, 2003; Sturm et al, 2004). Americans' average trip distance is twice as long as Europeans, likely because of the more compact land-use patterns in European

cities compared to the more spread out American cities (Pucher et al, 2003). The U.S. Census shows that "the percentage of all work trips made by walking fell from 10.3% in 1960 to only 2.9% in 2000" (Pucher et al, 2003). Furthermore, "in most European countries, at least a fourth of urban trips are made by walking or cycling, and a few countries - like Denmark and the Netherlands - report a nonmotorized travel rate of over 40%" (Pucher et al, 2003). This contrasts with Canada at 10% and the United States at 6%. The European trends may also contribute to the longer life expectancy seen in the Netherlands and Germany - two years longer than in the United States (Pucher et al, 2003).

According to Richard Killingsworth of the Active Living by Design program at the University of North Carolina's School of Public Health, "physical activity does not necessarily begin and end in the gym or fitness centre; it can be simple things such as gardening, walking instead of driving, and taking stairs instead of the elevator. Incorporating these activities into a daily routine can serve as a gateway to more vigorous activity" (Larkin, 2003).

The problem, according to some urban planners, is that cities in North America are not designed to invite physical activities like walking and bicycling, especially as a primary mode of transportation. This is attributed to certain design features that promote automobile use and discourage pedestrian activity. The same is also true to a certain extent for cities in the United Kingdom and Australia (Mason, 2000). Studies indicate that streetscape design influences the decision to walk for transportation (Giles-Corti et al, 2002), and density, land-use mix, connectivity of streets, and proximity of retail, workplaces and restaurants affect the decision to use non-motorized modes of travel and increase activity levels (Librett et al, 2003; Lopez, 2004; Sturm et al, 2004; Ewing et al, 2003a; Hoehner 2003).

3.1 The Sprawl Index

When studying urban development, planning researchers assess several design features of communities and, with different formulations, arrive at a "sprawl index". Many studies use some or all of the following features to rank areas according to sprawl levels:

Connectivity – This is the directness or availability of alternative routes, from one point to another within a street network. It can be defined as intersection per square mile or number of three-way intersections (indicating dead-end streets and crescents, as opposed to four-way intersections, which are found in areas where streets follow a grid pattern). Areas of sprawl have low connectivity, typified by long blocks, streets not built on grids and many dead-end and crescent streets. This discontinuous and indirect pattern of street layout is less conducive to walking and bicycling (Handy et al, 2002).

Density and intensity of development - This is a measure of the amount of activity found in an area, usually defined as population, employment or building square footage per unit area, people per acre, jobs per square mile or average block length. Areas of high sprawl have low density and typically consist of fewer people living on large lots in large areas far from businesses, jobs, stores and restaurants (Handy et al, 2002).

The term 'high density' is often incorrectly taken to mean 'high-rise'. Many areas in Toronto, however, achieve higher densities without high-rise buildings. The former city of East York, for example, has less than 12% of its residential units in buildings higher than 5 storeys, yet achieves a gross density of 63 residents per hectare. Conversely, the Peanut area near Don Mills Road north of Sheppard Avenue achieves the same residential density, but has 55% of its residential units in apartment buildings higher than 5 storeys (Environmental Defence, 2004).

Land-use mix - This is the proximity of different land uses within a given area. A mixed-use neighbourhood includes homes as well as offices, stores, restaurants and other services and amenities. The measurements for land-use mix include distance from each residence in a neighbourhood to the nearest store, or the number of different land uses within a given area. Areas of high sprawl typically consist of low mixed-use land patterns, with large residential areas without retail or businesses nearby (Handy et al,2002). This is a critical factor for achieving *effective* densities, rather than simply higher residential densities. A neighbourhood may have a greater number of homes (increased residential density), but if residents still have to use a car for everyday trips to work, shopping, and recreation, then sprawl, with its related health impacts, remains a pressing problem.

Aesthetics - This refers to the attractiveness or appeal of an area, which is an objective measure; it includes building design, landscaping and availability of amenities such as benches and lighting (Handy et al, 2002).

Urban planners have quantified these features in different ways into formulas and established various "sprawl indexes", ranking different cities or suburbs according to their sprawl index. Low sprawl areas are considered "pedestrian-oriented" and, by virtue of their design, promote activities such as walking and bicycling. They have high connectivity, close proximity of stores and workplaces, and pleasant aesthetics. Areas of high sprawl are considered more "automobile-oriented" and discourage walking and bicycling by their design features. Residents of these areas tend to drive rather than walk, even for short distances (Cervero et al, 2003; Saelens et al, 2003; Vandegrift et al, 2003).

3.2 Body Mass Index and the Behavioural Risk Factor Surveillance System

Some studies in the urban planning literature look at rates of obesity in areas with different sprawl indexes to see if there is a relationship between urban sprawl and obesity, and therefore increased risk of diabetes, hypertension and heart disease. The accepted measurement of obesity is the BMI or body mass index. This is calculated as weight (in kilograms) over height (in metres squared). A BMI of over 25 is considered overweight and a BMI of over 30 in considered obese.

Other studies have examined data collected by surveys or questionnaires, to determine if there are higher rates of certain illnesses in areas of high sprawl. A commonly used source of data in the United States is the Behavioural Risk Factor Surveillance System (BRFSS), an annual telephone survey of adults. This survey system provides self-reported information about health habits, health status, and some variables such as race, income, age, education and gender. In the past few years, transportation and

leisure-time physical activity have been included in many types of these U.S. national health surveys, making it possible to assess activity levels in different urban areas (Ham et al, 2004).

Using the Behavioural Risk Factor Surveillance System (BRFSS), Lopez (2004) conducted a study to see if people living in areas of high sprawl in the United States had higher rates of obesity. The study compared data between residents of different sprawl indexes to see if obesity was related to residence in an area of high sprawl, using a sprawl scale of 1 to 100 based on population density (because it is the most objective measurement). The results indicated that 35.3% of the total of 104,000 adults surveyed were overweight and 19.8% were obese. However, when other variables were taken into account such as race, income, age, education and gender, the risk of being overweight or obese increased with the higher sprawl index. Residents had a 0.2% increased risk of being overweight and a 0.5% increased risk of being obese for every one-point increase in the sprawl index. The range of sprawl index was 6.72 to 100.00, translating to a significant difference in BMI between residents of these communities.

Ewing et al (2003) created a sprawl index using density, land-use mix, street accessibility and degree of centring (the extent to which development is focused on a region's core and regional subcentre). Using the BRFSS, he found that people living in high sprawl areas were likely to walk less, weigh more and have greater prevalence of hypertension. The same was true for rates of heart disease and diabetes, but these relationships were not statistically significant. BMI declined as leisure time walking increased, and the more sprawling the community, the higher the BMI. Lopez concludes that "combined with other research from public health and urban planning, there is moderate support for the assertion that urban form can have significant (positive or negative) influences on health and health-related behaviours".

3.3 Walkability

Other studies have examined the relationship between "walkability" of neighbourhoods and physical activity of residents. Saelens et al (2003) compared physical activity and weight status of residents living in two neighbourhoods in San Diego, California. Accelerometers, small devices carried on a person's belt that measure activity, were worn by residents as an objective measure of physical activity levels. Walkability was determined by residents of the two neighbourhoods using a scoring system, which included parameters such as residential density, land-use mix, connectivity, walking/cycling facilities, aesthetics, pedestrian/automobile traffic safety and crime safety. This survey also included questionnaires about age, gender, ethnicity, height, weight and education. Residents of the high-walkability neighbourhood engaged in 70 more minutes per week of moderate to vigorous exercise than the low-walkability neighbourhood, even after adjusting for age and education. They also spent more time walking for errands and during breaks at school or work (presumably because of the favourable proximity of retail and restaurants), however this was not statistically significant after adjustment for age and education. Although 70 minutes per week may not appear to be a significant value, this translates to a weight loss of 1.8 kilograms over one year if not offset by caloric intake (Saelens et al, 2003). The residents of high-walkability neighbourhoods had lower BMI's overall. 60% of the residents of low-

walkability neighbourhoods were overweight (BMI>25) compared to 35% of the residents of the high-walkability neighbourhood.

A similar study by Cervero et al in 2003 looked at characteristics of neighbourhoods in the San Francisco area that encouraged or discouraged the choice of residents to walk or bicycle. This was determined using the previously discussed sprawl assessment factors such as density, land-use mix, proximity of employment and number of three-way intersections. The study found that the decision to walk or bicycle was influenced by whether the area was pedestrian and bike friendly (i.e. having characteristics of low sprawl). The findings also indicated that well-connected streets, small blocks, mixed land-uses and close proximity to retail activities (all characteristics of low sprawl areas) encouraged walking and cycling, although natural environmental factors such as steepness of hills and rainfall were more influential on the decision to walk.

Saelens et al (2003) reviewed a number of studies that examined environmental influences on physical activity. Consistently, he found that residents of neighbourhoods that were "high-walkable" report more walking than in "low-walkable" neighbourhoods. The denser the population and the more varied the land-use mix, the more likely people are to walk. He concludes that "transportation and planning research supports the proposition that the physical environment is associated with physical activity in the form of walking/ cycling for transportation. Because a large proportion of people in the U.S. and other industrialized countries live in the sprawling and exclusively residential environments associated with low levels of walking for transportation, land-use and design may already be having a substantial although generally undocumented impact on public health" (Saelens et al, 2003).

3.4 Obese are not a Preselected Group

Some critics of the theory that urban sprawl is related to obesity argue that people who do not exercise are a preselected group who choose to live in areas not conducive to walking and cycling. In other words, they would be obese wherever they lived and it is not necessarily the urban sprawl environment that causes their obesity. However, several studies (Saelens et al, 2003a; Saelens et al, 2003b) have not shown differences in minutes walked (when walking for *exercise*) between high and low-walkability neighbourhoods, but they consistently found that rates of walking trips for errands were higher in high-walkability neighbourhoods. This would imply that people who do not walk for exercise are not a preselected group choosing urban sprawl areas to live in, and that it may well be the factor of living in a neighbourhood not conducive to walking for errands that is contributing to their obesity.

3.5 Other Co-Morbidities Associated with Sprawl

Sturm et al (2004) concluded that residence in an area of urban sprawl significantly predicts a number of chronic medical conditions. The study uses a cross-sectional analysis looking at self-reported medical conditions and place of residence. A sprawl index was assigned to 38 sites across the U.S., and compared to data from "Healthcare for Communities", a phone survey that looked at a number of medical conditions. There was

an association between sprawl index and diabetes, hypertension and angina/heart disease, with *less* sprawl relating to *less* disease prevalence, although not statistically significant. This does, however, become significant for heart disease and hypertension when looking at street accessibility or land-use mix only. The study found, interestingly, that sprawl seems to have a disproportionate effect on the elderly and possibly the poor.

3.6 Increased Car Use

A study done at the University of Toronto in 2001(www.jpint.utoronto.ca) (Briggs, 2001) compared transportation patterns of citizens of York region, a suburb of Toronto, to residents of the City of Toronto, which is much less sprawled. The survey looked at 943,300 households in Toronto and 227,700 in York and asked information about number of vehicles owned, household size and ages of members, number of trips made daily, length of trips and destinations, and mode of transport (car, local transit, GO-Train (part of Ontario's interregional public transit system), walk and cycle). Residents of York owned 1.9 cars on average, while those of Toronto owned 1.1 cars on average. York residents walked and cycled less, and drove more than those in Toronto. The median trip length taken by car was longer in York than in Toronto, although in York this number decreased between 1986 and 2001, whereas it remained stable in Toronto. This indicates that people living in areas of high sprawl use cars more instead of walking or cycling, and it may indicate that as an area becomes larger and more sprawled, residents use their cars more for transportation, even for smaller distance trips.

3.7 The Next Step

The urban planning community in the United States is beginning to recognize the serious impact of sprawl, and are now making health-based decisions for urban development. Planned communities, such as Stapleton in Colorado, exemplify how neighbourhoods designed to promote physical activity are possible. In this planned community, there are smaller housing lots, more parks and open spaces, a vibrant town center with shops, restaurants, workplaces and theatres nearby. Eighty percent of working people use alternative modes of transportation (Larkin, 2003).

4. Injuries and Death from Traffic Accidents

4.1 Road Accidents

One of the outcomes of suburban expansion is the necessity of a much greater private vehicle use than is needed by urban dwellers, which leads to an increase in death and injury on the roads.

Road accidents represent a unique social phenomenon. It is something that most people are aware of, but of which few have a realistic perception. The statistics are staggering in themselves, approaching a million deaths each year worldwide, tens to hundreds of millions injured, and many incapacitated for life. It is the leading cause of death in the U.S. between the ages of 4 to 35, and third after cancer and heart disease in terms of years of life lost prematurely in the entire population (Subramanian, 2003). The

economic and social costs are simply incalculable. If this was an infectious disease, it would be called an epidemic. It is the sort of epidemic, however, that does not loom large in the media. This is because vehicular deaths and injuries have become a familiar and omnipresent part of the background. There are few people who do not have friends or relatives who have been involved in road accidents, yet we are largely unconscious of the risks we run every day when we set out in traffic.

Road fatalities and injuries are an inevitable consequence of the increased annual distance people must drive, the multiplicity of separate trips to engage in different activities, the dynamics of suburban commuting such as multiple lanes, high speeds, tractor trailers, conflicting and competing needs of different drivers, multiple access points and exits on both sides of the road, distracting advertisements and signs, parked cars and, of course, pedestrians.

A very valuable reference book dealing with the real nature of road accidents has been written by Wilde, 1994. The common belief is that driving offences and fatalities are caused by an identifiable but relatively small group of drivers. Also, it is believed that eliminating, punishing, or deterring this group litigiously is the answer to make driving "safe" for others. Although strong law enforcement is important in controlling accidents to some extent (and there is certainly a small group of very high risk offenders who should not be on the road), the effect on accident rates would be minor. There is a strong random component of the risk of accidents to the majority of road users. The individual can only do so much to minimize the risk of an accident. Wilde cites a large number of references for several jurisdictions in which punitive measures on offenders after an offence did little to affect accident rates. For example, data from California showed that drivers who had an accident two years running contributed to only 2% of the accidents in the third year.

4.1.1 Road Accident Statistics

There are many ways of quoting road accident statistics: the total for the country or province, the rate per population base, and rates per kilometers driven, per registered driver or per registered vehicle.

The fatality and injury totals for Canada over two decades are shown below (Transport Canada, 2002):

	1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Fatalities	4216	4120	4364	4068	4286	4154	4246	3963	3690	3501
Injuries	224297	237455	259189	264481	280575	278618	284937	262680	249217	249821
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Fatalities	3615	3263	3351	3091	3064	2949	2985	2927	2781	2936
Injuries	247588	245110	241935	230890	221349	217803	222551	227458	221121	227768

Over a twenty-year period, deaths have declined by approximately a third since a peak level in 1985. Meanwhile, the rate of injuries has remained about the same, as have the number of incidents leading to injury only, after declining approximately 20% from a peak in the late eighties. The significant reduction in deaths is attributed to improvements in vehicle safety technology, both in the cars themselves (seatbelts, airbags, crashworthy design) and in the road system (limited access highways and improved traffic signals). The smaller reduction in collisions indicates that driver performance is the limiting factor. As reported for 2000, about two thirds of the collisions causing fatalities occur on highways where the speed limits exceed 60 km/hr, that is, primary and secondary highways in rural areas (Transport Canada, 2003). In contrast, 70% of collisions involving injuries *only* occur in urban areas with posted speeds below 60 km/hr.

In indicating the effective risk to an individual, the rate per population base appears to be the most useful. According to information published by the Conference of European Ministers of Transport (CEMT, 2000), the fatality rate per million of population in Canada (100) is in the middle of the range for similar industrialized western countries (e.g. UK (63) and the Netherlands (70)) but one third less than for the US (155).

4.1.2 Effects of Urban Sprawl or Suburbanization

In the U.S., there are over 40,000 deaths per year with 3.4 million injuries (NHTSA, 2000; AAPH, 1999). Although accidents per mile driven have decreased over the years due to the physical improvements previously mentioned, the number of miles driven per person has increased inexorably, due to both increasing affluence coupled with expanding suburbanization/sprawl. There is considerable difference in distance driven, depending on location, such that in dispersed cities like Atlanta, the value has been estimated at 35.1 miles/day on average (TTI, 2001) compared with concentrated cities, e.g. Philadelphia, 16.7; Chicago, 19.7 and San Francisco, 21.1.

Much of the information relating to the influence of various factors on road accident rates has come from extensive research in the U.S., including the effects of urban sprawl as a factor. There is general information suggesting a difference between driving on urban and rural roads. For example, 60% of fatalities occur on rural roads, which account for only 39% of the vehicle miles travelled (NHTSA, 2002).

Different types of roads have different risk factors because of the way they are used (Lourens, 1999). Suburban sprawl roads are characterized by many conflicting driving operations such as turning, stopping and heavy straight through volumes, (Ossenbruggen, 2001). Overall statistical information is lacking for accident rates on suburban and urban roads separately. However, rates for different cities correlate with the suburban/urban mix (sprawl) for those cities, as shown below.

Note: more fatalities occur where the population density is much lower (sprawl layout).

US Total Road Fatality Rates/100,000 pop

High density	Low density
New York, 2.65	Houston, 9. 97

Philadelphia, 6. 98	Phoenix, 12.55
Chicago, 5.57	Dallas, 11.53
San Francisco, 2.54	Tampa, 10.65
Portland, 4. 17	Atlanta, 11.21
Detroit*, 10. 88	Los Angeles*, 4. 85

Note that some cities marked with an asterisk* are contrary to the expected pattern.

4.2 Pedestrians

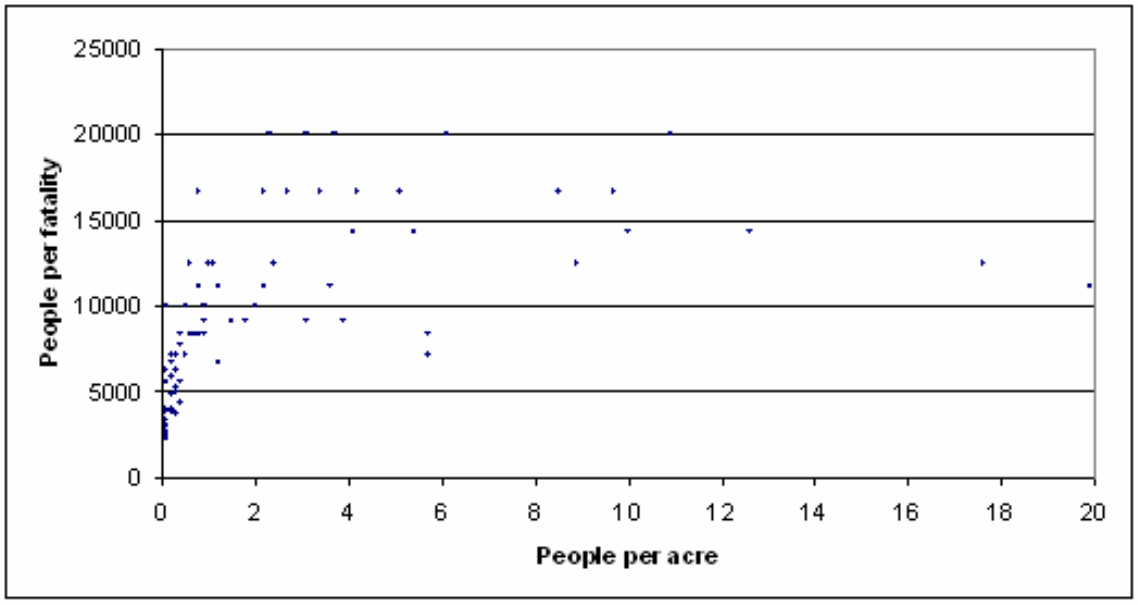
Suburbanization also affects accidents involving pedestrians. Totals in the U.S. at present indicate 6,000 fatalities and 110,000 injuries per year (Cohen, 1997; McCann, 2000). Suburban sprawl roads often combine features that raise the risk for accidents involving pedestrians. Road factors such as multiple lanes and high speeds, poor road design, few crosswalks and sidewalks, and inadequate lighting can be combined with behavioural factors such as alcohol abuse and pedestrian error (Hanzlick , 1999). Rates for the cities as a function of the urban/suburban mix (sprawl) tend to follow the same trends as shown for total road accidents, thus:

U.S. Pedestrian Only Fatality Rates/100,000 pop (NHTSA, 2000)

High density	Low density
New York, 2. 21	Houston*, 2.54
Philadelphia, 2.40	Phoenix, 4. 2
Chicago, 2. 25	Dallas, 3. 99
San Francisco, 3.49	Tampa, 5.72
Portland, 2. 98	Atlanta, 5.72
Detroit*, 5. 18	Los Angeles*, 2.64

*Contrary to expected pattern

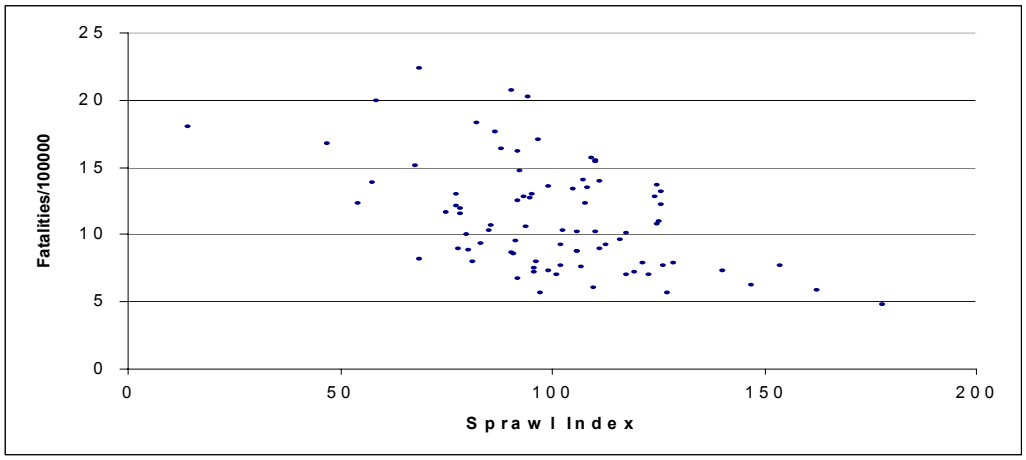
A detailed examination of the different risks commuters are exposed to as a consequence of living in low and high density urban areas has been presented (Lucy, 2003).



The risks of fatality arising from commuting long distances have been estimated for about 50 communities across the U. S. To illustrate the suspected reciprocal relationship between population density and fatality rates, the latter values are plotted as reciprocals (persons per fatality) in the above figure. The three highest densities (with the least fatalities) correspond to the city cores of Chicago, Philadelphia and Baltimore. The other points correspond to outlying counties surrounding these and other large cities. In comparison, Ontario population densities of some representative regions in and around the GTA are as follows: York Region (1.36 persons/acre), Durham Region (0.75), Peel Region (2.82), Halton Region (1.43) versus Toronto Municipality (15.3) (Natural Resources Canada, 1996). Traffic death rates are rather lower in Canada than in the U.S.; nevertheless the same conclusion is likely to be true, namely that traffic death risks are greater for people living in the outlying suburbs surrounding major urban centres – a sprawl layout.

In Lucy's treatment of the data he added an extra risk component attributable to homicides, specifically "homicides by strangers", on the presumption that only this risk would be applicable to commuters. This was included in order to address one of the often-stated causes of migration to low density suburban areas – the perception that homicide risks are much greater in high-density urban areas. Although the total homicide rates *are* much higher in densely populated areas, most homicides involve non-strangers. Another factor is that total homicide rates are actually much lower than traffic deaths, about 40% overall.

In two studies (Ewing, 2002; Ewing, 2003) an analysis was made of traffic accidents using a more complex indicator of the sprawl, for various communities across the US.



Source: Ewing, 2002

Sprawl is considered to be characterized by four main factors which generally occur together: low residential density; rigid zoning separation of residential from commercial and industrial uses; the absence of high activity town centers; and a stretched-out network of roads with limited access into and out of residential areas (low street accessibility), which makes extensive vehicle use essential to access services. A sprawl index (described earlier in this report) was devised for a total of approximately 83 urban and suburban regions, which accounts for about two thirds of the U.S. population. Using census data, various measures of population density were combined with measures of block size and street accessibility to generate a composite number, called an index. The higher the index, the more compact the locality.

When compared with fatality rates for the 83 districts, the sprawl index was found to vary inversely. Using the same concepts, about 450 counties were examined in detail, covering about two thirds of the U.S. population. The 10 most compact communities examined, which included some of the densest counties in large cities such as New York, Philadelphia, Boston and San Francisco, had an average sprawl index of 218 units and a fatality rate of 5.6 per 100,000. Conversely, for the 10 least dense areas in dispersed cities such as Cleveland, Atlanta and Minneapolis, the corresponding numbers were 69 units and 26 per 100,000, respectively (almost 5 times the fatality rate). Overall, the relationship indicates that a 1 % increase in the sprawl index function – i.e. increasing density – is associated with a 1.5% decrease in the fatality rate.

Another way of looking at the risk is as a function of distance driven. Road accident statistics are often quoted per unit of distance driven, daily or annually. This does not, of itself, prove that risk is proportional to distance driven, but the widely-used statistic suggests that it is plausible. It is also likely that people who live in low-density suburbs must, of necessity, drive a greater distance annually.

There have been a few estimates made of distance driven as a function of locality. For example, Frumkin (Frumkin, 2001) quotes a study by Holtzclaw et al, 2002, in which estimated annual miles driven showed an inverse relationship with density (number of households per residential acre). Thus, for three U.S. cities - San Francisco, Los Angeles and Chicago - and their surrounding suburbs, the results are surprisingly consistent.

# Households/ Res. acre	150	100	50	25	10
VMT/Household	3 - 4000	4 - 5000	6 - 7000	10 - 11000	15 - 16000

VMT = vehicle miles traveled

5. Mental Health Impacts of Sprawl

Only one study, done by a senior economist at the Rand Corp. of Santa Monica in California, found no adverse effects of urban sprawl on mental health. This was most likely because the study used a limited range of parameters to describe this problem: Major Depression, Dysthymic Disorder, General Anxiety Disorder and Panic Disorder. All other studies have found a positive correlation (Sturm and Cohen, 2004).

5.1 Long Commutes

U.S. studies seem to indicate that long commutes, increasing traffic delays and long work hours leave people overwhelmed with time demands. Between 1969 and 1990, the U.S. population grew only 21% but the number of car trips grew by 42% (Goldberg, 1999), meaning that more time was spent sitting in traffic. The average American spends 443 hours per year driving a car, and sprawl commuters spend 3 to 4 times more hours driving than individuals living in well-planned, dense areas (Sierra Club, 2002). More time driving means less time with family and friends, less time for oneself, and less time to contribute to community activities, from civic to religious involvement (Putman, 2000). Traffic congestion also impairs health, psychological adjustment, work performance and overall satisfaction with life (Novaco, 1990).

There is evidence that commuting is associated with more back pain, cardiovascular disease and self-reported stress (Koslowsky et al, 1995), as well as arthritis, asthma and headaches (Sturm and Cohen, 2004).

5.2 Loss of Easy Access to Facilities and Decreased Leisure Time

The mental health benefits of exercise and leisure are lost due to the sparse distribution of facilities in a poorly planned sprawled layout and lack of time commuters have to use them. Better mood, higher self-esteem and better cognitive functioning are all advantages of regular exercise, and depression and hypertension are exacerbated by lack of it (WHO, 2000).

5.3 Driver's Stress

One study showed that perceived traffic stress (a combination of the challenges of driving and parking, the potential for unintentional injuries, and pecuniary hardships and inconveniences of vehicle maintenance and purchase) was associated with both lower general health status and depression (Gee and Takeuchi, 2003 and 2004). Visual clutter and traffic, exhaust fumes, stress and anxiety that occur with commuting may contribute to increases in blood pressure, headaches and road rage (Curbow, 1999). Anger and frustration among drivers likely spills over into their work and home environments, and can greatly impact on family and other social relations (Frumkin, 2002).

Commuting travel impedance, both physical (which includes congestion, traffic jams, road construction, and long trip distances that delay the commuter's arrival at home) and subjective (perceived stress of travel), have been assessed with regards to impact on residential satisfaction and personal affect on home life. High impedance commuting was found to have adverse effects on blood pressure, mood, frustration tolerance, illness occasions, work absences, job stability and overall life satisfaction (Novaco, 1991). Job satisfaction and commitment declined with increased commuting distance on the road, but not with public transit use (Koslowsky, 1993; Gee and Tacheuchi, 2003).

It has been well documented that driving causes "physiologic arousal" known as driver "strain" (Hoffman, 1965): elevated heart rate, ECG changes (ectopic beats and ischemic changes), increased serum cortisol and catecholamine levels and reports of anxiety and agitation. At the other extreme, underload (monotonous tasks), extrinsic time pressures, unpleasant driving conditions, the consequences of error and conflict uncertainty also add to driver's stress (Belkic, 1994).

5.4 Road Rage

The two primary causes for aggressive driving are 1) being rushed or being behind schedule, and 2) increased congestion and traffic. Both of these issues occur more so as a result of urban sprawl (National Traffic and Safety Administration, 1998).

Besides the risk of death and injuries, commuting from suburban locations can have profound mental health effects (Koslowsky, 1995). One manifestation of mental health stress that has received considerable attention recently is the so-called "road rage", leading to violent disputes between drivers that sometimes results in injuries or death. One characteristic of this behaviour is that it often involves people who would not normally be expected to exhibit violence (Rathbone, 1999).

The term "road rage" has been defined as "an incident in which an angry or impatient motorist or passenger intentionally injures or kills another motorist, passenger, or pedestrian, or attempts or threatens to injure or kill another motorist, passenger, or pedestrian." (Rathbone , 1999). "Road rage" and "Aggressive behaviour" are differentiated as driving-related behaviours. Road rage exhibits itself as a confrontation between one or more other drivers and amounts to criminal behaviour if the incident is severe enough. Aggressive driving may include following another vehicle too closely, repeated and abrupt lane changes, and speeding. This behaviour may be unsettling to nearby drivers, but is not necessarily directed at anyone in particular; it may constitute a traffic offense if observed by police but is not considered criminal behaviour.

A number of jurisdictions in the U.S. have set up special law enforcement programs to deal with road rage. Surveys have been made of road rage incidents reported and also the effects of the various programs designed to reduce them. Not surprisingly, road rage incidents are most likely to occur on Friday afternoon, during peak travel times, and in good weather. Alternatively, during poor weather conditions, it seems that drivers are more resigned to the conditions and do not attribute them to neighbouring road users; in other words, their expectations are lower and their tolerance greater. On the other hand it is just at the end of the week and going home that drivers are most tired, rushed, full of expectancy, with even a sense of entitlement, that makes them most intolerant of other driver's behaviour, perceived or real. For similar reasons, incidents are more

frequent during the summer. Moderate rather than very high congestion seems to be a defining scenario. In medium congestion situations, drivers may feel that they are in competition with others for faster lanes; others will try to bypass queues at exits by cutting in front of others; however, when traffic is close to being stalled, resignation sets in and expectations are lowered (Rathbone, 1999).Other studies have suggested that, as expected, traffic volumes, travel distances and delays are risk factors (Harding, 1998; Parker, 2002).

From a review made of over 10,000 incidents of road rage reported from various sources such as news media, enforcement and insurance sources - a 60% increase in recorded road rage incidents occurred during a six-year period up to 1996 (Mizell, 1997). It also showed that, just as in the statistics of accidents as a whole, there is no identifiable minority responsible.

5.5 Impact on Well-Being

The World Health Organization defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Sprawl impacts negatively on well-being by increasing noise, declining aesthetics (scenic views), and interfering with recreation time (Riediker, 2004). Suburban respondents in one study demonstrated a lack of social support and increased caregiver stress (Lundeen, 1992).

5.6 Fear

Studies have shown that the greatest perceived barrier to physical exercise in sprawl communities was lack of a safe place in which to do so. Given the fact that treatment for mild cases of anxiety and depression include physical activity, it seems absurd that walking, jogging or cycling outdoors may not be safe for those living in a urban/suburban environment. Fear of heavy traffic, crime, lack of streetlights and sidewalks that could lead to pedestrian injury or death are a source of anxiety and a threat to well-being (Hancock, 2000). Areas most dangerous are consistent with sprawl and include: roads with high speed vehicles, multiple lanes, no sidewalks, long distances between intersections or crosswalks, and roads lined with apartments and commercial spaces (Hanzlick, 1999).

5.7 Posttraumatic Stress from Accidents

The impact of traffic fatalities on the psyche due to sprawl cannot be underestimated. Children and the elderly are particularly at risk, and places where crosswalks are not available are the most dangerous (Savitch, 2003). Thousands of pedestrians and drivers die every year in North America. The anguish and emotional scarring caused by the death of a loved one, permanent disabilities, and related pain and suffering, greatly impacts at every level of our social structure.

Throughout the world, physical injuries and deaths resulting from traffic accidents are increasing. Fourteen percent of traffic accident survivors have PTSD (Goldberg 1990) and 25% have psychiatric problems one year after an accident. One third have clinically

significant symptoms at follow-up, 18 months after an accident (Green, 1993). A United Kingdom study found that one in three children involved in road traffic accidents suffered from Post Traumatic Stress Disorder two months later. The child's *perception* of the accident as life threatening was the most important determinant (WHO, 2000).

5.8 Loss of Sense of Community

A sense of community is defined as "a feeling that members have of belonging, a feeling that members matter to one another and to the group, and shared faith that members' needs will be met through their commitment to be together". There are four aspects to the sense of community: membership, influence, integration and fulfillment of needs, and shared emotional connection (McMillan and Chavis, 1986). Societies that thrived in the past were integrative, emphasizing centrality, continuity and easy access. The physical and social construct of the sprawl environment is the antithesis of what has just been described, and promotes isolation (Bashir, 2002). Higher rates of television viewing, more time on computers, fears about crime, and little contact with neighbours have created disconnected communities lacking in social networks, which has led to a definite erosion of social capital.

Reduced social life also occurs because of increased time on the roads, lack of local schools, small stores or other places where people interact (WHO, 2000). The roads have created a *community severance effect* which is the divisive effects of a road on those in a locality (WHO, 2000). This severance effect is important because the protective effect on health of social support networks, which is particularly vital for children and the elderly, is seriously disrupted. Sprawl areas also lack gathering spots for teens and the elderly (Frumkin, 2004).

Sprawl lacks diversity and therefore forces people to be transient because they cannot grow old in these communities, due to the isolating and restrictive layout. This loss of community seems to be impacting many regions of North America (Frumkin, 2004).

5.9 Loss of Green Spaces

Loss of the natural environment - animals, plants, landscapes and wilderness - have a tremendous impact on human well-being, as humans are innately attracted to other living organisms (the biophilia hypothesis) (Frumkin, 2001). A balance between the natural and built environment impacts on well-being (Frumkin, 2004). Positive effects of the natural environments have been documented and include improved social and cognitive functioning, and decreased violence (Kuo et al, 2001; Taylor et al, 2001). More research is warranted in Ontario to determine the impact of unattractive sprawl, traffic noise and lack of green space on mental health. A study done in Chicago showed that residents of buildings with surrounding greenspace had a stronger sense of community, better relationships with neighbours and had less heated domestic conflicts (Sullivan et al, 2001).

Sprawl highly disturbs the natural environment and impacts negatively on biodiversity. Therefore, those leaving urban areas to seek a greater connection with nature in the suburbs are actually short-changed (EHP, 2004). Perceptions of poor air quality (pollution from traffic) and its role as a quality-of-life indicator have been

investigated and found to have a large impact on well-being. Although perceptions of air pollution did not reflect measured levels (which are not realistic anyway as the measuring stations are not located at a person's breathing level), residents were more disturbed by *personally* detectable vehicle-derived fumes, dust and dirt than other aspects of road- and traffic-related nuisances (Williams and Bird, 2003).

Heat Islands occur when natural vegetation, which provides shade and cools the air, is replaced by heat-absorbing surfaces such as building roofs and walls, parking lots and streets. Ambient air temperatures can increase by 6-8 degrees F, and those with health problems, including the elderly, are impacted the most (Klinenberg, 2002). Greenhouse gases from excessive automobile use also contribute to warming (Frumkin, 2002). A study looking at heat-stress related mortality in five cities of Southern Ontario between 1980 and 1996 showed that death in the elderly (over 64 years) were significantly increased during these times and that ongoing urban development and sprawl were expected to intensify heat-stress conditions (Smoyer, 2000).

5.10 Social Capital

Social capital is defined as the social, political, and economic networks and interactions that inspire trust and reciprocity among citizens (Putman, 2000). Other definitions have emphasized the importance of the common good, mutual obligation and "horizontal trust" (that is between those in similar social situations). The erosion of social capital reduces trust and exchange among citizens. In other words, less civic engagement leads to the loss of a sense of community. Social science has shown a positive association between social relationships and health, such that the higher the quality and quantity of these relationships, the greater the health benefits.

These health benefits are also laid out by Frumkin, Frank and Jackson (Frumkin, 2003). Studies have shown that social capital is eroded by long commutes that rob a person of time for recreation, voluntary associations, civic engagements and self care. Putnam writes in his book "*Bowling Alone*", that each ten additional minutes in daily commuting time cuts involvement in community affairs by 10%. Studies also have shown that persons with low social capital may be at risk for poor physical and mental health (Kawachi, 1999; Hawe et al, 2000). It has been suggested that commutes done by walking, bicycling, using transit, or carpooling may actually improve mental health and counteract the negative effects of using motor vehicles.

Also, studies support the fact that walkable (pedestrian-oriented), mixed-use neighbourhood designs can encourage the development of social capital, by enhanced levels of community and social engagement (Leyden, 2003).

6. Effects on Water Quality

The impact of water quality due to sprawl is also a concern. Rainwater, under normal conditions, percolates through the soil and is filtered through vegetation before reaching ground water reservoirs. In suburban sprawl areas where a lot of rural land has been covered with paving, asphalt, concrete and rooftops, water becomes surface runoff that enters streams and rivers without filtration of pollutants. One study found that 4% of rainfall in undeveloped grassland becomes run-off, as compared with 15% on suburban land (Zheng et al. 1999).

Parking lots and strip malls, after heavy rainfall, contribute significantly to non-point sources of pollutants (toxic run-off) entering streams and rural water sources. Sprawl areas produce 43% more urban runoff than more densely populated areas (Schmidt, 1998). Large areas of paved surfaces in suburban developments mean less water is absorbed, and can result in flooding (Schmidt, 2004). The loss of wetlands due to development also means less of a buffering zone for heavy rainfall, thereby also contributing to floods. Wetlands are also nature's way of filtering and purifying runoff water (EPA, 2002a).

7. High Risk Groups

7.1 Children

Childhood obesity and asthma have increased dramatically in the last 30 years and the built environment, particularly that of sprawl, is certainly a factor in the equation. Children are becoming habituated to a sedentary lifestyle and childhood obesity has reached epidemic proportions. Studies have shown a marked decline in the number of children aged 5 to 15 who are walking or biking to school over the last 20 years (Savitch, 2003). Physical activity is hindered when there is a lack of opportunity for after school exercise and there is a reliance on automobile transportation rather than walking, biking or mass transit. Obesity is an important predictor of pediatric hypertension and increases the risk of adult coronary artery disease, hypertension, dyslipidemia, osteoarthritis, diabetes mellitus and some cancers (Must, 1999; Pi-Sunyer, 1991).

Children are greatly impacted by the effects of sprawl. For children to do their life work they need schools, sports fields, friends' homes, libraries, shops, or places of worship. They also need privacy, tranquility, safety and community (Frumkin, 2004). There are decreased opportunities for children to incorporate physical activity, such as walking or biking to school, into their daily lives because of long distances and hazardous streets, and lack of safe sidewalks (CDC, 1999). Perceived traffic danger was the second leading barrier to children walking and biking to school in the United States (CDC, 2002). Suburban housing estates are often devoid of sidewalks, pathways and parks, and the absence of street lamps in many places discourages evening walks (Savitch, 2003). Reductions in childhood injury have been directly linked to the introduction of safety measures to housing construction, and community and roadway planning (Cummins and Jackson, 2001).

More highways are built to accommodate more sprawl, which leads to increased air pollution. A Denver study showed that children living within 250 yards of a road with 20,000 or more vehicles per day, were eight times more likely to get leukemia and six times more likely to get other cancers. This was due to carcinogenic car exhaust pollutants (VOCs) such as benzene, 1,3-butadiene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs) (Pearson et al. 2000). Aplastic anemia and leukemia have been associated with excessive exposure to benzene, especially in children living near high traffic density areas (Jermann, 1989). In 1997, another study showed that proximity to highways had the greatest impact on cancer risk (Knox and Gilman, 1997).

7.2 Women

There is a definite gender difference in the access to and use of cars. Women are less likely than men to be car occupants, and are more likely to have to walk. Although an excellent form of exercise, walking can have negative effects on a family's welfare if they live in an area where access to amenities such as food shops, health care services and social networks is limited. This is also an issue in sprawl areas, especially if there are few sidewalks or safe roads for pedestrian access to services (which are often an inconveniently long distance away). Walking as a mode of transport among low-income mothers is well documented (Bostock, 2001). If women have children, then the onus usually falls on the mother to shuttle the children to various activities. This is significantly pronounced in sprawl areas where distances are far and time spent chauffeuring can become inordinately stressful.

A study done in Los Angeles County showed that pregnant women who live near high traffic areas have a 10-20% increase in risk of having premature and low birth weight babies. It was found that for each one part-per-million increase in annual average carbon monoxide concentrations where women lived, there was a 19% and 11 % increase in risk for low-birth weight and premature births, respectively (Wilhelm, 2002).

A suburban study found that females were more likely than men to indicate problems in the areas of managing stress and feelings of sadness, worthlessness, and hopelessness (Lundeen, 1992). This may be because women experience a significant amount of stress in sprawl areas if they have full-time jobs, long commuting journeys, a burden of household duties including transporting children to school and after-school activities, taking elderly dependents to the doctor, running errands to the grocery store, and post-office or bank chores. The collective burden falls disproportionately on women (Frumkin, 2003).

7.3 The Elderly and People with Disabilities

The elderly and disabled, who may be homebound in a sprawl environment, experience more difficulty going from place to place, gaining access to medical and other health care and social services if they are not able to use a car, or if there are no care-givers/homecare aid to see to their needs. Overall, they are more isolated, and perhaps lonelier than the average person.

The two major issues that are relevant to the health of the elderly are mobility and community – both of which are threatened by sprawl. Elders who can no longer drive safely must have stores, places of worship, medical offices, recreational and cultural facilities close to home, as well as safe, maintained sidewalks (Frumkin, 2000). One large cohort study showed that living in areas with walkable greenspaces near one's residence positively influenced the longevity of urban senior citizens independent of their age, sex, marital status, baseline functional status, and socioeconomic status (Takano, 2002). Cardiovascular disease mortality in this group increases four fold when social supports are lacking (Greenwood, 1996).

The design of the built environment can prevent a person with disabilities from being physically active, using transportation systems and being socially integrated into their community. Persons in wheel chairs or using other mobility devices benefit from walkable, safe communities. Lack of sidewalks or curb depressions can prevent people

with disabilities from getting any physical activity at all. These are known as "environmental barriers" and include lack of access to mass transit routes, bus shelters or other public services. These issues impact on quality of life and health.

8. Methodological Appendix

A literature search was done at the Canadian Library of Family Medicine at the University of Western Ontario using the search phrases: "Health Effects of Urban Sprawl", "Urban Sprawl", "Mental health", "children", "elderly" ande "reproductive". Pubmed was used to access MEDLINE. Medline and other databases were searched using key words urban sprawl, public health, traffic, and air quality using and/or Boolean operators as a search strategy. PsycInfo, Web of Science, books and reports were searched using the above key words.

Problems encountered are that the terms "urbanization"," suburbanization", "urban development", "suburbs", "urban growth" are not well defined, in that they sometimes mean sprawl and sometimes not; therefore, articles were screened for applicability to the paper's purpose. Public Health website yielded some information documented in the reference section of this paper, and "Urban Sprawl and Public Health" by Frumkin, Frank and Jackson was helpful in establishing a framework. Additional articles were identified and obtained from the readings.

To broaden the field, experts in the field of air pollution and traffic were consulted for further direction and references. Appropriate references were selected.

Many websites were searched for information using the above terminology using Google. Searches were also conducted at the University of Toronto and Queen's University. At Queen's University, Medline (1966-2004) was searched using the Medical Subject Headings (MeSH) "Suburban Health" and "Suburban Population", as well as the keyword phrases "urban sprawl" and "suburban sprawl". These were then combined with the concepts represented by the Medical Subject Headings for "Public Health", "Environmental Health", Obesity, "Heart Diseases", "Diabetes Mellitus, Type I", "Diabetes Mellitus, Type II", "Obesity in Diabetes", and "Hypertension". The results were then further limited to English language citations.

9. Conclusions and Recommendations

In conclusion, this paper examines the relationship between sprawl and health, and challenges the present unrestrained sprawling growth patterns in southern Ontario.

Canadian and Ontario studies in the area of sprawl and health are very sparse. Studies done in the US, however, give us serious warning of what the future holds for the health of this province if we continue to let urban sprawl expand. These studies expose the harm that has already been inflicted on public health. There are indeed gaps of information needed to develop healthy public policy in this regard. The lack of specific analyses relating to the provincial situation points to the need for further research on the relationship between urban sprawl and public health. Both the dimensions of sprawl itself, locality by locality in and around Ontario cities, and traffic patterns and accident data in the same localities should be surveyed in more detail.

Road accidents, and the contributing road rage, represent the most underrated risk that people are exposed to, everyday of their lives and this paper explains a clear link between people living in sprawled, spread-out suburbs and an increased risk of road fatalities and injuries.

In order to decrease car use there needs to be more integrated communities providing all the amenities necessary for everyday living, including jobs, schools and social/health services within walking distance directly or through easy access to public transit. Walkable areas everywhere is critical to promote exercise and health as well as social capital. Protection of our greenspaces (including our farmland, forests, marshes and wetlands) is important to decrease the escalating summer temperatures in Southern Ontario, flooding and water degradation.

The direct and indirect human health implications of urban sprawl are far reaching and have tremendous impact. This review reminds us of the link between sprawl and the prevalence of diabetes, cardiovascular disease and obesity due to lack of exercise, and cardiovascular and respiratory disease, including asthma, related to air pollution. The elderly and disabled are further disadvantaged (Jackson et al, CDC, www.sprawlwatch.org). In all, lack of physical access in a community becomes a factor leading to more illness and even death (Gilderbloom et al, 1998). The sum of these impacts on public health supports a change in public policy toward more "livable communities".

While urban areas will continue to grow in order to accommodate an increasing population, this growth needs to be accomplished in ways that do not jeopardize human health. This means protecting natural areas, preserving agricultural land, and protecting air and water quality. This cannot be achieved unless land is used more wisely, and cities are built more compactly. It means providing and encouraging modes of transportation other than the private vehicle and creating communities that are environmentally sustainable (Hancock, 2000).

The conservation of recreational, usable and ecologically established greenspaces, such as the Green Belt is mandatory if we are to start repairing the environmental, social and medical problems that are already so serious. Conservation of greenspaces should then lead to efforts to create more integrated communities so that commuting and vehicular use is down to a minimum, and there is better access to amenities and services. Better transit system and services should be abundant, clean (non-diesel powered) and easily accessible (ie within walking distance from home).

There is a pressing need for more concerted research to identify mechanisms by which the built environment adversely and positively impacts health, and to develop appropriate interventions to reduce or eliminate harmful health effects (Srinivasan, 2003). Given that most of the studies to date point to the growing health effects of sprawl, why not practice prevention? Land-use and transportation policies have a direct bearing on public health in Ontario, and as such, health impact costs should be incorporated into and drive future planning. We have the choice to continue to build sprawling areas that contribute to increased air pollution, more time spent in cars, and disappearing greenspace; or the choice to build healthy, vibrant communities that offer a wealth of opportunities for walking, cleaner air, and the enjoyment of better health.

The public should be encouraged to abide by speeding regulations, use public transit more, car pool, ask their community political representatives for more suitable and easily accessible amenities and public transit systems.

The government should enforce speed limits more diligently, provide more ubiquitous public transit services which are clean and easily accessible, build more dedicated bicycle paths and lanes, create more sidewalks, pedestrian crosswalks, bridges and tunnels to help with road crossing, have more stringent surveillance and penalties of unclean truck emissions.

Physicians should be aware of their patient's living location and how this impacts on their well-being. Are they at risk of danger due to lack of walkable areas around their home? Patient's may have restricted access to medical and social services and may be quite isolated. Sprawl may be the reason for a patient's lack of socialization or exercise. Physicians should find out what their patient's commuting and driving habits and behaviour are like especially if they are already anxious and stressed. Questions about commuting stress should be asked, and how they feel after a long commute (could they be getting mild carbon monoxide poisoning?). Physicians should use the OMA asthma patient education guideline tools which can be downloaded off the web. Physicians should warn pregnant mother and children of the dangers associated with poor air quality both outdoors and inside road vehicles.

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