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VKT/GHG FORECASTING MODEL

The VKT/GHG Forecasting Model (the Model) is a detailed and comprehensive forecasting tool that enables an analyst to determine (by vehicle class, fuel type, license type and model year)[1] estimates for vehicle stock, fuel efficiency rates, fuel consumption, GHG emissions and, if required, fuel tax receipts quarterly for the first five years and annually for the next 20 years.

The Model was first developed in the mid-2000s to provide the BC Ministry of Transportation with forecasts of fuel tax revenues. Later it was extended to generate data (fuel consumption rates and estimates of VKT by vehicle class) for inclusion in the Ministry of Environment's Community Energy and Emissions Initiative (CEEI) data estimates for 2007 and 2010. In 2013, the Model was enhanced and licensed to TransLink for their internal use. And lately, the Model has been linked to the USEPA forecasts of crude oil prices, future fuel consumption rates by vehicle type, and expected vehicle sales profiles (e.g., proportion of electric vehicle sales to all sales) in order to make the Model more dynamic to changing vehicle technologies.

The Model has a large number of economic, demographic, technical and policy variables that the analyst can change in order to estimate the impacts on vehicle characteristics or behaviour. The Model accommodates any regional location (Regional District, municipality, rural area) and, indeed, with certain modifications can examine various districts within a municipality.

The Model follows a standard accounting framework:

> FUEL CONSUMPTION = STOCK * FUEL CONSUMPTION RATES (fuel efficiencies) * VKT (vehicle kilometres travelled) * PART-TIME RATES

[1] As detailed in the Flowchart, stock is split into 16 vehicle classes: small cars, large cars, pickups, SUVs, minivans, motorhomes, motorcycles, medium-duty pickups, medium-duty vans, heavy-duty city, heavy-duty highway, small buses, large buses, small transit, large transit, and taxies. Five fuel types are included: gasoline, diesel, hybrid, other (natural gas, propane, and ethanol) and electric. Two license types are specified: driving for pleasure only and driving to/from or for work purposes. The Model contains data for each of these vehicle types for each model year – 1990 to last forecast year where the 1990 model year includes all vehicles with model year less than or equal to 1990.

- Total Stock is a composite of the Active stock from the previous period plus vehicles that are Reactivated, that Move into the location from other locations in BC, that are Imported into the location, plus New vehicles purchased during that period:

  Total Stock = Active + Reactivated + Moved + Imports + New

- Historic fuel consumption rates[2] for each individual vehicle are derived from NRCan/USEPA estimates, where all appropriate values are adjusted to match the new 5 cycle methodology now used to estimate consumption rates (this increases consumption rates by between 3 and 9% depending on the type of vehicle). Consumption rates also are adjusted to account for weather conditions in each location. For vehicles not included in the NRCan/USEPA data, consumption rates are estimated econometrically based on vehicle type, fuel type, engine size, NVW (net vehicles weight) and GVW (gross vehicle weight) or from vehicle-specific data estimated by the USEPA..

  The Model allows the analyst to input different future consumption rate values for each vehicle type (e.g., California values) in order to test the impacts of changing consumption rates on overall future fuel consumption and GHG emissions (see "Policy Variables" below).

- F.T.E. VKT values[3] are estimated using a very comprehensive econometric analysis, regressing quarterly full-time VKT estimates for each vehicle (the database for the MetroVan/Fraser Valley regions contains approximately 500,000 different vehicles with total quarterly VKT estimates of approximately 3.2 million data points) against a series of explanatory variables linked to each individual vehicle. These variables include real fuel prices, real per capita incomes, vehicle age, age and sex of driver, exchange rates, population density, plus, within the MetroVan and Fraser Valley regions, transit variables such as access to conventional bus and to Skytrain, hours of bus service, hours of Skytrain service, transit fares, distance to the regional (municipal) town centre, and distance to the Regional District centre.

[2] Strictly speaking, values in the form of X litres/100 kms are fuel consumption rates whereas values in the form of Y miles per litre (or per gallon) are fuel efficiencies.

[3] Full Time Equivalent (FTE) VKT refers to the average number of kilometres travelled by each vehicle type assuming that all the vehicles in that group were on the road (e.g., registered) for the entire quarter. Accordingly, FTE VKTs will be slightly higher than the actual VKTs recorded. Multiplying the FTE VKT by the Part-Time rate will give the actual VKT that occurred.

The Model enables the analyst to change any or all of the above variables in order to test the impacts of such changes on future driving behaviour (see "Policy Variables" below).

- Part-time rates refer to the amount of time within a quarter that the average vehicle in a group is on the road (that is, registered with ICBC). These part-time rates vary by vehicle type and by model year. Various reasons cause part-time rates to be under 100%: new vehicles purchased after beginning of a quarter; vehicles moving into a location during a quarter; vehicles being re-registered or de-registered during a quarter (e.g. motorcycles). Multiplying the FTE VKT values by the part-time rates will give an estimate of the on-road VKT that actually took place.

Stock Forecasts

The Model generates forecasts of Total Stock by first determining the average historical trend in attrition rates for each vehicle type (e.g., gasoline SUV driven for Pleasure only for each model year) and removing these from the previous period's stock. This gives the remaining Active Stock. Similarly, the historical averages for vehicles being reactivated in a quarter are used to estimate the number of reactivated vehicles. Vehicles coming into a location from other BC locations (Moved) and from outside BC (Imported) are calculated based on historical averages linked to population migration levels. The sum of Active + Reactived + Moved + Imported represents the supply of Non-New vehicles in the quarter.

The demand for passenger vehicles is based on population (by age group – 16-24, 25-64 and 65+and by sex) multiplied by the expected stock-to-population ratios for each of these population groups. The Stock ratios can be manipulated by the analyst in order to account for, say, future declines in vehicle ownership by young people (a phenomenon now well recognised) and future increases in vehicle ownership by retirees.

The difference between the Non-New supply of Passenger Vehicles and the total demand for Passenger Vehicles represents the Total New Passenger Vehicles required in any quarter or year. For the base case scenario, total New Passenger Vehicles are allocated to the type of vehicle (e.g., the proportion of new gasoline Small Cars) based on the average proportions of the last two years. The allocation also takes into account differing model years for the New Vehicles – that is, depending on the quarter, a number of say, new gasoline Small Cars, will have a model year prior to the present year, some will have a model year equal to the present year, and some will have model year one year out. The proportions (different for each quarter) are based on the previous year's proportions.[4] The analyst is able to change these proportions, enabling the analyst to test, for example, an increase in the proportion of SUVs being purchased, greater hybrids being purchased, or the impact of electric vehicles coming into the mainstream (see “Policy Variables” below).

The total demand for recreational vehicles (motorhomes and motorcycles) and commercial vehicles is link to economic growth, with the difference between total Demand and Non-New Supply equates to the total New Recreational and total New Commercial. The proportions default to the historical values, but can be changed by the analyst.

Fuel Consumption Rate (aka Fuel Efficiency) Forecasts

Fuel consumption rates (by vehicle type and model year) are preserved for the Active and Reactivated vehicles while historical averages for the Moved and Imported vehicles are used for those forecasts (by vehicle type and model year). New vehicle fuel consumption rates, on the other hand, are completely variable: the analyst can choose to use default values (equal to the USEPA “reference case” forecast for fuel efficiency gains by vehicle class and fuel type) or one can select the USEPA “alternate case” or one can input custom values. Note that the historical consumption rate value for a particular type of vehicle is equal to the weighted average of vehicles in that category, rather than to some hypothetical value as determined by NRCan or the USEPA. This ensures that the fuel consumption rates for vehicles in a region correspond to the types of vehicles (make/model type, fuel type, model year, size, etc.) that actually are in the region.

VKT Forecasts

Estimates of VKT are determined econometrically based on a database of roughly 1.2 million data points within the MetroVan/Fraser Valley Regions. The equations are regressed for each vehicle class, fuel type and licence type (that is, there are separate equations for small car gasoline driven for pleasure vs small car gasoline driven to/for work). In this manner, the equations pick up the different driving behaviour (e.g., fuel price elasticities) for different types of vehicles. This is important since the reaction to a change in say, fuel prices or in transit fare cost can be quite different depending on the type of vehicle driven. The large number of data points also allows the regressions to be estimated at the municipal level providing a more accurate estimate of municipal VKT and municipal response to changing policy variables. Equations that were estimated for the City of Richmond, for example, showed that, while the impact of the opening of the

[4] For example, in forecast year X, there will be, say, 35.6% of total New Vehicles that are small gasoline cars, of which 48% are model year X, 35% model year X-1 and the remainder model year X+1.

Canada Line Skytrain is low (decreasing average VKT by ~25 kms/year) for MetroVan as a whole, the impact is quite significant (upwards of 500 kms/year) for vehicles located in Richmond.

The equations follow the general structure:

$$\log(kms) = \alpha + \beta_1 * q1 + \beta_2 * q2 + \beta_3 * q3 + \beta_4 * \log(Fuel) + \beta_5 * \log(Income) + \beta_6 * \log(Model\ Age) + \beta_7 * Sex + \beta_8 * Age16 + \beta_9 * Age65 + \beta_{10} * Dum\_2010q1 + \beta_{11} * CBD + \beta_{12} * RTC + \beta_{13} * Access + \beta_{14} * Bus\_Hours + \beta_{15} * Sky\_Hours + \beta_{16} * Density + \beta_{17} * EmpRatio + \beta_{18} * Fares + \beta_{19} * Gas\_15to9 + \beta_{20} * Exch$$

where the α and βs refer to coefficients, Fuel is a four quarter function of real fuel prices in the municipality or region[5], Income is a four quarter function of real per capita incomes in the municipality or region, Age and Sex variables relate to the principal driver, and Dum_2010q1 is a dummy variable included to capture any impacts from the Olympics.

The remaining variables are a series of policy variables linked to each vehicle (the calculations are determined at the Transit Area Zone – TAZ – which encompasses roughly a dozen postal code regions).

CBD and RTC refer to average distances from each TAZ to the Central Business District and to the Regional Town Centre (e.g., the municipal centre); Access corresponds to the average distance in each TAZ to a bus line or public transit pickup or station; Bus_Hours and Sky_Hours refer to the number of hours of Bus and Skytrain service in the region; Density is the population within the TAZ divided by its area in hectares; EmpRatio is equal to the employment-to-population ratio within the TAZ; Fares is the real dollar value of the monthly fare card; Gas_15to9 is the ratio of average gasoline prices in MetroVan compared to those in the Fraser Valley - this variable is included to account for drivers in MetroVan travelling to the Fraser Valley to purchase cheaper gasoline (due to no transit tax being applied to Fraser Valley fuel prices); and Exch is the exchange rate – included to capture people travelling to the US and filing their tank with cheaper fuel.

[5] A change in fuel prices (and incomes) affects driving behaviour over time – a change will have an initial, fairly small 1st quarter impact (since on average a price change takes place in the middle of the quarter resulting in a less-than-full impact), continue affecting behaviour over the next couple of quarters, but then people tend to adjust to the price (or income) change and go back slightly to their previous driving patterns.

It should be emphasised that the Model is totally flexible and can include any other variables (e.g., operating costs) that may impact driving behaviour as long as historical data are available back to 2001.

Policy Variables

As discussed above, the Model includes a large number of policy variables that the analyst can change to determine how such changes may affect driving behaviour.

1. **Fuel Prices**: Future fuel prices can be changed either by a change in crude oil prices (US$/bbl) and/or exchange rates or by changes in the various taxes applied to gasoline and diesel at the pump. Base case crude oil prices are derived from the USEPA "reference case" forecast, but a simple click invokes the USEPA "low crude oil" alternate case.[6] Taxes include the federal excise tax, the provincial tax, the carbon tax, the GST, and the regional transit tax. All of these taxes are easily manipulated by the analyst. Accordingly, if the analyst wants to determine how effective the carbon tax has been in reducing fuel consumption, changing this variable will give a quick, yet very accurate, answer. Likewise, what would be the impact if the transit tax is increased –transit tax receipts would increase but, at the same time, the amount of fuel purchased would decline thereby reducing overall consumption? Thus the Model accounts on one hand for the increase in taxes due to the increase in the tax rate, but also how that tax increase affects total fuel consumption which in turn decreases fuel purchases. Does increasing the transit tax or the carbon tax increase or decrease tax receipts? The answer is not so straight-forward.

2. **Real Per Capita Incomes**: Per capita incomes are determined at the municipal level. The analyst can select a default forecast of real per capita incomes based on historical values times a selected growth rate, or input a custom set of values. Per capita incomes highly influence driving behaviour; during the recent economic difficulties where average incomes fell, the average kilometres driven decreased fairly substantially, in part because some people switched to transit, some lost their jobs and did not drive to work, and some (many?) reduced their discretionary driving. An analysis of the income elasticity for MetroVan can be found at the website: http://pacificanalytics.ca.

3. **CBD and RTC:** Generally, the further a vehicle owner resides from major centres (such as from downtown Vancouver), the more driving they will do. While it is

[6] Note that the difference in the "reference case" and the low crude oil "alternate case" includes differences in fuel efficiency gains, since lower crude prices reduce the incentive to improve efficiencies). Lower crude prices also affect the Canadian exchange rate which has a dampening effect on lowering fuel prices in BC.

true that the values for CBD and RTC do not change for each TAZ, the population of vehicles within a TAZ do change over time and therefore the average values change over time. Thus, a re-development of an area far from the city centre will serve to increase average VKT, although the actual results would depend on the density, transit access, hours of transit availability, etc. (see below).

4. **Access:** Access is a variable that identifies the average distance within a TAZ to a transit pickup area or bus line or to a Skytrain station. This variable enables the analyst to assess the impacts of adding a bus line and/or Skytrain station within a TAZ. Access will change if there is a new bus line put in, but alternatively, average access will change if population increases differently in each TAZ.

5. **Bus-Hours and Skytrain Hours**: These variables relate to the number of hours of service that buses and/or the Skytrain have within the region. If TransLink increases the bus hours of service or, say, is proposing to put in a Skytrain station, this variable can be used to assess what the impacts will be on average VKT and thus fuel consumption.

6. **Density:** Changes in population will affect density and generally, an increase in density will lower average VKT. The analyst can make those changes at the TAZ level and, when incorporated into the Model, provide an accurate assessment of how density will affect overall VKT, fuel consumption and GHG emissions.

7. **EmpRatio**: This variable is the ratio of employment in the TAZ divided by the population. This variable is changed by a change in the population and/or by a change in employment.

8. **Fares:** While not a policy variable that a municipality has control over, the cost of the month fare card has a direct impact on average VKT – as the real dollar fare rate decreases, average VKT also decreases as people are incentivised to get out of their vehicles and take the bus or Skytrain. The analyst is able to change this variable, either by increasing/decreasing the future values by a percentage growth rate or by assigning a custom value.

9. **Exch:** The exchange rate has several impacts. First, it impacts Canadian dollar crude oil prices (and thus fuel prices). Second, it affects the number of people heading south to shop in the US. While in the US, people generally fill their tanks with much cheaper US gasoline or diesel and this has the effect of reducing the effective cost of fuel leading to slightly higher VKT. This increase in VKT may also be due to the actually increase in travel to the US. Either way, an increase in exchange rates has, historically, resulted in an increase in average VKT.

Perhaps a concreate policy example may help. Let's suppose that a city is planning a major re-development of a block, where a number of large residential buildings will be built. A number of variables will change here. First, the population of the location will rise, leading to an increase in population **density**. If future population is not reduced elsewhere in the municipality because of this re-development, then the increase density will reduce average VKT (although, because of the increase in vehicles that go along with increased population, the total VKT may increase). At the same time, depending on the location of the re-development (that is, from the **CBD** and **RTC**), average VKT would also change. As well, if the re-development has better-than-average service **bus hours** and/or **Skytrain hours**, average VKT will also decline. If, on the other hand, transit service is below average, average VKT could actually increase due to this variable. Similarly, if the location has better-than-average **access**, then average VKT will decline. Of course, if the re-development is accompanied by better transit (either in service hours or access), this too will affect driving characteristics.

The important conclusion is that, depending on the actual attributes of a location, a re-development may increase or may decrease average VKT – the only way to determine this is by assessing all of the variables that impact driving behaviour.

There are a number of other quasi-policy variables that the analyst can change that also affect overall fuel consumption and GHG emissions. These include:

- **New Vehicle Proportions**: This variable enables the analyst to assess the impacts of changes in the types of new vehicle purchased. With this variable, one can, for example, determine quite accurately how the introduction of electric vehicles will change vehicle demographics, fuel consumption and GHG emissions (even if it doesn't affect average VKT that much). The variable may also enable the analyst to assess the impacts of a policy that encourages, say, the purchase of smaller cars vs SUVs or Pickups (to counter, for example, the increasing share of new vehicles purchased lately that are minivans).

- **New Vehicle Consumption Rates:** This may be more of a provincial or federal government policy variable, but it does allow the analyst to assess the impacts of a policy that requires a reduction on rates over time.

- **Stock-to-Population Rates:** Vehicle ownership is changing. Young people are more-and-more rejecting vehicle ownership in favour of other means of transport (cycling, transit) or in favour of car-sharing. The analyst can make changes to those stock rates over time to determine the impacts. Similarly, older people are seeing on average an increase in vehicle ownership (mostly due to baby boomer couples unwilling to give up their individual vehicles – unlike their parents). Again, the analyst can make changes to those future rates to see how these changes will impact fuel consumption.

The Model is estimated quarterly for the first 5 years of a forecast – this enables an analyst to determine the time profile of impacts since the response to changes in fuel prices and incomes is not immediate, but rather take time to fully affect average VKT. The remaining 20 years of the forecast generate annual values.

A Flowchart of the Model is available at the web site: http://pacificanalytics.ca.