ASET Model System

Alberta Spatial Economic and Transport Model

FINAL

Alberta Spatial Economic Transport (ASET) Model Team
Alberta Transportation and HBA Specto Incorporated

Alberta, Canada

October 2019

Table of Contents

1. Introduction

The Alberta Spatial Economic and Transport Model (ASET) is a simulation system commissioned by Alberta Transportation and developed by HBA Specto Incorporated in Calgary, Alberta. It was developed over a period of three years (2016 to 2019) by a joint team of staff from both organizations.

The simulation is designed for two roles: forecasting and policy analysis. In the forecasting role, a primary objective is to predict the usage of different future transportation infrastructure and services by different types of users in the future, so that infrastructure can be constructed with an appropriate size and design to perform well under future travel volumes. In the policy analysis role, a primary objective is to understand the impact, in particular the economic impact, of delivering (or not delivering) future infrastructure and services, so that investments by Alberta Transportation have a positive net impact on the province, and public funds are directed to the best projects and services.

The system is divided into two parts, a Transportation Demand Model (TDM), and a Spatial Economic Model (SEM). The TDM is responsible for predicting the travel that occurs, by different modes and purposes, on different infrastructure, in particular future years, under different scenarios for each year. The SEM is responsible for predicting the spatial arrangement of different categories of households and industries, and the spatial interactions between them, and the development of land (e.g. construction of future buildings) to support this future spatial economy. The TDM and the SEM work together over a time-series simulation, from the base year of 2011 through the present and into the future, to provide forecasts and policy impact predictions for the future.

2. Model Overview

2.1. Spatial Detail

The province of Alberta has been divided into 524 land use zones (LUZ) following census boundaries. The 524 LUZ are further divided into 5,033 transportation analysis zones, referred to as the ‘5K’ TAZ system. The 5K TAZ are also aggregated to 3,271 zones for some purposes, referred to as the ‘3K’ TAZ system. The land in the province is further divided into 3,461,735 ‘parcels’, based on the cadastre of the province but with some adjustments including subdivisions of large land holdings, such as airports or ranches that could develop in the near future.

2.2. Transportation Demand Model

The TDM simulates the travel of a typical spring/fall weekday in the entire province. It has two primary components that feedback internally; a series of demand models that simulate how much and what type of travel occurs, and a series of assignment steps that simulate the resulting traffic congestion on the road network and loads on the transit network.

The TDM uses population, employment and school enrollment at the level of 3,271 transportation analysis zones (‘3K’ TAZ) generated in future years by the SEM. It produces ‘skims’ that describe the ease of travel between these zones, such as the time it takes to drive in the middle of the day, or how long one has to wait for transit in the morning rush hour.

2.2.1. Simulation of Demand

The total travel market in the province is subdivided into five different segments, each of which has different preferences and data sources, and each segment is modelled separately. One segment is all travel external to the province (the external travel model, ETM); that is, road trips starting or ending outside Alberta or passing through.

The internal travel market is subdivided into personal travel, such as commuting to work or school, shopping and recreation; and commercial travel, which is travel done by businesses, such as the long-haul shipping of goods, deliveries within a city and the provision of services. It is also subdivided by distance (80 km) to represent local travel versus intercity or long-range travel, which have very different goals and needs – short distance travel could be walking to the corner store, while long distance travel could be flying from Lethbridge to Grande Prairie. These two splits create four models: a short distance personal travel model (SDPTM), long distance personal travel model (LDPTM), short distance commercial vehicle model (SDCVM) and long distance commercial vehicle model (LDCVM).

The SDPTM is an advanced activity-based travel model; it simulates every resident in the province and their travel decisions individually, taking many demographic properties like age, income and work status into account. First, a series of ‘long term’ decisions are made, such as if the person has a driver’s license, how many vehicles the household owns, and their work and school locations. Then, a series of models assigns a ‘day pattern’ to each person; an agenda of trips and tours they will make – for instance, go to work in the AM peak, go from work to home in the PM peak, stopping to shop on the way, then go out to visit friends in the evening. The next set of models assign properties at the ‘tour’ level (from when the person leaves the home until they return); what the overall mode of travel is, and where the most important destination is; and finally, each individual trip has origins, destinations and modes modelled.

The LDPTM simulates tours to and from a primary destination by individuals or groups from a household; it is integrated with the SDPTM so that people who make long distance travel can't make short distance travel and vice versa. Long distance personal travel is of four purposes; business, recreation, visiting friends and relatives; and other (typically errands like shopping, medical etc.). A series of models assigns properties to each tour, including duration (same day travel is often to much closer destinations than overnight trips), destination; and mode, including car, intercity coach, air and (if enabled) high speed rail.

The SDCVM simulates individual tours from commercial establishments. Each tour is modeled with a vehicle type – heavy (tractor-trailer truck), medium (single unit truck) or light commercial vehicle (car, van, pickup) – and a purpose; to deliver goods, to perform services or for 'other' purposes such as vehicle maintenance. The tours are 'grown'; the vehicle travels out to make a stop, then considers whether to return to base or keep making trips.

The LDCVM simulates individual trips over longer distances; it begins with economic flows from the SEM in different classes of commodities. These economic flows are converted into physical shipments; some flows are diverted from the road network into notional rail, air or pipeline deliveries. The road flows are then assigned into individual vehicle types, with times of day and TAZ level origins and destinations.

The ETM is a trip-based simulation of road travel across the border of the province; it begins with observed (or projected for future years) count volumes. These crossings are assigned to either pass through to another external location or stop internally to a specific TAZ; times of day and vehicle classes (car / medium truck / heavy truck) are also assigned.

2.2.2. Traffic Assignment

A key component of the TDM is a series of networks representing the road and transit systems in the province; there are five of them representing the morning and evening peak periods, the midday interpeak, the evening and overnight. The road networks contain detailed information about the nature of each 'link' in the road system; the speed limit, capacity, number of lanes and so on. Transit networks represent the routes, stops and frequency of different transit services.

The trips produced by the five demand models are combined and 'loaded' onto these networks taking the best path available. As the number of vehicles on a link approaches capacity, congestion is simulated, and the travel speed drops. In the next iteration of loading, some vehicles will find alternate routes to avoid the congested areas – which also results in the congested areas speeding up. This process is iterated dozens of times until vehicles cannot improve their route choices.

These updated travel times are then fed back into the five demand models – if the roads near a downtown are very congested, then some people could switch to transit, decide to shop in a suburban mall instead of downtown or make other choices. This entire process of supply and demand iteration is repeated to convergence, and then the resulting travel cost ‘logsums’ (a composite measure of difficulty of travel by all available modes between pairs of zones, often called ‘skims’) are available for use in the SEM. A large number of travel measures are also available for more traditional transportation engineering analysis, like the number, type and purpose of vehicles on a road link by time of day; or the origin-destination patterns of a certain travel market.

2.3. Spatial Economic Model

The SEM is a spatially disaggregate input-output economic model that has two main components; Activity Allocation (AA), which simulates the location of different kinds of households and businesses and the spatial interaction between them; and Space Development (SD), which simulates the development of land with newly built or expanded buildings in which to locate these activities.

2.3.1. Activity Allocation

The AA module simulates the economic ‘activities’ in Alberta. There are hundreds of these in the ASET system, representing a type of household, business or government activity. Households are divided by size and income (with seniors allocated separately), while businesses and government activities are separated by industry; such as banking services, grain farming, or electric utilities.

These activities produce and consume different ‘puts’; inputs and outputs that quantify their interactions. Households produce labour and consume goods and services. Businesses consume labour, goods and services while each produces a specific type of good or service based on their industrial classification, along with some by-products. A special kind of ‘put’ is space; each activity consumes some appropriate floorspace; a household can choose to live in different types of housing, while businesses have a single appropriate type of space, like office or industrial space.

Each activity allocates the buying and selling of their puts to different locations within the province; there are 524 land use zones (LUZ) representing subareas of the province; towns, parts of cities, and rural areas. The activity is located in the LUZ where it consumes space, but it draws inputs from, and supplies outputs to, zones all over the province as well as notional import/export locations. However, the travel cost (the logsums/skims from the TDM) are included in this buying and selling, so a cheaper price is not always the most attractive if it comes from further away.

Consider a restaurant; it has a single output – restaurant meals – but requires many inputs. Restaurants hire accountants, use electricity, buy furniture and so on, but the three most important (highest cost) inputs are service-occupation labour, various kinds of food products, and appropriate floorspace. People are not willing to travel far for restaurant meals, so in the model they have a high travel cost. This means that a restaurant will tend to locate near its clients; which are primarily households. A restaurant will be willing to pay extra in rent to locate somewhere that is convenient to a customer base.

A food processor, on the other hand, might supply restaurants and supermarkets with food, but it is somewhat cheaper to ship processed food than to drive a family to a restaurant. It might require production labour and industrial floorspace, and will not be as sensitive to location.

AA thus simulates this entire process simultaneously across all activities, puts and LUZ; if the demand for a commodity in an area is high, the price will go up; the users in that area might get supply from further away and more suppliers might locate in that area. Some puts are elastic; households can choose to produce different kinds and amounts of labour to match the market need, for instance. Space consumption is elastic, allowing more activity in high demand areas even before SD can respond with increased development. AA iterates until all supply/demand curves are at equilibrium for all locations and puts.

2.3.2. Space Development

The SD module is a microsimulation of the process of land development. It considers all parcels of land in the province individually. Empty land near cities likely to develop is split into many potential parcels.

As SD considers each parcel, it considers a number of possible events that could take place; the most likely by far is that nothing happens; if the parcel is undeveloped it remains as undeveloped land, or if there is a building on the parcel, it remains as is. If there is a building on the parcel, the building can be renovated, added to, or demolished. If the parcel is empty, a new building can be created.

These decisions are guided by two main factors; the zoning of the parcel and the rent of the space. Zoning is a policy input to the model that determines what types of floorspace can be built, and at what intensities (measured in the Floor Area Ratio). In addition to zoning, greenfield sites can have phasing specified, so that the plans for the order of development are followed.

The higher the potential rent for a development compared to what exists now, the greater the probability that it will be built. The SEM uses the concept of ‘economic rent’ to measure the price of floorspace; this does not necessarily mean that a rent payment is literally being made for the space, but it represents that floorspace has value. Even a homeowner who has no mortgage still has the choice to sell their house or rent it out – by living in it instead, they are using up that value, in effect, paying rent to themselves.

The base rent for each space use is established at the Land Use Zone level by AA; the 524 LUZ represent mostly individual municipalities, like towns or counties. Mid-size cities like Grande Prairie or Airdrie are broken into 4-8 LUZ, while Calgary and Edmonton have around 75 and 60 LUZ respectively. This base rent represents the general price for a space type in a town or community; how much – for example – a luxury single family house costs in Brazeau County, or the town of Taber, or the Beverly area in Edmonton. It represents the overall effect of the accessibility of an area to buy and sell goods and services, as well as the relationship between supply and demand in an area – rents are lower in areas with a high vacancy rate.

However, within these areas, some parcels are more appealing for development (or redevelopment) than others. A series of ‘local effects’ adjusts the rent for each individual parcel; they represent the effect of the distance from the parcel to major and minor roads, to

LRT stations, to schools, parks and rivers. The price for a house in Beverly that backs onto the park and river will be higher than the same house in a lot backing onto Yellowhead Trail. However, the price for retail space in Beverly will be higher on busy 118th Avenue than on a quiet side street. The age of the building is considered in the same way; as buildings age, they are worth less in rent.

This combination of zonal rent and local effects goes into the parcel-by-parcel microsimulation; the decision to leave a parcel as is or to produce new space is affected by the potential value of the new space – if a parcel has an old building with low value (or empty land), is zoned for a higher use, is near local amenities (or far from noxious local effects) and the rents in the area are higher, it is more likely to have that development occur.

SD runs in each year of the simulation, calculating these probabilities and possibilities, and as a result predicting the changing quantity of space, in a way that is responsive to zoning, demand, travel system performance, and other things impacting market conditions. Before moving to the next year of the simulation, the total predicted quantity of development in each LUZ is assigned to the best individual parcels, which makes SD deterministic, and makes the detailed patterns easier to understand and visualize.

2.3.3. Macroeconomic Model

The macroeconomic forecast in the reference scenarios for the ASET model are an input to the model. This is to allow the model to conform to the official prediction of other ministries. The macroeconomic model in ASET consists of two parts:

1. **Technology Scaling**. Different growth rates imply different relationships. For instance, a higher growth in the health care industry, as compared to the growth rate of population, suggests higher per-capita expenditure on health care, as well as potentially more “health tourism” of people coming to Alberta for our world-class health system. Technology scaling adjusts the magnitude of interactions to provide a consistent internal economic explanation for differing growth rates.
2. **Economic impact of an alternate scenario**. When an alternate scenario (e.g. a scenario to evaluate the construction of future transportation infrastructure) is run it is compared to the reference scenario, and this comparison provides a forecast of the impact on the province-wide (control total) population and employment amounts. A third scenario can then be run, to predict the spatial organization of these changes. For example, a new set of interchanges along Highway 2 can draw employment towards the Highway 2 corridor in the alternate scenario, resulting in less employment in other areas of the province. But, the improved highway should also help the province as a whole grow. The third scenario would include this higher overall growth rate for employment for the province, partially mitigating the losses of employment in other areas of the province, and leading to even more gains in the Highway 2 corridor.

2.4. Model Interaction

The SEM represents the future year-by-year. In AA years (odd numbered years and also the year 2016), AA establishes prices including rents. SD runs each year, generating a year's worth of development. This increased floorspace goes back to AA, affecting the rents and prices in the subsequent AA year. As the ASET model runs through time, the two principal components communicate back and forth. Every few simulated years, an updated set of population and employment numbers are generated by the SEM. The TDM takes this new land use forecast, simulates the travel demand and the delay caused by this demand and determines the resulting travel cost logsums. These logsums then update the SEM's understanding of how accessible all the parts of the province are, and the process continues.

For example, consider a project that expands a congested highway accessing the town of Hypothetical, AB. With the higher-capacity network, the TDM will produce less congestion, and faster travel times to and from Hypothetical. The SEM will notice the faster times, and more people and businesses will locate there, increasing housing prices and rents. As there is now more activity, a developer might build more houses on nearby vacant land zoned for residential construction. After a few years when the TDM is rerun, there are now more residents within Hypothetical and some of the local roads might show congestion.

3. Data Sources and Processing

3.1. Base year and base data

The ASET model was constructed by observing the way the people and other entities in Alberta interact and travel. Behavioural models were constructed and estimated, based on theories from transportation, economics, real estate, and other disciplines, so that similar interactions can be forecasted in future conditions that are different from the observed conditions. The base year of the model was chosen as 2011, as this was the most recent national census year when the project began. Most data were collected for 2011, to represent cross-sectional behaviour, or for a period from 2011 through to 2016, to represent time-series behaviour. The most important data are summarized in this section.

3.1.1. Household and Population Data and place of residence

The primary source of information on the location of the people of the province was the 2011 national census. This is reported at different levels of geography, with substantial suppression of detail to maintain appropriate privacy. The census also provides micro sample data, these have much more detail about individuals, and households of individuals. A population synthesis procedure was followed to optimally combine these two data sources: individual samples from the micro sample data were reproduced in particular locations in the province, to optimally match the reported locational information. This provides the model with a 2011 synthetic population that is consistent with the reported spatial information, but that also has additional population characteristics at the household and person level that are useful for modelling.

The parcel database from Municipal Affairs (also called ASSET but with two 'S's) was used to add some spatial detail to this population synthesis, to support TAZ level modelling where the census data was not disaggregated appropriately. The location of residential buildings reported in the ASSET database was used as an input to the population synthesis. The ASSET database is described in section 3.1.4.

3.1.2. Employment at Place of Work

The primary source of employment data at place of work is the 2011 national census, with a special tabulation of the place-of-work data to the census tract (where available). This is reported by a broad categorization of both industry and occupation.

These data did not have the categorical detail necessary. Although the census occupation data does suggest whether people are working in office (white collar) or production (blue collar) facilities, it does not give us appropriate information on which industry is in production or office, and it does not have sufficient detail at the TAZ level. The ASSET parcel database was processed to identify potential employment locations, by type of structure. Statistical analysis to compare the employment data to the parcel data was used, with an approach that recognized that some municipalities do not report all of their non-residential buildings appropriately. This analysis provided a behavioural representation of the types of buildings used by each type of employee (occupation and industry) as well as the quantity of building space used by typical employees.

We also purchased the INFO CANADA employment database, which is a detailed inventory of business establishments, categorized by industry and by number of employees. After much effort, we decided to use the INFO CANADA data only sporadically, as a spot check. Any attempt to use it systematically was plagued by mistakes in the data, where the employees of large firms were placed in arbitrary branch offices, or central offices, rather than in their actual place of work.

As the employment data and the ASSET parcel database were processed through many iterations of Agile development, discrepancies between the two helped guide us through a number of parcel improvement strategies. These are all unique. As an example, we manually processed the locations of shopping malls and hospitals, to assign retail sales employees accurately and health employees appropriately to the correct TAZ.

3.1.3. Aggregate Economic Relationships

The SEM model represents the economy as a set of relationships between 'activities', which are generally categories of industry and household, but also include categories of government spending and other institutions. Each category of activity produces (as output) and consumes (as input) categories of goods, services, labour and/or space, which are referred to as "'puts'. In addition to active consumption by industries and households, the economic data also includes the amounts spent on construction, machinery and equipment, and intellectual property.

The interaction between activities via puts is what causes the spatial economy to function and represents the primary reasons people travel.

This information is organized in an input table to the SEM model, called the Aggregate Economic Flows (AEF) table. The activities in an AEF Table are the rows, divided into two sections for production (or make) and consumption (or use). The puts in the AEF table are the columns, and are organized into sections for goods and services, labour, and space.

The AEF table includes information from the Alberta Supply and Use Tables (SUT), Survey of Household Spending (SHS), Labour Force Survey (LFS), PUMF (Public Use Microdata Files) Individual and Hierarchical Census data, and commodity unit prices from Statistics Canada. It was developed in a 'learning by doing' process with HBA staff guiding AT staff.

3.1.4. Tax Assessment Data

The Municipal Government Act requires that each municipality assess property tax based on the market value of properties, and that the assessment data must be reported to the province by each municipality. This is called the ASSET database. This data provides essential information on the location and value of the buildings in Alberta, and hence the locations of population and employment, that can be used to help understand a number of things including:

- the origins and destinations of travel,
- the willingness to pay for locations (and hence the value of accessibility),
- the past nature of the land development (building construction) industry in Canada,
- the conditions under which higher intensity (higher Floor Area Ratio) developments are constructed including multi-story buildings,
- the physical constraints of geography (water, forest, etc.),

- the impact of zoning regulations on development patterns, and
- the age distribution of buildings (when they were built).

3.1.5. GIS Data and other spatial data

Spatial information is critically important for understanding travel and spatial economics. Thus, in the development of the model, we sought out Geographical Information System (GIS) files that described the location of economic activity in Alberta, the location of various physical land attributes that could influence future development, the location of different features that would be attractive to either industry or people, among others. A partial list of such data is:

- Municipality boundaries
- Location of shopping centres
- Forested vs non-forested land
- Water table features including swamp areas
- Rivers and lakes
- Protected lands included public parks and forest reserves
- School locations (primary and secondary)
- Indian Reserve land cadastres
- National Park cadastres
- LRT stations and lines

Other spatial information was not coded into GIS compatible layers, so it was processed manually. A partial list of such data is:

- Skyscraper locations
- Post-secondary school locations
- Hospital locations
- Large legal parcels containing multiple types of space

3.1.6. Land Development Data

The SEM predicts the location of future development. It is calibrated based on the past behaviour of developers. Developers in Alberta have constructed buildings in response to market demand in the past, and it is data on this development that we used to develop a behavioural model of developers seeking to maximize profits. The data is primarily ‘building permit’ data, reported for each municipality in Alberta. Building permits from 2009 through 2013 were used to calculate a total amount of development, and this was summarized into different categories, and the SD Bayesian Calibration procedure calibrated the model to these targets.

3.1.7. Cost of Travel

A critical element of spatial economic modelling, and of using economic theory to evaluate transportation plans, is a proper representation of the costs of travel. The ‘transport cost coefficients’ in the spatial economic model are numerical values to translate travel disutility into economic costs of travel. Travel disutility is calculated in the TDM model with consideration of mode and vehicles, and is, in general, a composite measure of the difficulty of making a trip between two locations. In the SEM, this travel disutility per trip is converted into a monetary cost per unit of trade, generally in willingness-to-pay-dollars per dollar of trade. For instance; for labor, the transport costs for a zone pair are expressed as dollars of commuting utility per dollar of labor, whereas for goods it is shipping cost per dollar of product shipped. This puts the costs of transport into the context of economic value and trade.

Two types of approaches were used for the calculation of the transport cost coefficients (TCC) depending on their type. For goods, five steps were followed:

- Calculate the average distance that each category of goods travel within Alberta using 2014 TCOD data, USA Freight Analysis Framework (FAF) data, and transport margins expenditure data from the input-output economic data.
- Calculate the transport cost per physical unit per trip. This uses transport margin data from the Input-Output table and the price per unit data comes from different sources.
- Calculate the transport cost per physical unit per kilometre.
- Calculate the TCC in terms of dollar per minute of travel.

For labour and the services, three steps were followed:

- Identify the behavioural transport money cost coefficient from the value of time relationships in the TDM.
- Calculate the price per hours worked per tour.
- Calculate the TCC in terms of dollars of hours worked per tour and per composite cost.

For the puts using composite cost (or logsum) skims, three types were defined: logsum50, logsum150 and logsum300. They were used to represent that the sensitivity to travel cost is not linear with respect to distance, and some services are less sensitive to travel cost at long distances than at short distances.

3.1.8. Transportation Data

The transport model component of ASET consists broadly of two components; demand models that produce a representation of the amount of travel in the province (primarily the number of trips between transportation zones, by time period and mode), and network assignment that takes these trips and produces a representation of the cost of travel in the province (primarily the travel time by road and public transit between zone pairs, by time period and mode).

The demand models require primarily the same sorts of data the SEM needs; the synthetic population already described is used in a very detailed way in the travel demand models, and the employment at place of work by industry and occupation is the other primary input. Three additional types of input are needed for the demand models.

School enrollment is needed for the SDPTM, to correctly generate school travel by students; this was sourced from Alberta Education. The LDPTM requires visits to provincial and national parks; this was taken from Alberta Environment and Parks, and from Parks Canada. The ETM required as input the number of external vehicles at each external border crossing, along with time of day shares and vehicle type shares; these were taken from count stations.

The network assignment component of the transport model requires transportation networks in the EMME network format. There are two types of networks; a road network that represents the principal roads in the province, and a transit network that overlays the road network, describing the transit routes. These networks vary by time period – transit more than roads, but there are lane reversals and the like in Calgary and Edmonton – so there are actually five versions of each, for a given scenario year. Developing these was a lot of work.

The Calgary and Edmonton regions both have EMME models with road and transit networks as part of their Regional Transportation Models (RTMs); Alberta Transportation has an EMME model with the road and transit networks of the Regional Municipality of Wood Buffalo. These three road and transit networks were converted to a common standard coding system – for instance; the permitted modes on a link need to be specified and these three models use different letters to represent different vehicle types, so a conversion needs to be done so that there is a consistent scheme throughout the province. Additional zone connectors were created to accommodate the ASET '3K' TAZ system, which aggregates Calgary and Edmonton RTM zones into larger ones.

However, the ASET project also involved coding a road network as well as the local transit networks in the remainder of the province. The road network began with the use of Alberta Transportation road inventory data, but substantial manual processing was needed after the import; in addition, roads outside of AT jurisdiction needed to be coded in the cities and towns. This "remainder" network is combined with the Calgary, Edmonton and RMWB networks.

For the LDPTM, an additional set of transportation data was needed to represent intercity coach and air; the schedules and fares for existing services were reviewed, and input files were developed to represent the terminal-to-terminal travel times and costs for all reasonable services (including appropriate connections).

3.2. Future year input data

3.2.1. Future Demographic Forecasts

The Government of Alberta Treasure Board and Finance (TBF) maintains demographic forecasts for the province for about 20 years, e.g. to 2045. These were used to establish the base scenario's future population.

Processing

The TBF forecast was used for years in the more distant future, whereas census data was used for 2011 and years closer to the present. A smooth adjustment procedure in early years of the forecast was developed, to enable this transition.

The model works primarily in household categories, whereas the demographic forecast works in categories of individuals. A population synthesis process was used to populate households into the entire future province (aspatially, i.e. a "one zone synthesis") to provide a household forecast consistent with the demographic forecast.

3.2.2. Future Economic Output

The Government of Alberta Economic Development and Trade (EDT) maintains an economic modelling system without spatial detail, but focusing on economic relationships, as a Computable General Equilibrium system. This system forecasts the growth rate of different industries.

Processing

To be consistent with both ministries, we used these growth rates to establish the future output of different industries in Alberta. For industries not represented in the EDT model, we used similar growth rates from other industries. The spatial economic model has other factors of production that are not tied to industry, as accounting factors included in Statistics Canada tables, which are also expanded using growth rates from related industries.

3.2.3. Future Transportation Network

For future scenarios, road and transit networks were sourced from Calgary, Edmonton and the RMWB models to represent planned projects in those areas. Alberta Transportation staff identified proposed projects for future scenarios, which were coded into the network. A small amount of additional local network (and capacity on existing network) had to be added in mid-sized cities like Red Deer and Grande Prairie, where greenfield areas were expected to develop in the future.

3.2.4. Future Parcels

Municipalities in Alberta control their growth through the planning process, as authorized under the Municipal Government Act. There are different levels of *statutory* plans. A Municipal Development Plan (MDP) is required for all municipalities with a population of 3,500 or greater, but detailed plans are usually included in Area Structure Plans (ASP), Neighbourhood Area Structure Plans (NASP), or Neighbourhood Structure Plans (NSP).

We reviewed and geocoded the MDPs for most municipalities, and, for larger municipalities, reviewed ASPs and many NSPs.

We used development templates, called “future parcel templates”, to represent the plans for future developments. This is because the model needs to represent the diversity of land within a development in a specific way, whereas planning documents for the future are not yet specific. For example, we have several templates for new residential subdivisions that include land zoned for a combination of different residential densities, local retail, and schools, and allocates some land for local parks. These templates are a quarter-section in size (64.75 hectares) but are used multiple times and/or trimmed down to match the actual outline of each planning area.

For larger growth areas, the plans are broken into “phases”. Each phase is released for development when the model has consumed most of the land from the previous phase. This represents each developer’s control over the pace and phasing of development, in conjunction with low-level planning operations to approve development within a pre-approved plan.

4. Model Calibration

Model calibration refers to the process of adjusting particular model inputs so that the model outputs better match observations. The model inputs most commonly adjusted are *parameters*, which are numerical inputs that represent behaviour.

We separate *model calibration* from model estimation. *Model estimation* is described above with the data that was used for estimation, and includes statistical processing of data to develop mathematical and computational representations. After the data and estimated models are incorporated into the ASET representation, calibration refers to further parameter adjustment to match target data based on observations.

In 'random utility discrete choice' type models that are commonly used in ASET (and, indeed, are the standard in transportation forecasting globally), calibration is frequently used to correct biases that may have existed in sample data, by matching model outputs to known aggregate targets. This is called adjusting "alternative specific constants" (ASCs). In these sorts of models, calibration is also frequently used to adjust global choice sensitivity to inputs, again because sample data used in estimation may be collected from people who are more (or less) likely to change their behaviour, as compared to the general population. This is called adjusting "sensitivity parameters" (SPs).

4.1. SEM Calibration

4.1.1. Economic Flow Distance and Trip Length Calibration

Modern economies are very diverse, and even within a narrow categorization trade does not occur to the closest or cheapest supplier. This is elegantly captured in the 'random utility discrete choice' theory that has enabled modern transportation and economic models. We provide value to citizens and enable our economy when we provide transportation that allows people (and goods and services) to travel to a diverse set of destinations for a diverse set of purposes. A single numerical parameter that represents diversity within each category is used to ensure that we represent an appropriate amount of travel in each category, and assign an appropriate economic value to the quantity of travel that occurs in different situations, or that is induced or suppressed through our future infrastructure plans. This is done through a procedure called Trip Length Calibration. The targets for trip length calibration for goods were initially derived from the Trucking Commodity Origin Destination (TCOD) data. However, during calibration it was clear that that TCOD data were limited for certain puts, so supplemental targets were developed using Freight Analysis Framework (FAF) Data on freight movements from the United States. The targets for trip length calibration for labour and other personal trips were established within the City of Edmonton from the City of Edmonton regional travel survey. With these targets, each category's parameter representing the amount and value of diversity was adjusted to match the targets.

4.1.2. Option Weight Calibration

Option Weight Calibration refers to adjusting the ASCs for the individual 'technology options' that represent the ways that households and activities can respond to local conditions or future conditions by consuming or producing differently.

Households

Households have been given technology options so that the supply of labour and the demand for residential space is elastic in the model.

For residential space, the quantity of space consumed is represented by blending three discrete options, small, average and large homes (allowing the model to respond in a continuous nature even though it is built on discrete choice theory). Housing is represented through types that include structure type (single family, attached, multifamily, etc.) and also a separation into quality (called ‘luxury’ and ‘economy’).

For labour, households can choose each of the occupations, as well as the “Not Working” category. These are discrete options, and the real conditions of households are blended from them. (For example, a household with one member working half-time as a retail salesperson and another member working full time as an engineer would be represented as 25% “Not Working”, 25% in the labour category “L13 – RetailSalesService”, and 50% in the labour category “L03 – AnalystProfessional”).

The options for households were set up in this way so that Alberta households can respond to changing housing markets and labour markets, by switching occupations, labour force participation, and housing, within the possibilities and probabilities that have been observed in different places and conditions across the province.

Industry

Industry primarily uses non-residential buildings, but agriculture industries also use cultivated land as a space type. Industry has been given options to consume more or less space per quantity of production, depending on space availability. This allows industry to concentrate in areas of high demand (with more production per square meter of space) even before SD responds with more development in high demand areas. The calibration of ASCs ensures that the base year quantity of space used by each industry is correct, with regional variation depending on prices and conditions.

Importers and Exporters

Alberta interacts with the world economy. To represent this interaction, while still focusing the model on the situation within Alberta, the rest of the world is represented more abstractly than the province. Rather than representing household types and industry, we represent the economy of the world as exporters of Alberta’s production in each put category, and importers for Alberta’s consumption in each put category. In general, we establish potential exports large enough to consume all of what Alberta produces, and potential imports large enough to provide all of what Alberta needs. We calibrate the ASCs of these exporters and importers so that in the base year they only provide or consume the observed quantities from the economic data. In this way, in future scenarios and future conditions the world can respond to what is happening in Alberta by consuming more (or less) of Alberta’s production, or supplying more (or less) of Alberta’s needs.

4.1.3. Floorspace Calibration

The parcel level data from the ASSET assessment information reported by municipalities covers millions of parcels, and inevitably has errors and omissions. Meanwhile, the representation of the quantities of space needed by households and industry is based on province-wide data, so it does not account for regional preferences nor the unique requirements of each business establishment within each activity category. As well, the employment information and the population information reported from the census is also subject to measurement error. These three imperfect sources (measured space, modelled space requirements, and census-reported locations) interact together in the ASET model, establishing a market-clearing price for each type of space in each zone, and we also have observed data on space prices.

The landscape of prices across the province and within municipalities represents the willingness to pay for location. It is essential that we represent this willingness to pay, as transportation infrastructure and policy in the future will provide improved access to new locations that will only be valuable if people are willing to pay for those locations and any associated new development.

Floorspace Calibration is a procedure that respects the model of space requirements zone-by-zone, as well as the census location information zone-by-zone, and somewhat adjusts the quantity of space by type in each zone to better match the observed price data. In the incremental development of the model, the space requirements and location information are also adjusted, in response to mismatches during a round of Floorspace Calibration.

The primary reason for Floorspace Calibration is to strike an appropriate middle-ground between data sources that are subject to errors, inconsistencies, and complexity. It also serves as a quality control system, identifying errors and inconsistencies in early rounds of the incremental development of the ASET model, which are subsequently addressed through supplemental data collection in the parcel improvement processes.

4.1.4. Developer Calibration (SD)

We have developed a “Bayesian Expected Value Calibration” for the Space Developer module.

The Bayesian approach allows an appropriate blending of observations of developer behaviour and theory of developer behaviour. For development types with an abundance of data (such as single-family dwelling construction), the calibration relies almost entirely on data, whereas with less frequent developments (such as high-rise hotels and senior care facilities) the calibration relies on cost functions and profitability formulas.

Expected Values are important in calibration. In reality, a high-rise may or may not be constructed in a particular zone (vs, say, an adjacent zone) depending on a wide range of cumulative minuscule influences that are impossible to measure, such as the opinion of individual developers or neighbours, or detailed soil condition surveys. Instead of calibrating to try to match individual parcel developments, we match the expected value to total amounts at higher levels of aggregation, such as the average rate of high-rise construction in the inner city of Calgary over 5 years.

A non-linear parameter search optimization is used, so that targets can be arbitrary and overlapping. This is semi-automated to reduce the demand on analysts but consumes computation resources for days or even weeks because of the need to calculate the impact of every parameter on each of the millions of parcels repeatedly.

4.2. TDM Calibration

The SDPTM was adapted directly from the model developed at The City of Calgary, so it is already calibrated for Alberta conditions. The SDCVM was adapted directly from the model from the City of Edmonton, and also required no calibration.

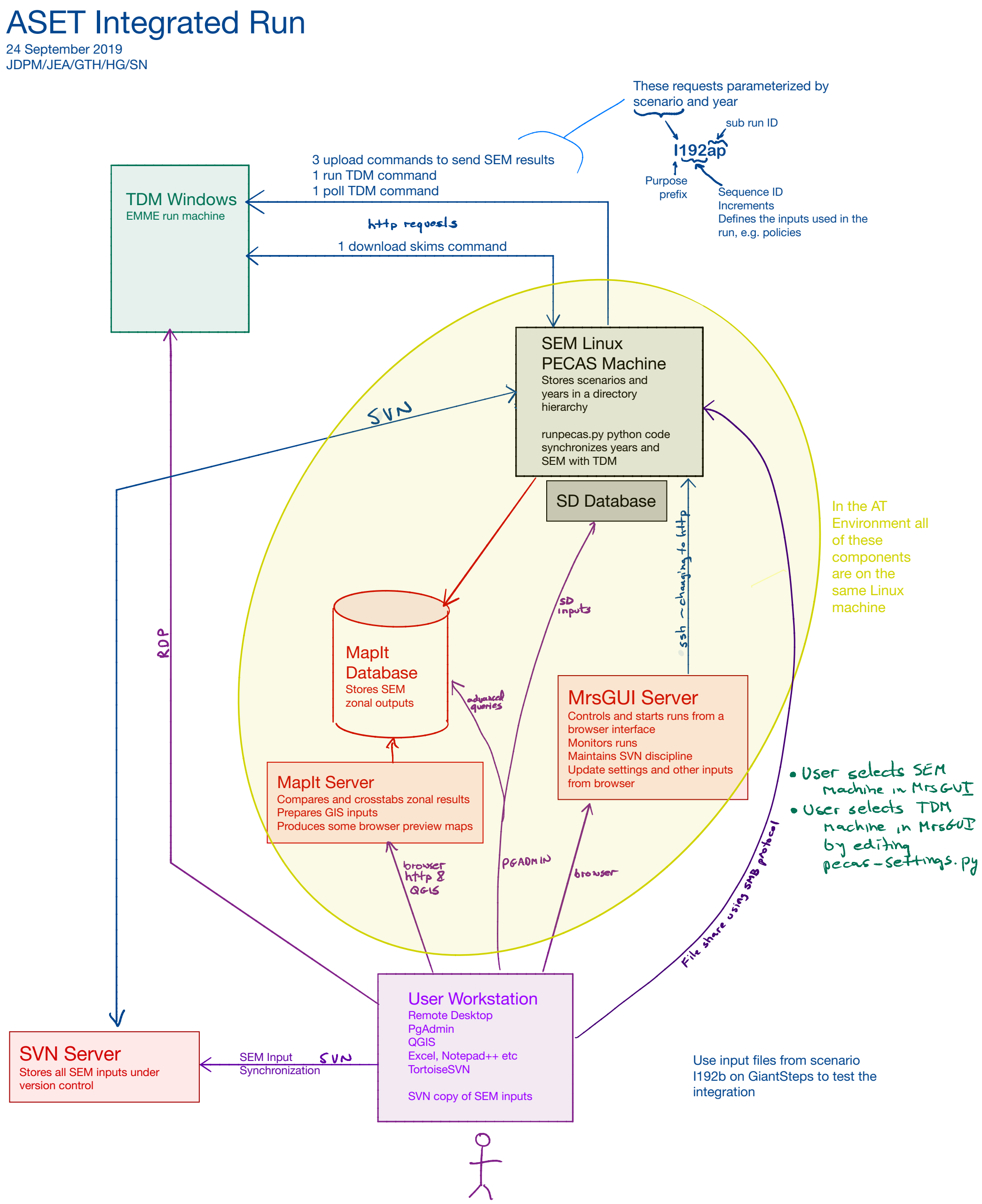
The LDPTM had a substantial data source available, the Travel Survey of Residents of Canada (TSRC). The TSRC is a federal survey designed to look at tourism; it does not have fine geographies (smaller than municipalities) but it does have the information needed to calibrate the main components of the LDPTM. Travel within Alberta was extracted from a multi-year TSRC composite dataset; it was used to calibrate the generation rates (by census division), the same day/overnight split, the mode share and trip length, as well as the destination attraction and the origin-destination split. These were all done separately for the four different purposes in the model; mode share and trip length also observed the same day / overnight split.

The LDCVM model uses economic flows from the SEM, so reflects the SEM calibration.

5. Model Operation and Outputs

5.1. Integrated Model Operation

The figure below shows some of the primary data flows in a full integrated run of the ASET model.



The figure is simplified, but critical components and data flows are:

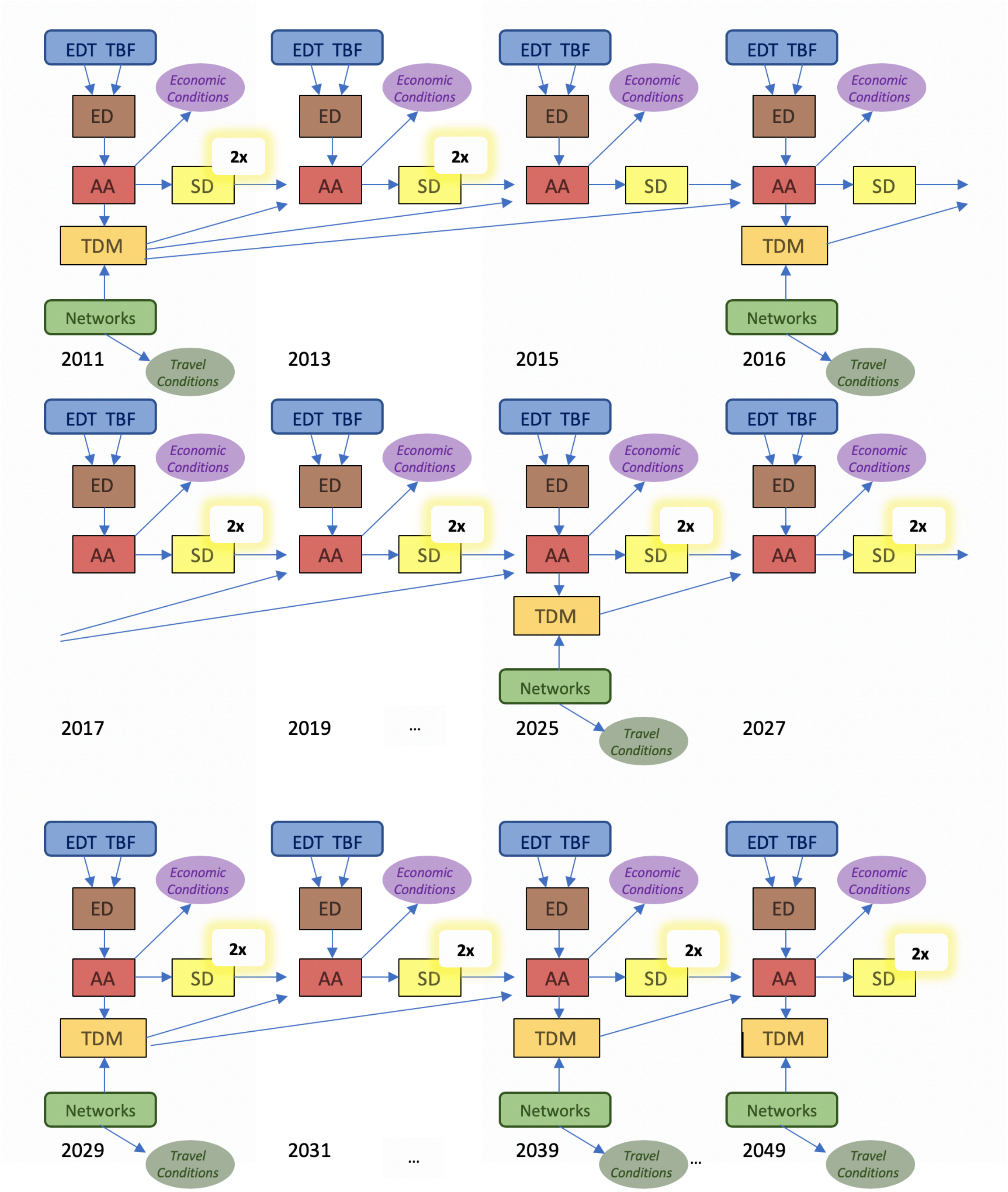
- **User Workstation**. The ASET users generally sit at their own workstations. They prepare SEM inputs on their own machine, using common tools such as Excel and Notepad++, and send these inputs to the SVN version control server. They interact with MrsGUI to control runs. They edit spatial inputs and produce maps of spatial outputs using the QGIS GIS system (or other GIS system). They select and view outputs using file sharing, or through the MapIt browser interface which connects their GIS to web-mapping services.
- **SVN Server**. The subversion server maintains copies of all SEM input files for all scenarios, so that runs can be reproduced and audited.
- **TDM Windows Server**. This is a server that runs the TDM. Users often connect to it using Remote Desktop, to use the interactive tools provided by EMME. The SEM can run the TDM for a given year on the TDM Windows Server, with land use information going to the TDM server from the SEM, and future travel conditions ('skims') coming back to the SEM. Users can also run the TDM by itself, using Remote Desktop.
- **SD Database**. The parcel representation of Alberta is stored in the Space Development database, which normally resides on the SEM run computer, but can be edited using PgAdmin or QGIS on the users' computers.

5.2. Running Scenarios

Runs of the ASET model are called "scenarios" since they represent one possible future outcome for the province. The ASET model has one reference scenario that is the base forecast for the province, and other reference scenarios that represent different possible outcomes for the province. Many reference scenarios are refinements of previous reference scenarios, based on improved knowledge or assumptions about some element of the future. Reference scenarios are usually prefixed with "I" to indicate the full integration between the SEM and the TDM. Other scenario types include Policy scenarios ("P") that differ from a reference scenario through a different set of future policies or infrastructure that is under evaluation; Sensitivity scenarios ("S") that differ from a reference scenario through some combination of external inputs not under policy control within Alberta; and Test scenarios ("T") that are used to test the model operation itself, or to train staff in how to use the model.

Scenarios can be run from the command line or using the web-based tool "MrsGUI". MrsGUI aids the user in setting up scenarios and directs the communication between the run computer and the subversion server. This communication, when directed by MrsGUI, occurs in a defined way to ensure the ability to defend, audit and repeat runs of the model.

5.2.1. Years and Modules – Full Model System



Legend:

EDT TBF	Economic Development and Trade Economic Forecast
	Treasury Board and Finance Population Forecast
ED	Economics and Demographics
AA	Activity Allocation (runs every other year)
SD 2x	Space Development (runs every year)
TDM	Transport Demand Model

The figure above shows the sequence of modules, with SD running every year, AA running in odd years as well as in 2016, and the TDM running in 2011, 2016, 2025, 2029, 2039 and 2049.

Note that many scenarios have extrapolated to 2080, to review potential very long-term impacts, even though the official horizon forecast year is 2049. Beyond 2049 there are no updated networks and no TDM runs, SD and AA continue running with 2049 TDM outputs to 2080, and EDT and TBF forecasts are extrapolated.

5.2.2. Adjusting model inputs

The model has been calibrated for the year 2011 (the base year) and validated for the years 2011 through 2016. In general, model inputs that are changed to define different scenarios reflect different possibilities for future years. These include:

- Different total growth possibilities, e.g. a “low growth” scenario.
- Land zoning adjustments reflecting future year permitted development, e.g. subdivision plans or new industrial zoning for planned industrial areas.
- Spatial constraints directing certain industries or household categories to certain groups of LUZs, e.g. to reflect an external forecast of the spatial distribution of the forestry industry.
- Adjustments to construction costs or development fees in certain areas.
- Changes to the transportation network, e.g. the construction of a new freeway, or improved local access to high growth communities and neighbourhoods (which primarily effects the TDM but also has an impact on SD).

For many “P” and “T” scenarios, the policy or test is an incremental small change, so the TDM can be run automatically through communication as shown in the figure above. For some “S” scenarios, and some new “I” scenarios, the travel model networks may need to be manually adjusted to add links in areas of new development, so the TDM component may need to be run manually.

5.3. Output Processing

The model produces a forecast of the spatial distribution of activity and interactions for each year, as well as the use of the provided transportation network. This is a large volume of information on the full spatial economy and the transportation system used to support it. A few example outputs that are commonly reviewed include household locations, traffic volumes on links, housing prices, job locations, commuting patterns, shopping interactions, etc.

The travel model outputs (such as vehicles on links, transit trips by route) are interactively presented in the EMME software. Additional analysis can be done using the trip list .csv files produced by the model.

The SEM zonal outputs are loaded into the MapIt database. The MapIt database can be viewed and reviewed in several ways:

1. MapIt web service prepares spatial comparisons of many standard outputs between scenarios or for one scenario over time and shows rudimentary maps in the browser.
2. PgAdmin can be used to write queries for other standard outputs, including non-spatial outputs. Standard views are available for the most common outputs.
3. QGIS can connect directly to the MapIt database, but also has a plugin to quickly import MapIt URLs for production-quality mapping and further investigation.

The SEM parcel level outputs are stored in the SD Database, which can be viewed using QGIS.

When comparing two scenarios, the model produces measures of benefits. This is used to evaluate the policies defining each “P” scenario. It provides an indication of the value of the policy to different activities in different locations, based on how they interact with each other. These benefits can be decomposed spatially and categorically. The total benefit measure is generally “drilled down” to review some of the larger benefits (and disbenefits) by location and category. This can identify problem areas, which can lead to a fine-tuning of policy inputs and a new “P” scenario that performs better than the original scenario, because the policy under consideration has been made more effective. Once a policy is fine-tuned in this way through the use of the model, the resulting full composite benefit calculation is used to calculate return-on-investment for the policies.

6. Model Update and Maintenance

6.1. Year by year updates

In the course of using the ASET model, the present will become the past, and new data on those years will become available. These can be reflected in the model in several main ways:

1. Updating the network for current years (e.g. the 2016 network is the most current, but eventually there could be an as-built 2020 network.)
2. Updating zoning plans and regulations in the model for future development, as municipalities publish new plans.
3. Adding in existing 2011-2020 parcel-level development to the model as an input to the model, rather than as an output from the model
4. Updating 2011 conditions, including 2011 in-effect zoning, based on new data describing 2011.

If 2011 is updated beyond minor adjustments, several calibration exercises should be undertaken, to update the model to the updated data:

1. SD calibration,
2. Floorspace calibration, and
3. Flow distance calibration (SEM).

Potential updates to the travel model were identified in some detail in travel model document TDM 04, depending on data availability.

7. Conclusions

The Alberta Spatial Economic and Transport model provides a rich representation of the travel that occurs in Alberta now and in the future, with an economic basis that provides defensible land use projections and measures of economic impact to be used in policy analysis. Alberta Transportation will use the model to help plan infrastructure and services that provide the best value to Albertans in the future, in terms of network performance, while also supporting economic growth and household welfare.

The model's integrated and holistic nature shows the impact of policies and plans both locally and provincially, and the secondary and cumulative effects on different locations, industries, and household categories. The strong economic basis to the model gives it an advantage over other platforms, as it focuses on the reasons for travel rather than simply on the quantity of travel.

The model is spatially detailed and provides a time-series outlook that supports both low-level and high-level planning. It aids in the selection and refinement of proposed projects. It provides a range of output metrics from the provincial to parcel level. These include overall measures of economic benefit and performance, summary statistics, and visualizations of the future of the province.

The ASET model should be a valuable asset for the Government of Alberta for many years to come.

8. Bibliography

The following documents were delivered as part of the ASET model.

AA 01. Outline of AA Files
AA 02. ASET Model Design
AA 03. The AEF Table
AA 04. Employment and Space Synthesis
AA 05. Constraints Allocation
AA 06. Transport Cost Coefficients
AA 07. Technology Options
AA 09. Rent Estimation
AA 10. Imports and Exports
AA 11. AA Calibration
ED 01. ED General Document
MR 02. Model Inputs and Integrated Run
MR 03. Model Integration
MR 04. PECAS Analysis and Visualization
MR 05. Examining Immediate Effects of Policy
SD 01. SD General Document
SD 02. Deterministic SD
SD 03. SD Set Up Process
SD 04. Parcel Improvements
SD 05. Future Parcels
SD 06. SD Calibration
SD 07. Modifying Zoning
SD 08. Adaptive Phasing
TDM 01. Modelling Autonomous Vehicles
TDM 02. Long Distance Freight Model Data
TDM 03. External Travel Model
TDM 04. Travel Model Future Enhancements

TDM 05. Base Year Population Synthesis

TDM 06. Long Distance Commercial Vehicle Model (LDCVM)

TDM 07. Long Distance Personal Travel Model (LDPTM)

TDM 08. Travel Demand Model (TDM) – Spatial Economic Model (SEM) Data Interactions

TDM 09. Travel Model Overviews

TDM 10. Travel Demand Model User Guide

TDM 11. ASET Network Coding Quick Reference Sheet

TDM 12. Short Distance Commercial Vehicle Model (SDCVM)

TDM 13. Short Distance Personal Travel Model (SDPTM) – Calgary Addendum

TDM 14. Future Year Population Synthesis

TDM 15. Emission Model

TDM 16. Synthesizer Program

VC 01. AA Input Files

VC 02. AA Input Files 02

VC 03. Employment Synthesis

VC 04. Employment Synthesis 02

VC 05. Technology Options

VC 06. Labour Make and Use

VC 07. SD Inputs

VC 08. SD Calibration Results

VC 09. Household Calibration

VC 10. Targets and Tolerances for Space Calibration

VC 11. Iterative Calibration

VC 12. Population Synthesis

VC 13. Population Growth

VC 14. Future Parcelling

VC 15. Treatment of Imports and Exports

VC 16. Hospitals Site Spec

VC 17. Oil Extraction

VC 18. Running Highway II Scenarios

VC 19. Long Distance Commodity Flows to TDM

VC 20. AT ASET Alternate – GBA Analysis Potentials

VC 21. AT ASET Alternate – GBA Hands-on with Post processor

VC 22. AT ASET Model – LDCVM SEM Interaction