Estimating Air Quality Health Impacts Associated with Various Policies & Planning Decisions:
Informal Discussion Paper

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Environmental Protection Office
Toronto Public Health

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I Introduction

This report has been prepared as an informal piece to facilitate discussions among staff working for the City of Toronto. It is not a comprehensive piece on models. It is intended as a summary that will provide City staff with a common understanding of the steps involved in modeling air quality and its impacts on health. It summarizes information on models and reports that are being discussed by City staff.

There are three broad steps in the estimation of air quality health impacts associated with policy or planning decisions:

1. To estimate the emissions associated with the business as usual scenario and with the alternate policy or plan;
2. To estimate ground-level concentrations for air pollutants of concern for the business as usual and alternate scenarios at a temporal and spatial resolution that makes sense for the emission source and action being examined (e.g. 24-hour or annual readings; 1 km or 50 km resolution);
3. To estimate, where appropriate, the health outcomes associated with the ground-level concentrations for the business as usual and alternate scenarios. (In some cases, it will make more sense to discuss health outcomes in qualitative terms, using the change in ground-level concentrations as the indicator of health outcomes.)

1. Estimating Emissions

The first step in the modeling process is to estimate the air emissions associated with the various policy or planning options. While this may sound like a relatively easy exercise, it is often a very difficult and time consuming step in the process. It requires knowledge of how a particular policy or planning decision can impact on the behaviour of different populations (e.g. will it increase the number of kilometers traveled, create more congestion, increase the speed of travel, reduce the use of electricity, encourage a shift to alternative fuels). It requires an understanding of the emissions associated with existing technologies (e.g. different types and model years of cars and trucks, age and type of furnace, age and type of air conditioner), emerging technologies (e.g. diesel particulate filters, biodiesel, hybrid electric vehicles, solar water heaters, solar panels for space heating), and the relative share of those technologies under the current situation (e.g. how many homes are heated with oil, how many have air conditioners, how many older vehicles are on the road). And it requires an understanding of how technologies, populations and behaviours are expected to change over time under the business as usual and alternate scenarios.

This first step can include the use of models designed to estimate how a policy will impact on factors such as human behaviour and traffic flow. It can also include the use of: road count data and cordon studies conducted by transportation planning departments; data on the number of transit buses, school buses, trains, planes, boats in current use; data on the quantity of natural gas and electricity used by households, commercial enterprises and institutions, etcetera. It also requires the use of a variety of equations and models developed by consultants, academics and/or government agencies such as the U.S. EPA to provide estimates for missing data (e.g. estimating road dust emissions) and to do computations on different data sets (e.g. combining fleet composition information with road counts and emission factors).

2. Estimating Ground-level Concentrations of Air Pollutants

The second step in the process is to determine how the air emissions identified in the first step will be distributed and dispersed over time and space. The first stage in this second step involves deciding how to allocate the estimated emissions spatially and temporally. For example, one has to decide:

- If emissions from area sources such as furnaces are distributed evenly over the grids or allocated using knowledge of land uses;
- What portion of furnace emissions should be allocated to which months; and
- What portion of the vehicle emissions should be allocated to "rush hours" versus other hours each day.

Once these judgements are made, the data are fed into a dispersion model that will estimate how those emissions will disperse through the atmosphere given factors such as the height of their release (e.g. ground level or out of a tall stack), weather conditions (e.g. cool, dry and windy or hot, humid and stagnant), topography (e.g. flat, sloped or hilly), shape of the terrain (e.g. a canyon of tall buildings or an open field), proximity to the lake, etcetera. The products of this step are estimated or forecast concentrations of air pollutants. These forecasts can be produced for different air pollutants, varying heights from ground-level, varying time periods (e.g. hourly, daily, monthly or annually) and at varying spatial resolutions (eg. 2 km grid or 50 km grid). The products of this step will be as good as the emission data inputs, the judgements and assumptions applied, and the model used.

Models that can be used to estimate air pollutant concentrations associated with industrial facilities include ISCST3, AERMOD and CALPUFF. Regional modeling of air pollutants can be done with models such as CMAQ and CALPUFF.

3. Assessing Health Impacts

The third step in the process is to assess the health impacts associated with the varying scenarios. This can be done in a qualitative way, or in some instances, quantitatively.

With a qualitative assessment, reference can be made to the number of health outcomes associated with air quality across the City or region to remind decision-makers of its importance as a health risk factor. Discussion can then focus on the differences in concentrations of air pollutants between scenarios with reference to the health literature which highlights the health impacts associated with varying concentrations.

In some situations, where the policy or planning decision has the ability to affect a broad region and to substantially impact on ground-level concentrations of air pollutants, it may be desirable to quantitatively estimate the health outcomes, and possibly the economic costs associated with those health outcomes, for the different scenarios that have been examined.

Two Canadian models that have been developed to estimate health outcomes and the economic costs of those health outcomes include the Illness Costs of Air Pollution (ICAP) produced for the Ontario Medical Association (OMA) by DSS Management Consultants, and the Air Quality Benefits Assessment Tool (AQBAT) produced by Health Canada as an improvement upon an earlier model developed by the Federal Government known as the Air Quality Valuation Model (AQVM).

II Estimating Emissions associated with Policies

This first step in the process is hard to describe because it will vary with each policy or planning decision that is involved. In some cases, another department in the City may have the capacity to determine how a particular policy or decision might impact on the behaviour of residents, commuters and/or business and/or on the volume and flow of traffic. In other cases, models and/or research done by academics or other governmental agencies can be used. And in cases, it will be the proponent's responsibility to estimate the emissions associated with a proposed facility or application.

In situations related to transportation systems, once a policy or planning decision's impact on traffic flow and volume has been estimated, models can be used to estimate the emissions that will be associated with the traffic predicted. It is currently common practice in North America to use the Mobile6 model to estimate emissions associated with traffic counts for roadways, but Mobile6 is intended for use for very large regions. It is not intended for use in microenvironments.

1. MOBILE6 Model

MOBILE6 is an EPA model that can be used to estimate emissions from highway vehicles. MOBILE6 calculates emissions of hydrocarbons (HC), nitrogen oxides (NO_x), and carbon monoxide (CO) from passenger cars, motorcycles, light- and heavy-duty trucks. It accounts for the emission impacts of factors such as changes in vehicle emission standards, changes in vehicle populations and activity, and variation in local conditions such as temperature, humidity and fuel quality. MOBILE6 can be used to calculate current and future emission inventories of these emissions at a national and local level (USEPA, 2003).

The MOBILE model was first developed in 1978. Since that time, it has been updated many times to reflect new information about vehicle emissions, new emission standards, and modeling needs. Although some updates were made to MOBILE in 1996 with the release of MOBILE5b, MOBILE6 represents the first major revision to the MOBILE model since MOBILE5a was released in 1993 (USEPA, 2003).

The MOBILE6 model is useful when modeling emissions over large regions but has a number of limitations:

- It averages emissions over large areas (i.e. the Mobile6C model used in Canada estimates mobile emissions for the entire province and then distributes them on the basis of province-wide age-distributions and province-wide vehicle kilometers traveled (vkt) distributions);
- It cannot be use for grids smaller than 4 to 12 km;
- It does not accurately estimate emission trends over time;
- It does not reflect differences in vehicles, model-years, fuels or road counts for various roadways (Sloan & Singh, July 2005).

2. MicroFac Model

The MicroFac model has been under development for over 10 years by Rakish Singh who began his work at the US EPA. Singh has been working with the Waterloo Centre for Atmospheric Science (WCAS) for 2.5 years now as a Research Associate. His model estimates emissions for roadways using emission rates for different classes of vehicles and model-years and corrects for fuel type, weather conditions and road gradient to produce emissions that appear to be very accurate. Verification testing conducted to date indicates that the results are very tightly correlated with real emissions and that the estimates are much more accurate than those produced with MOBILE6 (Sloan & Singh, July 2005).

The MicroFac model can be used to estimate emissions of carbon monoxide (CO), nitrogen dioxide (NO_2), fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}) and carbon dioxide (CO2). Singh is currently working to incorporate methane emissions into the model as well. The results of MicroFac can be fed into a number of other dispersion models including CALPUFF, CALINE4 and AERMOD to produce ground-level concentrations for roadways.

MicroFac can be used alone without consideration of background air levels or with background air levels built in. It has a very high temporal resolution; it can be used to estimate emissions accurately for minutes or hours. It has very good spatial resolution; it can be used to estimate emissions accurately for areas that are smaller than 100 meters. Consequently, it can be used to produce results for site-specific situations in a way that the MOBILE6 cannot. With MicroFac, as with any model, the accuracy of the results improve as the accuracy of the inputs increases (i.e. road counts, class of vehicles, model-years, etcetera) (Sloan & Singh, 2005).

WCAS has prepared a research proposal with Greg Evans from U of T and Jeff Brooks from Environment Canada to develop this model into a user-friendly system that combines emission estimates and dispersion modeling. WCAS is also very interested in doing small demonstration projects with municipalities to showcase the model's abilities (Sloan & Singh, 2005).

III Modeling Air Pollutant Concentrations in Toronto/GTA

1. CALPUFF Model

For several years, Chris Morgan of the Air Quality Improvement Branch of Toronto's Technical Services Division has been overseeing the development of a Toronto-specific modeling tool that is based on the CALPUFF model developed by the U.S. EPA. He has worked with staff, students, and consultants such as Anthony Piccone (formerly of Earth Tech and now with Golder Associates) to build an in-house Toronto-specific CALPUFF model for the City of Toronto. He is now working with the GTA Clean Air Council to expand this model to include all of the communities in the GTA (Morgan, 2005).

The CALPUFF model is a dispersion modeling tool developed by the U.S. EPA to handle complex terrain, long source receptor distances, and chemical transformations and deposition. It addresses several important limitations presented by the AERMOD and ISCSTC models:

- ISCST3, which is a steady-state, straight line plume model, cannot respond to spatial variability related to changes in terrain or dispersion variability related to surface conditions; and
- Both AERMOD and ISCST3 use spatially invariant wind fields based on single-station wind observations and neither accounts for transport time.

The CALPUFF model is used with the meteorological model, CALMET, which produces a 3-dimensional wind and temperature field, and 2-dimensional fields of mixing heights and other meteorological variables. It is a non-steady-state Gaussian puff model that includes:

- algorithms for chemical transformations, wet deposition, and dry deposition; and
- algorithms for assessing the impact of primary and secondary particulate matter on visibility.

It can address multiple processes and multiple sources within one spatially varying meterological field. It can be used over a the entire expanse of the Toronto Area. It can include a PRIME algorithm to deal with the effect of near-source buildings on dispersion. It includes a Thermal Internal Boundary Layer (TIBL) module to address the effect caused by the lake. Terrain variations are built into its meterological model. It can report ground-level concentrations of air pollutants over varying periods (e.g. in hourly, daily, or annual averages).

a. Toronto-Specific CALPUFF Model

The Toronto-specific CALPUFF model can be used to estimate concentrations of sulphur dioxide (SO_2), NO_2, PM_{10}, and CO. It can also be used to estimate secondary $PM_{2.5}$ that results from the transformation of sulphur oxides (SO_x) and nitrogen oxides (NO_x) to sulphates, nitrates and ammonia, but it cannot estimate secondary $PM_{2.5}$ that is derived through more complicated chemical reactions. It is possible that the model could be used to estimate concentrations of ozone in time, but at present this task is limited by the dearth of data respecting ammonia levels in the air (Morgan, 2005)

Emissions data for City sources were originally obtained from Environment Canada (using the 1995 Criteria Air Contaminant inventory) and the Ministry of the Environment for point sources, non-mobile area sources, mobile sources and biogenic (natural) sources. The emissions data were provided as annual emissions, which had to be distributed across the year, months, days and hours to provide good temporal estimates (Morgan, 2005).

The **point source data**, which were missing a significant amount of stack info such as velocity and stack height, was upgraded using US EPA protocols to estimate the missing information. The top 50 point sources in Toronto, which are responsible for 97% of point source emissions, were modeled as discrete point sources (Morgan, 2005; Earth Tech, 2003).

Area and mobile source data provided were city-wide for each source type, and therefore had to be distributed using spatial surrogates such as land use maps and vehicular maps. Both area and mobile source emissions were distributed spatially into 1 km grids and 2 km grids. Originally, EPA methods were used to apportion the emissions spatially, but that method only resulted in 4 land use classes; only one of which applied to Toronto. So, land use classes were broken into 11 non-mobile and 5 mobile land-use source categories that were then used to apportion emissions from area and mobile sources spatially across the City. Movers, snow blowers and other non-road vehicles were classified under "population" while the "lakeshore" classification includes dockside operations and marine vessels. "Roadways" include cars, trucks and re-suspended dust (Earth Tech, 2003; Morgan, 2005).

Air quality monitoring data for ozone (hourly) is used in CALPUFF in the equations related to the transformation of SO_2 and NO_x to sulphates, nitrates and ammonia. Ammonia measurements were not available so "typical background" levels were used. Meterological data was processed on a 2 km grid resolution. The model is set up to provide air concentrations on a 1 km or 2 km density grid. Point, area and area-traffic source data (1995), which consists of hourly emissions for SO_2, NO_x, CO and PM_{10}, were input into CALPUFF as separate files that can be run separately and summed (Earth Tech, 2003; Morgan 2005).

b. Preliminary Modeling Results for Toronto

Modeling results produced by EarthTech for the City in 2003, found that:

- Area sources are typically the largest contributors to maximum ground-level concentrations in the City;
- The entire City will substantially exceed the Ontario **AAQC for PM_{10}** of 50 ug/m3 at some day during the year;
- Point sources produce one small PM_{10} hotspot on the western side of the City;
- It appears that area sources contribute to one very large hotspot in the northeastern part of the City, but this result reflects poor estimates of PM_{10} emissions from area sources such as wood-burning fireplaces (i.e. it is not a real “hotspot”);
- Roadways create two real PM_{10} hotspots; one in the downtown core and one in the northeastern quadrant;
- There are no exceedances of the **AAQC for SO_2** [which speaks to the weakness of the AAQC];
- Area sources dominate for their contribution to air levels of SO_2, particularly the Island Airport and marine activities;
- There are no exceedances of the **AAQC for NO_2** [which speaks to the weakness of the AAQC];
- There are three NO_2 hotspots; one in the northeastern quadrant; one near the islands; and one in the northwestern quadrant;
- There are no exceedances of the **AAQC for CO**; and
- Higher concentrations of CO are similar in pattern to NO_x and PM_{10} maps [reflecting the strong correlation between these three air pollutants] (Earth Tech, 2003).

c. Evolution of Toronto Model

The Toronto-specific CALPUFF model is constantly being improved and modified so the 2003 report, prepared by Earth Tech, cannot be viewed as the state of the model today. Much of the data for emissions from point sources, area sources and mobile sources were originally drawn from Environment Canada’s databases which provide “top down” estimates. This “top down” data is gradually being replaced with “bottom up” data that is more specific and/or more accurate (Morgan, 2005).

For example, the **point source** data has been improved over time by ensuring that the top 50 sources are accurately located on the map, adding actual stack heights to the model, and adding the velocity of emissions to the model. The original point source data, that was bound by confidentiality agreements, is now being replaced with data from the National Pollutant Release Inventory (NPRI)I that is not bound by confidentiality agreements (Morgan, 2005).

With **area sources**, the original data was derived from city-wide estimates that were allocated across the City using a number of assumptions and/or models. Over time, this data is being replaced with “bottom up” data as well. For example, dry cleaners are now being identified on aerial maps and accurately assigned to their proper locations, and their emissions data are being replaced with more accurate estimates derived by using EPA emission factors for the particular facilities. In addition, Technical Services now has detailed information related to electricity and natural gas use by postal code from which it can more accurately estimate and allocate emissions from area sources (Morgan, 2005).

With **mobile sources,** the original data was based on city-wide estimates that were allocated across the City using a number of assumptions and/or models. This data is gradually being replaced with "bottom up" data such as traffic counts and cordon studies. Technical Services now has information on the number of school buses, transit buses, airplanes, trains and boats traveling into and around the City.

The development of the Toronto model is currently limited by a few factors:

- the ability of other departments to provide the data requested in a timely fashion due to resource constraints; and
- the ability of Technical Services to input the data into the model due to resources constraints.

At present, "bottom up" information is being added to the model in response to specific project requests and/or for specific locations and is therefore patchy (Morgan, 2005).

d. Information Gaps

Technical Services has identified several gaps in the data needed for the Toronto model:

- Transboundary inputs are still missing although some progress is being made on the front with Environment Canada;
- Regional inputs are still missing although it is expected that a good deal of this data will be provided if and when the GTA Clean Air Council modeling project proceeds;
- The information respecting truck use in the City is very poor.

Information respecting truck use in the City is poor for two reasons. One, while the Transportation Planning Department has the ability to identify what portion of the vehicles identified in road counts are trucks, it does not have the time to analyse this data for Technical Services. Secondly, the cordon surveys, conducted by Transportation Planning to identify the number of kilometers traveled and the frequency of trips taken in and around Toronto, are based on residential surveys. Consequently, they do not capture or reflect the traveling patterns of trucks which can have a significant impact on emissions and air quality (Morgan, 2005).

IV Estimating Health Impacts from Air Pollutant Concentrations

Staff in Toronto Public Health are aware of two Canadian models that can be used to estimate the health impacts associated with ambient levels of air pollutants; the Illness Costs of Air Pollution (ICAP) model developed for the Ontario Medical Association; and the Air Quality Benefits Assessment Tool (AQBAT) model being developed by Health Canada.

1. ICAP Model 2005

Developed by DSS Management Consultants Inc. (DSS) for the Ontario Medical Association (OMA), the ICAP Model estimates the health impacts associated with air pollutant concentrations fed into the model. It also estimates the economic costs associated with the health impacts.

The ICAP model has been developed and posted on the OMA website in a simplified manner that allows people across the province to produce estimates for a variety of scenarios for a variety of geographic locations across the province. As currently posted, the ICAP model must be used at a census division level and must have "forecasted" air pollutant concentrations submitted in annual average levels for all air pollutants, except ozone, which is handled as an 8-hour maximum (DSS, 2005).

a. Air Quality Estimates

For the 2005 ICAP, air quality data collected by the National Air Pollution Surveillance (NAPS) system run by Environment Canada between 1985 and 2003 were used, along with air quality data collected on the international border by the U.S. EPA between 2000 and 2003. Annual averages from between 25 and 99 Canadian monitoring stations and 46 to 237 U.S. monitoring stations were used for $PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO. and 8-hour maximums were collected from 172 Canadian and 153 US monitoring stations, for 2000 and 2002 for the whole country. Krieging was used to estimate the air pollutant concentrations at all of the points in between air monitoring stations.

The population-weighted centroid for each census division was calculated. The air pollution estimates for these points were used as the air pollution estimates for the respective census divisions (DSS, 2005).

Background concentrations, derived by DSS for the Ministry of the Environment in 2005, were subtracted from air pollution concentrations to ensure that health impacts applied to anthropogenic air pollution only. In this context, background concentrations apply to those emissions coming from natural sources (DSS, 2005).

b. Health Impact Estimates

The 2005 ICAP for OMA uses population statistics from the 2001 census from Statistics Canada. Base incidence rates (i.e. health statistics for the population) were obtained from the following sources:

- Morbidity health outcomes from health statistics available for Ontario for 2002 from the Canadian Institute for Health Information (CIHI);
- Base incidence rates for minor illnesses are not reported in a standardized way, nor reported through a central database, therefore, minor illness estimates were based on illness rates from a study by Vedal in 1998;
- Base mortality rates were obtained from death statistics by Statistics Canada for 2002 (DSS, 2005).

The model can be used to produce estimates 4 broad categories of health outcomes: premature deaths (PD), hospital admissions (HA), emergency room visits (ERV), and minor illnesses. These categories include 23 specific health effects that have been clearly associated with air pollution. Currently, estimates are not provided under "visits to doctors' offices" because of insufficient data, although this category is included in the model on the website and could be used by those who want to insert their own data (DSS, 2005).

Concentration-response functions (CRFs) or risk coefficients were derived for each air pollutant, for each health outcome, and for different age groups based on the epidemiological studies. These CRFs are used as the default CRFs but the model allows users to change the CRFs. In each case, health outcome estimates are derived by multiplying the number of exposed people in a particular age/vulnerability group by the associated per capita health risk by the base incidence rate for the specific health outcome of interest (DSS, 2005).

Premature deaths related to total, respiratory, cardiovascular (**CV**), cardio-respiratory (CV and respiratory combined), and lung cancer were included in the 2005 ICAP. Premature deaths were captured for adults and elderly, but not for children and infants, due to a dearth of epidemiological evidence for that age group. All Concentration-Response Functions (CRFs) for acute premature deaths were derived from time-series studies (DSS, 2005).

The CRFs used for **acute premature deaths** for the different causes for different air pollutants were derived from the following studies:

- For ozone – Dominici, 2003 - for total deaths;
- The CRF for ozone was 4 times less than it would be if it were based on a recently published meta-analyses conducted by Bell, 2005, Ito, 2005, and Levy, 2005;
- For SO_2, NO_2, and CO – Dominici, 2003 -- for total deaths;
- For PM_{10} – Dominici, 2003 -- for total and cardio-respiratory deaths (who did not separate CV from respiratory deaths);
- For PM_{10} – Ito et al., 2003 -- for CV and respiratory deaths;
- For $PM_{2.5}$ – Burnett and Goldberg, 2003 – total deaths;
- For $PM_{2.5}$ --Goldberg and Burnett 2003 – CV deaths; and
- For $PM_{2.5}$ – Ito et al, 2003 -- for respiratory deaths (DSS, 2005).

The 2005 ICAP model attributes fewer acute premature deaths to PM_{10} than the 2000 ICAP model did as a result of a change in the modeling used to make estimates from time-series studies; a change recommended by the Health Effects Institute (HEI) established jointly by the U.S. EPA and industry. On the other the 2005 ICAP estimates acute premature deaths for $PM_{2.5}$ and some of the gaseous air pollutants which the 2000 ICAP model did not do (DSS, 2005).

Chronic premature deaths were estimated for $PM_{2.5}$ only because it was determined by the OMA that there was not sufficient epidemiological evidence with which to estimate CRFs for PM_{10} or the gaseous air pollutants (DSS, 2005). The CRFs were derived from cohort studies that followed populations of individuals over many years.

Two large-scale cohort studies have been conducted in the United States; one originally done by Pope et al in 1995 and one done by Dockery et al in 1993. Krewski re-analysed the database used by Pope et al in 2000 and strengthened the analytical foundation of the original analysis. And in 2002, Pope et al. improved upon the database by doubling the follow-up time for subjects which resulted in three times as many recorded deaths. Because the epidemiological methodology employed by ICAP captures both acute and chronic deaths, acute premature deaths were not estimated separately for PM2.5 (DSS, 2005).

The CRFs for chronic premature deaths for $PM_{2.5}$ for total, cardiopulmonary and lung cancer-related deaths were derived from Pope et al. 2002. ICAP 2005 found there were seven times as many chronic premature deaths as acute premature deaths. Most of the premature deaths in the 2005 ICAP estimates were associated with cardiovascular illnesses and most applied to people over 65 years of age (DSS, 2005).

Under ICAP 2005, all CRFs related to **morbidity** (hospital admissions, emergency room visits and minor illnesses) reflect acute impacts only based on time-series studies, because long-term studies were not available. The estimates for morbidity are likely to underestimate air pollution's impact upon health outcomes because chronic outcomes are not included. All morbidity estimates reflect the influence of PM_{10}, $PM_{2.5}$ and ozone only; no estimates were provided in ICAP 2005 for the other gaseous air pollutants (DSS, 2005).

Estimates for hospital admissions apply to three age groups: those under 18, adults, and those over 65. ICAP 2005 includes all CV and respiratory illness types in the hospital admissions while the 2000 ICAP used only 6 specific types of hospital admissions. The categories of respiratory hospital admissions include total, asthma, chronic obstructive pulmonary disease (COPD) and pneumonia, while the categories for cardiovascular admissions include total, coronary artery disease, congestive heart failure and dysrthymia (DSS, 2005).

The CRFs for **hospital admissions:**

- For ozone -- two studies conducted on Toronto populations by Burnett et al. in 1997 and 1999 -- for CV illnesses and respiratory causes;
- For PM_{10} and $PM_{2.5}$ -- Burnett et al. in 1997 -- all types of respiratory admissions;
- For PM_{10} and $PM_{2.5}$ -- Burnett et al. in1999 -- all other types of admissions except congestive heart failure admissions for 65 years and older, which were derived with Ito in 2003 (DSS, 2005).

Most of the hospital admissions in the 2005 ICAP estimates were associated with cardiovascular illnesses and apply to adults and the elderly; very few were attributed to respiratory causes or to children (DSS, 2005).

Estimates for **emergency room visits** exclude severe illnesses to avoid double counting with hospital admissions. This category is broken into three groups; under 18, adults, and over 65. The numbers estimated with ICAP 2005 are dominated by the elderly age group. The number of emergency room visits are much greater with ICAP 2005 than with ICAP 2000 due to the inclusion of emergency room visits for $PM_{2.5}$ in the 2005 version (DSS, 2005).

The CRFs for emergency room visits were derived from the following studies for the following health outcomes and air pollutants:

- For ozone – Jaffe et al., 2003 -- for respiratory cases;
- No CRF was included for CV cases even though it is likely that ozone affects CV emergency room visits;
- For PM_{10} – Stieb et al, 2000 (St. John, New Brunswick) -- for CV and respiratory cases;
- The CRF for CV emergency room visits for PM_{10} may over-estimate health outcomes; and
- For $PM_{2.5}$ – Steibe et al, 2000 -- for CV and respiratory cases (DSS, 2005).

While ICAP has the capability of estimating increases in **visits to doctor's offices** as a result of air pollution, it was decided that there was insufficient literature on the relative risks for doctor's office visits from which to derive CRFs for this category for ICAP 2005. This gap in ICAP is deemed significant in terms of estimating the healthcare costs, lost productivity and pain and suffering associated with air pollution. There are placeholders in the OMA ICAP 2005 model so that users can input their own risk coefficients for doctor's office visits to estimate outcomes (DSS, 2005).

The scientific literature related to **minor illnesses** has not advanced significantly since ICAP 2000 in terms of relative risks that could be used to derive estimates of minor illnesses. ICAP 2005 uses the 1998 report by Vedal et al. to derive CRFs only for PM_{10} and only for the youngest and the oldest age groups. Estimates were not made for adults. Consequently, the number of minor illness estimated with ICAP 2005 likely underestimates the true burden of illness associated with air pollution (DSS, 2005).

There are two sources of uncertainty associated with the minor illness estimates; the estimated risk factors are less reliable and the base incidence rates must be estimated as well. Three health outcomes were included in minor illnesses: minor restricted activity days, restricted activity days, and asthma symptoms days. The numbers estimated for Ontario in 2005 are heavily dominated by restricted activity days. Children under 18 account for the majority of these outcomes (DSS, 2005).

c. Economic Impacts

The economic impacts were estimated for the four broad health categories.

For premature deaths, the economic numbers represent the risk in premature mortality that is borne by all members of a population. The value of a statistical life (VSL) is the amount of money people are willing to pay to shift the risk of premature death for themselves based on work by Krupnick in a report published in 2004. The VSL for this study is lower that the VSLs applied to other studies and will tend to produce low economic damages for premature deaths (DSS, 2005).

For Pain and Suffering, the economic costs are derived with a similar approach to that used for premature deaths.

For Cost of Treatment, healthcare costs includes institutional care plus medication. The estimated costs of treatment reflect the number of cases multiplied by the healthcare costs associated with a particular illness and the age of person (DSS, 2005).

For Lost Productivity, estimates of lost-time vary with the severity of the illness, and applies to caregivers as well as to patients. The costs for lost-time are based on the average wage rates for each census division for 2003 (DSS, 2005).

A Monte Carlo simulation was used to estimate upper and lower ranges of estimated damages (DSS, 2005).

d. Flexibility of 2005 ICAP Model

The 2005 ICAP model can be downloaded from the OMA website. It is easy to use.
It can be used to produce health/economic cost estimates for seven air pollutants; ozone, PM_{10}, $PM_{2.5}$, sulphates, carbon monoxide, sulphur dioxide and nitrogen dioxide separately or in combination (DSS, 2005).

It can be used to produce estimates for five broad categories of health outcomes – premature mortality, hospital admissions, emergency room visits, doctor's office visits, and minor illness - - with 24 specific health outcomes separately or in combination, for three different age groups where the data is available. It can be used to produce estimates for up to seven economic parameters (DSS, 2005).

The ICAP 2005 model on the OMA website is currently designed so that air pollutant concentrations and temporal weight, base illness rates, concentration response functions (risk coefficients), background levels of air pollutants, and economic coefficients can be changed by the user.

It cannot however, currently be used with a spatial area smaller than a census division. Nor can it be used for health outcomes that are not included. Nor can it produce air levels in response to different policies or actions; the policies or actions must be translated into forecast emissions and air pollutant concentrations first.

e. ICAP can be Modified

According to Ed Hanna, President of DSS, the OMA has indicated that ICAP is to be made available to the public. We are welcome to use the model as it on the OMA website or to modify it for our own use.

If we were going to produce a Toronto-specific ICAP, we could identify a number of new default scenarios that could be put into the model once so they would not have to be re-inserted for every policy question. We could have TPH-specific risk coefficients and background levels of air pollutants put into the model as the new defaults The economic valuations should still come out okay even if we change the risk coefficients; one exception might be related to premature deaths (Hanna, 2005).

While the ICAP 2005 model on the OMA website is currently designed to work to a census division level, the model could easily be modified to work to a census tract level (i.e. 1 major block). This modification would involve changing one code only (Hanna, 2005).

The ICAP model could be modified to include new health effects as well. When using ICAP, Hanna noted that it is important to pick the time horizon that is correct for the policy being analysed because it is time consuming to input information required for many different time forecasts. Annual averages are best for policy purposes, but the model could be used for monthly, daily or annual averages (Hanna, 2005).

ICAP is quite compatible with the CALPUFF dispersion model. One does have to be careful when working with these two models to correctly align them temporally (i.e. use the same time-weighting for air quality as is used for ICAP) and spatially (i.e. ensure that the maps are lined up). He noted that when modeling the impacts on a local area, one has to have very specific emissions information in order to provide useful health data (Hanna, 2005).

ICAP was used with the CALPUFF model to estimate the health impacts associated with the phasing-out of Ontario's coal-fired power plants using a census division resolution. It was also used with a census tract resolution to estimate the health impacts associated with various transportation options being considered for the City of Ottawa (Hanna, 2005).

f. Application of ICAP: Policy - Coal-Fired Power Plants

The Ontario Ministry of Energy contracted the services of DSS and RWDI to estimate the health impacts associated with several scenarios related to the phase-out of coal-fired power plants in Ontario.

The air modeling was done to an intermediate level of precision using CALPUFF and CALMET with a 20 km resolution. Secondary PM_{10} was calculated from emissions of NO_x, SO_x and volatilve organic compounds (VOCs) (MOE, 2005).

Health damages were forecast largely based on $PM_{2.5}$. Most of the PM_{10} reported with the modeling was $PM_{2.5}$ and therefore was treated as such from a health perspective. No background adjustments were needed because the CALPUFF results were for incremental contribution only (MOE, 2005).

Health impacts were estimated using ICAP 2005. Population parameters, drawn from the 2001 census data, were used to forecast 2003 population parameters. The population in each census division was divided into 3 age groups: less than 19, adults and greater than 65. Base incidence rates for all health outcomes were obtained from for Ontario for 2002 from the Canadian Institute for Health Information (CIHI) 2002). Four health categories impacts were examined; doctors' office visits were not included (MOE, 2005).

g. ICAP Application: Planning - Transportation Corridor Alternatives

Six transportation alternatives were identified for the Alta Vista Corridor in Ottawa. A consulting firm, Delcan, provided DSS with the forecast changes in air quality, specifically for PM_{10}, for each of the six alternatives. DSS identified the census tracts that would be affected by the Alta Vista transportation corridor and obtained demographic data for each from Statistics Canada (DSS, 2004).

The demographic data were entered into the ICAP model, and health risk and associated potential health costs were estimated for each alternative. PM_{10} was used to estimate health impacts; ground-level ozone was not included in the analysis because of the impacted area is quite frequently distant from the emission source. The other air pollutants were not included because the epidemiological evidence for them was considered insufficient and because of the significant co-variance between these other air pollutants and PM_{10}. The relative health impacts, it was decided, would be reflected in the relative impacts associated with PM_{10} (DSS, 2004).

Delcan provided forecasts for PM_{10} for each of the six alternatives for 49 receptors along the corridor for the 2003 to 2021 period. It was assumed that the air concentrations would remain constant over the forecast horizon (2003 to 2021), although population changes were reflected (i.e. they did not calculate the change in vehicle numbers, nor the change in vehicle emissions) (DSS, 2004).

Thirteen separate health outcomes were reported under 4 categories of health impacts; premature deaths, hospital admissions, emergency room visits, and minor illnesses. Three age groups were used; children, adults and elderly. Economic damages were reported for four categories: lost productivity, health care costs, pain and suffering, and premature deaths (DSS, 2004).

The analysis was done for 42 census tracts individually and together. The results were produced for an annual cycle for 19 years. Altogether, 30,000 discrete health risks were calculated for each one of the 6 alternatives. Results were aggregated for ease of reporting. Results were reported in three formats: absolute magnitude, percentage difference, and relative magnitude (DSS, 2004).

The absolute magnitude was not so great (e.g. 2 premature death, 1 hospital admission, less than 1 emergency room visit and 35,000 to 45,000 minor illness per year). Over the time horizon, population drives the trends with increases overall vulnerability of the population. In relative terms however, it was found that some scenarios pose less risk for health impacts (i.e. 2 to 10% less) relative to the base case, while others posed increased risks (i.e. 10 to 18% more) (DSS, 2004).

The comparative economic analysis indicated the same relative relationships for each scenario but provided economic values to those impacts over the 19 year period (DSS, 2004).

h. Interpretation of Results and Uncertainties

The linear exposure-response functions built into ICAP means that estimated health outcomes are insensitive to absolute air pollution concentrations when doing comparative analyses among alternatives. In other words, inaccuracies in the risk coefficients will not affect the preference ordering among alternatives, only the absolute numbers derived from them. The same thinking applies to the economic valuation (DSS, 2004).

Uncertainties affecting the outcomes include those associated with the exposure-response functions (i.e. risk coefficients), air pollution forecasts, population forecasts, and economic values. ICAP includes a Monte Carlo simulation routine that can be used to generate uncertainty bounds for key forecasts. Given that many of the uncertainties would apply equally to each of the alternatives, the relative ordering of the alternatives is expected to remain the same, except with respect to air pollution forecasts (DSS, 2004).

2. AQBAT Model

The AQBAT model, under development by Health Canada, is very similar to the ICAP model. Ambient air concentrations are fed into the model and the model estimates the health impacts associated with those concentrations, and then calculates the economic “costs” associated with those health impacts (Stieb, 2005).

The AQBAT model, which is not yet quite ready for release, should be very easy to use. According to Dave Stieb at Health Canada, in-house training can be provided by Health Canada staff to health units if needed. The AQBAT model can be run on a regular computer using the excel program with an add-on program called “at risk” that can be purchased for about $800.00 US (Stieb, 2005).

The parameters such as risk coefficients and baseline population data on AQBAT can be changed by the users. The assumptions used in the model respecting health statistics, risk coefficients, etcetera, are actually built into the program so they can be viewed while using it (Stieb, 2005).

a. Application of AQBAT

Stieb indicated that AQBAT and ICAP would be most helpful when used to assess a significant intervention that is expected to have a substantial impact on air quality for a fairly large area. He thinks that it may not be useful to apply AQBAT to a planning decision that affects a very localized area because air quality is a fairly subtle risk factor and the health benefits will be very small when applied to a very small area and population (i.e. better to simply use the air quality concentrations derived). He noted that because risk coefficients are developed from epidemiological studies that have used ambient air monitors to estimate exposure for a community, they will likely underestimate the health impacts associated with air concentrations for specific communities that are situated in high-exposure settings (i.e. busy traffic corridors)(Stieb, 2005).

V Various Policies and Planning Scenarios – Steps Involved

1. Priority Scenarios:

Within Toronto Public Health, the following five scenarios have been identified as ones that should be given high priority for modeling:

a. Creation of a Pedestrian Zone

Question: What health benefits would be associated with the air quality changes that could result from the creation of a pedestrian zone in downtown Toronto (one that allows for service deliveries during certain hours, public transit and taxis only)?

Value of Analysis: Results could inform decision-making on this issue. This policy is potentially within the City's control.

Expected Impact on Air: Could have a significant impact on air quality downtown and potentially across the Ctiy.

Influencing Factors: There could be considerable resistance to the idea of removing space from roadways for vehicles. It would have to be coordinated with improvements to public transit across the GTA. Emissions from transit buses would have to be examined as part of the plan.

Steps:

- Need to understand how the creation of a pedestrian zone would affect road counts and traffic flow into and around the City.
- Need to determine how the changes in road counts and traffic flow would affect emissions inside and outside the pedestrian zone (e.g. might reduce light-duty vehicles but not heavy-duty diesel vehicles, faster movement may reduce overall emissions).
- Allocate emissions across the City and then model with a dispersion model.
- The forecast concentrations of air pollutants could be fed into ICAP or AQBAT to produce estimates of health outcomes on an annual basis and with a short-term horizon.

b. Congestion Charges

Question: What health benefits would be associated with the change in air quality that could result from the application of congestion charges to vehicles entering downtown Toronto, Monday to Friday, from 8:00 am to 6:00 pm?

Value of Analysis: Results could inform decision-making and public opinion on the issue. The policy is potentially within the City's control.

Expected Impact on Air: It could have a significant impact on air quality in downtown Toronto and potentially across the City.

Influencing Factors: There could be considerable resistance to this idea. It would have to be coordinated with improvements in public transit service across the GTA. Emissions from transit buses would have to be examined as part of the plan.

Steps:

- Need to understand how road congestion charges would affect road counts and traffic flow into and around the City.
- Need to determine how the changes in road counts and traffic flow would affect emissions inside and outside the congestion charging zone (e.g. might reduce light-duty vehicles but not heavy-duty diesel vehicles, faster movement may reduce overall emissions).
- Allocate emissions across the City and then model them with a dispersion model.
- The forecast concentrations of air pollutants could be fed into ICAP or AQBAT to produce estimates of health outcomes on an annual basis and with a long-term horizon.

c. Network of Bicycle Lanes

Question: What health benefits would be associated with the change in air quality that could result from the creation of a network of bicycle lanes on roadways across the City?

Value of Analysis: Results could inform decision-making on this issue. This policy is within the City's control.

Expected Impact on Air: Could have a substantial impact on air quality along roadways and possibly across the Ctiy.

Influencing Factors: There is likely to be huge resistance to the idea of removing space from roadways for vehicles but likely to be substantial support for the creation of bike paths.

Step 1: Evaluate the impact that a network of bicycle lanes could have on air quality and human health in the City.

- Need to estimate the impact of the goal on the use of bicycles, public transit and vehicles across the City, which may require indepth research (e.g. survey of population to determine who would ride bicycles if safe and direct routes were provided; what distances would they ride; and what modes would they be transferring from).
- Would need to estimate emissions associated with the modes being displaced and the areas of the City where emission reductions could occur.
- Could model impacts on air quality in two ways: to see localized impact on specific roadways; with CALPUFF to see impact on ambient air quality across the City.
- Could feed ambient air pollutant concentrations into ICAP or AQBAT to produce health estimates on a seasonal basis and over a long time horizon for the City as a whole.
- Could use traffic corridor health studies to qualitatively assess health impacts associated with localized air levels on specific streets modeled under the business as usual and bike lane scenarios.

Step 2: Evaluate specific bicycle lane plan options for air quality and human health impacts

- Need to identify the routes that would be most useful to bicycle commuters.
- Need to identify several plans for bicycle lanes for the different areas of the City.

- Need to estimate how many people would take the different routes provided and what modes each of them would be shifting from (i.e. public transit or cars).
- Need to estimate the emission reductions associated with the shifts and where those emission reductions will be experienced (i.e. what roadways).
- Could model impacts on air quality in two ways: to see localized impact on specific roadways; with CALPUFF to see impact on ambient air quality across the City.
- Need to also consider the exposures of the bicycle riders (i.e. are they riding on roadways or on routes that are removed from roadways?)

d. Achieve the 20/20 Goals

Question: What health benefits would be associated with the change in air quality that could result from achieving the 20/20 Goals of reducing energy use in all homes and vehicles in the GTA by 20% by 2020?

Value of Analysis: Results could inform the social marketing program, motivate individuals across the GTA, and ensure continued funding for the program.

Expected Impact on Air: Could have a substantial impact on air quality across the GTA.

Influencing Factors: This is goal that must be achieved through social marketing; it cannot be mandated. It is a goal that can be supported by structural changes such as increased service for public transit (e.g. more parking provided for GO Train/Bus services across the GTA).

Steps: (20% reduction in home energy use)
- Need to know how much oil, natural gas and electricity are used for residential use in the GTA.
- Need to estimate the extent to which the 20/20 program can have an impact on home energy use based on the evaluation of the program.
- Need to apply the reduction expected to all three types of energy used in homes.
- Would have to allocate those emissions across the City and then run them through a dispersion model.
- The air pollutant concentrations could be fed into ICAP or AQBAT on a seasonal basis with a long time horizon (e.g. 20 years).

Steps: (20% reduction in use of vehicles)
- Need to know how many single-occupancy vehicles are operated in the GTA, the emissions associated with those vehicles, and how those emissions are distributed across the City.
- Need to estimate the extent to which the 20/20 program can have an impact on vehicle use based on the evaluation of the program.
- Need to apply the estimated reduction in vehicle use to the fleet of vehicles used in Toronto.
- Need to estimate how that reduction would be achieved (i.e. how many had shifted to other modes, what modes are selected and for what distances, and in what seasons; how many shifted by telecommuting, etcetera).
- May require some sort of survey of present-day commuters on factors that could affect their behaviour.
- Once the modal shifts are calculated, the change in emissions would have to be estimated, distributed across the City and across seasons, and then modeled to estimate air quality for different times of the year.

- The forecast air pollution concentrations could be fed into the ICAP or AQBAT model on an annual basis with a long time horizon (e.g. 10 to 20 years) to estimate the health impacts.

e. Community Profiles

Question: How can we use models to assess the health impacts of new developments, facilities, or plans on local air quality in different communities across the City?

Value of Analysis: Results could inform decision-making related to the certificates of approval for facilities, development applications, or redevelopment plans proposed for specific communities.

Expected Impact on Air: Modeling could be used to estimate the cumulative impacts of all emission sources on the local air quality for a specific community when evaluating the proposal.

Influencing Factors: The ideal situation would be to have community profiles developed for every community in the City, which could be time-consuming and resource-intensive.

Steps:
- Need to identify the data that is missing from the Toronto-specific model today that would be required for an accurate community profile.
- Need to develop a plan to collect and input the necessary data.

2. Other Scenarios:

Within Toronto Public Health, a number of other scenarios have been identified that could be modeled for their impact on human health.

a. Increasing Percentage of Low Emission Vehicles

Question: What health benefits would be associated with the change in air quality that could result from increasing the percentage of low emission vehicles on the road?

Value of Analysis: Could be used in messaging for social marketing.

Expected Impact on Air: Depends on goal set.

Influencing Factors: Would have to use social marketing to encourage.

Steps:
- Need to know the percentage of low emission vehicles currently being driven in the City.
- Need to estimate the emissions associated with the business as usual scenario and the scenario aimed for.
- Feed forecast emissions into the dispersion model and distribute across the City to estimate air pollutant concentrations for the two scenarios.
- The forecast air pollutant concentrations could be fed into the ICAP or AQBAT model on an annual basis with a medium time horizon (e.g. 10 years).

b. Retiring Older Vehicles

Question: What health benefits would be associated with the change in air quality that could result from the accelerated retirement of older vehicles?

Value of Analysis: Results could be used to advocate for a policy shift at the Provincial level or for a program run by a non-profit organization.

Expected Impact on Air: Possibly substantial impact on air quality along traffic corridors in a relatively short period (2-3 years).

Influencing Factors: There are policy tools (i.e. Drive Clean) and programs (i.e. Car Heaven) that could be used to attain this goal.

Steps:
- Need to know something about the number of "older vehicles" in Toronto.
- Need to estimate the emissions associated with older vehicles versus new ones.
- Emissions from the two scenarios would have to be distributed across the City and modeled with a dispersion model to produce estimated air pollutant concentrations.
- Those concentrations could be fed into ICAP or AQBAT on an annual basis with a short time horizon (e.g. 5 years).

c. Retrofitting TTC Buses with DPF

Question: What health benefits would be associated with the change in air quality that could result from retrofitting existing or new TTC buses with diesel particulate filters?

Value of Analysis: Could inform a decision that is largely within the City's control. Could be used to encourage the investment needed for TTC by the City or other level of government.

Expected Impact on Air: Could have a substantial impact on air quality along traffic corridors and a modest impact on air quality across the City.

Influencing Factors: With ultra-low sulphur diesel becoming standard fuel in 2006, TTC buses could be retrofit for about $10,000 each (relatively small amount given that transit buses can cost about $400,000 each).

Steps:
- Need to know the number and age of the buses currently run by TTC, the average number of kilometers traveled per year, and whether older buses are assigned to shorter routes or fewer hours.
- Need to calculate the percentage reduction expected per pollutant per model-year cohort (group buses in categories with similar emission standards) for Diesel Particulate Filters.
- Emissions forecast into the future by about 15-20 years to see the full benefits of the investment.
- The emissions would have to be allocated across the City and modeled using a dispersion model.
- The forecast air pollutant concentrations could be fed into ICAP or AQBAT on an annual basis with a long time horizon (e.g. 15-20 years) to estimate health outcomes.

d. Fueling TTC buses with 20% Biodiesel

Question: What health benefits would be associated with the change in air quality that could result from fuelling all TTC buses with B20?

Value of Analysis: Could influence a decision within the City's control.

Expected Impact on Air: Could produce slight improvements in air quality along traffic corridors. Could produce substantial reductions in greenhouse gases (GHG) from Corporate fleet.

Practicality of Goal: The policy is within the City's control. B20 is currently expensive but also produces GHG benefits.

Steps:

- Need to determine what percentage reduction in air pollutants would be expected with B20 for different model year buses.
- Using the emission information calculated for 2.a., the percentage reduction per pollutant expected for B20 could be applied to the emissions associated with the fleet today (should be compared against the fleet using ultra low sulphur diesel which will be commonplace next year).
- Emissions would be distributed across the City and modeled using a dispersion model.
- The forecast air pollutant concentrations could be fed into ICAP or AQBAT model on an annual basis with a short to long time horizon (e.g. 5-20 years).

e. Replacing Buses with Hybrid Electric Vehicles

Question: What health benefits would be associated with the change in air quality that could result from the replacement of retiring TTC buses with diesel-electric hybrid electric vehicles (HEVs)?

Value of Analysis: Would inform corporate purchasing policy over which the City has some influence. Could be used to encourage funding from City or other levels of government.

Expected Impact on Air: Policy could have a significant impact on air quality on traffic corridors and a substantial impact on air quality across the City. Policy would significantly reduce greenhouse gases from Corporate fleet as well.

Influencing Factors: HEVs are expensive but provide many benefits including fuel savings.

Steps:

- Working with TTC, determine the schedule for replacement of older buses over the next 10 years.
- Estimate the emissions of the TTC fleet of buses under a "business as usual" scenario over the next 10 years.
- Using emission information for HEVs from the published literature, estimate the emissions that would be released from the TTC if all retired buses were replaced with HEVs over the next 10 years.
- Distribute the emissions across the City and model with dispersion modeling.
- Feed forecast air pollutant concentrations into the ICAP or AQBAT model on an annual basis and over a long time horizon (e.g. 20 years) to produce health impact estimates.

f. Retrofitting & Refueling Off-Road Diesel Equipment

Question: What health benefits would be associated with the change in air quality that could result from retrofitting all off-road equipment in the City with Diesel Oxidation Catalysts (DOC) and requiring them to use ultra-low sulphur diesel (ULSD)?

Value of Analysis: Could inform a Municipal by-law respecting off-road equipment in the City.

Expected Impact on Air: Policy could have a significant impact on air quality in localized areas within the City, and potentially a substantial impact on air quality across the City.

Influencing Factors: The City of New York passed a by-law to this effect. This by-law would require considerable investment from the industry targeted, but the costs could be low relative to the value of the equipment targeted.

Steps:

- Need to know what type of off-road diesel equipment is used in the City, and how many pieces of each type, and which ones might be worth retrofitting.
- need to find out how many pieces of the equipment are in the City, what type of equipment is used, and age etcetera.
- find out what types of equipment can be retrofitted with DOCs, and if so, what emission reductions can be expected, particularly if they are fueled with ULSD.
- need to know the costs and practical limitations associated with that retrofitting?
- estimate the emissions for the two different scenarios, distribute emissions, and then model the two different scenarios. .
- It may be more useful to use a microenvironment approach to this question (i.e. model the impact of one construction site on one neighbourhood using a dispersion model that provides very tight spatial resolution).

g. Retrofitting Heavy-duty Diesel Trucks with Diesel Oxidation Catalysts

Question: What health benefits would be associated with the change in air quality that could result from the retrofitting of all heavy-duty diesel trucks with diesel oxidation catalysts that travel through the City?

Value of Analysis: Results could be used to encourage the Provincial government to develop a policy to encourage a change.

Expected impact of Policy: Could have a significant impact on air quality across the GTA.

Influencing Factors: There would be huge political resistance to this policy because the truck industry is financially very strained by rising fuel prices and cost pressures.

Steps:

- Estimate the number of heavy-duty diesel trucks coming into and out of Toronto each day.
- Determine what type of trucks are used in the City (i.e. model-years, weight, etcetera).
- Estimate emission reductions expected for the different types of trucks expected with a DOC.
- Allocate emissions across the City and model with a dispersion model.
- The forecasted air pollutant concentrations could be fed into the AQBAT or ICAP model on an annual basis with a long time horizon to estimate health impacts.

h. Prohibit Selling of Off-road Diesel

Question: What health benefits would be associated with the change in air quality that could result from the prohibition of use of off-road diesel use in the City?

Value of Analysis: Results could inform a policy within the City's control.

Expected Impact on Air: Could have a significant impact on local air quality in certain areas of the City, and potentially a substantial impact on air quality across the City.

Influencing Factors: This policy would not significantly increase costs to sector targeted, but could have significant impact on emissions of sulphur dioxide and on air levels of fine particulate matter.

Steps:
- Determine how much off-road diesel is sold in the City
- Estimate emissions associated with the use of this fuel relative to on-road diesel.
- Allocate emissions and model with dispersion model.
- Feed modeled results into ICAP or AQBAT on a seasonal basis and over a long time horizon to estimate health impacts.

i. Upgrading Wood Fireplaces/Stoves

Question: What health benefits would be associated with the change in air quality that could result from upgrading all wood-burning fireplaces/stoves to EPA-certified standards?

Value of Analysis: Results could inform social marketing program that could be developed by the City or some other level of government.

Expected Impact on Air: Could have a modest impact on outdoor air quality across the City and a substantial impact on indoor air quality in individuals' homes.

Influencing Factors: Could be difficult to encourage a significant shift due to costs to individuals.

Steps:
- Need to know how many fireplaces and/or woodstoves are used in Toronto and how frequently.
- Have to estimate the difference in emissions between existing fireplaces/stoves and EPA-certified.
- Allocate emissions across the City and by season and model with a dispersion model.
- Feed modeled results into the ICAP or AQBAT model to estimate health outcomes on a seasonal basis with a long time horizon.

j. Converting Wood-burning fireplaces/stoves to Natural Gas

Question: What health benefits would be associated with the change in air quality that could result from converting wood-burning fireplaces/stoves in the City to natural gas?

Value of Analysis: Results could inform policy and be used in social marketing.

Expected Impact on Air: Could have a substantial impact on air quality in some localized areas in some seasons, and significant impact on indoor air quality in the homes of individuals.

Influencing Factors. Change-overs can be quite expensive although people may have other reasons to do so such as convenience.

Steps:
- Same as above except need emission information for natural gas fireplaces/woodstoves.

k. Converting all oil-fueled furnaces to natural gas?

Question: What health benefits would be associated with the change in air quality that could result from converting all oil-fuelled furnaces in the city to natural gas?

Value of Analysis: Results could inform policy and be used to support education and/or programs developed by the City or the Province.

Expected Impact on Air: Could have a modest impact on air quality in parts of the City. Could have substantial greenhouse gas benefits for the City.

Influencing Factors: This shift in fuel use could produce long-term savings for individuals and could therefore be achieved with the appropriate program delivered by the Province or the City.

Steps:
- need to know how many homes/businesses in TO are heated with oil.
- calculate the emissions differences between oil and natural gas.
- allocate the emissions and model them with a dispersion model.
- The air pollutant concentrations could be fed into ICAP or AQBAT to produce estimates on a seasonal basis with a long time horizon.

l. High Efficiency Street Cleaners

Question: What health benefits would be associated with the change in air quality that could result from the replacement of the City's street cleaners with those that are highly efficient at lifting and capturing PM_{10} from the roads?

Value of Analysis: Results could inform corporate policy and could provide justification for cost differential.

Expected impact on Air: Could potentially have a significant impact on air quality along traffic corridors in Toronto, potentially on air quality across the City.

Influencing Factors: The Technical Services group is already looking at this option.

Steps:
- Analyse the emissions associated with roadway "dust".
- Analyse emissions reductions associated with the use of high efficiency street cleaners that vacuum the "dust".
- Allocate emissions across the City and model with a dispersion model such as CALPUFF.
- The air pollution concentrations could be fed into the ICAP or AQBAT model to produce health estimates on a seasonal basis and with a long time horizon.

m. Increasing Frequency of Street-cleaning

Question: What health benefits would be associated with the change in air quality that could result from increasing the frequency of street-cleaning across the City by two-fold?

Value of Analysis: Could inform corporate policy. Could provide justification for cost of increased service.

Expected Impact on Air: Could have a substantial impact on air quality along traffic corridors in Toronto, potentially modest impact on ambient air quality across the City.

Practicality of Goal: The Technical Services group is already looking at options associated with street cleaning. It is within the City's control.

Steps:
- Analyse the emissions associated with roadway "dust".
- Analyse emissions reductions associated with a doubling of street cleaning service. .
- Allocate emissions across the City and model with a dispersion model such as CALPUFF.
- The air pollution concentrations could be fed into the ICAP or AQBAT model to produce health estimates on a seasonal basis with a long time horizon.

n. Designated Streetcar Lanes

Question: What health benefits would be associated with the change in air quality that could result from the use of designated streetcar lanes across the City?

Value of Analysis: Results could inform policy within the City's control.

Expected Impact on Air: This policy could have a significant impact on air quality along traffic corridors in the City, and potentially a substantial impact on air quality across the City.

Influencing Factors: The City has already moved to designate a streetcar lane along one major roadway. This policy is within the City's control although there are considerable objections to it as well.

Steps:
- Need to understand what designated streetcar lanes will do to the number of vehicles and flow of traffic in and around streetcar routes. It may be that transportation planning and/or TTC have done this analysis already.
- Need to estimate emissions associated with the current system and with the traffic patterns expected to result from this policy. MicroFac may be appropriate for this.
- Feed estimated emissions into a dispersion model such as CALPUFF or CALINE. There may be questions about whether CALPUFF is the appropriate model for this kind of analysis.
- It may be more appropriate to compare localized air quality readings against the health studies conducted on traffic corridors.

o. Compact Land Use

Question: What health benefits would be associated with the change in air quality that could result from intensifying land use development?

Value of Analysis: Results could inform policy and be used to support the policy. (We would need to figure out how to define the goal for this policy for this analysis.)

Expected impact of Policy: Depends upon the definition of the goal.

Influencing Factors: Would have to find some way to specify this goal to make it measurable and meaningful for Toronto. There is a commitment to this goal in the Official Plan.

Steps:

- Would have to find some way to define this goal and then determine what areas of Toronto would be affected by it.
- Would have to estimate the emissions associated with that goal, which could be a complicated task (e.g. how does compact development affect modes of traffic, roadway congestion, etcetera.)
- Would have to allocate the emissions and model them with a dispersion model.
- Could feed results into ICAP or AQBAT on a seasonal basis with a long time horizon.

p. Idling Vehicles

Question: What health benefits would be associated with the change in air quality that could result from reducing idling from all vehicles in the City by 20%?

Value of Analysis: Results could be used with education campaigns and to support the idling control by-law.

Expected impact of Policy: Little impact expected on ambient air quality except in localized areas where chronic or frequent idling is a concern.

Influencing Factors: Goal could be achieved with social marketing and by-law enforcement.

Steps:

- Estimate the emissions associated with idling vehicles in Toronto. (This sounds like a complicated task).
- Estimate the emissions reductions associated with a 20% reduction in idling. This step is easy once the first step is done.
- Feed the emissions in to a dispersion model.
- Compare results for localized areas to health studies conducted on traffic corridors.

References

DSS Management Consultants. (2005) "Ontario ICAP Model Version 2.0: Software Refinements and Revised Provincial Damage Estimates". Prepared for the Ontario Medical Association. July 2005.

DSS Management Consultants. (2004). "Alta Vista Transportation Corridor Alternatives Assessment: Health Risks from Air Pollution Emissions", Prepared for Delcan Corporation, Jan 2004. (Confidential)

Earth Tech Canada, "CALPUFF Modelling System", Prepared for City of Toronto, Technical Services, Air Quality and Improvement Branch, September 2003.

Hanna, Ed. (2005). Interview re: ICAP with Ed Hanna, President, DSS Management Consultants, July 5, 2005.

Ministry of Energy, DSS Consultants, RWDI. (2005) "Cost Benefit Analysis: Ontario's Coal-Fired Electricity Generation" May 2005.

Morgan, Christopher. (2005). Meeting re: Toronto-specific CALPUFF Model with Chris Morgan, Air Quality Improvement Branch, Technical Services, City of Toronto. July 6, 2005.

Sloan, Jim & Rakish Singh. (2005). Meeting with Jim Sloan and Rakish Singh, Waterloo Centre for Atmospheric Science (WCAS) re: MicroFac Model. July 22, 2005

Stieb, Dave. (2005). Interview re: AQBAT with Dave Stieb, Epidemiologist, Health Canada. July 27, 2005.

Systems Applications International Inc. (1997). "Evaluation of Modeling Tools for Assessing Land Use Policies and Strategies". Prepared for Office of Mobile Sources, U.S. Environmental Protection Agency. August 1997.

U.S. Environmental Protection Agency (USEPA). (2003). "Frequently Asked Questions on Mobile6" Prepared by the Office of Transportation and Air Quality, US EPA, November 2003.